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Final report

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1 Acknowledgments

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2 Executive summary

The main objectives of the project SMAR/2005/074 were to select and test local cocoa clones in different locations, to screen the progeny of crosses between productive and resistant genotypes, to demonstrate integrated management options with reduced material inputs and to assess technology uptake by farmers. The research methods involved participation of farmers so as to encourage the uptake of basic approaches to farm improvement in addition to enhancing capacity for field research by the partner institutions.

The initial focus of the project was Sulawesi. A variation to the project later extended activities into Papua and West Papua. In three provinces in Sulawesi, farm trials were established in early 2008 in Pinrang, BoneBone, North Kolaka, Kolaka and Polman. In each trial twelve clones were tested, including selections from local farms, hybrid crosses of genotypes with useful resistance and/or productivity characteristics and comparative standards (including a highly regarded international clone). Pesticides were not applied until 2012, when they were necessary to determine yield potential. High yield, bean size and fat content were demonstrated in some of the local clones tested. The field data also demonstrated resistance to vascular-streak dieback (VSD) in three clones. Productivity was low at two sites due to factors such flooding, pink disease and root rot. At the other three sites high yields were evident in the introduced clones. Comparison of the standards in these sites showed that the average yield was higher in Pinrang than in N. Kolaka or Polman. The average number of flowers was also higher in Pinrang. Severity of cocoa pod borer (CPB) infestation did not differ significantly between sites but a higher susceptibility occurred in one of the standards regardless of the location. However, in comparison to other sites, Phytophthora pod rot and VSD were lower in Polman and N. Kolaka, respectively. Under the variation, five productive clones were propagated by side-grafting in a demonstration trial in Mandopi, West Papua. These clones were later regrafted in other locations. To screen hybrid crosses and clones, a cocoa research site with a nursery, and a hybrid and clonal trial were established in Soppeng, Sulawesi. However the trials were damaged by a fire in 2009 and therefore moved to East Java. A high level of VSD resistance was demonstrated in some of the hybrids resulting from crosses between parents with known VSD resistance (such as PBC123 and KEE2). Physiological characteristics of genotypes with known CPB resistance were examined as part of a PhD study by one of the main Indonesian collaborators and head of cocoa breeding at ICCRI. Lignification, the density of channels in the sclerotic layer and the number of trichomes differed between resistant and susceptible genotypes. Field screening followed by molecular typing showed that resistance traits occurred in both the Forastero and Trinitario cocoa types. In the initial two years of the project, training days conducted in each of the five clone test sites by Australian and Java-based project staff introduced pest/disease and cultural management methods to local farmers.

A pest/disease training manual and a translation from a manual published under ASEM/2003/015 in Papua New Guinea were produced. In February 2010 a five day course on cocoa management was held by the ACIAR project and Mars Inc. in Jayapura, Papua for 18 local extension and university staff, with three staff from the Cocoa and Coconut Research Institute, Papua New Guinea assisting with training. Demonstrations of four cocoa management options were established in road-side locations in Papua and West Papua with the participation of local farmers. The project established links with a program on commodity development in rural communities under the International Fund for Agricultural Development; the West Papuan demonstration site was used for the cocoa training module conducted by the University of Papua under this program. A PhD project conducted at the University of Sydney under a JAF scholarship is nearing completion. A survey on uptake of technology by farmers in Sulawesi and West Papua showed that relatively high use of material inputs and low labour inputs are favoured for cocoa management, that extending cocoa farms into new land to obtain land entitlements is prevalent in Sulawesi, and that the level of exposure to various training programs was high in Sulawesi.

3 Background

This project built upon a previous ACIAR Project (CP/2000/102) which introduced and tested methods of local selection with the help of farmers of apparently superior cocoa genotypes on farms in two provinces in Sulawesi. As demonstrated by CP/2000/102, the high genetic diversity of the cocoa currently planted in smallholdings is a sound basis for local selection of pest/disease resistance and improved yield and quality.

This project addressed further issues, particularly the severity of vascular-streak dieback and consequent dramatic decrease in farm productivity, the need to combine promising traits in hybrid progeny, a need to disseminate effective management approaches that require low material inputs and the lack of understanding of the socioeconomic factors influencing farmer perception and uptake of technologies to improve farm productivity (and therefore family incomes). The project was initially focussed in three provinces in Sulawesi but later extended under a variation to include Papua and West Papua. Unlike Sulawesi farmers, many local farmers in these provinces have little understanding of cocoa management and the challenges therefore differ from those in Sulawesi (where many farmers have had extensive exposure to cocoa technologies from international programs and chemical companies). Management level in many Papuan/West Papuan farms is low and this has been exacerbated by increased infestation by cocoa pod borer leading to extensive and disheartening losses. An important aim of the project was to introduce better quality planting material and cultural (low cost) management methods to Papuan/West Papuan farmers. This project aimed to develop methods to manage on-farm problems and improve cocoa yield and quality. In Papua and West Papua it was seen as important to demonstrate different options of cocoa farm management levels using a model developed in PNG under an earlier project, ASEM/2003/015, to show farmers the potential for improving cocoa yield with a relatively low level of material inputs. Furthermore, in Papua and West Papua many university and government staff conduct few practical field activities and a purpose of the project was to introduce concepts of field testing and demonstrations that involved the participation of local farmers.

4 Objectives

Aim of the proposed project: To improve cocoa production through farmer involvement in demonstration trials of potentially superior and pest/disease resistant genotypes and integrated pest and disease management practices.

Objective 1: With farmer participation, to test cocoa clones for improved yield, quality and pest/disease resistance and to demonstrate on-farm selection and testing of cocoa.

Activity 1: Select and obtain material of promising clones for demonstration trials based on results from earlier ACIAR project, Mars program trials etc.; establish farmer groups (see Objective 4); select more local clones with putative resistance or higher quality/yield.

Activity 2: With farmer participation, establish small demonstration trials in each of three provinces of Sulawesi (West, South-East and South) to test promising clones and local selections.

Activity 3: To assess the field trials for pest/disease resistance and yield and quality of cocoa.

Activity 1(variation): Select sites and local clones for clone testing trials. Site selection will depend on the farm locations of participating farmers and accessibility of the site to researchers, extension staff and other farmers.

Activity 2 (variation): Establish a clone testing trial in each of two locations in Papua and West Papua (possibly near Jayapura and Manokwari) that is similar in design to the trials currently underway in Sulawesi, with a focus on selection of superior local clones as well as local testing of some of the best clones identified in Sulawesi.

Activity 3 (variation): Assessment of clones

Objective 2: To field test a wide range of clones and the progeny of crosses between high yielding and pest/disease resistant cocoa clones to develop superior genotypes and study the nature of resistance to cocoa pod borer and VSD.

Activity 1: Establish a replicated progeny trial at one site in Sulawesi.

Activity 2: Establish replicated clonal trials at one site in Sulawesi to test a wide range of clones for pest and disease resistance, yield and quality.

Activity 3: Screen cocoa clones and hybrid progeny for pest and disease resistance, yield and quality.

Activity 4: Study the nature of CPB and VSD resistance (PhD project).

Objective 3: To demonstrate integrated management of cocoa pod borer and diseases, including the use of locally developed control measures such as pod sleeving and regular complete harvesting.

Activity 1: Establish demonstration plots of improved IPDM on farms.

Activity 2: Work with farmers to establish demonstration/trial plots on their own farms

Activity 1 (variation): Consultation with farmers and local extension officers and IFAD. Assessments of availability of resources, including labour (in association with socioeconomic surveys conducted under Objective 4, see below).

Activity 2 (variation): Establishing IPDM trials preferably with a farmer group but possibly with individual farmers. Farmer selection should be partly based on farmer interviews conducted for Objective 4. Plots demonstrating various options to be established based on method used in PNG-based ACIAR projects (ASEM/2003/015, CP/2006/114).

Activity 3 (variation): Farmer participatory assessment of the trials. It is expected that farmers could be trained to conduct basic assessments (such as counts of diseased and healthy pods). University of Papua students may also be involved in assessments through their final year projects (Scripsi).

Objective 4: To disseminate knowledge arising from the field demonstration-trials and assess uptake by farmers of improved cocoa management employing new cultivars and integrated pest/disease control methods.

Activity 1: Establish farmer groups and identify farmer leaders willing to participate in on-farm research**.**

Activity 2: Undertake educational activities with farmer field schools in cooperation with Dinas Perkebunan to disseminate knowledge to a wide network of participants and foster approaches that could be adopted by farmers to test novel methods on their farms.

Activity 3: Conduct in-person surveys of participating farmers and others to assess (i) changes in their understanding and adoption of management strategies that could be used to overcome pest/disease and production problems, (ii) their understanding of methods of on-farm testing of new ideas, and (iii) the socio-economic benefit of the project.

Objective 4 (modified: To assess uptake by farmers of improved cocoa management employing new cultivars and integrated pest/disease control methods.

Activity 1 (variation): *Conduct a detailed socio-economic household survey within each of the Districts where the trials have been established to develop insights into farm decision-making processes and limitations on improvements in cocoa farming.*

Activity 2 (variation): Assess community perceptions towards the trials in both locations through field interviews and a small-scale survey.

5 Methodology

Objective 1: With farmer participation, to test cocoa clones for improved yield, quality and pest/disease resistance and to demonstrate on-farm selection and testing of cocoa.

5.1 Clone Testing

5.1.1 Selection of cocoa clones for testing

Promising cocoa clones were selected for testing in multi-location trials in Sulawesi. Selections were obtained locally from farms by Mars Inc, Mars Symbioscience, a previous ACIAR project and ICCRI. ICCRI included clones obtained from crosses that combined productivity and resistance traits. For example, KW 617 is a selection from a cross between the VSD-resistant Malaysian clone PBC123 and TSH858, a particularly productive clone, yet susceptible to VSD. Five clone trials were established in three Sulawesi provinces: South, West and South-East Sulawesi. In 2007 the material for grafting was collected and grafted onto rootstock seedlings obtained locally and maintained in a local nursery for 3-4 months before planting (Fig 1). At each site, 12 clones were tested, including two common standards, PBC123 and a very high yielding clone M01 (selected with the participation of a local farmer by Mars Inc.). Three of the sites had four clones in common (PBC123, and the local farmer selections M01, GeniJ and M05) which acted as comparative standards. The clones included in the trials and the locations in which they were tested are shown in Table 1.

Fig 1. A mature top-grafted cocoa seedling

Table 1. Clones selected for testing in locations A –E (A, Pinrang;

B, Bone-Bone C, Polman ,; D, North Kolaka; E; Kolaka)

Selection/ origin	Clone	Province and site in Sulawesi					Total no. sites
		South		West	South-East		
		A	B	C	D	E	
Malaysia	PBC 123	1	1	1	1	1	5
	BR 25			1		1	1
	KKM 22				1	1	2
ICCRI	DRC 15	1				1	2
	ICCRI 03		1			1	2
	ICCRI 04	1				1	2
	KW 617			1			1
	KW 523			1			1
	KW 516			1			1
ACIAR	Aryadi 02		1			1	2
	Harris II					1	1
North Luwu/Luwu Mars	M01	1	1	1	1	1	5
	M04	1	1			1	3
	M05	1		1	1		3
	M06	1			1		2
	MT					1	1
	Terobok G		1				1
	TR01	1					1
	PCK	1					1
	Patila		1				1
	YD 75		1				1
	SS.Rewang		1				1
	Panimbu R.	1	1		1		3
	RB	1					1
Sekang, Soppeng Mars SS	Moktar			1	1		2
	Darno 02				1		1
	ILH			1	1		2
	Hasbi Tori			1			1
	Nasir Rauf			1	1		2
BPTP Sultra	Lambandia 2					1	1
East Luwu, Mars	Geni-J	1		1	1		3
	Hari-J		1				1
Pinrang, Mars	Pw/Pg 01				1		1
	Ma/Pg 01		1				1

5.1.2 Clone trials in Sulawesi

To establish the five trials the top-grafted clonal seedlings were planted at each of the sites between December 2007 and March 2008. The locations of the trials were Pinrang and Bone-Bone in South Sulawesi, North Kolaka and Kolaka in South-East Sulawesi and Polewali-Mandar (Polman) in West Sulawesi. In each trial, the clones, planted in 8 tree plots, were distributed randomly within four replicate blocks (Fig. 2). Thus the total number of trees in each trial was 384 initially. Some trees were lost during the trial but usually 5-8 trees remained to be assessed in each plot. Prior to fruiting the trees were evaluated for branch diseases. Pod evaluation began in April 2010. With the exception of the early stages of seedling establishment, pesticide chemicals were not applied until February 2012 when two sites (Pinrang and N. Kolaka) were sprayed for cocoa pod borer and Phytophthora pod rot to allow assessment of yield potential. Therefore at these two sites, the clones were assessed for almost two years for productivity and resistance free of pesticide applications. Pesticide application has not yet begun at two other sites, in Polman and BoneBone, and these will continue to be evaluated until the end of 2012.

