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2 Executive summary

HORT/2010/011, 'Improving cocoa sustainability in eastern Indonesia', addressed two interacting issues: the decline in cocoa productivity on smallholdings and the effects of changes in the value chain and regulatory framework. As in two previous ACIAR projects, CP/2000/102 and SMAR/2005/074, the main focus was on the livelihood of smallholder cocoa growers in Sulawesi and West Papua. The project developed previous research partnerships with a focus on productivity, pest and disease management, soil fertility, the development of extension models, and the impact on smallholders of policy settings, market-related frameworks and large-scale cocoa development activities.

In addressing the four objectives of the project we showed that:

(1) In an outstanding trial jointly managed by the project lead organisation (BPTP) and Mars Inc. on a depleted soil at Bone Bone, compost but not mineral fertilisers significantly increased plant growth and pod yield, to the extent of making cocoa production possible on this site. Compost probably increased availability of nutrients by promoting the activity of soil microbes involved in nutrient cycling. The addition of compost and NPK did not increase pod yield as much as compost alone. In East Java, supplying compost increased productivity and decreased VSD severity. At other sites in East Java and Sulawesi, there was no clear correlation between VSD severity and soil factors. There was no evidence from analysis of leaf nutrient composition of an association between any nutrient deficiency and the occurrence of the new VSD symptoms. The fertiliser trials showed that more detailed study is required before mineral fertilisers can be used effectively, whereas benefit from the use of organic manures and composts is immediately evident. These trials provided evidence that much NPK fertiliser is probably being wasted by the tendency for agencies to give blanket recommendations for its use, particularly as the mixture commonly available in Indonesia is formulated for flooded rice.

(2) Studies of VSD-infected cocoa demonstrated that a few clones had mainly original symptoms (yellowing of leaves with distinct green spots) while others had mainly new symptoms (necrotic patches on green leaves). Evidence was accumulated that the disease is basically the same as that originally described in Papua New Guinea, caused by *Ceratobasidium* (*Oncobasidium*) *theobromae*, except that the response of the plant to infection has become much stronger, involving much more necrotic reaction of vascular and leaf tissue of the type associated with disease resistance in other plants. Basidia and basidiospores observed on sporocarps were identical to those originally described from Papua New Guinea. The change in symptom expression has allowed the fungus to emerge from the xylem and sporulate on cracks formed on the attached leaves, resulting in sporulation being much more common than previously observed when sporulation was confined to leaf scars formed by the fall of diseased leaves. This would account for the increased incidence of the disease in recent years, associated with the occurrence of necrotic symptoms (previously, sporulation and infection occurred only when leaf fall exposed xylem in leaf scars during periods of wet weather). In most vigorously growing clones, the branches continued to grow beyond an infection at the base of the branch, evidence that the necrotic symptoms are an expression of greater plant resistance. The resistance of well-known clones first identified 4 or 5 decades ago is unchanged and recommendations for control remain unchanged. There was evidence that the occurrence of the new symptoms is influenced by a climatic variable – with increasing altitude the occurrence of new symptoms decreased greatly, along with the incidence of VSD in general. A preliminary method was developed for direct amplification of DNA of the causal fungus in infected plant tissues, and this will facilitate further study of the pathogen which has been limited by its poor growth in culture.

(3) The influence of location on performance of genotypes was demonstrated in multi-locational clone tests and in data obtained from earlier trials; evaluation of productivity is still in progress but initial results continue to show very high productivity by some clones over a range of environments. Strong resistance to VSD still occurs in many clones

regardless of the type of symptoms, although some high yielding clones are susceptible to VSD. ICCRI continues its effective cocoa breeding program to combine pest and disease resistance with high yield and quality, while Mars Inc. has begun a very large breeding program in South Sulawesi in which the best of these clones are being crossed to combine useful traits.

(4) Extension models were compared and a farmer-centred extension model implemented. Integrated Pest and Disease Management (IPDM) demonstration plots showed over 2-fold increases in yield in well managed compared with control plots. It was shown that farmers exposed to these demonstration sites improved their management methods much more than other farmers. The project has left a legacy of active farmer groups, based around nurseries and clone collections to provide improved planting material and demonstration plots of the best management methods. Stakeholder surveys indicated that certification schemes increased productivity, but also labour requirements, while imposition of an export tax had little impact on farm-gate prices while favouring the development of downstream processing that contributed to a more complete local cocoa industry. Several surveys showed that he national government cocoa rehabilitation program, GERNAS, involving multiplication of selected clones through somatic embryogenesis in tissue culture, encountered serious problems of clone selection (clone selection was influenced by their ease of propagation in tissue culture rather then solely by agronomic factors) and distribution of massive quantities of plants from a central facility in East Java (by the time new planting material reached farmers in Sulawesi, it was often overgrown and pot-bound, leading to poor development of the trees); these could have been overcome by promoting a decentralised nursery and propagation program based on traditional methods - this would have allowed timely distribution of the very best clones and would have left a valuable legacy of small nursery businesses in Sulawesi for propagation of new cocoa clones as they emerge from the active breeding programs of ICCRI and Mars Inc.

Six Australian Honours students, including an Endeavour Scholarship recipient, and local Indonesian students, including three PhD students (two supported by JAF) were supervised by project staff and conducted their field studies at project trial sites in Sulawesi. Postdoctoral research conducted in Indonesia and at the University of Sydney by an Indonesian project leader (Agus Purwantara), developed techniques to examine the impacts of soil amendments on soil microbial diversity, activity and abundance, work of fundamental importance in promoting the use of organic amendments to sustain soil fertility.

The project developed methods for local field-based pest/disease/soil research backed up by molecular studies that can be used for a range of applications. A farmer-engaged extension model, which was rolled out to groups in four subdistricts, involved establishment of new nurseries to raise plants for farm rehabilitation and establishment of options for Integrated Pest and Disease Management (IPDM) that enabled assessment of management methods by farmers. A pilot study introduced the idea of linking community health information to cocoa extension activities, based on the observation that labour shortage is a limiting factor in good cocoa management and that this is affected by farmer health. A model farm and extension centre in West Sulawesi developed on the initiative of Agus Purwantara will continue to be used for district farmer meetings and training; this farm demonstrated the potential to rehabilitate *Imperata cylindrica* (alang alang, kunai) grassland by planting cocoa and *Gliricidia* shade trees, and the value of integrating goat husbandry with cocoa (the *Gliricidia* provides ideal fodder for goats, and this promotes the pruning of the shade trees which have a tendency to become overgrown, and goat manure is a valuable adjunct for compost preparation). The clone collections and IPDM sites provide long-term resources for farmers and extension services. An application suitable for Android phones, called ‘likeCocoa’, was developed to provide current information for cocoa farmers.

The ongoing collaboration with Mars Inc. has been an outstanding success, resulting in amplification of the ideas and activities underlying the project way beyond what would have been possible in an ACIAR project alone. The company extensively prospected for new cocoa varieties among the great genetic diversity of cocoa growing on farms, and collaborated in the clone testing trials of the project as well as conducting many other trials, leading to the establishment in Sulawesi of one of the world's most ambitious cocoa cross-breeding programs. This program involves crossing the best clones selected in these trials and clones introduced from elsewhere, with the aim of selecting the best hybrid progeny that are expected to combine high yield and quality with pest and disease resistance. This program supports and extends the effective breeding program at ICCRI. These clone selection, testing and breeding programs, to which the ACIAR cocoa projects have contributed, have produced some outstanding clones with potential yields of 3,000 kg/ha/yr, double that of standard clones. The project has been actively involved in the Cocoa Sustainability Partnership, which aims to facilitate linkages along the supply chain, including with NGOs and government agencies, to standardise recommendations for best management practices on farms. These public-private forums have the potential to guide future research and development activities. The greater upstream involvement of Indonesia in the market value chain will also improve cocoa sustainability and benefit farmers.

3 Background

While cocoa has been grown in the Indonesia archipelago for centuries, it is only since the early 1980s that the industry expanded to its current level in Sulawesi, which now contributes over 60% of the total production of Indonesia (currently the world's third largest cocoa producer). This spontaneous and largely unregulated expansion was driven by smallholder farmers who brought planting material back from Malaysia after working there as labourers on plantations (Ruf and Yoddang, 2000). Cocoa is now the main source of income for over 500,000 smallholder farmers in Sulawesi and income from cocoa has driven great economic development in Sulawesi. The boom in smallholder production was based on availability of land and labour, fertility of forest soils, minimum pest/disease damage, and efficient cocoa buying chains that give farmers about 85% of the world price. However, the industry in Indonesia is now experiencing a decline in productivity, an issue addressed by the 6th Indonesian International Cocoa Conference in Bali (2014). The decline is thought to be due to decreasing soil fertility due to exhaustion of the natural fertility of forest soils converted to cocoa farming in the 1980s and an increased incidence of pests and diseases, especially Cocoa Pod Borer (CPB), Phytophthora Pod Rot and Canker, and Vascular Streak Dieback (VSD). Globally, demand for cocoa beans for chocolate manufacture is growing strongly. At a conference in Singapore in March 2015, 'Cocoa Revolution (Emerging Markets, Processing Trends, Yield and Quality Improvement)' it was stated that: "ever-growing demand from Asia will lead to a potential chocolate deficit in the near future, leading to rising cocoa bean prices."

Previous ACIAR cocoa projects (CP/2000/102, SMAR/2005/074, ASEM/2003/015) in Indonesia and PNG have introduced methods of selection of improved cocoa clones from among the great genetic diversity of cocoa on farms, methods of grafting these onto mature trees to test clones and improve plantings, and Integrated Pest and Disease Management (IPDM) involving mainly cultural measures, and have influenced national policies and programs such as GERNAS and cocoa breeding at the Indonesian Coffee and Cocoa Research Institute (ICCRI). However, other aspects of cocoa production requiring further research to sustain smallholder livelihoods have been identified, including reduced productivity due to depletion of soil fertility and increased damage by pests and diseases. Since 2004 the symptoms of VSD have changed dramatically and the disease has become more common and is perceived as a bigger problem than CPB; the reasons for this dramatic change in disease symptoms and severity required further study. Also, farmer adoption of sustainable farming practices has been erratic, reflecting ineffective extension linkages and poor functioning of market-based incentives, and these were addressed in the project.

Key issues

The key factors in declining yields are thought to be poor management of cocoa trees, depletion of the natural forest soil fertility, increased pest and disease losses and poor bean quality. On top of declining productivity, the cocoa market is beginning to impose certification of production. Consequently many smallholder farmers have switched to alternative crops and overall cocoa production in Sulawesi has declined in recent years.