	A	B	C	D	E	F	G	H	I	J	K	L		D	A	I	C	G	E	B	L	H	K	J	F	
	A	B	C	D	E	F	G	H	I	J	K	L		D	A	I	C	G	E	B	L	H	K	J	F	
	A	B	C	D	E	F	G	H	I	J	K	L		D	A	I	C	G	E	B	L	H	K	J	F	
I	A	B	C	D	E	F	G	H	I	J	K	L		D	A	I	C	G	E	B	L	H	K	J	F	III
	A	B	C	D	E	F	G	H	I	J	K	L		D	A	I	C	G	E	B	L	H	K	J	F	
	A	B	C	D	E	F	G	H	I	J	K	L		D	A	I	C	G	E	B	L	H	K	J	F	
	A	B	C	D	E	F	G	H	I	J	K	L		D	A	I	C	G	E	B	L	H	K	J	F	
	A	B	C	D	E	F	G	H	I	J	K	L		D	A	I	C	G	E	B	L	H	K	J	F	
	J	H	D	F	A	G	K	L	E	B	C	I		G	A	I	J	B	E	F	C	H	K	L	D	
	J	H	D	F	A	G	K	L	E	B	C	I		G	A	I	J	B	E	F	C	H	K	L	D	
	J	H	D	F	A	G	K	L	E	B	C	I		G	A	I	J	B	E	F	C	H	K	L	D	
II	J	H	D	F	A	G	K	L	E	B	C	I		G	A	I	J	B	E	F	C	H	K	L	D	
	J	H	D	F	A	G	K	L	E	B	C	I		G	A	I	J	B	E	F	C	H	K	L	D	IV
	J	H	D	F	A	G	K	L	E	B	C	I		G	A	I	J	B	E	F	C	H	K	L	D	
	J	H	D	F	A	G	K	L	E	B	C	I		G	A	I	J	B	E	F	C	H	K	L	D	
	J	H	D	F	A	G	K	L	E	B	C	I		G	A	I	J	B	E	F	C	H	K	L	D	

Fig. 2. Typical layout of clone testing trial. Each clone (designated by a letter) is planted in rows of 8-tree plots in each of four blocks. In two trials (Pinrang and Polman) clones were planted in two rows of four trees.

Trees were evaluated for leaf and branch diseases, insect damage, and flowering every month. VSD severity was scored as 0, no infection; 1, 10% or less branches with symptoms of infection, 2, 10-25% branches infected; 3, 25% or more branches infected.

Pod evaluation conducted was twice per month at each harvest (see Fig. 3). Pods were scored for CPB as follows: 0, no infection (healthy); 1, low infection, less than 10% beans affected; 2, 10-50% beans affected; 3 over 50% beans affected (normally 100% loss). Phytophthora pod rot (PPR) was scored by estimating the proportion of the pod covered with the brown discolouration typical of a PPR lesion: 0, no lesion; 1, 10% or less; 2, 10-50%; 3, over 50% of the pod surface discoloured. Beans collected from a few consecutive harvests were dried and then pooled for analyses. Average yield per tree (kg dry beans) was calculated and extrapolated to provide an estimate of yield per 1000 trees (approximately 1 ha). Bean quality characteristics including fat and shell content were determined in the cocoa quality laboratory at Mars Symbioscience, Makassar.

Fig. 3 KW 617 pods (centre) ready for evaluation in Polman. The productivity of this clone created strong interest among the local farmers to collect and propagate it.

In Mandopi, West Papua, five productive clones were introduced from Java and Sulawesi and propagated in a demonstration trial by side-grafting onto mature cocoa trees near the management demonstration site (see below). A high rate of establishment was achieved; however, access to the site became difficult due to political unrest and the material was regrafted by BPTP West Papua in other locations in Manokwari and Pravhi. The productivity of these clones (demonstrated by the trial and the new grafts) has led to their being sought after by farmers for grafting on their own farms.

Objective 2: To field test a wide range of clones and the progeny of crosses between high yielding and pest/disease resistant cocoa clones to develop superior genotypes and study the nature of resistance to cocoa pod borer and VSD.

5.2 Testing clones and hybrid crosses

Activities under this objective were led by ICCRI. The objective included a PhD study of mechanisms of CPB resistance undertaken and completed at Gadja Madah University by one of the project leaders and the head of cocoa breeding at ICCRI, Agung Susilo,.

5.2.1 Screening hybrid crosses and clones

Parental genotypes were selected for promising VSD or CPB resistance and productivity characters. Five parental genotypes were used including ARDACIAR 10 (formerly Aryadi2 a selection from the previous ACIAR project CP/2000/102 and later released by the Ministry of Agriculture as Sulawesi 3), KEE2, ICCRI03, Sulawesi 1 (PBC123) and Sulawesi 2 (BR25). Three of these genotypes had known resistance to VSD and one had been demonstrated to be one of the most CPB-resistant genotypes yet tested. For some hybrid crosses, maternal/paternal reverse crosses were conducted by hand-pollination. Seedlings were raised from the seeds obtained from the crosses. These progeny hybrids were then distributed to sites in East Java and/or Sulawesi for screening.

As part of this objective a research site was established in Padali, Soppeng on land provided by a research partner in the project, Dinas Perkebunan South Sulawesi. It was expected that this site could be used for field testing cocoa genotypes as well as establishing a clone collection. Soppeng District Dinas Perkebunan officers were involved in maintaining the site with the research component managed by ICCRI staff. Land was cleared and temporary shade was planted for cocoa trials. A nursery was built using a design commonly implemented by Mars Inc. (see Figs. 4,5,6)

Fig. 4 Nursery under construction in Padali, Soppeng

Fig. 5 Padali site under preparation for clone and progeny trials

A clone collection was established for screening in Padali, Soppeng and in East Java. Unfortunately a fire destroyed the Sulawesi trials; however, progeny hybrids and clones continued to be assessed in East Java (see Results). To assess the severity of VSD in the tested clones and hybrids a 6-score system was used. Trees were evaluated visually and allocated a score from 1 (low levels of infection with no discernible effect on yield) up to 6 (high level of damage and leaf loss, possibly complete dieback in some branches and clear impact on pod yields).

Table 2 . The number of hybrid seedlings planted in Padali, Soppeng by June 2009

No	Cross combination	BLOCK			
		I	II	III	IV
1	ICCRI 03 x KW 514	50	50	50	50
2	ARDACIAR 10 x ICCRI 03	50	50	50	50
3	KKM 22 x ARDACIAR 10	50	50	50	50
4	PBC 123 x KW 514	50	50	50	26
5	PBC 123 x DRC 15	50	50	50	50
6	BR 25 x ARDACIAR 10	50	50	50	50
7	ICCRI 03 x DRC 15	50	50	50	50
8	ICCRI 03 x ARDACIAR 10	50	50	50	50
9	DRC 15 x PBC 123	40	50	0	0
10	ARDACIAR 10 x M01	50	0	0	0

Fig. 6 Hybrid cocoa seedlings planted in Soppeng 2009

5.2.2 Studies of CPB resistance

This study formed part of a PhD degree completed during the term of the project by the cocoa plant breeder at ICCRI (Agung Susilo). Initially both VSD and CPB resistance were to be included in the study but due to practical and time limitations only CPB resistance was addressed by the study. Later the cocoa breeder continued with genetic segregation studies of VSD resistance supported by Mars Inc., USDA and the World Cocoa Foundation. This CPB-resistance study had four components:

1. Characterize the physical and chemical compounds of cocoa pod which contribute to antixenosis and antibiosis mechanisms of resistance to CPB. The clones examined were KW 514 (resistant), ARDACIAR 10 (or KW 570, resistant), KW 411 (moderately resistant) and RCC 72 (susceptible). Pods from three replicate plants were sampled including young pods ± 3 month-old and mature pods. Transverse sections were prepared for micro-chemical treatment. Microscopic analysis was carried out to identify trichomes in the upper mesocarp layer, granules of tannin distributed through the mesocarp and lignification of the sclerotic layer. Analysis of placental tissue was done to characterize the compounds of tannin, glucose and protein using a gravimetric method.

2. Evaluate the effect of pod development on pod characteristics related to CPB resistance. Different pod samples were taken prior to maturity at 3, 3.5, 4, 4.5, and 5 months. Microscopic examination was carried out as described above.

3. Confirm links between expression of CPB-resistant characteristics with the expression of CPB-resistance in a CPB endemic area under natural infestation. Twenty five clones were collected from cocoa farms in different regions of Indonesia and tested in Central Sulawesi in a randomized block design with 4 replicate blocks, each plot consisting of 4 – 6 plants propagated by side grafting. The plants' response to CPB was evaluated by assessing the harvested pods over a 14-month period for the percentage of infested beans, number of larval entry holes, and number of larval exit holes. The degree of susceptibility was determined by the proportion (%) of beans that were unextractable (see Table 6, Results). Yield performance of the tested clones was evaluated by assessing the number of pods, number of beans per pod, and the dry weight of the beans. To assess CPB-resistance, one pod per plot at different stages of maturity (3, 3.5 and 4 months) was detached and examined microscopically as described above.

4. Evaluate the genetic diversity of the tested clones based on DNA sequencing. The clones were tested along with 12 national clones and seven international clones from the International Cocoa Genebank, Trinidad (ICG, T) which served as references. The analysis was conducted using Simple Sequence Repeat (SSR) with 15 primers. The quantitative data were analyzed for variance analysis (α = 5 %), principal component analysis and canonical correlation. Molecular data were analyzed using GenAlEx. Qualitative data such as lignification intensity, were observed and recorded.

Objective 3: To demonstrate integrated management of cocoa pod borer and diseases, including the use of locally developed control measures such as pod sleeving and regular complete harvesting.

Training days for local farmers were conducted by Australian and Java-based Project staff using the five clone test sites as focal points. A demonstration of different levels of management was established in BoneBone, North Luwu but farmers requested only the highest management option. A similar demonstration was established in Pinrang. This was used for farmer training activities and by students from Hasanuddin University, Makassar for their final research projects. A trial was established by BPTP Sulsel in Tongkajan, Luwu, South Sulawesi to test the effect of compost/fertiliser treatments on yield.

In Tongkojoan , Luwu a demtrial was established in 2009 with the cooperation of a local farmer group under the management of BPTP Sulsel. Trees were provided with either organic fertiliser, inorganic fertiliser (a standard applications rates), a combination of the two or left untreated (control). The organic treatment was supplied by filling trenches between tree rows with pod and pruning waste supplemented by a mix of microbial promoters to increase the rate of decomposition. The number of pods harvested, dry bean weight, and CPB/PPR incidence (VSD was not severe in this area) were recorded in 2010 and 2011.

At two locations in Papua and West Papua, plots to demonstrate varying levels of material and labour management inputs were established. Farmers participated in preparing the sites. The farmers in Alang-Alang, Papua were resettled Wamena people and those in Mandopi, West Papua belonged to the Arfak tribe. Over-heavy shade required extensive pruning at both sites which the farmers did with enthusiasm. Each site had four plots including a control with the normal low level of management. The first treatment included pruning, sanitation and regular harvesting, a second added fertilizer and recycling farm waste as compost or in trenches with promoting microorganisms, and the third added targeted pesticide use to the treatments applied in the first two plots. Training of farmers and local extension staff was incorporated into the establishment of demplots. The plots consisted of 25 trees colour-coded with paint to indicate the treatment. In Mandopi, University of Papua staff maintained the site and it was also used by students for field research projects. In Alang Alang the demplots were initially maintained by BPTP Papua staff but transport costs and local troubles impeded this.

In Jayapura in February 2010 a five day training course was conducted by ACIAR/Mars Inc. with theoretical and practical components. For the latter the Mars nursery/field centre and ACIAR project demonstration sites in Alang Alang were used. The participants included local extension staff, university staff from West Papua. Three staff from the Cocoa and Coconut Institute in Papua New Guinea participated in the workshop as trainers.

Objective 4 (modified). To assess uptake by farmers of improved cocoa management employing new cultivars and integrated pest/disease control methods.

A farmer survey was designed (see below) to assess pre-existing farm management practices in three target Districts across three provinces: Polewali-Mandar in West Sulawesi, Luwu Utara in South Sulawesi, and Kolaka Utara in Southeast Sulawesi. 200 farmers were randomly surveyed in each District, with field interviews completed in Polewali-Mandar and Luwu Utara. The field data were fed into an electronic database for subsequent analysis. In addition to the farmer survey, one lead farmer in each District was selected to maintain a ‘Farmer Diary’ of their daily farm activities. These diaries commenced in October 2008 continued for 12 months.

A questionnaire used by BPTP Sulsel for the socioeconomic survey in Objective 4:

Questionnaire

BPTP Sulawesi Selatan - ACIAR Project No. CP-2005-074

Cocoa Technology Adoption Survey

Interviewer: ……………………………. Tanggal:…………………….……………….

Lokasi / Desa…………………Kec.……..…………………Kab…………................

A. Kondisi kebun

Q1. Jumlah lokasi kebun …………

Q2. Jarak kebun dari rumah: Kebun 1…………. Kebun 2………. Kebun 3.………

Q3. Luas kebun……………………… Jumlah Pohon…………………………………

B. Lahan

Q4. Lokasi kebun 1 (dibeli / warisan orang tua / buka sendiri dari hutan)

Lokasi kebun 2 (dibeli / warisan orang tua / buka sendiri dari hutan)

Lokasi kebun 3 (dibeli / warisan orang tua / buka sendiri dari hutan)

Q5. Kegunaan lahan kebun sebelum ditanami kakao:……………………………

………………………………………………………………………………………………

Q6. Status tanah: 1) Sertifikat BPN; 2) tanah Negara / kawasan hutan; 3) Surat keterangan Tanah (SKT) dari camat / desa; 4) lainnya………………………………

Q7. Nilai kebun: Rp ……. juta / ha (produktif), Rp……. juta / ha (tidak produktif)

Q8. Ketersedian lahan: (Sudah sempit / masih ada)

Q9. Catatan mengena proses pembukaan lahan baru

……………………………………………………………………………………………….…
……………..……………………………………………………………

C. Rehabilitasi kebun

Q10. Tahun berapa kebun kakao dibuka………… Rata2 umur pohon ….…….

Tanaman paling muda ……………….. Tanaman paling tua …………………....

Q11. Pernah melakukan rehabilitasi? (ya / tidak)

Kalau ya, Sambung samping ……. %: Penanaman baru …….%

Sumber entries: ……………………………………………………………………….