The Indonesian government has increased regulation of the industry and provided the stimulus for increased domestic processing through the introduction of an export tax. These policies have encouraged companies such as Barry Callebaut, Nestle and Cargill to construct large domestic processing plants in the last few years, following the earlier example of Mars Inc. However, declining local production has caused a shortfall of supply and these plants are running below capacity, a key issue address by the 6th Indonesian International Cocoa Conference in Bali.

Justification

After nearly three decades of rapid expansion during the ‘cocoa boom’, cocoa production in eastern Indonesia faced serious challenges to its long-term sustainability, with total production starting to decline in established growing regions. The total cocoa dry bean production in Indonesia (over 60% from Sulawesi) of 560,000 metric tons in 2005/06 fell to 545,000 tons in 2006/07, 485,000 tons in 2007/08, and 475,000 tons in 2008/09 (International Cocoa Organisation, 2008/09). The decrease in cocoa production is mainly due to a reduction in average farm productivity from a high in 2003 of about 1300 kg/ha/yr (which was exceptionally high for smallholders, globally) to commonly 400 to 600 kg/ha/yr. This substantial decrease has been due to a number of factors, including:

- declining soil fertility, reflecting the exhaustion of the fertility of natural forest soil (‘forest rents’) with little systematic attempt to maintain soil fertility, as evident in the general yellowing of cocoa foliage seen in some districts,
- the increased impact of pests and diseases since the 1980s, especially CPB, Phytophthora Pod Rot and Canker, and, since 2004, VSD which has shown a marked change in symptoms and increased incidence and severity throughout the region,
- competing uses for land in cocoa-growing regions, such as for maize and oil palm production,
- increasingly limited forest resources available for conversion to agriculture, due to heightened demands for forest conservation (including carbon sequestration), and
- generally poor farm management practices, often limited by labour shortages, at a time of increased difficulty in growing cocoa sustainably compared with the initial relatively trouble-free period of cocoa production during the ‘boom’ period of the 1980s and 90s.

In the face of decreased productivity of cocoa, labour shortages and other factors, many farmers have converted to other crops, such as maize and oil palm. With increased domestic processing and increasing consumer demand, cocoa has great potential for improving livelihoods of farmers in a socially, environmentally and economically sustainable way, but this requires intensification of management of existing cocoa plantings, as opposed to the former pioneering approach in which farmers migrated to forested areas, cleared forest for cocoa planting, exploited the short-term soil fertility typical of tropical forested lands, and practised a form of cocoa foraging rather than professional, intensive management (Ruf and Yoddang, 2000, 2004; Curry et al., 2007).

Market and consumer requirements and direct involvement of international firms in buying and processing, and national government interventions (in addition to a number of government and NGO programs such as GERNAS) provide important opportunities for farmers to address productivity issues and to develop more sustainable practices in new and changing regulatory frameworks.

Key problems and issues that needed to be addressed in the light of declining production and its impact on smallholders were soil fertility, management of pests and diseases, adaptation of local clones in different environments, the lack of effective extension services and limited farmer uptake of better farm management methods, lack of understanding of impacts on farmers of market and government involvement and how cocoa sustainability could be improved through engagement with farmers in the supply chain. There was an urgent need for government staff to increase their engagement with on-farm problems through field studies and an increased endeavour and connection with farmers in local participatory research, teaching and extension services.

Four broad priorities that required research were: (1) an improved understanding of the effect of inorganic and organic fertilisers and microbial diversity in the soil on productivity and pest and diseases; (2) the relationship between the increased incidence and damage caused by VSD and the change in symptoms observed in the last decade and possible contributing environmental/host/pathogen factors, and the lack of capacity among project partners for pest/disease research; (3) the potential of local cocoa genotypes in a range of environments; (4) effectiveness of farm-based and farmer-engaged extension methods (such as IPDM participatory trials) and the role of market certification and policy development in promoting the uptake of more efficient and environmentally sustainable farming practices. This project aimed to address these priorities.

Pod harvest and breaking in Cendana Hijau, Wotu, South Sulawesi.

4 Objectives

The project's overall aim was to address cocoa sustainability issues on the farm and within the value chain, and to demonstrate that cocoa can be profitably produced on existing farms, thereby reducing the need for further migration and clearing of forest. In more detail, the project objectives were as follows:

Objective 1: To investigate the effect of improved soil management on cocoa production, quality and damage caused by Cocoa Pod Borer, Phytophthora diseases and Vascular Streak Dieback

1.1 To compare soil fertility and cocoa production, foliage nutrient concentrations and damage by CPB, PPRC and VSD at selected contrasting pairs of sites (e.g. sites with high or low VSD damage, high or low PPRC damage, high or low production, good or poor levels of management, generally chlorotic or normal dark green foliage, hill country or alluvial plains), sites treated with various organic fertilisers (in ICCRI, Mars and CSP trials), and sites with different times since conversion of forest to cocoa.

1.2 To establish at one site in Sulawesi and one in West Papua on-farm trials of the effect of different levels and combinations of inorganic and farm-sourced organic fertilisers on cocoa production, soil fertility, foliar nutrient concentrations and the impact of CPB, PPRC and VSD, in order to determine useful soil fertilisation recommendations for smallholder cocoa producers and for further multilocation testing in participatory trials (Objective 4.1).

1.3 To study the effect on cocoa yield, pest and disease incidence, and soil fertility of some currently produced composts of cocoa wastes and other farm-sourced organic wastes (for example by the Mars Symbioscience compost program), and of microbial promoters and other commercial products (e.g. chelating agents) applied to soil (this will primarily be delivered by involving Hasanuddin University (UNHAS) students in research activities).

Objective 2: To investigate the causes of the changed symptoms and severity of VSD in cocoa

2.1 To assess the incidence, severity and symptoms of VSD in the comparisons of selected sites (1.1 above) and in the fertiliser trials (1.2 above) in order to study possible edaphic causes of the changes in VSD. In the comparisons between sites with high or low incidence and damage by VSD (1.1 above) to also measure climatic variables, and to analyse regional climatic data, to determine if these are correlated with the changes in VSD.

2.2 To isolate and characterise the VSD pathogen and secondary pathogen(s) and endophytes from diseased trees using both traditional methods of fungus culturing and morphological studies and new methods of DNA amplification and sequencing to determine whether a change in the pathogen and associated organisms is responsible for the changed VSD situation.

2.3 To facilitate detailed studies by UNHAS staff and students of the epidemiology of VSD and other pests and diseases in fertiliser, clonal and IPDM trials.

Objective 3: To continue on-farm testing and dispersal of improved planting material

3.1 To complete the evaluation of the current ACIAR multi-location clonal trials for resistance to VSD and, as trees begin to bear pods, by assessing yield and quality of beans and resistance of pods to CPB and Phytophthora pod rot, with particular emphasis on performance of clones at particular sites.

3.2 At each IPDM site (4.1 below), to also establish small collections of the most promising clones from the earlier ACIAR and Mars Inc. cocoa selection programs and the ICCRI breeding program for ongoing multi-location testing, for demonstration to farmers and as local sources of budwood, and at these sites, to assess the performance of clonal material from other sources (e.g. the somaclonal material distributed in the GERNAS program) on nearby farms.

Objective 4: To improve the extension systems and policy settings that affect sustainable cocoa production in Indonesia

4.1 With farmer participation, conduct workshops to design and establish IPDM trials at one strategic location in Sulawesi and one in West Papua. These would be similar to those used in ASEM/2005/014 and SMAR/2005/074 but including more soil fertilisation options in addition to the one currently recommended under ASEM/2003/015, along with tree management and regular complete harvesting options. These trials will be established on farms with the participation of farmers and farmer groups and provide a focus for farmer field schools and farmer-to-farmer extension of management options. These trial sites will be integrated into evolving local extension systems and support will be provided to participating extension agencies to replicate them elsewhere. In West Papua, these trials will focus on the socially-appropriate integration of cocoa production into existing farming systems through intercropping. This objective will be integrated with the wider network of similar participatory trials managed by Mars Inc. as part of their technical extension activities.

4.2 To establish and test interactive models for knowledge transfer to extension services and farmers, including the use of web-based and mobile phone technology. These systems will deliver information on cocoa management and the activities in the participatory trials (4.1), clone trials (3.1, 3.2) and fertiliser trials (1.2, 1.3) to all extension services at the District level, including Dinas Perkebunan, District-based Extension Centres, GERNAS-built Resource Installations, private-sector buyers, and Research Institutes. The Cocoa Sustainability Partnership, of which Mars Inc. is the major partner active in the field, will be heavily involved in the development and testing of these systems which will also be used to deliver information on cocoa prices.

4.3 To assess the role of market-based incentives and private-sector certification schemes, such as UTZ Certified and Rainforest Alliance, in facilitating knowledge transfer and shaping farmer behaviour in eastern Indonesia, and to contribute to initiatives such as the National Reference Group on Cocoa, which has recently developed national indicators for sustainable cocoa certification. Mars Inc. is in the process of instituting cocoa certification in Sulawesi and this will provide an opportunity to assess its impact on farm management.

4.4 To develop policy recommendations to support recent government programs (such as GERNAS), and to ensure a sustainable transition to future programs upon completion of GERNAS. Policy findings will be presented to government in collaboration with key industry associations, such as ASKINDO and the Cocoa Sustainability Partnership.

5 Methodology

5.1 Objective 1: Improved soil management

Objective 1: To investigate the effect of improved soil management on cocoa production, quality and damage caused by cocoa pod borer, Phytophthora diseases and vascular-streak dieback

Objective 1.1: To compare soil fertility and cocoa production, foliage nutrient concentrations and damage by CPB, PPRC and VSD at selected contrasting pairs of sites (e.g. sites with high or low VSD damage, high or low PPRC damage, high or low production, good or poor levels of management, generally chlorotic or normal dark green foliage, hill country or alluvial plains), sites treated with various organic fertilisers (in ICCRI, Mars and CSP trials), and sites with different times since conversion of forest to cocoa.

East Java

The focus of this activity has been on comparison of VSD severity in locations with differing environmental conditions. Resources available to our project partner (ICCRI in East Java) did not enable them to assess pod production and disease and so the study focussed on VSD. Ten cocoa-growing sites in East Java varying in altitude and rainfall were selected for evaluation for VSD severity (see Table 5.1.1). VSD occurred at all the sites but intensity varied greatly, even in similar clones, indicating strong site effects. The severity of VSD was evaluated on individual trees in each site (along a transect of 100 trees) using a scoring system ranging from 0 (no VSD detected) to 6 (tree death). VSD was evaluated for three years in 2012, 2013 and 2014. Nutrient content of healthy mature leaves and soils, as well as other soil properties, were evaluated at the soil laboratory in ICCRI. At each site, topsoil samples (0-20 cm) were collected from the base of every 10th tree in the transect and the sub-samples combined providing a sample of about 1 kg. Samples were collected at least 0.5 m distance from the trees. Fully expanded leaves (2-3 leaves below the tip or flush) were collected from a number of healthy branches, combined and air dried for nutrient analysis.

Table 5.1.1. Location, rainfall and altitude of cocoa plantings evaluated for VSD in East Java

No	Location	District	Altitude	Annual rainfall (mm)	No. wet months	No. dry months
1	Gn Raung-JTN	Banyuwangi	490	2532	8.6	2.5
2	Sumber Baru-JTN	Banyuwangi	410	2532	8.6	2.5
3	Pager Gng-Kembu	Banyuwangi	262	2167	7.3	3.3
4	Kaliputih-Kembu	Banyuwangi	130	2167	7.3	3.3
5	Pacauda-Sule	Banyuwangi	4	2233	6.5	4.2
6	Antokan-Bjs	Jember	232	2161	6.4	5
7	Banjarsari-Bjs	Jember	104	2161	6.4	5
8	Gerengrejo-Bjs	Jember	38	2161	6.4	5
9	Kaliwining	Jember	45	1891	6.6	4.4
10	Sumber Asin	Malang	580	2302	8.5	3.5

.

Sulawesi

Soil parameters were determined at two clone test sites in South Sulwesi (Objective 3.1).

Objective 1.2: To establish at one site in Sulawesi and one in West Papua on-farm trials of the effect of different levels and combinations of inorganic and farm-sourced organic fertilisers on cocoa production, soil fertility, foliar nutrient concentrations and the impact of CPB, PPRC and VSD, in order to determine useful soil fertilisation recommendations for smallholder cocoa producers and for further multi-location testing in participatory trials (Objective 4.1).

Trials to test the effect of soil amendment with compost and/or mineral fertiliser on cocoa productivity and pest and diseases were established in Sulawesi and East Java. Because access to West Papua was difficult, the proposed trial there was replaced with an IPDM demonstration and on-site training workshops run by UNIPA (see Objective 4.1). The situation of West Papuan cocoa farmers differs from that of other parts of Indonesia (see SMAR/2005/074 reports) in that they lack previous exposure to basic (cultural) management methods (while many Sulawesi and Javanese farmers have already participated in training programs). Further, while the logistics of establishing fertiliser trials were manageable in East Java and Sulawesi, this was not the case in West Papua. However, soil samples were collected from demplots in West Papua and analysed in the BPTP Maros soil laboratory (see Section 4.1).

Soil amendment trials were established at Kaliwining, East Java (ICCRI), Lera, Wotu, East Luwu, South Sulawesi (Hasanuddinin University) and Bone-Bone, North Luwu, South Sulawesi (BPTP Sulsel). One year after establishment of the trial in Lera, the farmer compromised the trial by applying fertiliser to the whole location on the advice of a local agribusiness company. Consequently, a new (replacement) trial was established in Bantaeng, in an area severely affected by VSD, under the management of Hasanuddin University.

On two occasions, soil tests using equivalent samples were duplicated in two or three laboratories to check variability of analyses between labs. While some variability is expected, the comparative tests were conducted to confirm whether methods and reporting from the three labs are consistent or need improving. This formed part of a capacity building component in the project (two of the laboratories were run by project partners, and one was raised to a status of a certified soil lab under guidance from ACIAR).

East Java compost trial

In East Java, a multi-clone trial was established by ICCRI staff in Kaliwining near Jember to test the effect of two levels of a manure-based compost on pests and diseases of cocoa. The prevailing problem in the location was infestation by *Helopeltis* sp. CPB infestation was low or absent. The trial consisted of 3 blocks each containing the same 20 clones, with 8 trees per clone per block (total 480 trees). Compost was prepared from cow manure and coffee husks. Three treatments were included:

1. Control – no supplement to soil
2. 10 litres compost per tree per annum
3. 20 litres compost per tree per annum

Foliar and pod pests/diseases including *Helopeltis*, VSD and *Phytophthora* disease (with pods still on trees) were evaluated at regular intervals. Soils sampled from the three treatments were analysed at the ICCRI soil laboratory. The local soil is known to be low in boron.

Bone Bone compost/fertiliser trial

The Bone Bone trial was established at the BPTP Sulsel sub-station in North Luwu, under the responsibility of project partners BPTP Sulsel and Mars Inc. The soil is infertile and effects of nutrient deficiency could be seen in the local tall coconut. Baseline soil data are shown in Appendix 1, Table 1. Unproductive cocoa on the site was infested with CPB and black pod, but VSD incidence was extremely low. Clear signs of calcium deficiency were observed on the moribund cocoa trees. These trees were removed to establish a new trial using PBC123 top-grafted clones. Planting holes were prepared with equivalent treatments of compost and fertiliser and the 4-5 month-old seedlings planted in late December 2011. The trial with a total of 512 trees consisted of four blocks with plots of 16 trees (4 x 4) per treatment. The distribution of plots in each block was randomised.

The area was shaded unevenly by tall coconut and so *Gliricidia* shade trees were planted to provide even shade. In May 2012, after seedlings were well established, 8 treatments (in a 3-factor factorial design) were applied:

1. Control
2. Inorganic (mineral) fertiliser: NPK (“Ponska”, 2 x 187 g/tree/year) and urea (2 x 125 g/tree/year)
3. Compost 2 x 5 kg/tree/year (provided by Mars Inc.)
4. Lime (dolomite) 2 x 2.5 kg/tree/year
5. Mineral fertiliser/compost in the above quantities
6. Mineral fertiliser/lime
7. Compost/ lime
8. Mineral fertiliser/lime/compost

Growth, flowering, pod and bean production and foliar diseases were evaluated monthly from July 2013. The nutrient content of soils and leaves, as well as other soil properties, in each treatment were evaluated regularly. The middle 4 trees and border 12 trees were evaluated separately. Since the trial was planted with young clonal plants, evaluation of pod yield, bean quality and pod diseases did not commence until late 2013. Bean quality characteristics were analysed by Mars Inc. in their laboratory in Makassar. Beans were harvested and dried and 300-400 grams for each treatment used for the quality analyses.

Bantaeng compost/fertiliser trial

The trial in Bantaeng replaced the Lera trial which was discontinued in 2012. This trial was located on a farm with mature cocoa trees in Tana Loe. Similar treatments as in Bone Bone (above) were used, but less compost was applied and the mineral fertiliser consisted only of NPK. The 8 treatments (P0 – P7, see Section 7.1) were replicated in three blocks consisting of 16-tree plots. The trial layout is shown below:

P0U1	P2U1	P6U2	P7U2	P4U3	P6U3
P4U1	P5U1	P3U2	P4U2	P0U3	P7U3
P6U1	P1U1	P0U2	P5U2	P2U3	P1U3

P3U1	P7U1	P1U2	P2U2	P5U3	P3U3

Pod production, VSD and Phytophthora Pod Rot incidence were evaluated each month.

Comparisons between laboratories

Soil samples from three plots (representing three treatments) were collected from the Bone Bone trial site, mixed and divided into amounts of approx. 700 g. The soil was sent to three soil laboratories: Maros (BPTP), ICCRI and Gadjah Madah University for analysis.

Objective 1.3: To study the effect on cocoa yield, pest and disease incidence, and soil fertility of some currently produced composts of cocoa wastes and other farm-sourced organic wastes (for example by the Mars Symbioscience compost program), and of microbial promoters and other commercial products (e.g. chelating agents) applied to soil (this will primarily be delivered by involving Hasanuddin University (UNHAS) students in research activities).

Effect of organic and mineral supplements on cocoa productivity and soil microbiota

Soil microbial activity

Soil samples were taken from the Bone Bone trial site and Polman soil amendment trial in Mapilli, using standard procedure. Microbial activity was measured using the Fluorescein Diacetate Assay and CO_2 respiration (Solvita Kit, USDA).

DNA from soil was extracted in the UNHAS lab facility (see below) or Bogor and target genes were amplified using specific primers.

Testing a chelator-based foliar nutrient product

"Biomax", a liquid nutrient mix consisting of trace elements, plant nutrients and chelators developed in Malaysia for organic application was tested on cocoa in Polman affected by pests/diseases and on seedlings to determine effects on growth. Farmers and the Polman Dishutbun director and staff expressed the need for improving cocoa nutrition and alleviating disease impacts by supplying cocoa with nutrients other than NPK and were interested in trialling the nutrient product and obtaining samples (however, the product is not yet released commercially, Max Hunt, pers. comm). The chelator-based nutrient product has been formulated from trace elements and chelating substances; it includes over 60 elements and compounds but has no significant N content. In previous tests in Malaysia, Cambodia and Thailand the product indicated a positive effect on growth, yield and disease control in crops such as Stevia, dragon fruit, paddy rice, cassava and papaya (Terry Goh, pers. comm.). The formulation can be mixed with biochar (prepared from sugar cane or oil palm) and applied to the top soil or applied directly as a foliar spray. Treatments in small trials were applied on farms in West Sulawesi to young plants (to assess effects on growth) and mature trees (to assess effects on VSD severity) in March/April 2014 and evaluations commenced in May 2014.

5.2 Objective 2: Studies of VSD in relation to changes in severity and new symptoms

Objective 2: To investigate the causes of the changed symptoms and severity of vascular-streak dieback in cocoa

Objective 2.1: To assess the incidence, severity and symptoms of VSD in the comparisons of selected sites (1.1 above) and in the fertiliser trials (1.2 above) in order to study possible edaphic causes of the changes in VSD. In the comparisons between sites with high or low incidence and damage by VSD (1.1 above) to also measure climatic variables, and to analyse regional climatic data, to determine if these are correlated with the changes in VSD.

The increased severity of VSD in Indonesia, which appears to be associated with changes in the characteristic symptoms of the disease, was investigated. This entailed both field evaluation of VSD in different locations and infection of different cocoa clones and the development of isolation and PCR protocols to identify the pathogen and other microorganisms associated with infected plant tissues. Field studies formed part of the PhD of an Indonesian lecturer at the University Muslim Indonesia, Makassar, and an Australian Honours study with the field component entirely in Sulawesi. Both projects were co-supervised by Philip Keane and used established clone trials and other farm sites for field studies. VSD severity and the frequency of symptoms on infected branches (original symptoms, characterised by whole leaf chlorosis with distinct green spots and rapid leaf drop after symptom development, and new symptoms characterised by development of necrotic patches on green leaves and prolonged attachment of leaves) were determined on individual clones and at different times of the year.