Jenis Klon: …..……………………………………………………………………………

Q12. Kebun ditinggal dan pindah lokasi? (Ya / tidak)

D. Kondisi kebun

Q13. Pemangkasan: (Ya / tidak). *Menurut observasi - Kurang 1 2 3 baik*

Q14.Panen Sering: (Ya / tidak). Setiap ……. Hari

Q15. Pembersihan buah yang busuk (ya/tidak)

Q16. Sanitasi: (Ya / tidak). Sanitasi apa? …………………………………………

Pupuk	**Volume / aplikasi**	**Frekuensi**	**Harga**	**HOK / Aplikasi**
UREA				
KCL				
SP-36				
NPK……………				
Pupuk kandang				
Lain………………				

Q17. Sumber pupuk kandang (kalau ada) …………………………………………….

Q18. Jumlah ternak: Sapi….. Kambing ….. Babi …... Ayam ……kerbau…..ikan…

Q19. Masalah hama / penyakit di kebun. Urutkan sesuai tingkat permasalahan.

Masalah	**Obat**	**Jumlah**	**Frekuensi**	**Harga**	**HOK**

Q20. Pengendalian gulma / rumput di kebun:

Obat	**Freq**	**Jumlah**	**Harga**	**HOK**
Penyiangan				

Q21. Pelatihan yang pernah diikuti:

(Disbun SLPHT / ACDI-VOCA / CSP / Syngenta / AMARTA / BPTP / …………)

Q22. Program penyuluhan yang sedang berjalan:

(Disbun SLPHT / ACDI-VOCA / CSP / Syngenta / AMARTA / BPTP / ………….)

E. Produksi Kebun dan Pendapatan

Komoditas	Produksi	Harga	Berapa hari kering
kakao			

F. Tenaga kerja

Q23. Bayar orang untuk kerja di kebun? (ya / tidak). …………. HOK / bulan

Kalau ya, kegiatan apa? …………………………………………………………

Q24. Terima upah di kebun orang lain? (ya / tidak) ………… Hari / bulan

Kalau ya, kegiatan apa? …………………………………………………………

Q25. Upah tenaga kerja (TK) lokal……..……Rps/hari (dikasih makan/ tidak)

Q26. Ketersediaan tenaga kerja local. (susah / banyak)

Q27. Sumber pendapatan lain yang penting

……………………………………………… / Rp ……….. / bulan

Q28. Relatif pentingnya pendapatan dari kakao?

100% / 75% / 50% / 25% dari pendapatan total keluarga

Q29. Lain2 (system bagi-hasil, borong, gadai, kerja kelompok)……………………
…………………………………………………..……………………………………
…………………………………………………...…………………………………..…………
…………………………..………………………..…………………………

G. Pemasaran dan keuangan

Q30. Kapan terakhir jual biji kakao?................

Berapa harga kakao terakhir? ………………..

Berapa harga tertinggi dalam setahun terakhir ini?.............................

Q31. Siapa yang membelli kakao (pengumpul / pedagang / kelompok / eksportir)

Q32. Perbedaan harga di pasar untuk biji kakao bermutu baik?.......................................

Q33. Fasillitas kredit (bank / tengkulak / kelompok / simpanan / keluarga / tidak ada)

Potongan tengkulak …………Rp / kg

Bunga ……………Rp / ………………

Q34. Anggota kelompok tani: (ya/tidak).

Q35. Manfaat dari kelompok tani:

i) Bantuan pemerintah ……. ii) Pemasaran bersama …………….

iii) Kerja kelompok ………… iv) Bisa menerima peyuluhan ………

v) Simpan-pinjam ………… vi) Pasokan saprotan ………………..

vii) Sertifikasi produk ……… viii) Menjual sembako ……………….

H. Latar Belakang Partisipan

Q36. Nama: ……………………. (LL / P) Q37. Umur ………………………………

Q38. Bahasa / Suku………………………… Q39. (Kawin / Belum) Jumlah anak…………

Q40. Pendidikan Anak

1	2	3	4	5	6	7	8	9

6 Achievements against activities and outputs/milestones

Objective 1: With farmer participation, to test cocoa clones for improved yield, quality and pest/disease resistance and to demonstrate on-farm selection and testing of clones

no.	activity	outputs/ milestones	completion date	comments
1.1	Activity 1: Select and obtain material of promising clones for demonstration trials based on results from current ACIAR project, Mars trials etc.; establish farmer groups (see Objective 4); select more local clones with putative resistance or higher quality/yield.	Clones identified for testing, in multilocation trials	July-November 2007	Useful local clones continue to be identified through farmer interactions with project staff and Mars field staff; some extremely high yielding cocoa clones have been identified and tested in this work These superior clones are readily adopted by farmers (e.g. M01 has become very popular in Sulawesi). PBC123 (now called Sulawesi 1) has become very popular because of its resistance to VSD as well as its excellent yield and quality traits
1.2	Activity 2: With farmer participation, establish small demonstration trials in each of three provinces of Sulawesi (West, South-East and South) to test promising clones and local selections.	Trials in West, South and Southeast Sulawesi established	December 2007 to March 2008	Five trials established by top-grafting selected clones are divided into four replicate blocks testing 12 clones with two standard clones (PBC 123 and M01) common to the trials. Fertiliser (NPK and/or urea) applied approx. 3X year Plants were treated with fungicides at the establishment stage (less than 1 year old); in Pinrang, some spraying is still conducted for leaf damage by insects Weed control is manual From an early stage, clones were assessed for VSD resistance in branches Two years after planting, most of the clones produced pods assessed for resistance to CPB and PPR and for productivity. Bean quality assessed from the combined collections of a number of harvests.

1.3	Activity 3: To assess the field trials for pest/disease resistance and yield and quality of cocoa.	Clone evaluation of pod bearing trees in four sites	2009 - 2012	Four of five clone trials (using topgrafted clones) with the same design and number of clones were evaluated. Pro-forma and consistent evaluation method were developed. Bone Bone site was badly impacted by pink disease . Clones assessed e.g. M01 and M04 (good bean quality but susceptible to VSD), KW617 (high yield but did poorly in some blocks), GeniJ (good yield and VSD resistance), MO5 (VSD resistance), PCK (CPB resistance, a large bean size and high fat content). Strong site differences were apparent, with yield of standard clones at Pinrang being significantly higher than at two other sites (N. Kolaka and Polman).
1.4	Activity 1(Papua variation): Selecting sites and clones for clone testing trials in Papua and West Papua.	Variation: sites identified for clone trials in Papua and West Papua Promising local cocoa trees identified	March 2010 Jan-March 2010	Clone testing trial in West Papua aimed to test a mix of ICCRI and Sulawesi selections
1.5	Activity 2 (Papua variation): Establish a clone testing trial in each of two locations in Papua (possibly near Jayapura and Manokwari) that is similar or identical in design to the trials currently underway in Sulawesi.	Trial established in West Papua to test five clones	2011	Five productive clones supplied by ICCRI and Mars Inc. sidegrafted onto mature cocoa in a demtrial in Mandopi maintained by BPTP and University of Papua staff.
1.6	Activity 3 (Papua variation): Assessment of clones in each of the trials		2011-2012	Good success rate of sidegrafts recorded but access to site restricted due to unsettled political conditions so BPTP and UNIPA had difficulty assessing clones. However, the clone material was later transferred and regrafted at the UNIPA farm.

PC = partner country, A = Australia

Objective 2: To field test a wide range of clones and the progeny of crosses between high yielding and pest/disease resistant cocoa clones to develop superior genotypes and study the nature of resistance to cocoa pod borer and VSD.

no.	activity	outputs/ milestones	completion date	comments
2.1	Activity 1: Establish a replicated progeny trial at one site in Sulawesi.	Hybrid seedlings first grown under temporary shade which was replaced with permanent shade	Hybrids planted 2008 at Padali where Disbun land was set aside for experiments	Three blocks were destroyed by fire in August 2009; shade trees and hybrids destroyed; The nursery building was badly damaged and later collapsed Hybrid testing continued in Jember, East Java where hybrid populations were closely monitored
2.2	Activity 2: Establish replicated clonal trials at one site in Sulawesi to test a wide range of clones for pest and disease resistance, yield and quality.	Top-grafted clone selections planted at Padali, Soppeng: 5 clones, 600 trees in 3 blocks Shade seedlings raised in box nursery	March 2010	Some of this collection remains but was damaged in the 2009 fire *Leucaena* sp. were planted to replace shade trees destroyed by Aug 2009 fire
2.3	Activity 3: Screen cocoa clones and hybrid progeny for pest and disease resistance, yield and quality.	Clones planted recently Hybrids: further crosses made in Jember for initial screening in East Java	Dec, 2011	Evaluation was conducted in Jember
2.4	Activity 4: Study the nature of CPB and VSD resistance (Ph.D. project).	Ir Agung W. Susilo's PhD thesis accepted; closed and open examinations passed in April 2010 at Gadjah Mada University, Central Java.	April 2010	The topic was modified to assessment of pod characteristics (and genetic background) in relation to CPB resistance Copies of the thesis, title in English: "Study on the characteristics of cocoa resistance to cocoa pod borer (*Conopomorpha cramerella* Snell.)" provided for La Trobe University, University of Sydney and Mars Inc.

PC = partner country, A = Australia

Objective 3: To demonstrate integrated management of cocoa pod borer and diseases, including the use of locally developed control measures such as pod sleeving and regular complete harvesting.

no.	activity	outputs/ milestones	completion date	comments
3.1	Activity 1: Establish demonstration plots of management methods on farms using cultural management methods, trunk injection of phosphonate, fertilisation and sanitation.	Management trial (two treatments and 4 replicates) established in Pinrang Phosphonate demonstration by bark painting for PPR control in Bone-Bone Skripsi study evaluating symptom development in VSD-infected cocoa clones in Pinrang Trial established with farmers in Luwu to test the effect and costs-benefits of compost/ fertiliser application on 800 2 year-old BR25 sidegrafts; monthly evaluation by BPTP	January 2010 May 2010 2011 2012	Two treatments: control and management by pruning (cocoa and shade trees), sanitation (frequent complete harvesting and disposal of all damaged and healthy pods) and fertiliser application. Evaluated as part of Skripsi (Third year) project by student at UNHAS A Luwu farmer group (at Tongkajang) has been working with Rainforest Alliance on certification for sustainable cocoa production; Mars Inc. currently conducting training on certification of sustainable cocoa,and have implemented composting program in Luwu BPTP and Mars Inc. are working closely with farmer groups including the Tongkajang group, Luwu; Mars Inc. and government institutions, especially BPTP and Dinas Perkebunan, are cooperating closely in cocoa producing regions such as Luwu (and also as members of the Cocoa Sustainability Partnership e.g. in Padali, Soppeng, see 2.1 above)
3.2	Activity 2: Work with farmers to establish demonstration/trial plots on their own farms.	Farmers establish plots with better management and improved clones in Lambandia, South-East Sulawesi. SIdegrafting of clonal material from the trials becomes widespread	August 2009	Propagation of improved clones by grafting is now widespread in Sulawesi; there has been an exponential rise in the number of nurseries and production of rootstock seedlings for grafting Some clones such as KW617 are popular with farmers putting pressure on the availability of budwood material for grafting
3.3	Activity 1 (Papua Variation):	ACIAR/Mars Training workshop	February 2010	Training on IPDM methods; different options of labour and material input for

	Consultation with farmers and local extension officers.	in Jayapura for UNIPA and BPTP staff; visiting trainers from PNG Farmer/village leaders in Papua (Wamena group) and West Papua (ArFak group) agreed to establish plots demonstrating cultural pest and disease management techniques on their farms. ;	February 2010	farmers were established in demplots near a road for greater visibility at Alang-Alang, near the Mars Cocoa Development Centre; cocoa researchers from PNG joined the workshop and helped to plan and establish the demplots with farmers, based on earlier ACIAR work in PNG 21 participants in the Jayapura workshop were awarded certificates on completion of the workshop training Composting methods were demonstrated to farmers by BRIEC staff as part of the workshop; other methods including side- and top-grafting and nursery management were demonstrated by Mars Inc staff Local Wamena transmigrant farmers attended workshop field training days; village and tribal leaders attended on the opening and closing days Village leaders in Mandopi, Manokwari (Pak Moses) and Kelompok IV, Mandopi, 100 members in total of which 30 are active farmers (farmer leader, Pak Heipan), participated in field activities in March and provided a high level of cooperation and interest in IPDM; farmer group was actively involved in establishing demplots (see below)
3.4	Activity 2 (Papua Variation): Establish demonstration plots of IPDM options on farms, depending on outcome of Activity 1, preferably with a farmer group but possibly with individual farmers. Options will include cocoa and shade management, regular and complete harvesting, fertilisation, sanitation, pod sleeving and targeted application of pesticides. This will be aligned with an IFAD program to improve quality of a range of products including cocoa.	Demtrial with varying levels of input established in Papua (Alang-Alang) and West Papua (Mandopi) International Fund for Agricultural Development (IFAD)-funded training for cocoa module conducted by UNIPA (Dr Antonius Suparno) using the Mandopi demplots; 25 IFAD-funded staff trained IFAD trainees shown compost making using Promi-method developed by BRIEC	Feb and March 2010 April 2010 May 2010	Four plots including the control (usual farmer practice) with 25 trees per plot, buffer rows included, were established Plots were established as part of the training workshop in Jayapura, Papua and the workshop for farmers and local project staff in Mandopi, West Papua Visibility and proximity to a road was ensured in both locations Higher flowering in treated plots demonstrated by a University of Papua final year student study High incidence of *Helopeltis* (Alang-Alang) and PPR (Mandopi). CPB was a severe problem in both locations. VSD incidence was low (fertile soils and sufficient rain even in dry periods perhaps play a role) Due to the distance of Alang Alang from Jayapura, vehicle and other costs, the Variation budget allocated for BPTP was insufficient for them to evaluate the Alang Alang demplot (prices are considerably higher in Papua compared to other regions of Indonesia). Therefore, BPTP Papua focused on establishment of a clone testing trial.