A La Trobe University Honours study in Sulawesi investigated VSD incidence and frequency of necrotic and chlorotic symptoms in relation to altitude. In two cocoa growing locations, in West and Central Sulawesi, transects from low (about 50 m) to higher altitude (over 600 m in Central Sulawesi) were evaluated for incidence and severity of VSD for both original and new symptoms. Clones were mixed, particularly in Central Sulawesi, but relatively uniform (mainly Sulawesi 2) at the West Sulawesi site.

Objective 2.2: To isolate and characterise the VSD pathogen and secondary pathogen(s) and endophytes from diseased trees using both traditional methods of fungus culturing and morphological studies and new methods of DNA amplification and sequencing to determine whether a change in the pathogen and associated organisms is responsible for the changed VSD situation.

Hasanuddin University (Faculty of Agriculture) provided a building on their old campus to be used as a laboratory for students to conduct project research on cocoa pests and diseases, student projects and an ACIAR-supported PhD study. This facility with a glasshouse continues to be used for glasshouse experiments but a PCR facility developed by the project was established in another laboratory in the Agronomy Department on the main campus of the university. An important aspect of this objective was the development of capacity at Hasanuddin University for PCR-based methods for research on pests and diseases. Other potential applications of the facility became evident, for example using DNA sequences to characterise local agricultural plants (see Impacts, Scientific).

In particular, probes (DNA sequences) that could detect fungal DNA in cocoa tissues infected with VSD could enable the identification of secondary pathogens, in addition to the primary pathogen, *Ceratobasidium theobromae* (syn. *Oncobasidium theobromae)*, endophytes and alternative plant hosts. This was challenging as supplies commonly used for molecular work, such as liquid N were unavailable, power supply was unreliable and necessary equipment such as a plant/culture incubator were not available.

Objective 2.3: To facilitate detailed studies by UNHAS staff and students of the epidemiology of VSD and other pests and diseases in fertiliser, clonal and IPDM trials.

Topics and students participating in third year projects related to cocoa research by the ACIAR project are listed in Table 5.2.1.

Table 5.2.1. Skripsi (fourth year projects) supported by ACIAR project under Objective 2.3

N0.	Student	Topic of third year research project
1	Sri Wahyuni	Level of infestation of VSD, black pod and CPB at the UNHAS/ACIAR fertilizer trial, Bantaeng
2	Akbar Hakkar	Effect of *Trichoderma* soil applications on Phytophthora pod rot in Bantaeng
3	Muh. Ridwan K.	.Assessing microbial populations in soil in response to soil amendments in Bantaeng
4	Sunaryo Syam	Applying extracts of the fruit, ‘Maja', to control *Phytophthora palmivora* in Kab. Bantaeng
5	Arman	Identification of soil microorganisms in soil of cocoa trials treated with organic and inorganic supplements
6	Fitriani	Severity of infestation of cocoa pods with Conopormopha crameralla ((Lepidoptera : Gracillaridae) at peak and low harvest times
7	Desi Natalia Paseno	Growth of cocoa seedlings in response to foliar treatment with *Trichoderma* sp. and leaf extracts of *Gliricidia* sp.
8	Selpiana	Testing some promoting microorganisms on cocoa seedlings
9	Ari Wijaya Kusuma	Studies of mycorrhiza on cocoa seedlings
10	Aslam Nur Akhsan	Testing application and determining dosage of *Trichoderma* sp. to enhance cocoa seedling growth

In another study, UNHAS graduate students under the guidance of Dr Vien Fachruddin and two graduate students prepared a clone/CPB experiment in the clonal trial at Anreapi, Polman. Evaluations were conducted by Skripsi third year students. Six clones were selected ranging from CPB-resistant to CPB-susceptible: Husbitori, BR25, KW617, M01, PBC123 and Geni J. Developing pods 8 cm or less (30 per clone per block) were sleeved. They were then exposed to CPB infestation and assessed for entry/exit holes and damage (15 pods) and for egg laying (15 pods).

5.3 Objective 3: To continue on-farm testing and dispersal of improved planting material

Objective 3.1: To complete the evaluation of the current ACIAR multi-location clonal trials for resistance to VSD and, as trees begin to bear pods, by assessing yield and quality of beans and resistance of pods to CPB and Phytophthora pod rot, with particular emphasis on performance of clones at particular sites.

Data from the SMAR/2005/074 trials collected by BPTP and Mars Inc. technical staff were analysed for significant differences among clones in site, production, CPB and Phytophthora Pod Rot incidence and severity. These sites were used for clonal comparisons by two La Trobe University Honours students, Skripsi students and a Hasanuddin PhD study.

Phytophthora inoculations: Local cocoa clones in two trials (Anreapi, Polman and Tiwu, Pinrang) were evaluated for stem canker incidence. Artificial inoculations of both stems and pods were conducted by Agus Purwantara on the clones in the sites and the results compared with field incidence.

Objective 3.2: At each IPDM site (4.1 below), to also establish small collections of the most promising clones from the earlier ACIAR and Mars Inc. cocoa selection programs and the ICCRI breeding program for ongoing multi-location testing, for demonstration to farmers and as local sources of budwood, and at these sites, to assess the performance of clonal material from other sources (e.g. the somaclonal material distributed in the GERNAS program) on nearby farms.

Clone tests consisting of single 16-tree plots (8 x 2) of clones tested in common at a number of locations were established in Jan - March 2012. The clone test sites taken together were therefore multi-location trials testing 12 clones in common. Some of these clones had been selected by ICCRI following progeny testing of hybrid crosses conducted in East Java and this provided an opportunity to test promising material in Sulawesi (which remains the main centre of cocoa production in Indonesia). Some collections/tests were established near to the IPDM sites. One reason for this is that in addition to improved management, farmers urgently seek better planting material and the clone tests could act as an additional demonstration of selection and testing of local clones. Thus in both Sulawesi and West Papua, farmers were exposed to demonstrations of improved clones, improved management and methods of local clone selection. The uptake and performance of cocoa propagated by SE under GERNAS has been evaluated by various organisations (ICCRI as reported in Padang, 2012; UNHAS, and this project). However, the performance of genotypes has not yet been evaluated.

The following clone test sites were established:

a. Parumpanai, Wasuponda, Luwu Timor (Farmer: Hanase)
UNHAS (with Disbun in Luwu Timor)

b. Cendana Hijau, Wotu, Luwu Timor (Farmer: Munir)
UNHAS (with Disbun in Luwu Timor)

c. BPTP Bone-Bone substation, Luwu Utara
BPTP Sulsel (Benyamin)

d. Tampumia, Luwu (BPTP Sulsel, Nur'laila) later moved to Toangkajang (Farmer leader: Hussain)

e. Sumarang, Polman (BRIEC Bogor, Disbun Polman) (Farmer leader: Patta)

f. Pravhi, Manokwari, West Papua, (UNIPA and BPTP Pabar, two sites, one of which is used for farmer and officer training under the ACIAR project)

Clones were planted in single plots of 16 trees per clone (2 rows with 8 trees/row). Clones were common to the sites (above) providing multi-location replicates. The clones tested included: M01, M06, KB1, 45, THR, KW523, PR, KW617, KW 515, TSH, PBC123 (Sul1)

Monitoring:

Prior to pod production, growth of the young trees was monitored and, in some of the sites, any pests/diseases recorded; in particular, VSD was assessed by scoring severity for each branch (at least while the trees were still small). Productivity continued to be evaluated as the trees matured. With insufficient technical staff, the most remote of the clone tests, in Wasuponda, could not be monitored.

Bantaeng:

Local clones were also established by side grafting to give a trial with three replicate blocks. Repeated grafting was been necessary for successful establishment of the following clones: PBC123 (S1), BR25 (S2), M01, M04, Scavina, GTB, 45, M06, BRT, THR, Local ML, Local NW.

5.4 Objective 4: To improve the extension systems and policy settings that affect sustainable cocoa production in Indonesia

Objective 4.1: With farmer participation, conduct workshops to design and establish IPDM trials at one strategic location in Sulawesi and one in West Papua. These would be similar to those used in ASEM/2005/014 and SMAR/2005/074 but would include more soil fertilisation options in addition to the one currently recommended under ASEM/2003/015, along with tree management and regular complete harvesting options. These trials were established on farms with the participation of farmers and farmer groups and provided a focus for farmer field schools and farmer-to-farmer extension of management options. These trial sites were to be integrated into evolving local extension systems and support was to be provided to participating extension agencies to replicate them elsewhere. In West Papua, these trials were to focus on the socially-appropriate integration of cocoa production into existing farming systems through intercropping. These demonstrations were to be integrated with the wider network of similar participatory trials managed by Mars Inc. as part of their technical extension activities.

IPDM demonstrations of management options

Following consultation with local farmers, village heads and extension staff, sites were selected for IPDM demonstrations trials on working cocoa farms with the cooperation of the farmer's family. The model was based on that developed by ASEM/2005/014 in PNG and usually included 4 treatments, including unmanaged (i.e. normal practice), labour intensive with low material input (pruning, weeding, regular removal of infested pods), and higher material inputs, including fertilisers and pesticides. Experience in PNG with similar trials had shown the effectiveness of demonstrating a range of management options to farmers. The farmers were able to observe the results of the treatments and select the management level that suited their circumstances. The importance of exposure to farmers in the district, for example by locating the trials by a roadside, was also shown in ASEM/2005/014. However, the models allowed some flexibility after consultation with farmers (for example, farmers in Sumarang, West Sulawesi chose a fifth treatment, see Section 4.2),

The locations of the IPDM trials were in West Sulawesi (2 sites), South Sulawesi (1 site) and West Papua (2 sites with one of these being maintained to 2015), as follows:

1. Beluak, Anreapi, Polman (Farmer: Mastape)
2. Sumarang, Campalagian, Polman (Farmer: Alawuddin)
3. Cendana Hijau, Wotu, Luwu Timor (Farmer: Munir)
4. Pravhi , Manokwari, West Papua (2 sites)

Four treatments were applied to plots of 25 trees adjacent to each other and distributed in order of treatment along a pathway or roadside:

1. Control (remains unmanaged)
2. Cultural – regular pruning, weeding, sanitation of diseased pods
3. Cultural with fertiliser application (inorganic and/or organic)
4. Cultural, fertiliser and targeted pesticide applications

In Sumarang, a 5th treatment using organic management methods was included.

Soil sampling and analysis: At IPDM and clone sites, top soil (0-5 cm) was collected and analysed for various properties at the Maros BPTP lab. Four sub-samples were collected about 0.5 m from cocoa trees within the zone of lateral roots, and combined and mixed to provide samples for analysis.

In West Papua, in 2012, composite soil samples were collected from the IPDM plots before and after fertiliser application. Each sample consisted of three pooled cores at the depth of 0-20 cm and 20-40 cm. The soil samples were air dried, crushed and sieved through a 2 mm soil sieve. The samples were analysed by BPTP Maros soil laboratory for properties using the standard soil analysis.

Organic IPDM trial

With collaboration between farmer groups, Mars Inc. and the ACIAR project, two successive organic trials were established, the first in Tampumia, Luwu and the second in the same district at Toangkajang. The objective was to test the effect of organic soil amendments on pests and diseases using a larger area than other trials. The first trial at Tampumia was discontinued due to lack of cohesion within the local farmer group. The farmer owner had little support from the farmer group and had a large workload. At Toangkajang, an active farmer group that received regular training by BPTP Sulsel (and was involved in activities in ACIAR SMAR/2005/074) was approached. The leader of the farmer group had already used organic soil amendments for three years (although he had also used pesticide sprays). He agreed to use his farm for an IPDM test under an MOU with the ACIAR project and Mars Inc. The site is treated organically (with no inorganic fertilisers or pesticides). Comparative data on pest/disease incidence, yield and soil properties were obtained from this site. The site is used for training the farmer group, visiting farmers and extension staff.

Tampumia trial:

An area of 3.5 ha of young- mature cocoa was selected with the cooperation of the farmer group leader. The age of plantings differed with about 1 ha being planted with 2-year-old cocoa, and the remainder with 5 -year-old cocoa. The cocoa was affected by Phytophthora stem canker. A companion plant, neelam, used for perfume oil, was a companion plant on the farm.

From July 2012, no pesticides were applied and compost only (provided by Mars Inc.) replaced fertiliser use. For compensation, three cows were provided by the project. This would also provide a source of manure for compost, in addition to the local compost shed (with pod husk shredder) built under the guidance of Mars Inc. Evaluation was conducted by BPTP and Mars Inc. staff. Three plots (25 tree plots) within the treated area were evaluated. Three plots (25 trees) were selected as controls for conventional management and treated with pesticides. (In addition sleeving to control CPB was conducted in 3 further plots)

Toangkajang trial:

The trial consisted of an organically treated area of 1.3 ha including 3 plots of 16 trees evaluated within this area, and unmanaged control plots (3 plots of 16) and a managed control plot (3 plots of 16 trees). The farmer only applied compost to the 1.3 ha 'organic' cocoa. The area had already been treated with compost (with little or no inorganic amendment) for the previous three years. The farmer also discontinued using pesticide chemicals. Losses were compensated according to an MOU agreement. Evaluations were conducted by Mars Inc. (the control plots) and BPTP and the farmer (organic plots).

Applying a participatory extension model

In Sulawesi, farmers have received a lot of training. For example 24 training projects focussing on cocoa have been conducted in Polman District in the last two decades, including three USAID projects, local extension activities, and the national initiative through GERNAS. These programs have generally provided top down, spoon-fed solutions that satisfy donor milestones but rarely evaluate impacts. It was apparent that these conventional approaches tend to alienate local researchers and extension staff, and disempower farmers. An important theme in the ACIAR project was to test another extension approach.

Farms in the Anreapi district formed the focus of the project extension model. The model was based on Participatory Action Research (PAR) with high levels of input from farmers and a hub/spoke model loosely based on the Mars Field Training method (described by Fiona McKenzie and Hiswaty Hafid). The active participation of farmers in research was the foundation of the initial ACIAR cocoa project in Sulawesi (CP/2000/102) in which farmers were encouraged to identify superior trees (higher yielding, healthy) on their own farms and participate in the comparative testing of clones established from these trees. This approach has been taken up with great success by Mars Inc, resulting in the identification of many superior clones.

A technical assistant from BRIEC, Bogor (Pak Sunarya), was based in the area to participate and assist farmers. Disbun Polman (Pak Faisal) was also involved. The IPDM trials involve farmers testing for themselves a range of management options. In addition, these trials had similar underlying aims to those in earlier ACIAR cocoa projects in Sulawesi, in that 'farmer experimentation' was encouraged. The underlying idea was to help farmers to think experimentally (i.e. to compare different clones or management methods).

Thus, the trials have a 'research' component in that they provide some indication of how the treatments work in improving productivity and reducing pest and disease problems. Mainly, they were a way of involving farmers in making choices in solving their own problems. Thus, even the extension aspect is more than just exposing the farmers to methods of improving their cocoa production and reducing pest and disease problems, but was about showing them how they could do their own comparative observations.

However, in the current project an extension approach that was even more farmer-centred than the IPDM demonstrations was tested.

<u>Testing a farmer-centred approach</u>

Visits by project staff Fiona McKenzie and Hiswaty Hafid were made to CDC and CVCs (Cocoa Village Clinics) in April 2012. A "Cocoa Assessment Report" was completed, promoting an holistic extension approach. An account of this approach compared to traditional (top-down) approaches is given in Neilson and McKenzie (2016) and is the subject of a Masters thesis at Hasanuddin University by Kartika Fauziah.

Farmers brought up the problems they perceived as little understood or as priorities to be addressed, including: nursery management (Pak Arifin), inorganic (mineral) vs. organic fertilisers (Pak Supriadi), canker treatment (Pak Syarifuddin), sanitation and pruning (Pak Sukyur), preparation and drainage and using IPDM trial sites (Pak Masape). Based on farmer group meetings, local extension and other staff proposed other trials involving genotype comparisons, mixed plantings and their economics, rehabilitation using clones, selection and management of shade, cultural management methods, recycling of waste and types of compost, effective pesticides or biopesticides, farmer group organisation, administration and planning field days.

Surveys on uptake of technology following training

A group of 25 farmers (target farmers) exposed to participatory training in West Sulawesi (see above) were compared to 25 non-target farmers, who had received no training in the ACIAR program. All farmers were from the village of Duampanua, Anreapi. This was the location of the IPDM demplots established side-by-side along the village road to compare and demonstrate different levels of management on productivity and other variables, such as pest and disease incidence. The targeted farmers had received training at the IPDM site, or other activities as part of the participatory extension model tested by the project (see above). The non-target group had had no involvement in these activities.

A second survey was conducted to directly assess the impact of a farmer training workshop conducted in December 2015 at the Saung Kakao training centre at Mapili in Polman, West Sulawesi. The workshop included demonstrations of farm rehabilitation by side grafting and replanting with suitable cocoa clones, recycling farm waste through composting, soil amendment, mixed farm methods (with goats) and discussions on various issues facing farmers. The farmers participating in the workshop came from four sub-districts: Mapili, Anreapi, Tapango and Matakali. The farmers (36) were surveyed before the workshop (December 2015) and again in June (2016) on level of adoption of technologies introduced in the workshop.

West Papua

The level of exposure of farmers in West Papua to GAP (Good Agricultural Practice) and better management of farms has been very low in comparison with Sulawesi (see above). In West Papua IPDM plots were established with a Javanese immigrant farmer and an indigenous farmer. These sites were used for training (e.g. by UNIPA and ICCRI). In addition, local indigenous farmers in Oransbari were trained by UNIPA and BPTP Pabar in cooperation with the local Dinas Perkebunan staff.

Objective 4.2: To establish and test interactive models for knowledge transfer to extension services and farmers, including the use of web-based and mobile phone technology. These systems will deliver information on cocoa management and the activities in the participatory trials (4.1), clone trials (3.1, 3.2) and fertiliser trials (1.2, 1.3) to all extension services at the District level, including Dinas Perkebunan, District-based Extension Centres, GERNAS-built Resource Installations, private-sector buyers, and Research Institutes. The Cocoa Sustainability Partnership, of which Mars Inc. is the major partner active in the field, will be heavily involved in the development and testing of these systems which will also be used to deliver information on cocoa prices. ICCRI and UNHAS have joint responsibility. A team at UNHAS (led by Daniel) designed an interactive web-site under this objective.

Objective 4.3: To assess the role of market-based incentives and private-sector certification schemes, such as UTZ Certified and Rainforest Alliance, in facilitating knowledge transfer and shaping farmer behaviour in eastern Indonesia, and to contribute to initiatives such as the National Reference Group on Cocoa, which has recently developed national indicators for sustainable cocoa certification. Mars Inc. is in the process of instituting cocoa certification in Sulawesi and this will provide an opportunity to assess its impact on farm management.

A JAF-supported PhD study, which is still under way, contributed the main component of this objective. A survey of 158 cocoa farmers was conducted in West Sulawesi to ascertain the impacts of certification on farmer livelihoods through a comparison of certified versus control farmers. A workshop was held in March 2013 with industry participants to discuss findings. This was followed up with a second survey of 147 households in 2013 (certified and control) to examine the relationship between certification and extension delivery.

Objective 4.4: To develop policy recommendations to support recent government programs (such as GERNAS), and to ensure a sustainable transition to future programs upon completion of GERNAS. Policy findings will be presented to government in collaboration with key industry associations, such as ASKINDO and the Cocoa Sustainability Partnership.

Impact of Export Tax

Drawing on an earlier 2008 ACIAR-funded survey (n=197), a repeat survey was undertaken in October to December 2012, to ascertain the effects of an export tax on farm-gate prices. This therefore collected data about 16 months before and 20 months after the export tax was introduced. Respondents (n=200) were randomly selected from the same villages surveyed in 2008 to avoid the potential local effects of market accessibility on prices. Prices were adjusted based on prevailing world cocoa prices and exchange rate.

GERNAS

Two separate studies were conducted to assess the GERNAS program. The first (Published as Gusli et al., 2012) evaluated the actual present conditions of SE trees (i.e. clones produced *en mass* in Jember by somatic embryogenesis and tissue culture and distributed in Sulawesi), planted between 2009 and 2011, to record actions taken by the farmers in response to problems with SE trees and to evaluate their success. The survey was conducted in the provinces of South Sulawesi and West Sulawesi that are the two largest cocoa growing regions in Sulawesi and reasonably represent all of the cocoa producing areas in Sulawesi. Three kabupatens (regencies) of variable climate regimes and topography were purposely selected in each province. The farms surveyed were selected randomly from a list provided by visited farmer groups known to have planted SE cocoa plants in 2009, 2010 and 2011. A common questionnaire was used for all of the data collection.