Objective 4: To disseminate knowledge arising from the field demonstration-trials and assess uptake by farmers of improved cocoa management employing new cultivars and integrated pest/disease control methods.

no.	activity	outputs/ milestones	completion date	comments
4.1	Establish farmer groups and identify farmer leaders willing to participate in on-farm research.	Links established with active farmer group in Luwu	October 2009	Compost/fertiliser trial established and monitored by BPTP (with Mars Inc. and Dinas Perkebunan)
		Papua/W. Papua (variation): links made with Wamena migrant government village in Papua and with an ArFak group in West Papua	Training conducted in February and March 2010	Farmers in Papua were interested to learn the cocoa management methods introduced by the workshop in February but are dependent on the directives of their tribal and village leaders; social structures play a critical role in training and development activities Farmer group (with village leader Pak Moses) in West Papua had close involvement in the training workshop and established demplots under the direction of Mars Inc. and other project staff
4.2	Undertake educational activities with farmer field schools in cooperation with Dinas Perkebunan to disseminate knowledge to a wider network of participants and foster approaches that could be adopted by farmers to test novel methods on their farms.	Farmer training days conducted by Australia- and Java-based project staff	July and November 2009	Farmer training day held in Polewali, July 2010, attended by Dinas Perkebunan, other government officers, and staff and farmers working under the Gernas program
		ACIAR monograph/ handbook “Integrated pest and disease management for sustainable cocoa production” produced in IPDM Project in PNG and translated into Bahasa Indonesia by ICCRI will be used in farmer training programs	November 2009	Copies distributed
		A field booklet on pest and diseases of cocoa (edited by ICCRI with contributions from project staff) published	February 2010	Over 200 copies distributed by ICCRI and BPTP to extension staff and farmers in Sulawesi, Java and Papua
		West Papua (Variation): two		

		Dinas Perkebunan Officers responsible for developing training programs for cocoa farmers in West Papua participated in workshop/field activities in Mandopi, West Papua; 12-14 officers will attend workshop planned for July 2010	March 2010	Dinas Perkebunan, Manokwari, responsible for the GERNAS and GERMAS programs (the latter is a long-running extension program for cocoa training established when West Papua was formed)
4.3	Conduct in-person surveys of participating farmers and others to assess (i) changes in their understanding and adoption of management strategies that could be used to overcome pest/disease and production problems, (ii) their understanding of methods of on-farm testing of new ideas, and (iii) the socio-economic benefit of the project.	A survey of 600 farm households across North Luwu, Polman and Kolaka Utara was conducted, with results entered into a statistical database (SPSS) Impacts of research and training on local farmers assessed in return visits	March 2010 2009	Socio-economic surveys completed in North Luwu and Polman and North Kolaka An analysis of these results has been completed at the University of Sydney as part of a JAF PhD study by Mr Rafiuddin Palinrungi. A draft report on ‘Institutional factors affecting the adoption of sustainable cocoa practices by Indonesian smallholders’ was prepared (in Bahasa Indonesia) in coordination with research partners at BPTP Sulsel. The introduction of the national GERNAS program in 2009 provided an opportunity for the project to engage with program design, with a policy paper produced for the government in collaboration with CSP and ASKINDO. GERNAS has had a significant impact on technology adoption amongst farmers in many areas through various input subsidies and technical support packages: the project incorporated some these impacts within the analysis conducted by the PhD study (still to be finalised)

Objective 4 (modified): To assess uptake by farmers of improved cocoa management employing new cultivars and integrated pest/disease control methods.

no.	activity	outputs/ milestones	completion date	comments
4.4	Activity 1 (Papua Variation): Conduct a detailed socio-economic household survey within one of the Districts where the trials have been established to develop insights	A household survey similar to the one conducted in Sulawesi has been adapted to local conditions in Papua and was conducted in July 2010.	2010	The survey results were analysed, although follow-up in the field was not possible due to difficulties in obtaining entry permits into Papua.

	into farm decision-making processes.			
4.5	Activity 2 (variation) Assess community perceptions towards the trials in both locations through field interviews and a small-scale survey.	Impacts of research and training on local farmers assessed	2011	Interviews were conducted with farmers in villages surrounding the clonal trial sites. There was surprisingly little awareness of the trials beyond the participating farmers, leading to the development of more active communication strategies.

7 Key results and discussion

7.1 Multi-location testing of local clones

7.1.1 Yield and bean characteristics

Clones in the five trial sites varied considerably in their performance. The clones, including standards, performed poorly in Kolaka and BoneBone - the BoneBone site was affected by flooding, pink disease and an unknown root rot which killed a number of adjacent trees. Therefore, in order to compare results from clones common to different sites the data obtained for comparative standards from the other three sites were analysed. These standards included three genotypes with known VSD-resistance (PBC123, M05 and GeniJ) and a susceptible yet productive clone, M01.Yields varied greatly among clones as indicated in Table 3 and between sites (Fig. 7). The higher yield in Pinrang was linked with higher flowering (Fig. 8). This is a clear site effect (as opposed to clonal effect) and the reason for it remains uncertain. Even though all three sites were managed by regular pruning and other appropriate cultural practices, possibly the timing or extent of pruning differed at the Pinrang site, thus accounting for the greater amount of flowering in the standard clones.

Table. 3. Yield (kg dry beans in 2011, mean, SEM) per 1000 trees for some of the clones tested at three locations in Sulawesi. Note particularly high yields in Pinrang. KW 617 yield was extremely variable (see standard error) but trees in one of the blocks were high yielding. In comparison some clones were low yielding or did not produce pods (see M05 Kolut and Ilham Polm). Location codes: Pin, Pinrang; Kolut, N. Kolaka; Polm, Polman.

Clone tested and location	Kg dry beans/2011	Std. Error
PCK Pin	1650.0	208.1
PBC123 Pin	1387.5	211.0
M04 Pin	1272.5	200.6
M01 Kolut	1142.5	277.0
M01 Pin	1042.5	223.5
GeniJ Pin	1035.0	92.1
M06 Pin	957.5	160.6
RB Pin	862.5	85.3
PBC123 Kolut	837.5	189.7
NR Kolut	582.5	85.0
M06 Kolut	510.0	77.0
KW 617 Polm	507.5	248.0
M05 Kolut	125.0	30.1
Ilham Polm	0.0	0.0

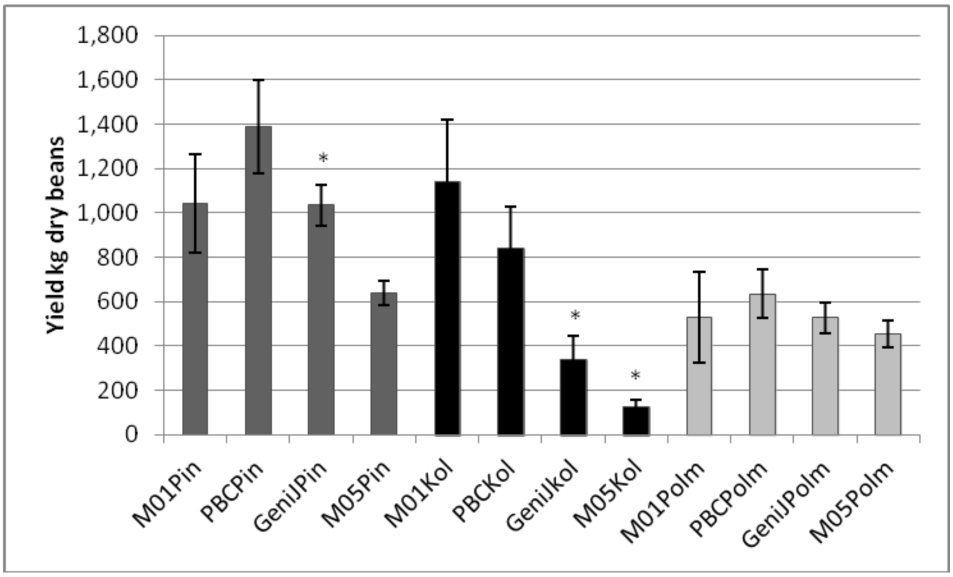

Fig 7: Yield (kg dry beans, mean, SEM) per 1000 trees in 2011 in standard clones tested in three locations in Sulawesi: Pinrang, dark grey bars; N. Kolaka, black bars; Polman, light grey bars. Note yields in GeniJ differed significantly (*p<0.05*) between Pinrang and N. Kolaka.

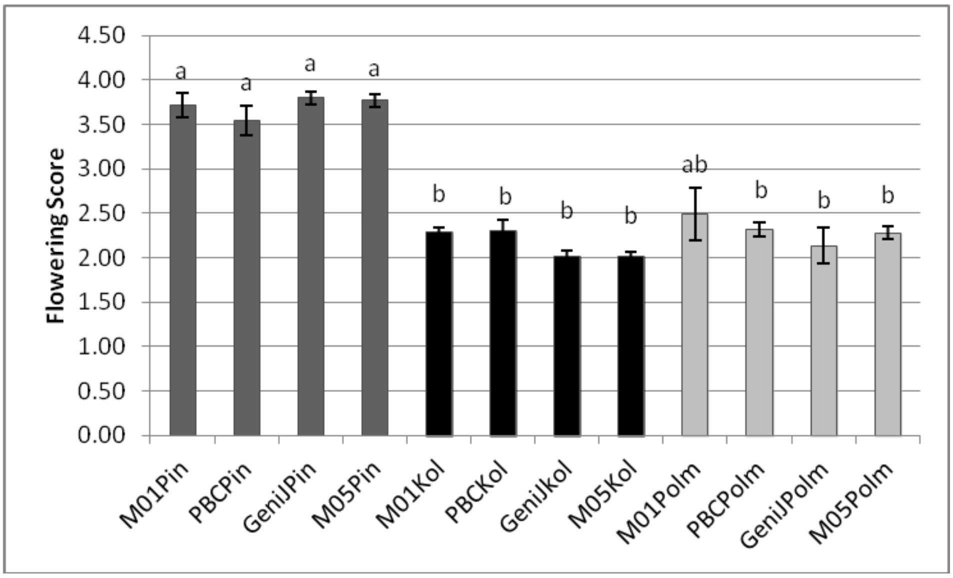

Fig 8 Flowering score (mean, SEM, scale 0-5) in standard clones tested in three locations in Sulawesi: Pinrang, dark grey bars; N. Kolaka, black bars; Polman, light grey bars. Means with the same letter are not significantly different (P<0.05).

Table 4 indicates that cocoa beans in some of the clones tested in all three sites (Pinrang, Polman and N. Kolaka) had good quality characteristics with a low bean count (number of beans per 100g) and large bean size, a high fat content (exceeding 50%) and a low shell content . It is uncertain whether the location affected bean characteristics but it is evident that the bean size of the standard M01 was slightly smaller in Pinrang than in the other two sites. Better quality clones such as M01 and M04 (both selections from Luwu) were also VSD susceptible in the trials, while more VSD-resistant clones such as PBC123 and M05 had a smaller bean size and lower fat content (Table 4).

Table 4. Bean characteristics of some of the clones tested in Sulawesi. Clones are ranked according to bean size from highest to lowest. VSD resistant (VSDr) clones including M05 and PBC123 had smaller beans and a lower fat content than M04 and M01 which were VSD susceptible (VSDs) in the trials. Moderate quality was found in the beans produced by GeniJ but this clone was particularly susceptible to CPB (CPBs).

Site	Clone	Bean Count	Moisture	Bean Size	Fat Content	Shell	Other
		(no. beans/100g)	(%)	(g)	(%)	(%)	
Pinrang	M.04	56.00	7.87	1.79	51.60	10.59	VSDs
North Kolaka	M.01	59.00	8.67	1.69	48.50	11.47	VSDs
Polman	KW 516	61.00	-	1.65	49.40	27.40	
Polman	M01	62.00	-	1,.60	48.20	22.11	VSDs
Pinrang	RB	62.33	7.26	1.60	50.70	11.37	
North Kolaka	Pnb Red	63.00	-	1.59	49.30	12.17	
Polman	KW617	65.00	-	1.55	48.50	21.17	
Pinrang	TR.01	64.33	7.69	1.55	49.70	13.91	
Pinrang	M.01	67.00	8.65	1.49	48.90	14.59	VSDs
Pinrang	Gen.J	67.00	8.26	1.49	49.10	11.94	VSDr CPBs
Pinrang	Pnb.Red	69.00	8.52	1.45	50.20	15.87	
North Kolaka	Geni.J	71.00	10.69	1.41	48.90	15.46	VSDr CPBs
North Kolaka	M.05	74.00	8.99	1.35	47.90	15.82	VSDr
Polman	KW523	95.00	-	1.06	48.90	20.36	
Pinrang	PBC123	95.67	8.68	1.05	47.90	14.71	VSDr
North Kolaka	PBC123	104.00	10.92	0.96	47.70	14.96	VSDr
Pinrang	M.05	110.00	-	0.91	48.00	20.25	VSDr

7.1.2 Pest and disease severity

Figures 9 and 10 indicate that CPB severity did not differ significantly between sites but that the standard GeniJ was susceptible regardless of the site. Table 5 also indicates a high number of 'resistant' clones in Pinrang. This is likely to be the effect of higher yield in Pinrang compared to other sites and therefore a dilution effect. The higher yield appears to be linked to a higher average number of flowers produced (see Fig. 8) and not a lower CPB infestation rate. Therefore, the 'resistance' to CPB is probably an outcome of limited egg laying by the CPB population in peak harvest times exposed to a large number of available pods. However, this explanation does not apply to Husbitori, which was the most resistant of the clones in all three trials. Husbitori produced few pods due to its high susceptibility to VSD. Therefore the apparent CPB resistance of this clone (Table 5) is likely to be constitutive to the pods and not an effect of dilution due to heavy pod production. This clone could be examined further for CPB resistance. It has promising bean characteristics but due to its poor yield caused by of its susceptibility to VSD has not been popular among the local farmers.

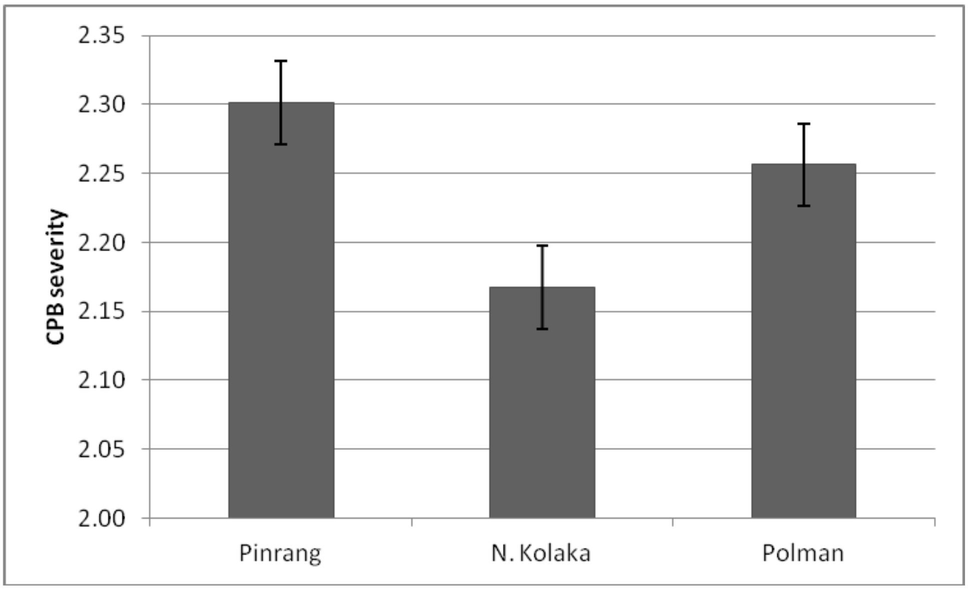

Fig 9 Average CPB severity (mean, SEM, scale 0-3) in four standard clones tested at three locations in Sulawesi. Differences between sites were not significant

Table 5. CPB severity (scale 0-3) ranked from low to high in some of the more resistant and more susceptible clones tested in three locations in Sulawesi. A large proportion of the clones with low CPB severity were located in Pinrang, indicating a site effect. However, GeniJ was the most susceptible of the clones, regardless of the location at which it was tested. Location codes: Pin, Pinrang; Kolut, N. Kolaka; Polm, Polman.

Clone	CPB severity	Std. Error
Husbitori Polm	1.31	0.14
PCK Pin	1.73	0.04
Tr01 Pin	1.79	0.03
BR25 Polm	1.80	0.14
M04 Pin	1.85	0.11
PBC123 Pin	1.89	0.09
M06 Pin	1.99	0.11
RB Pin	2.19	0.02
KW523 Polm	2.34	0.22
ICCRI 04 Pin	2.36	0.10
M01 Polm	2.30	0.20
DRC15 Pin	2.51	0.11
Genij Pin	2.67	0.09
Genij Kolut	2.61	0.15
Genij Polm	2.62	0.17

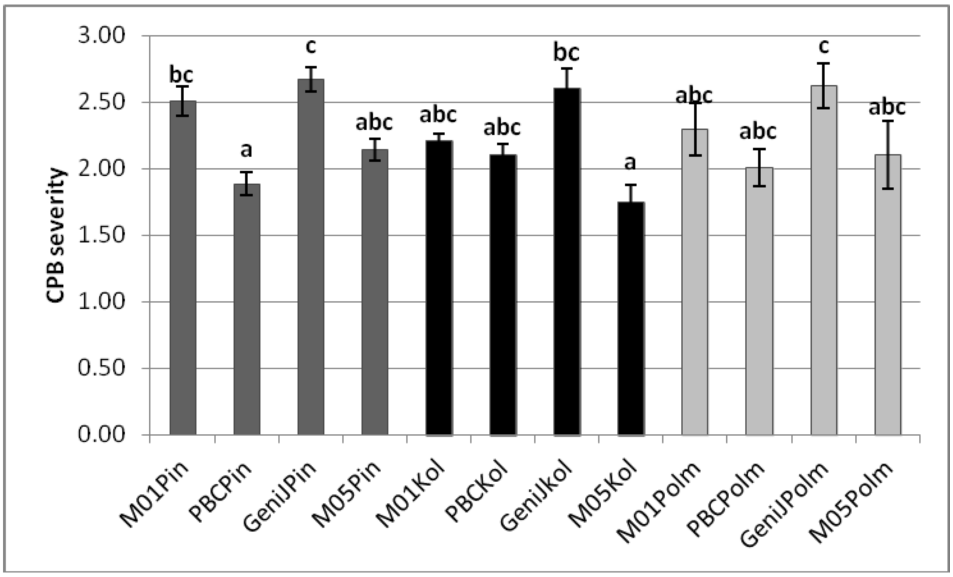

Fig 10 CPB severity (scale 0-3) in standard clones tested in three locations in Sulawesi: Pinrang, dark grey bars; N. Kolaka, black bars; Polman, light grey bars. Note the higher CPB susceptibility of Geni J in all of the locations. Means with the same letters are not significantly different (P<0.05).

Both the intensity of VSD and PPR were shown to be dependent on the site in which the standard clones were grown (Fig 11, 12, 14, 15). In the standard clones, VSD intensity was signficantly lower in N. Kolaka (Fig. 11), while PPR intensity was lower in Polman than the other two locations (Fig. 14). PPR intensity did not differ between clones but VSD resistance was confirmed in PBC123, M05 and GeniJ (see Fig 12). Figure 13 shows that VSD increased from 2010 to 2011 in Polman presumably due to high sporulation caused by the particularly wet conditions of 2010 (Fig 13) but that the resistance of PBC123 was maintained in relation to the more susceptible BR25.

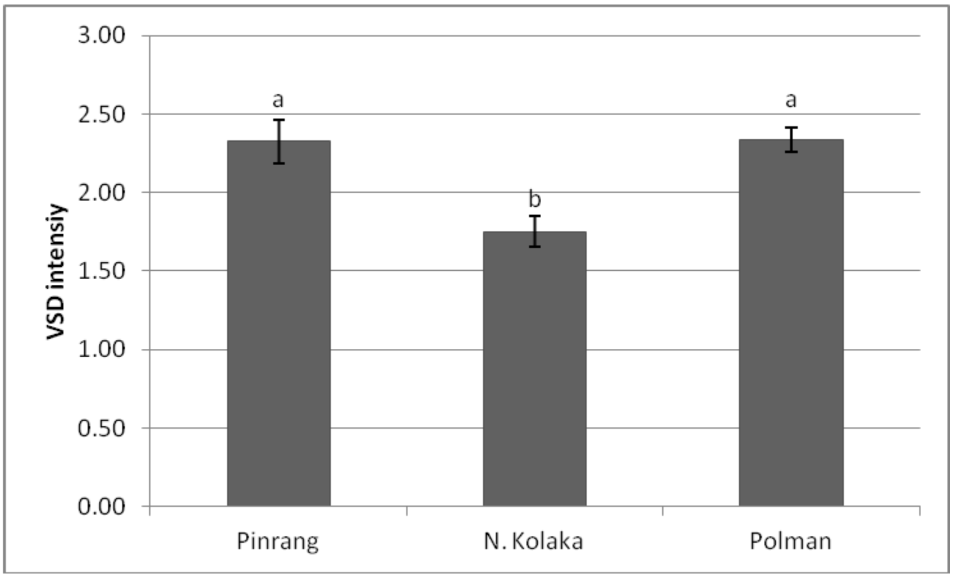

Fig 11 Mean VSD intensity (SEM, scale 0-3) in four standard clones tested at three locations in Sulawesi. Means with the same letter are not significantly different (P<0.05).

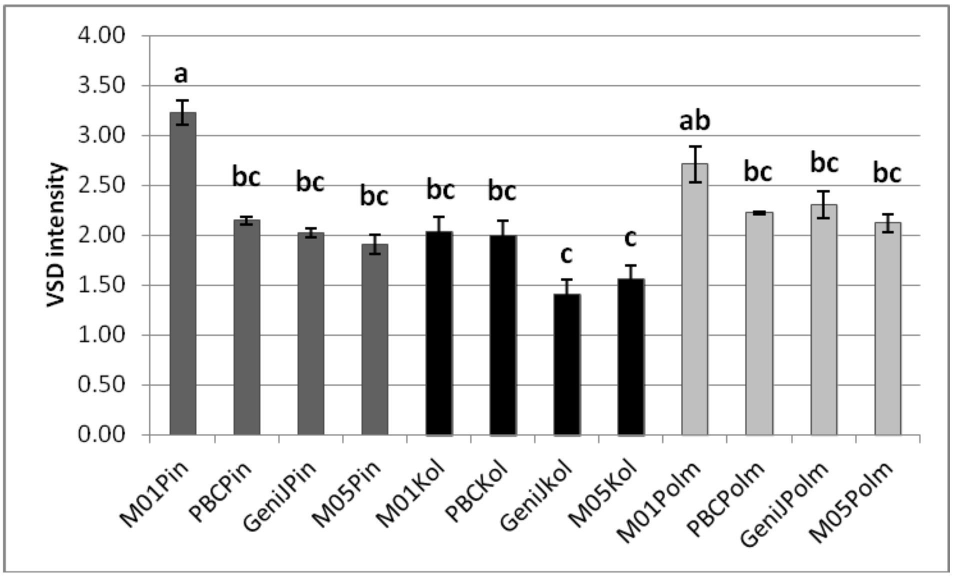

Fig 12 Mean VSD intensity (SEM, scale 0-3) in standard clones tested in three locations in Sulawesi: Pinrang, dark grey bars; N. Kolaka, black bars; Polman, light grey bars. Means with the same letters are not significantly different (P<0.05).

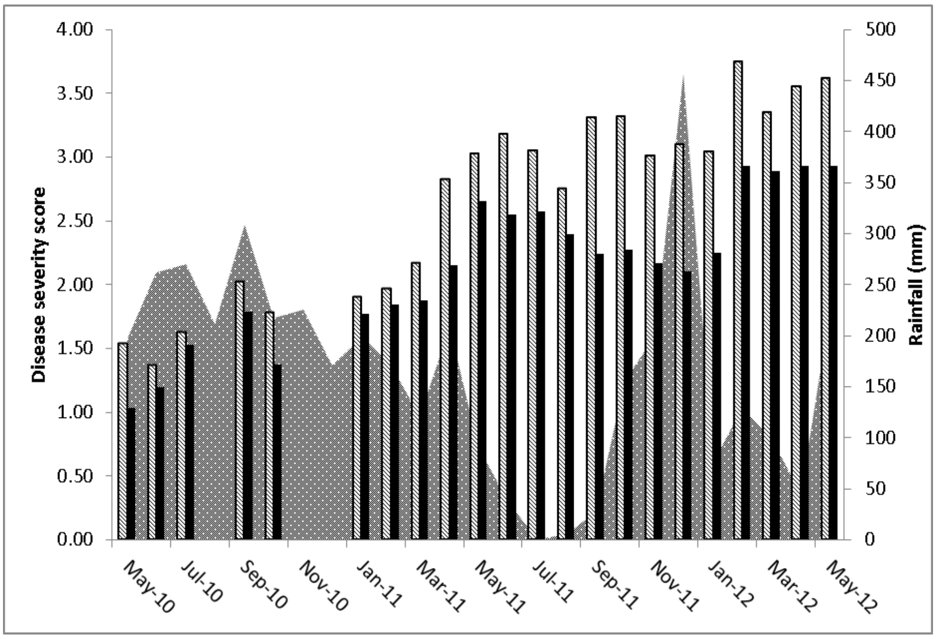

Fig.13 Mean VSD severity (scale 0-3) in PBC123 (black bars) and BR25 (grey bars) in the clone trial in Polman from 2010 to 2011. The monthly rainfall (shaded area, right axis) was higher than usual in the dry season of 2010. Even though VSD severity increased in both clones during this period, a lower severity was maintained in PBC123 indicating its greater resistance.

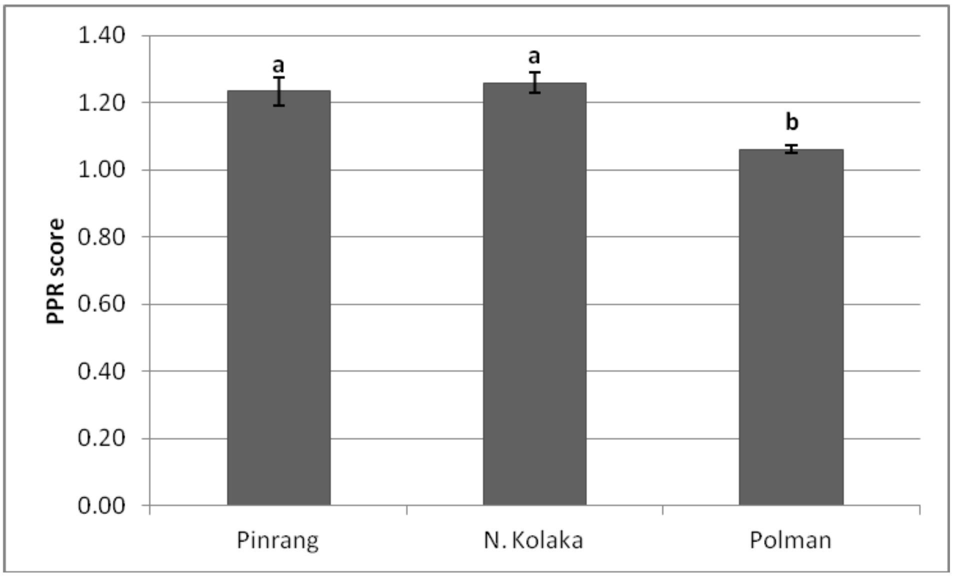

Fig 14. Mean (SEM) PPR intensity (scale 0-3) scored in three locations for the common standard clones.