A second survey was conducted by UNHAS in 2013 to assess the impacts and farmer perceptions of the GERNAS program. The results of the survey were reported by Arsyad and Bulkis (2014), although some data were lost due to computer theft affecting some of the results (Jeff Neilson).

6 Achievements against activities and outputs/milestones

Objective 1: To investigate the effect of improved soil management on cocoa production, quality and damage caused by cocoa pod borer, Phytophthora diseases and vascular-streak dieback

no.	activity	outputs/ milestones	completion date	comments
1.1.1	Select sites for targeted site comparisons: identify sites with high/low VSD, high/low yield, chlorotic/dark green foliage, various organic fertiliser treatments, longstanding cocoa/ forest soils (three replicate sites per comparison)	Contrasting sites with replication selected for comparisons	Nov 2011 (East Java) Aug 2012 Feb 2014	Cocoa growing sites selected in East Java at different altitudes and evaluated for VSD severity included: Kendenglembu, Banyuwangi District: low altitude, high humidity, wet Sungeilembu, Banyuwangi: low altitude, dry, high VSD severity Jatirono, Banyuwangi: high altitude, wet, lower VSD severity Sumber Asin, Malang added in 2012 Sites selected in Sulawesi for an Australian Honours study
1.1.2	Evaluate selected sites for soil resources and foliar nutrients, yield of cocoa, impact of CPB, Phytophthora diseases and VSD	Soil and leaf analyses; VSD evaluation	Jan 2013 Aug 2014 Ongoing	Soil and leaf samples collected; rainfall recorded and dry season length recorded in East Java; VSD assessed at different altitudes in Java and Sulawesi. Correlations between severity/frequency of symptoms and altitude, and severity and dry season length identified. The main factor(s) reducing VSD and affecting symptoms at higher altitude have not yet been identified and still need investigating (likely to be temperature).
1.2.1	Select sites in Sulawesi and West Papua for fertiliser trials and arrange with local farmers or farmer groups for use of land; consult bupatis	Farmers identified who are willing to have trials on their land	Dec 2011 Dec 2012 (new trial established in Bantaeng)	Sites and hosts for trials: 1. Kaliwining, East Java (ICCRI Research Station) 2. BoneBone, North Luwu, South Sulawesi (BPTP Substation) 3. Bantaeng, South Sulawesi (UNHAS) moved from Wotu, East Luwu, South Sulawesi One fertiliser trial (3) has replaced a trial established in East Luwu which was compromised by the farmer one year after establishment.

1.2.2	Prune and prepare cocoa & shade; evaluate yield, soil properties & pest/disease incidence and severity at the selected sites as baseline data	Preliminary evaluation of yield, soil properties, VSD and other pest/ diseases completed.	September 2011 July 2014 Ongoing	Initial soil samples analysed in Bone Bone and trial area prepared for planting. Soil analyses available for comparison between labs. For comparison, production evaluated in controls (representing baseline production).
1.2.3	Design and establish fertiliser trials	*e.g. 8 treatments applied to existing mature trees, 4 blocks (reps), 16 (4x4) - tree plots (outer trees being guard rows, data only from inner 4 trees), 512 trees per experiment; testing of different amounts and ratios of inorganic and organic fertilisers*	Dec 2011 July 2012 Ongoing	Kaliwining:, 3 blocks, 20 clones, 2 levels of compost (coffee husk/sheep manure) Bone-Bone, planted 4 month-old PBC123 clonal plants, 4 blocks, 512 trees, 3.5 m spacing 8 treatments of mineral fertiliser, compost, lime and combined treatments in factorial design; 16-tree plots Bantaeng: mature cocoa trees, 8-tree plots, 8 treatments of compost, lime and fertiliser. Trees in Bantaeng compost/ fertiliser trial side-grafted in 2013 by the owner farmer with 3 clones common to all plots which delayed evaluation of the treatments.
1.2.4	Evaluation of fertiliser trials	Regular evaluation of soil resources and microbe activity, foliar nutrients, cocoa production, VSD infection and losses from other pests and diseases, particularly PPRC and CPB. Modification of fertiliser treatments for use in on-going IPDM plots (4.1)	On-going Dec 2014 Ongoing	Kaliwining, East Java: monthly foliar and pod pests/diseases including *Helopeltis*, VSD and *Phytophthora* disease unaffected by treatments Bone-Bone: PBC123 evaluated for growth and foliar diseases. Results suggest that mineral fertilisers such as NPK products and urea applied to soils that are leached and acidic (commonly pH 4-5) do not lead to higher production or tree health. Compost was the most effective treatment. Bantaeng trial: evaluation delayed after the farmer grafted his largely unproductive trees in the trials. Evaluation of grafts will be continued by UNHAS.

1.3.1	Small field trials established to test response of cocoa to several composts prepared locally, including composting in shallow trenches between row	e.g. three treatments (compost, inorganic fertiliser, control), 8-tree plots with treatments applied between 2 rows of 4 trees, 4 reps	November 2012 Jan 2015 Jan 2015	A trial in Mapilli, Polman with three treatments: no amendment, compost or fertiliser, investigated the effect of organic soil amendment on soil microbial populations and productivity. An organic IPDM using the trench compost method (see 4.1) is being evaluated jointly by two project partners and the participating farmer. Soil microbe activity and DNA has been determined at various sites with organic/control treatments including Mapilli and Bone Bone. Extractions were performed at the UNHAS molecular facility (see 2.2) and Bogor, and analysed at the University of Sydney Arief Iswanto and Mars Inc. testing *in situ* composting in trenches between cocoa trees as a way of retaining cocoa pod husks in the field to return organic matter to the soil. Due to CPB infestation and advice from other sources, most farmers remove cocoa pods from the field and so lose organic matter from their plantations. The objective of this trial was to show how *in situ* composting in trenches between cocoa trees can improve cocoa production and absorption of applied mineral fertilisers. Earthworm populations and new roots accumulating in the compost trenches are also being assessed. A chelator-based nutrient and trace element product tested previously in Malaysia was trialled on a small number of trees in Polman; responses from local cocoa farmers and project partner Dinas Kehutanan/ Perkebunan indicate a high level of interest in testing nutrient applications that could increase yields and/or decrease losses from pests and diseases. The aim was to help farmers critically evaluate new products rather than take advertised benefits at face value.

1.3.2	Measure nutrients in the common locally produced composts, nutrients and microbe activity in the soils, nutrients in foliage in the compost trials	Data on nutrient content of composts; data on changes in soil and foliar nutrients due to compost application; data on changes in microbe activity in soils	Feb 2014 Nov 2014 Ongoing	In Mapilli, Polman total bacteria and actinomycete populations were 10-fold higher in soils treated with organic than mineral fertiliser while populations of total fungi were 2-fold higher. In the Bone Bone fertiliser/compost trial microbial activity was significantly higher in the treatments that included compost. Leaf nutrient analyses did not differ between treatments, however total biomass was significantly higher in compost treatments. Further study is needed on the effect of soil amendments on nutrient availability to cocoa trees.
1.3.3	Design student projects based on fertiliser trials	Small, targeted studies using the different sites (e.g. fertiliser trials, comparative sites).	Jan – April 2012 (commenced)	See below (Objective 2.3)

PC = partner country, A = Australia

Objective 2: To investigate the causes of the changed symptoms and severity of vascular-streak dieback in cocoa

no.	activity	outputs/ milestones	completion date	Comments
2.1.1	Assess all selected comparative sites (1.1) for VSD incidence, severity and symptoms, and climatic and other factors	Data on VSD for all comparative sites; relate VSD to environmental factors	Feb 2013	East Java comparative sites: VSD evaluation using 6-score system at ten cocoa sites indicated the highest average VSD severity to be 3.12 and the lowest, 1.30 Significant positive correlation of severity with dry season length, but not total rainfall (see above 1.1.1 and 1.1.2 above) An Honours project through La Trobe University found a significant decrease in the occurrence of new symptoms with increasing altitude.
2.1.2	Assess fertiliser trials (1.2, 1.3) for VSD incidence, severity & symptoms;	Data on VSD in all treatments; relate VSD to soil properties and foliar nutrient concentrations	Feb 2015	VSD evaluated monthly at two sites. This has been difficult in the fertiliser trial at Bone Bone because a VSD resistant clone (PBC123) was used in the trial and the site has a low incidence of VSD.

2.2.1	Isolate pathogen and associated fungi from VSD at all comparative sites (1.2) and at various other sites from leaves with the original and the new symptoms; establish more widespread and regional collections for taxonomic treatment	Isolates obtained from leaves showing different symptoms;	Feb 2015 Ongoing	DNA of causal pathogen of VSD was isolated from collections in West, South and South East Sulawesi and Kerala, India, and the ITS region amplified (see below) Microscopy of fungal sporophores formed on VSD infected branches in wet season March 2012, February 2014 in West and South Sulawesi found the fungus to be identical to the original *Oncobasidium (Ceratobasidium) theobromae* described as the cause of VSD. Further collections and sequences needed.
2.2.2	Prepare DNA extracts of fungus isolates, amplify with PCR and send for sequencing	Data to add to the taxonomic and biological understanding of the VSD pathogen and associated fungi; better understanding of regional variability and occurrence of other fungi possibly associated with VSD infections.	Dec 2014	A PCR facility was developed with project partner UNHAS. Isolates from VSD-infected petioles and leaves were subcultured in liquid media. It was difficult to obtain pure isolates of the pathogen for molecular study. *C. theobromae* was identified by morphological and molecular methods. Sequences were submitted to Genbank.
2.2.3	Develop reliable method to probe *Oncobasidium* and *Ceratobasidium* spp. in infected cocoa tissues and other plants	Method developed to detect fungi directly in infected plants	Feb 2015 Ongoing	Protocol for direct amplification from infected plant tissue was developed but remains inconsistent. Cocoa plant DNA extracts were prepared from petiole tissue: fungus matching *C. theobromae* was isolated using universal primers. Primers designed specifically for *C.theobromae* were tested also. If consistent methods developed other plants could be tested with this method. Other fungi in VSD-infected tissues, possibly weak pathogens such as *Guignardia* sp., also detected with universal primer pair

2.2.4	Develop DNA probe for testing on other plants, particularly putative hosts	Extractions conducted of other plants including orchids; putative host(s) identified *Responsibility*: BRIEC, UNHAS,	May 2014 Ongoing	See above Lack of availability of a plant pathology incubator caused difficulties for isolation of the causal pathogen of VSD. A simple incubator using copper tubing has been made and can reduce the temperature to 25^{o}C. Standardise isolation procedure; apply to a number of fungal pathogens that can be studied by post-graduates and staff
2.3.1	Initiate post-graduate study under supervision of Dr Purwantara, BRIEC, and Australian team	A trained scientist in plant pathology or other discipline at UNHAS	Completed July 2012 Sept 2013 Feb 2014 Ongoing	PhD completed in July 2014. Final seminar presented by Ayu Parawansa with ACIAR project staff attending Papers presented to International Plant Pathology Congress Beijing 2013 and Pakistan Plant Pathology meeting, Karachi, 2014 by Dr Ayu Parawansa Supervision and guidance for a JAF supporting a study of variability of VSD (Junaid Mohammed, Univ of Sydney) and other post-graduate studies on VSD (one application has been submitted)
	Initiate small Scripsi projects on the biology of VSD designed for UNHAS and UNIPA students	Establish further understanding of the nature of the changed VSD situation	April 2012 (commenced) Feb. 2014	Student research projects on VSD have been initiated (organised by Dr Vien Sartika Dewi, UNHAS) Six third year student projects underway in Bantaeng with studies of pest/diseases and soil properties at project trial sites.
	Initiate student studies of fertiliser, IPDM and clone trials including socioeconomic aspects (see 4.1)	CPB, PPR, Canker, socioeconomic studies undertaken e.g. through Skripsi	April 2012 March 2013	Student research projects have been initiated (organised by Dr Vien Sartika Dewi, UNHAS). Three fourth year B.Ag.Sc. students from La Trobe University completed their final projects on VSD and socioeconomic aspects of the project in second semester 2011. CPB study: effect of clone on infestation. Young pods bagged and exposed after two months to natural CPB infestation. Pods were investigated for entry holes/exit holes, damage to beans

PC = partner country, A = Australia

Objective 3: To continue on-farm testing and dispersal of improved planting material

no.	activity	outputs/ milestones	completion date	Comments
3.1	Continue to evaluate performance of clones in trials established under SMAR/2005/074 and variation	Pod characteristics determined – cocoa quality and yield, resistance to Phytophthora pod rot and CPB; resistance to VSD of mature trees	Dec 2012 Dec 2013	Evaluation of the clone trials planted under SMAR/2005/074: four manuscripts prepared, one accepted. These sites are now used for other studies including a CPB study (see above), Honours and PhD field work. Attached pods were inoculated with *Phytophthora palmivora* to test resistance of clones in Sept/Oct 2013 at the Polman (Anreapi) and Pinrang clone trials; results of artificial inoculations correlated with field resistance. Farmer selected clones (Mars) M05 and M06 showed useful resistance to *Phytophthora*.

3.2	Conduct on-farm testing in Sulawesi and Papua (at the same sites as the IPDM trials - 4.1.1) of clones of promising progeny in small clonal collections that include the best clones from previous ACIAR and Mars projects and new clones arising from the ICCRI breeding program	Data on performance of clones from SMAR/2005/074 and crosses in ICCRI on farms at multiple locations Evaluation of clones (ICCRI, and Disbun Kehutan dan Perkebunan)	July 2013 December 2014 Feb 2014 Dec 2015	Multi-location clone test sites were monitored for growth and later for pest/disease resistance. Clone test at Sumarang: a high rate of tree death occurred during the long dry season of 2014 Pod production monitored in peak harvest at Tampumia, Wotu and Bone Bone clone tests. Improved clones brought to Papua previously by project staff were grafted by farmers in Pravhi and other locations. UNIPA agriculture students have been trained in grafting techniques. A second IPDM site has been established in Pravhi and used for training by BPTP and UNIPA staff Evaluation of production in West Papua; determine bean characteristics from Sulawesi and local clones Multi-site clones tests indicate high flowering rates in clone 45 and the most vigorous growth in M06 in all four sites evaluated (ICCRI). Both clones have been reported to be productive and moderately resistant to VSD and *Phytophthora* on farms. Following an ICCRI submission, clones M01 and 45, that were also tested in the ACIAR project, were recognised as recommended clones by Indonesian Ministry of Agriculture and named Masamba Cocoa Clone (MCC)1 and 2. Aryadi 2 (identified in project trials as CPB-resistant) is renamed Sulawesi 3. VSD resistance ranking of important clones was confirmed at several sites in the Honours Project of Sue Bryceson (LaTrobe University) and PhD Project of Ayu Parawansa (UNHAS). Production and bean quality in the clones will be evaluated to provide site-specific data on performance The clones being tested at the five locations are in an early stage of pod production (with the exception of clones lost in Sumarang to the dry season of 2014).

PC = partner country, A = Australia

Objective 4: To improve the extension systems and policy settings that affect sustainable cocoa production in Indonesia

no.	activity	outputs/ milestones	completion date	Comments
4.1.1	Select one site in Sulawesi and one in West Papua, near to the fertiliser trials, on farms for establishment of participatory IPDM trials; consult Bupatis	Sites selected; local authorities and extension agencies have some ownership of work	Dec 2011	IPDM demonstrations of 4 (or 5) options using 25 tree plots adjacent to each other and next to a road or pathway have been established: in West Papua (Pravhi), West Sulawesi (Anreapi, Sumarang) and South Sulawesi (Wotu). Demplots monitored for costs and production by farmers themselves.
4.1.2	Conduct workshop to plan and establish in Sulawesi a participatory IPDM trial involving graded options of pruning of cocoa and shade, weekly complete harvesting of healthy and any damaged pods, different fertilisation treatments, and use of pesticides and pod sleeving (To involve farmer groups, AIAT and all collaborating extension agencies)	Trial designed and established by farmers, possibly 6 treatments, 4 replicates, 16-tree plots (4x4, only centre 4 being measured); AIAT and all extension agencies empowered to establish similar trials in home districts Evaluation of organic treatment on 1.3 ha in Toangkajang, Luwu commences and compared to control plots in neighbouring farms	Mar 2013 Dec 2014 (evaluation ongoing) Feb 2015	ACIAR workshop held in the West Sulawesi included head of Dishutbun, extension officers and farmers and other project partner staff. Requirements of farmers discussed and prioritised. Regular meetings with local farmer groups and Dinas extension officers held as part of a process of implementing a farmer-engaged extension model (see below). Extension model being tested in Polman that is based on farmer-led innovation. Farmers identify priority areas meriting attention. A nursery constructed, Sulawesi clones propagated for side-grafting their unproductive trees. Sul 2 has a short harvest season which suits farmers who also grow paddy rice. Management of PPR (one of the farmers' designated priorities) will be approached by cultural methods and trunk injection with phosphonate. Tampumia organic trial was discontinued due to lack of farmer group involvement. The trial was moved to Toankajang in Luwu. The site continues to be monitored by the project. The site is treated organically and is used for training a farmer group, visiting farmers and extension staff

4.2.3	Establish in West Papua participatory IPDM trial as for 4.1.2	As above	Sep 2013 June 2015	West Papuan IPDM plots (which have been difficult to visit by Australian staff due to travel restrictions) were established in West Papua. ICCRI staff have helped with monitoring and training activities. UNIPA staff have conduced initial training in Oransbari, West Papua. Pravhi site has been evaluated for soil nutrients at two depths. Soil data obtained; a new IPDM demonstration plot was established in Pravhi with an immigrant Javanese farmer. This plot is being used for training purposes
4.2.1	Develop and maintain a web-based technical resource kit.		December 2013 Completed	A website has been designed by UNHAS with the main pages already in place. The site is linked to CSP. The website is designed to allow queries from farmers and other producers to be submitted to a board of scientists and other experts. It is expected that the site will have a telephone sms link but an issue is the expense per text message. CSP and University of Sydney collaborate on the communication system with BRIEC (Arief Iswanto) as consultant. Due to the prior experience of the Cocoa Innovation Project (CIP) funded by WCF the project will work through CSP drawing upon CIP developments in this area. Access to affordable mobile networks linking text messaging to website limits the practicality of the system. ICCRI project developed an App, under “likecocoa” an information service using Android telephones which many communities now use.

4.2.2	Conduct a comprehensive review of cocoa-related extension services in Sulawesi		April 2012	A report of a study/assessment of extension providers to Sulawesi cocoa farmers provided the basis for developing a farmer-responsive (or even farmer-driven) extension approach based on farmer experimentation. The model is loosely based on the Mars spoke and hub training model (Hiswaty Hafid and Fiona McKenzie, 2012) and formed the basis of the rollout in Objective 4. Book chapter for the FAO has been published (Neilson and McKenzie, 2016).
4.2.3	Set up email- and handphone-based contact systems for all extension services and invite extension services to use IPDM sites for extension			See above (website development)
4.2.4	AIAT leads the roll-out of extension methodologies with similar IPDM participatory trials (unreplicated) with farmers		April 2013 Aug 2012	Under the direction of BPTP (AIAT) Sulsel farmers from two subdistricts in West Sulawesi visited centres in Toangkojan and/or Tarengge for training. The farmers were hosted by Mars Inc. staff in Tarengge and were able to visit farmers applying good cocoa management practices. They returned home with renewed enthusiasm to plant and rehabilitate their own cocoa. The rollout activity organised by the project in 2012 met with positive feedback and stimulated farmers in West Sulawesi to implement improved practices on their own farms. This was replicated in the extension period with other farmer groups: 20 – 25 farmers and local extension staff visited farmers in Luwu (Toangkajang) and Tarengge (Mars Cocoa Academy) where they receive training and took part in field visits for 2 days.