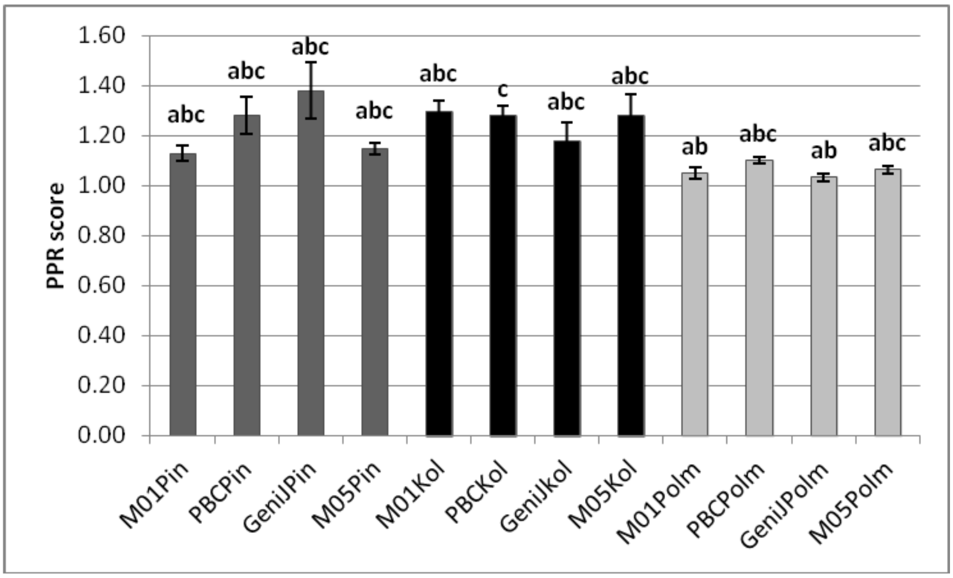

Fig 15. Mean (SEM) PPR intensity (scale 0-3) in standard clones tested in three locations in Sulawesi: Pinrang, dark grey bars; N. Kolaka, black bars; Polman, light grey bars. Means with the same letters are not significantly different (P<0.05).

Objective 2: To field test a wide range of clones and the progeny of crosses between high yielding and pest/disease resistant cocoa clones to develop superior genotypes and study the nature of resistance to cocoa pod borer and VSD.

7.1.3 Pod characteristics related to cocoa pod borer resistance

A study of pod characteristics related to cocoa pod borer (CPB, *Conopomorpha cramerella* Snell.) resistance was carried out to identify criteria for selection. An initial study was performed to characterise physical and chemical characteristics in the cocoa pods of CPB resistant genotypes by microscopic observation of trichomes, tannin granules and lignification of the sclerotic layer. The CPB-resistant clone KW 514 and the moderately resistant clone KW 411 had higher values of trichome density and a higher frequency of tannin granules than the susceptible clone RCC 72. However, no difference between resistant and susceptible genotypes was found for the concentration of tannin, glucose and protein compounds in the placental tissue. A higher trichome density and density of tannin granules was correlated with a low number of entry holes. Tannin granules may suppress the passage of larvae through the mesocarp probably due to a toxic effect. A more compact lignified layer was observed in the two most resistant clones compared to the moderately resistant and susceptible clones. Trichome density and tannin granule density were found to decrease as the pod matured, while the lignification of the sclerotic layer increased. This indicates that mechanisms of CPB resistance could differ with pod age.

Fig. 16. Sulawesi 3 (KW 570 in the ICCRI collection, selected in Soppeng with farmer Aryadi and later named ARDACIAR10). It was released by the GOI in 2012 following testing for CPB resistance, productivity and quality. The clone also has moderate VSD resistance.

Microscopic studies of naturally formed channels in the sclerotic layer indicated differences occurred in channel density between the resistant and susceptible genotypes. Comparisons were also made of sclerotic layer thickness and hardness and chemical characteristics in the different pod layers. The CPB-resistant clones ARDACIAR 10 (farmer selection Aryadi 2 from ACIAR Project CP/2000/102, see Fig. 16) and KW 514 had more lignin in the sclerotic layer than KW 411 and RCC 72.

7.1.4 Field studies of CPB resistance

Further studies of the relationship of pod characteristics associated with resistance were performed with 25 clones (Table 6). The plants' response to CPB infestation was evaluated in the field in Central Sulawesi over a 14 month-period. A positive correlation was found between the percentage of infested beans and the number of exit holes ($r = 0.62^{*}$). The number of exit holes was positively correlated with the exit/entry hole ratio ($r = 0.59^{*}$), and the ratio was negatively correlated with the number of entry holes ($r = -0.51^{*}$) and with the number of entry holes penetrating the sclerotic layer ($r = -0.46^{*}$). This result indicated that the CPB damage was directly affected by the number of living larvae inside the pod, and indirectly related to the number of larvae that successfully entered the pod. Resistance was positively correlated with the thickness of the sclerotic layer between primary furrows at different stages of pod maturity. The thickness of the sclerotic layer was positively associated with the number of entry holes and the number of entry holes through the sclerotic layer, but negatively correlated with the exit/entry hole ratio.

The lignification process forming the sclerotic layer is most likely to be a part of the resistance mechanism. The thickness of the sclerotic layer could be used as a quantitative measurement of lignification. In particular, the lignification of the sclerotic layer can be used as an indirect criterion for selection using the thickness between primary furrows. Differences were observed among the selected resistant clones of KW 570 (ARDACIAR 10), KW 566 (Paba/V/81L/1) and KW 397 (Na 33) as compared to the susceptible and very susceptible clones of KW 48 (ICCRI 04), KW 516 (PABA/VIII/78B/2), and KW 564 (PABA/IX/90O/2). Histological analysis of the lignified tissue showed that more cells had differentiated into woody tissue in the sclerotic layer of resistant clones, suggesting an enhanced physical barrier to larvae movement occurs in this layer. The results suggest that the lignified layer particularly obstructed the emergence of the larger, last-instar larvae. The thickness of the sclerotic layer between primary furrows at 3, 3.5 and 4 months of pod age showed a higher canonical correlation coefficient than at other ages. Resistant clones had consistently more compact lignified tissues than susceptible clones. High values of broad sense of heritability of the degree of lignification were demonstrated in the resistant and moderately resistant genotypes used in the study i.e. 0.75, 0.89 and 0.92 for KW 570 (ARDACIAR 10), KW 566 (Paba/V/81L/1) and KW 397 (Na 33), respectively.

7.1.5 Genetic typing of CPB resistant clones

The selected resistant clones were shown to be genetically different based on DNA fingerprinting analyses, belonging to either Trinitario or Forastero groups. DNA finger printing analysis indicated high genetic variation for the tested clones as shown by the number of alleles, observed heterozygosity (Ho) and expected heterozygosity (He) of loci. For the tested clones, 98 alleles (6.53 per locus), with an Ho of 0.60 and He of 0.71 were detected, which were equal to or higher than the international clones (95 alleles (6.33 per locus), Ho 0.49, and He 0.74). A similar analysis of the Refractario collection from Ecuador showed a lower Ho of 0.55 (Zhang *et al*., 2008), and of the Forastero collection from Brazil showed an even lower Ho of 0.35 (Sereno *et al*., 2006). The tested clones were grouped into two genetic backgrounds refered to as DR1, DR2 and DR 38 of Trinitario and IMC 67 of Forastero. The resistant clones i.e. KW 566 (Paba/V/81L/1), KW

570 (ARDACIAR 10) and KW 397 (Na 33) were clustered in a different group that indicated a somewhat different genetic background. In a further breeding program, these genetic parameters will be used as criteria to produce the best crosses. Data on genetic distance and the heterozygosity level among the tested clones will facilitate improved crossing in breeding programs for CPB resistance.

Table 6. Variables (means) related to CPB resistance in cocoa clones tested in Central Sulawesi The clones' response to CPB were grouped as resistant (R), moderately resistant (MR), moderately susceptible (MS), susceptible (S) and highly susceptible (HS). Numbers within a column followed by the same letter are not significantly different (Duncan's Multiple Range Test, α=5%)

No.	Clone	Unextractable beans %	No.of entry holes	No.entry holes via sclerotic l.	No. exit holes	Exit/entry hole ratio
1.	KPC01	64.26 MS	30.78 a	22.89 ab	5.36 abcdef	0.21 def
2.	KPC02	76.95 S	17.68 bcde	12.77 cdef	7.04 a	0.51 ab
3.	PBC123	72.97 S	22.52 abcd	16.36 abcd	5.51 abcde	0.26 cdef
4.	BR25	66.16 MS	14.21 bcde	10.49 cdef	7.00 a	0.49 ab
5.	Bal209	69.45 S	25.13 abc	18.73 abc	2.38 fg	0.09 ef
6.	ARDACIAR25	63.01 MS	12.87 de	8.03 def	3.38 bcdefg	0.26 cdef
7.	Toli-toli	60.92 MS	19.9 abcde	14.12 cdef	5.51 abcde	0.30 bcde
8.	Nob1	67.74 MS	18.38 bcde	14.45 cdef	4.41 abcdef	0.26 cdef
9.	Nob3	66.50 MS	31.01 a	24.22 a	2.81 defg	0.09 f
10.	ARDACIAR10	35.78 R	11.44 de	6.69 ef	2.47 efg	0.22 def
11.	Paba/VIII78B2	83.19 HS	25.90 ab	18.72 abc	6.41 ab	0.25 cdef
12.	ICCRI03	48.37 MR	10.55 de	7.80 def	2.81 defg	0.31 bcd
13.	Pengawu	62.95 MS	17.95 bcde	13.55 cdef	3.43 bcdefg	0.19 def
14.	Na32	62.43 MS	14.65 bcde	11.19 cdef	4.71 abcdef	0.32 bcd
15.	Na33	40.29 R	10.21 e	6.93 ef	1.03 g	0.13 def
16.	HF3	65.20 MS	14.35 bcde	8.56 def	3.26 cdefg	0.22 def
17.	HF2	64.74 MS	15.82 bcde	11.44 cdef	5.01 abcdef	0.33 bcd
18.	Pound7	69.07 S	20.1 abcde	15.18 cdef	2.73 defg	0.25 cdef
19.	KKM22	51.01 MS	13.47 cde	7.82 def	5.65 abcd	0.45 abc
20.	ICCRI04	75.50 S	10.85 de	8.06 def	5.22 abcdef	0.48 ab
21.	Paba/V/81L/1	42.12 R	25.80 ab	15.22 bcde	2.55 efg	0.09 f
22.	Paba/IX/90O/2	91.72 HS	11.09 de	9.52 def	5.88 abc	0.55 a
23.	ARDACIAR26	44.62 MR	11.71 de	6.41 f	3.33 cdefg	0.33 bcd
24.	Sausu Piore	62.02 MS	19.7 abcde	13.03 cdef	3.97 bcdefg	0.20 def
25.	Paba/I/Pbrk	53.41 MR	21.5abcde	13.41 cdef	3.64 bcdefg	0.16 def

7.1.6 Screening clones and hybrid progeny for VSD resistance

Cocoa clones (including international clones and clones of hybrid progeny) were screened for VSD resistance in the ICCRI research station, Kaliwining, Jember (Table 7). Twenty three clones were tested for VSD resistance using a score for VSD damage from 1 (low damage, little or no effect on yield) to 6 (high level of damage to branches, dieback and significant reduction in yield). The clones tested included selections from hybrid populations and introduced clones from Reading University (supported by the previous ACIAR project CP/2000/102). The results indicated that the response to VSD varied from highly susceptible to resistant among the tested clones. Some of the introduced clones (RU code) indicated potential VSD resistance. The selected genotypes from hybrid progenies varied in resistance (Table 7). For example, selections from progeny of PBC123 (VSD resistant) and TSH 858 (VSD susceptible) ranged from susceptible to resistant. The most resistant of the genotypes tested was the Malaysian clone, PBC123, already known for its durable VSD resistance and now planted widely in Sulawesi as Sulawesi 1. KW 617, a hybrid of TSH 858 and PBC123 (Sulawesi 1), was resistant in this trial. KW617 was also tested in the clone trial in Polman (see above, Section 8.1) where it was moderately resistant to VSD. Resistance in the Kaliwining trial was also detected in ICCRI 07 and Sulawesi 03 (which is also resistant to CPB) – see Table 7.

The hybrid progeny of crosses between three clones used as either the male or female parent were screened for VSD damage (Table 8). Differences in susceptibility were obtained between hybrids obtained from crosses of different clones (so that KEE2 x TSH858 hybrids were more susceptible than other hybrids). The sex of the parent in the crosses between these three clones did not have a significant effect (Table 8). However, Table 9 indicates that the sex of the parent affected the relative VSD susceptibility of progeny obtained between ARDACIAR 10 (Aryadi 2) and ICCRI 03 with a higher number of progeny in category 6 (the highest level of VSD damage) where the maternal parent was ICCRI 03. KW162 (PBC123) is well known for its durable resistance to VSD, having been selected in a rigorous breeding program during severe VSD epidemics in Malaysia (Table 7). The results in Table 8 suggest that in the crosses where this clone was a parent (whether acting as the male or female parent) the progeny were resistant. The data in Table 9 also indicate a high resistance in progeny of the PBC123/KEE2 cross since a lower number of progeny resulting from this cross occurred in the higher categories (4, 5 and 6) compared to lower categories of VSD damage.

Table 7. Evaluation of some cocoa genotypes to VSD infection in ICCRI's experimental station in Kaliwining, Jember. Trees were scored from 1 (little damage, no effect on yield) to 6 (high level of damage, dieback in some branches and significant reduction in yield)

No.	Genotype	Mean score	Resistance class
1.	NIC 7	5,50 A	Highly susceptible
2.	Sulawesi 1 (PBC123)	1,93 E	Resistant
3.	RU I - SCA 11	5,17 A	Highly susceptible
4.	RU I - SPA 9	3,23 C	Moderately susceptible
5.	RU I - BORNE 7 A2	3,00 D	Moderately susceptible
6.	RU I - KER 3	3,13 D	Moderately susceptible
7.	RU I -BORNE 7 A6	2,60 D	Moderately resistant
8.	RU I - EQ X 3360-3	3,87 B	Susceptible
9.	ICCRI 07	2,02 E	Resistant
10.	Sulawesi 3 (Aryadi 2)	2,18 E	Resistant
11.	TSH858 x PBC123	1,67 E	Resistant
12.	PBC123xTSH858	2,97 D	Moderately resistant
13.	KEE2 x NIC7	5,13 A	Highly susceptible
14.	Prop.ICS 60	6,00 A	Highly susceptible
15.	TSH858 x PBC123	4,62 B	Susceptible
16.	TSH858 x PBC123	5,25 A	Highly susceptible
17.	TSH858 x PBC123	4,37 B	Susceptible
18.	TSH858 x PBC123	4,20 B	Susceptible
19.	KW163 x KEE2	2,43 D	Moderately resistant
20.	TSH858 x NIC7	3,25 C	Moderately susceptible
21.	TSH858 x PBC123	3,92 B	Susceptible
22.	TSH858 x ICS13	4,03 B	Susceptible
23.	RU III - CCN .51	3,67 C	Moderately susceptible

Table 8. The mean score of VSD damage to hybrids of three parental clones as male and female. VSD severity was scored using a scale from 1-6 (see Methodology).

Female	Male			Mean
	TSH 858	KW 162	KEE 2	
TSH 858		2.6	3.7	3.2
KW 162	2.5		2.7	2.6
KEE 2	4.0	2.5		3.3
Mean	3.3	2.6	3.2	

Table 9. The number of trees (with percent of the total shown in brackets) per category of VSD damage evaluated in Kaliwining Experimental Station, Jember. The progeny of reverse male/female cross between ARDACIAR 10 (or Aryadi2) and ICCRI03 were included in the assessment.

Hybrid	Score (category) of VSD damage						Total no. trees
	1	2	3	4	5	6	
ARDACIAR 10 XICCRI 03	24 (39.3)	9 (14.8)	11 (18.0)	3 (4.9)	8 (13.1)	6 (9.8)	**61**
KEE 2 X PBC123	32 (36.4)	23 (26.1)	14 (15.9)	6 (6.8)	4 (4.5)	9 (10.2)	**88**
BR25 X ARDACIAR 10	16 (12.8)	18 (14.4)	20 (16.0)	18 (14.4)	11 (8.8)	42 (33.6)	**125**
ICCRI 03 X ARDACIAR 10	33 (12.3)	60 (22.4)	56 (20.9)	38 (14.2)	28 (10.4)	53 (19.8)	**268**
ARDACIAR 10 X KKM 22	3 (2.1)	16 (11.3)	30 (21.3)	29 (20.6)	24 (17.0)	39 (27.7)	**141**

Objective 3: To demonstrate integrated management of cocoa pod borer and diseases, including the use of locally developed control measures such as pod sleeving and regular complete harvesting.

In Pinrang student studies of the demonstration sites indicated a greater number of flowers produced in the treated plots compared to the unmanaged control plots. This was similar to the finding of a University of Papua student in Mandopi, West Papua who found that the pruning treatment stimulated flowering but no significant difference was found between the plot managed by pruning and sanitation only and the other treatments (which included compost application). Both demonstration sites in Papua and West Papua were affected by local unrest related to local government elections and access became restricted. Presently activities under a new project continue in West Papua in Pravhi, nearby Manokwari and with local farmers in Oransbaru. The project included training days with the five Sulawesi clone tests as focal points, farmer and extension staff training in Papua and West Papua (see Methodology). Practical manuals for farmers were produced under the project (one as a translation of a manual produced in PNG by ASEM/2003/015). The trial established in Tongkajan demonstrated a significantly higher yield in the combined compost/fertiliser treatment compared to the control and compost or fertiliser only but no significant difference was discerned between the other treatments. One explanation for this might be that the control trees had been previously been treated with compost and, therefore, the soil had a greater amount of organic matter than soils in neighbouring farms.

A demtrial was established In Luwu, Sulawesi to test the effect of organic, inorganic and combined treatments on yield and pest/diseases. No effect of soil amendment on yield was apparent: Figure 17 shows yields for 2011.

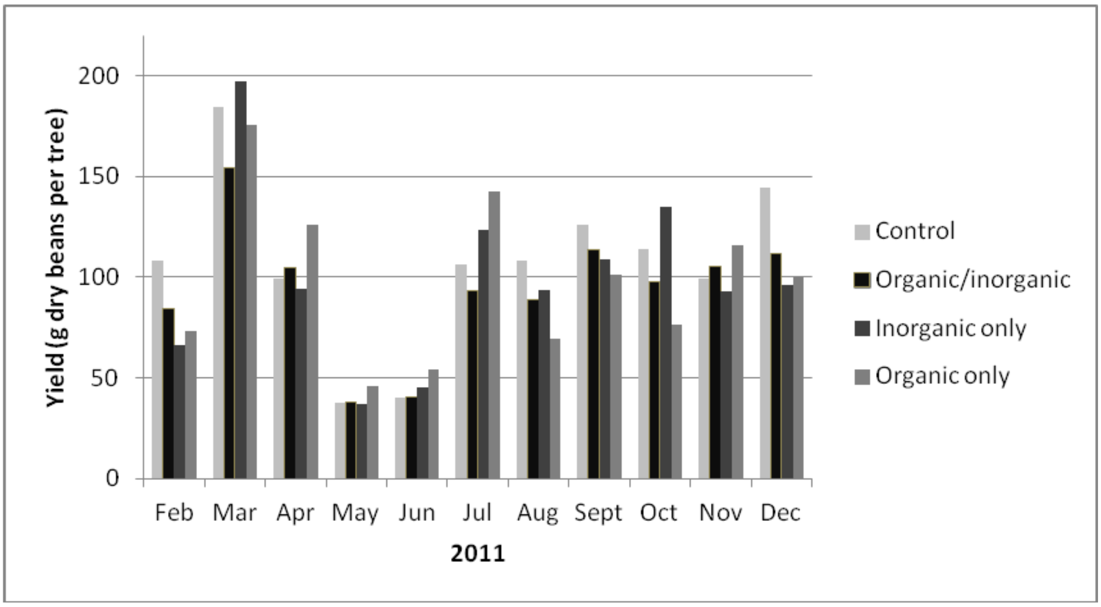

Fig 17. Yield (g dry beans per tree) for each month of 2011 at Tongkojan, Luwu. The peak harvest in 2011 was unusually low and early presumably because of the heavy 2010 rains and consequent loss of flowers.

Differences were not apparent in CPB and PPR incidence between the trees receiving different amendments. Figure 18 shows the CPB incidence in ripe pods in 2011 and Fig 19 the PPR incidence in the same period. Very high rates of CPB infestation are apparent while PPR incidence was clearly weather-dependent increasing markedly in the late wet season.

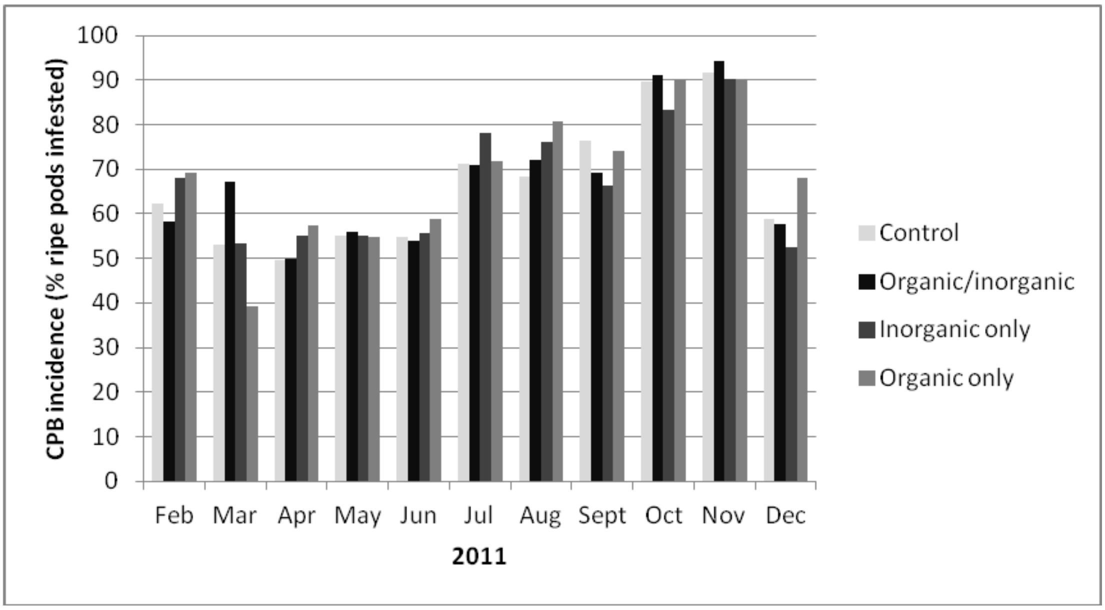

Fig 18. CPB incidence in ripe pods in 2011. CPB evaluations were conducted on the pods harvested from 10 trees in each of the four treatments. The higher incidence in the low harvest season is typical for CPB-infested cocoa.

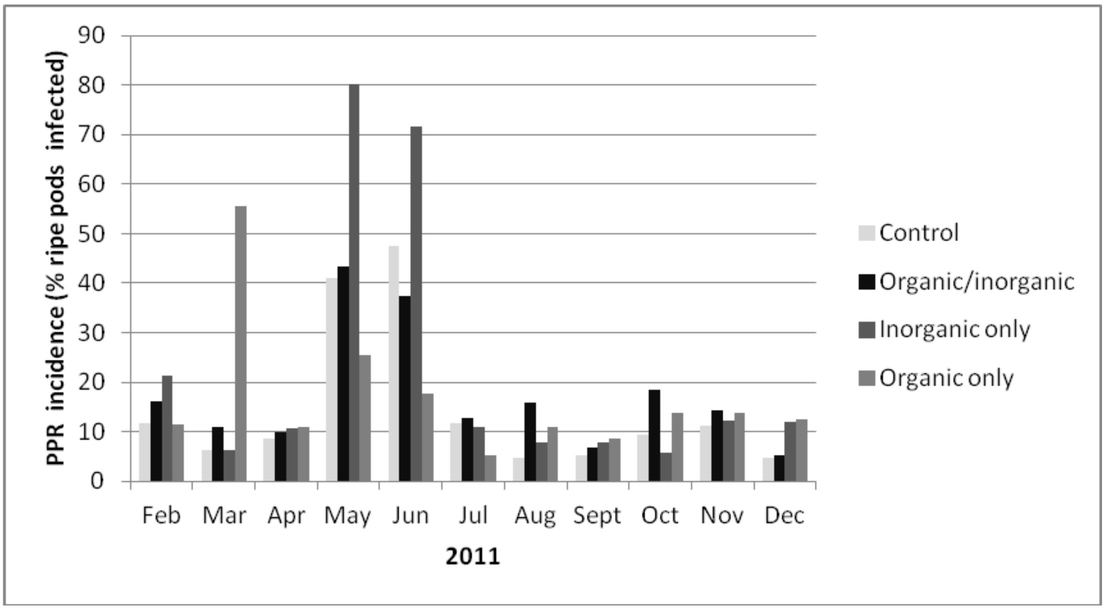

Fig 19. PPR incidence (%) in ripe pods in 2011. PPR increased sharply in the late wet season. No clear pattern or effect by the soil amendments on PPR infection rates could be discerned.

Objective 4 (modified). To assess uptake by farmers of improved cocoa management employing new cultivars and integrated pest/disease control methods.

Results of the surveys indicated that highly labour-intensive management techniques are unlikely to be adopted by farmers considering the current socio-institutional settings of production. This is apparent from:

a) The large number of respondents purchasing new land to expand the area under cocoa production, rather than rehabilitating existing farms. Many farmers own a number of units (averaging 2-3, Table 10). However, some farmers purchased more units of land with no formal documentation of ownership (Table 11).

b) The high use of labour-saving agricultural inputs (Table 10) such as urea fertilisers (rather than compost), herbicides (rather than manual weeding), and insecticides (rather than pod sanitation or sleeving), although pruning is an apparently widespread activity.

c) Competing demands for rural labour, including the option to seek work in expanding urban areas

The surveys revealed differences between three districts (in three Sulawesi provinces). Tree age was advanced in all the districts especially in Kolaka where 69% of the cocoa trees (compared to 42% in Polman) were over 15 years old. It is likely that increased pest/disease problems and decline in productivity are linked to increasing tree age. The long period that many areas have been under cocoa also suggests that soils may have been partially exhausted. The high use of inorganic fertiliser compared to organic amendments may have led to decreased organic matter content and therefore the sequestration and availability of micronutrients. However, a large proportion of farmers surveyed were in the process of replanting (Table 10) and this could account for some of the decline in productivity in Sulawesi since 2007. Cocoa small holdings were usually between 1 and 2 ha (Tables 10, 12) but many farmers extended their holdings by adding new pieces of land (Table 11). The motivation for this is uncertain as documentation of ownership was generally lacking for the additional units of land purchased (Table 11).

Table 10. The average farm size, units of land owned, fertiliser usage and frequency of pesticide application in Polman (West Sulawesi), Lutra (South Sulawesi) and Kolaka (South-East Sulawesi)

District	Average farm size (ha)	Average yield (kg/ha/yr)	Mean number of units of land	Side Grafting (%)	Re-planting (%)	Fertilizer usage (kg/ha/yr)	Average frequency of pesticide application per year
Polman	1.9	286	3	37	28	218	9
Lutra	2.8	353	2	60	50	360	11
Kolaka	2.0	642	2	27	36	470	8
Average	2.2	427	2.3	41	38	349	9

Table 11. Type of documentation of landownership for additional pieces of land obtained or purchased by farmers. Many farmers added new units of land to their initial landholding. Note the particularly low proportion of farmers in Polman holding a certificate for their land holdings, compared to the more informal stamped agreements between parties (e.g. SPPT) and the dramatic decrease in formal documentation of ownership from the first to last units of land that farmers obtained.

		Status of land ownership (%)		
		SPPT	**Certificate**	**SKT**
Polman	Unit I	84.5	15.5	0.0
	Unit II	69.4	9.3	0.0
	Unit III	42.0	4.1	0.0
	Unit IV	23.8	0.5	
	Unit V	13.5	0.5	
Lutra	Unit I	66.7	32.9	0.5
	Unit II	48.8	20.8	0.5
	Unit III	20.3	8.2	0.0
	Unit IV	5.5	3.5	
	Unit V	2.5	1.0	
N. Kolaka	Unit I	56.0	40.5	1.0
	Unit II	36.5	17.5	0.5
	Unit III	15.0	9.0	0.5
	Unit IV	2.5	1.0	
	Unit V	4.0	1.5	

Table 12. Size distribution of cocoa smallholdings in three districts

Percent cocoa small holdings in three categories of size			
Districts	**< 1 ha**	**> 1-2 ha**	**> 2 ha**
Polman (West Sulawesi)	16	62	22
Lutra (South Sulawesi)	13	62	25
Kolaka (SE Sulawesi)	6	65	29

Other key points to emerge from the surveys conducted were:

1) Most farmers surveyed have, at least, experimented with side-grafting techniques, using a variety of clones from a diversity of sources, suggesting that quality and reliability of budwood is an important issue.

2) VSD is now considered by many farmers to be the most important pest or disease problem affecting cocoa production, and therefore requires greater attention from research and extension providers.

3) Cocoa farmers in Sulawesi (this is less true in Papua) have been exposed – sometimes repeatedly – to various ‘extension’ activities. Levels of agronomic

knowledge are generally quite high, although prescribed crop management techniques are not always well suited to existing socio-economic systems.

4) Farmers are keen innovators and are continually adapting technical advice to meet their specific needs – a system of 'extension' that responds to this reality is required.

5) Prior technical advice from various extension agents (government, NGO and private sector) has tended to be both unidirectional and temporary. The relative technical dynamism amongst farmers would be more effectively garnered through longer-term two-way communication models.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The project staff working on the trials were trained to apply scientific methods to field studies (which is still not common in Sulawesi or Papua). The variability of the data obtained demonstrated the importance of replication which Indonesian staff and students could apply to their own studies. The cocoa breeder developed skills in molecular typing during his PhD study and has since applied these skills to identifying markers for VSD resistance in post-doctoral studies supported by the World Cocoa Foundation and USDA. The identification, often by farmers on their own farms, and testing of improved cocoa clones from among the great genetic diversity of cocoa on farms in Indonesia has proved successful, with many clones with superior properties having been identified in the ACIAR Projects linked to the broader activities of Mars Inc. Many clones were superior in some traits but inferior in others, indicating that they should become the basis of an intensive cross breeding program to combine useful traits. Socioeconomic survey methods were applied in village surveys conducted in Sulawesi and West Papua by BPTP staff, UNIPA (In West Papua) and their Australian counterparts. Analysis of some of these results was conducted as part of a PhD study in University of Sydney. The methods developed could be applied to other agricultural systems under the BPTP mandate, including rice and livestock systems, allowing better targeting of interactions with farmers.

8.2 Capacity impacts – now and in 5 years

The project supported the PhD study of a cocoa breeder (under Objective 2) and was linked to a JAF-supported PhD study of an economist (under Objective 4). The involvement of BPTP and University of Papua staff in project activities has increased their capacity and interest to pursue further research into the pests/diseases, selection and agronomy of cocoa. A permanent research site on land managed by Dinas Perkebunan in Soppeng, South Sulawesi was developed under the project. A nursery was constructed, a water pump installed and trials established (see Methodology). Research activities were managed by Australian staff and ICCRI. This also involved training local Dinas Perkebunan officers in establishing replicated trials under uniform shade conditions. A fire destroyed many of the shade and cocoa trees and the nursery was damaged beyond repair. Shade trees that were lost were replaced and some of the cocoa trees still survive. The site is still used for local research activities. In the future, if a nursery is built the site could be used by local and provincial government for field trials or establishing a cocoa collection. To date, cocoa research and development in Sulawesi has been restricted by the lack of a permanent research station situated in the main production area; ICCRI is located in East Java, historically the centre of cocoa production during the colonial period, where conditions are very different from those in Sulawesi. One of the main objectives of the ACIAR cocoa projects has been to facilitate research and development activities in Sulawesi by staff based in ICCRI.

The clone Aryadi 2 (ARDACIAR 10, KW570) identified as CPB-resistant in the previous ACIAR project and studied further in PhD research supported by this project was released by the Ministry of Agriculture as Sulawesi 3. As a released clone this can now be produced and distributed by government departments or commercially by farmer organisations. Two other officially released clones, Sulawesi 1 (PBC123) and Sulawesi 2 (BR25) widely distributed by the GERNAS program were two standard clones in the clone trials conducted by this project. Sulawesi 1 is productive and VSD-resistant and is now widely propagated. Sulawesi 2 and 3, however, could be particularly useful in the future as parental material for hybrid crosses that combine productivity and resistance characteristics.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

The clone test trials conducted under Objective 1 showed the potential for farmers to increase their cocoa yield even without pesticide inputs. The average annual production of dry beans in Pinrang, for example, was about 550 kg/ha at the time the trial was established (communication Ade Rosmana, UNHAS) but the average yield for 1000 trees (approximately 1 ha) in the Pinrang clone trial in 2011 was 1,200 kg showing at least a two-fold increase. Since dry beans at the farm gate have received about 18,000 rp in the last two years, the increase in annual income for this particular farmer would be at least 9,900.000 IDR or 1080 Australian dollars. Some other clones, such as PCK, showed even higher yields. Some planting material from the clone trials was collected by local farmers for top- or side-grafting. It has been evident during the project that superior planting material and its propagation by top-grafting of seedlings or side-grafting of mature trees is rapidly taken up by farmers. An important aspect of this project was to demonstrate that cultural methods, including recycling farm waste into compost, could substitute for high cost chemical inputs. Demonstrations of cultural management methods in Pinrang and in West Papua showed higher flowering rates compared to unmanaged controls. The clone test trial in Pinrang had a significantly higher average number of flowers in standard clones and yield compared to the other clone test sites suggesting the two factors are closely linked. Greater flowering is likely to be related to the timing and degree of pruning. Such basic practices can significantly increase yield and therefore income. However, the socioeconomic study indicated that farmers choose low labour/high material inputs over labour intensive methods. A high proportion of their income is therefore allocated to chemical fertilisers, such as urea, and pesticide chemicals. The clone tests and demonstration plots showed the possibility of increasing yields without high levels of material inputs. However, the shortage of labour remains a problem.

8.3.2 Social impacts

An aim of the project was to demonstrate the potential of selecting for improved local genotypes to improve farm production in association with improved cultural management methods. The possibility to increase production on existing farms increases income and therefore stability of the local community. Demonstrations of improved farm management would therefore have the effect of encouraging farmers and their families to work with existing cocoa farms and not to clear land in new areas.

Obstacles to improved farming methods in Papua and West Papua are largely social. Project work could only be conducted with the approval of two parties: the tribal chief and the village head. This issue was addressed by a workshop conducted by ACIAR in Bali in 2011. The project activities encouraged the exchange of information between different ethnic groups by introducing Java and Sulawesi based staff to local farmers during training workshops. University of Papua and BPTP staff (mainly from Java or Sulawesi) could also use the project as a platform from which to engage with cocoa farmers.

8.3.3 Environmental impacts

Under objective 3, training conducted for farmers in Sulawesi and farmers and extension and university staff in West Papua included demonstrations of composting pod husks and other farm waste. A method of filling trenches in between rows of cocoa trees with farm waste treated with a mix of compost-promoting microorganisms was introduced to participants in training workshops conducted by BRIEC staff. This has been shown to stimulate new root growth and is now being adopted by cocoa estates in East Java (personal communication, Arief Iswanto). By cultural management methods and composting of farm and other organic waste, impacts from pesticide chemicals can be reduced. ICCRI and other project staff also consistently recommend the use of shade trees which, if not too dense, alleviate stress to cocoa trees and severity of diseases such as VSD. The use of shade trees is also a requirement in certification of cocoa which is becoming increasingly important. The project also demonstrated through the use of improved planting material and management the possibility of intensifying production on existing cocoa farms. The socioeconomic survey showed that there is pressure on farmers to expand their cocoa farms into new land, including fallow and forest land, rather than intensification. For a lasting environmental impact that would reduce the pressure for cocoa planting to expand into forested land, the social causes of farm expansion would need to be addressed.

9 Communication and dissemination activities

The aims and activities of the project were published in GRO-cocoa and Biocontrol News and Information. A manuscript from the clone trials to be submitted for international publication is still under preparation. A paper on the results of the clone test trials (Objective 1) was presented to the National Cocoa Symposium and Expo in Padang 2012.

A training course conducted jointly by the ACIAR project and Mars Inc. in Jayapura targeted local extension and university staff. It also provided an opportunity for CCI staff from PNG to learn about Indonesian cocoa farming practices and provide their own input from experiences with cocoa farmers in PNG. Training manuals (produced by ICCRI) including a translation of a publication from another ACIAR project were distributed to farmers and extension staff. In Bali, ACIAR hosted a workshop to address the problems of working in Papua and West Papua. Since then there has been considerable unrest and the ACIAR country office now discourages Australian staff to visit these provinces. Two articles were published in the CSP News bulletin, and a strategic policy paper was released related to the GERNAS government policy in late 2008.

10 Conclusions and recommendations

10.1 Conclusions

The socioeconomic study under Objective 4 indicated that social (not technical) factors underpin the poor management of existing cocoa farms in many parts of Sulawesi. Sulawesi farmers have been exposed to a range of technical methods but continue to invest in high cost chemicals and new land to put under cocoa with low management. The project (as have previous ACIAR and other projects) demonstrated the capacity to increase yields and incomes with low material inputs. Cocoa grown in this manner, potentially supported through certification schemes, could have beneficial impacts on farmer income, local communities and the environment. Farming practices in Papua are affected by different factors. A lack of knowledge among farmers of Good Agricultural Practice and pest/disease management, in addition to social factors such as the structure of local hierarchies, influence the poor management of many Papuan farms. Problems caused by CPB are relatively recent in Papua and have often caused farmers to abandon their cocoa farms. Social unrest also affects access by local extension staff. This project showed that selecting and propagating superior local genotype material by top-grafting of seedlings and side-grafting of mature cocoa combined with simple management practices such as pruning, frequent complete harvesting and waste recycling are sufficient low-cost methods to substantially improve farm yields and bean quality. Social factors continue to provide an obstacle to developing more culturally intensive and environmentally friendly methods of cocoa production. It is clear that sustainability in the Indonesian cocoa industry requires a much better understanding of the social and economic systems that underpin cocoa production. Attempts should be made to identify the role of cocoa within sustainable rural livelihood strategies in cocoa-producing regions.

10.2 Recommendations

The importance of introducing improved planting material combined with management was revealed by the research studies in this project. Improved cultural management methods and the use of more pest/disease resistant genotypes with good yield and cocoa quality characteristics are priorities in both Sulawesi and Papua/West Papua. It is apparent that social factors affecting the use of basic technologies differ between the two regions. Thus very different approaches should be taken according to the social setting in which cocoa farming is practised. Some of the recommendations below are being addressed by ACIAR project HORT/2010/011which commenced in April 2011.

1. Some of the clones in the multi-location trials should be tested further for their yield, quality and resistance characteristics, and they should form the basis of an intensive cross-breeding program to combine useful traits in the on-going development of superior cocoa clones (this work is being progressed at ICCRI).
2. A better understanding of the relation of declining soil fertility and/or structure as well as other environmental factors to pest/disease severity and productivity is needed
3. Vascular streak dieback has been devastating to farmers Sulawesi-wide (but is not a serious problem in Papua or West Papua). The nature of the causal pathogen(s), and possible causes of increases in disease severity (including environmental and edaphic factors, see point (1)) as well as the recent emergence of necrotic

symptoms not observed previously need investigation (and are being addressed in HORT/2010/011)

4. Encouraging the use of organic sources and farm waste to raise organic carbon content of the soil is a further urgent need in Sulawesi.
5. In Papua/West Papua, which has more fertile soils, improving basic management methods, especially pruning and sanitation, as well as the propagation by side- or top-grafting of higher yielding genotypes is a priority.
6. Further understanding is needed of the effect of certification of cocoa (the requirements of certification bodies and the process of implementation of certified cocoa) on the adoption of technologies and better farm practices which take environmental concerns into account. In addition, further studies are needed of the role of certification and/or policy on the socioeconomic obstacles to intensification of cocoa (which would in turn alleviate pressures on the environment)
7. The cocoa village surveys indicated a high level of innovation in farmer practices; farmers adapt technologies according to the particular growing conditions of their cocoa and their access to resources. Since many farmers in Sulawesi have been exposed to training programs by government, international and private organisations over the last ten or so years, an extension model that encourages innovation and greater decision making by farmers should be tested.
8. Surveys conducted by this project found that many farmers extend their cocoa growing farms into new areas even when their families lack the capacity and resources to manage these areas. This points to a need to address these issues at a policy level. The regulatory mechanisms already in place as well as requirements for new mechanisms need further study.
9. For a number of social and political reasons Papua/West Papua has become more difficult to work in and direct collaboration of local institutions and farmers with overseas staff is problematic: strategies could be put in place which would enable new programs to be implemented via local government or educational institutions. The University of Papua and BPTP West Papua are active in cocoa research and development and are on-going collaborators in HORT/2010/011.

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