4.2.5	Extension officers return to a work shop later in the project to report their activities with IPDM trials in their local districts	Reports of experiences of farmer involvement and results by all participants	Feb 2014	A farmer meeting in Anreapi gave positive feedback from farmers and extension service officers on visits to Luwu Raya. Additionally, farmers indicated preference for a farmer-engaged model (see below) as seen by the clear outcomes rolled out to four subdistricts.
4.2.6	Provide recommendations and subsequently intervene in extension systems in the two model districts	New extension models established in 2 districts and appropriately documented Extension centre in West Sulawesi provides on-going training for four farmer groups. Activities at the centre have expanded with more nursery space, a trial to test organic amendments, microbial studies	September 2012 July 2013 Completed in 2016 (extension period)	Extension model being tested in Anreapi, Polman with a farmer group (8 participants). In a participatory approach farmers listed their own priorities for improving their farms. Following the model the farmers' have implemented activities including the construction of a nursery (the farmers provided the labour and some materials themselves), rehabilitation of unproductive cocoa by side-grafting with BR25 (Sulawesi 2) – but only this clone used for rehabilitation Four new nurseries were built by farmer groups in different sub-districts. Roofing, polybags and seedlings were provided by the project, and project staff based in Mapilli provided on-going training. Survey completed to evaluate the extension model applied in Polman (comparing target and non-target farmers). A survey assessing impact of a training workshop has also been completed.
4.2.7	Follow-up meetings held with Bupatis of participating districts to ensure awareness and ownership of project	Trials become an integral part of government extension activities in the district	Feb 2014 Sep 2014	Dinas Perkebunan senior personnel have been informed about project activities and consulted in East Luwu and Polman Head of Agriculture and Forestry for Polman District, H. Adul Salam, attended a project workshop and farmer training session in Kuajang, Binuang with some of his staff. The meeting was opened by the District Vice-Bupati Nasir Ten farmers (from Polman, Luwu and Luwu Timor) visited Hari Kakao in Makassar (14 Sept, 2014). They gave feedback to the meeting which was opened by the Governor and included senior Ministry officials concerned with the national cocoa program (GERNAS) which met with limited success.

4.3.1	Nationwide review of cocoa certification schemes	A database of certification schemes and their reach is established and maintained	completed – now adopted by CSP	A database of certification schemes has been compiled and is being held at CSP.
4.3.2	Case-study of farmer impacts from certification (use of surveys and monitoring)	Recommendations provided on the farm impacts of sustainable certification	Field surveys undertaken in 2012 and 2013	Report released April 2013 followed by various dissemination workshops. Draft report of 2013 survey (effects of certification on training activities) prepared. Book Chapter has been published by Fold and Neilson.
4.3.4	Engagement with the National Reference Group on Cocoa	Input to standard setting and stakeholder workshops		Results from the 2012 and 2013 farmer surveys on certification have been presented and discussed at National Industry forums, including those hosted by ASKINDO and CSP.
4.4.1	Review of GERNAS implementation in 2 districts	Policy recommendations for post-GERNAS government policy *Responsibility*: Univ of Sydney, UNHAS Post-doc, AIATs	Jan 2013 (initial report) August 2013	Pak Arsyad reported in internal project meeting on GERNAS survey being conducted by UNHAS social science department in Faculty of Agriculture Review completed.
4.4.2	Discourse analysis of cocoa development policy in Indonesia	Presentation of dominant development discourses *Responsibility*: Univ of Sydney, UNHAS Post-doc	Nov 2013 July 2014	Honours thesis completed through University of Sydney (Alex Meekin, 2013) Export tax study published in the Proceedings of Malaysian International Cocoa Conference.
4.4.3	Involvement in industry stakeholder meetings and policy development	Policy input developed on a needs basis *Responsibility*: CSP, UNHAS Post-doc	Ongoing	Various team members have been actively involved in quarterly meetings of CSP working groups. Jeffrey Neilson presented a paper on land use and environmental pressures related to cocoa farming and the decline in national production at the International Cocoa Conference (May 2014), Bali,

7 Key results and discussion

7.1 Effect of improved soil management on productivity and pests/diseases, especially VSD

7.1.1 Sites with contrasting intensities of VSD

East Java

This study aimed to test the hypothesis that VSD severity was associated with site-specific soil nutrient imbalances. However, we found no correlations between VSD intensity and soil or leaf nutrient contents. For example, at Antokan and Banjarsari, soils were fertile with a high CEC, high exchangeable calcium and potassium, although organic matter content (%C) was generally as low as the other sites, yet VSD severity was relatively high at these sites (Appendix 2 and Tables 7.1.1, 7.1.2).

At a number of locations both in Java and Sulawesi a clear drop in VSD severity with increasing altitude was observed – in some cases reaching almost nil (see Table 7.2.4 and 7.2.5). Average VSD severity also appeared higher with longer dry seasons, but the correlation was not statistically significant.

Table 7.1.1 Topsoil pH, macronutrient concentrations, carbon-nitrogen ration (C/N), cation exchange capacity (CEC) and base saturation (BS) at ten cocoa sites in East Java with varying VSD severity (means shown in the final column, see Appendix 2). At each site, every 10th tree along a transect of 100 trees was allocated a VSD severity score from 0 (free of infection) to 6 (tree death) and the average taken.

Location	**pH**	C	N	C/N	P	S	Na	K	Ca	Mg	CEC	BS	MeanVSD severity
			%		ppm		Exchangeable cations (cmol/kg)					%	
Gn Raung	5.2	1.89	0.24	7.6	54.7	46	0.76	2.19	3.47	0.93	15.9	48	**0.93**
Sumber B.	5.4	0.94	0.13	7	69	91	0.2	1.81	3.09	1.01	17.2	35	**0.96**
Pager Gng	5.9	0.78	0.12	7	37	61	0.5	0.92	5.32	2.89	14.3	67	**0.96**
Kaliputih	5.5	1.06	0.13	8	25	19	0.47	2.37	9.24	3.47	18.6	84	**1.35**
Pacauda	5.8	0.45	0.08	6	47	20	0.31	0.94	9.66	2.93	15.1	92	**1.14**
Antokan	5.3	1.27	0.18	7	208	128	0.46	3.43	10.22	2.81	20.5	82	**1.17**
Banjarsari	5.4	1.15	0.19	6	132	129	0.8	4.46	10.91	1.9	21.9	82	**1.19**
Gerengrejo	5.9	1.21	0.16	8	87	112	0.83	0.51	8.95	3.59	19.2	72	**1.29**
Kaliwining	6.5	1.65	0.26	6	13	21	0.4	2.8	11.18	4.43	26.1	72	**0.89**
Sumber A.	5.3	1.36	0.2	7	6	2	0.23	3.15	9.65	3	26.3	61	**0.01**

VSD severity decreased with increasing altitude (supporting observations in Sulawesi, see 7.2 below) and greater VSD severity occurred in some locations with a relatively long dry season, but there were insufficient data points for significant correlations.

Table 7.1.2 Leaf nutrient concentrations (% or ppm) at nine sites in East Java with cocoa plantings varying in mean VSD severity (shown in the final column and see Table 7.1.1)

Location	N	P	K	Ca	Mg	S	Mn	Fe	Cu	Zn	Mean VSD severity
	%						ppm				
Gn Raung-JTN	1.94	0.18	2.28	1.34	0.43	0.74	84	76	8.6	57.4	**0.93**
Sumber Baru-JTN	1.93	0.17	2.39	1.54	0.45	0.72	101	108	16.5	40	**0.96**
Pager Gng-Kembu	1.85	0.19	1.97	1.52	0.48	0.62	246	113	5.75	74.7	**0.96**
Kaliputih-Kembu	2.54	0.17	2.09	1.33	0.39	0.52	167	79	5.5	62	**1.35**
Pacauda-Sule	2.07	0.14	2.13	2.63	0.47	0.71	442	101	8.5	76	**1.14**
Antokan-Bjs	1.87	0.17	1.93	1.65	0.44	0.61	216	82	2	64	**1.17**
Banjarsari-Bjs	1.72	0.19	2.19	1.55	0.51	0.62	230	83	3	70	**1.19**
Gerengrejo-Bjs	2.08	0.18	1.93	1.56	0.43	0.57	174	122	5	52	**1.29**
Kaliwining	2.42	0.15	0.38	1.92	0.37	0.77	41	161	5	24	**0.89**

7.1.2 Compost/fertiliser trials

East Java compost trial

Table 7.1.3 shows the effect of compost/manure application on soil properties one year after treatments commenced. Surprisingly, exchangeable cations, CEC and BS were all negatively affected by the liquid manure treatments.

Table 7.1.3 Effect of two levels of compost treatment on soil macro- and micronutrient content, pH, C/N ratio, Cation Exchange Capacity (CEC) and Base Saturation (BS) in the Kaliwining compost trial.

Soil component	Control	Treatment of manure	
		10 kg / tree	20 kg / tree
N (%)	0.14	0.22	0.19
P_2O_5 HCl (mg/100g)	215	428	417
P_2O_5 Bray I (ppm)	93	288	280
C (%)	1.73	2.54	2.38
C/N	12	12	13
pH H_2O	5.85	5.87	5.95
pH KCl	5.16	5.32	5.36
Na (C-mol/kg)	0.14	0.13	0.04
K (C-mol/kg)	1.94	0.18	0.04
Ca (C-mol/kg)	14.91	2.09	0.94
Mg (C-mol/kg)	4.05	0.60	0.17
CEC(C-mol/kg)	23.23	14.52	15.03
BS (%)	90.58	20.68	7.86
SO_4 (ppm)	4	5	7
Fe (ppm)	1	2	2
Cu (ppm)	8	9	9
Zn (ppm)	8	30	24
Mn (ppm)	205	170	285

Table 7.1.4 Effect of three levels of compost supply on VSD severity for all clones. VSD was evaluated by scoring trees 0-3 (no infection to severe infection) and the mean (and SE) of three replicate blocks determined. Individual clones were also assessed (data not shown).

Treatment: compost (litres per tree)	Mean VSD score (+/- SE)
0	0.98 +/- 0.13
10	0.70 +/- 0.01
20	0.65 +/- 0.05

Yield and pest/diseases

In the first year, pod production was increased over the control (no amendments) from 15 to 18 and 21 pods per tree for the 10 kg and 20 kg per tree compost application, respectively. Soil analyses show no increase in pH, S, or exchangeable basic cations or micronutrients (except Zn) in treated plots over the control but substantial increases in total and available P (by 70-90%), N and carbon content.

Pest and disease incidence in the trial: There was no effect of compost treatment on incidence of *Helopeltis* sp. (Appendix 3). Average VSD severity for all twenty clones in the trial was decreased by the compost treatments (Table 7.1.4). Data were also obtained on the performance of individual clones in relation to soil amendment with compost (data not shown).

Bone Bone Fertiliser/Compost trial

Baseline soil data:

The soil at this site has a high sand content and low clay content (Appendix 1, Table 1). Typically for many Sulawesi farmland soils, N concentration was low-critically low (normal ranges after Nelson et al. (2011) and Fahmy (1977) are given in Table 7.3.1). Cation Exchange Capacity (CEC), soil carbon (%) and C/N ratio were higher in the fallow area than the old cocoa site. It appears that CEC was determined largely by the organic matter content (omc). The low concentrations of exchangeable cations, high H and acidity and the low base saturation levels indicate high rates of leaching. The detection of exchangeable Al, and relatively high concentrations of Fe and Mn, suggest toxicity might affect plant growth. Soil P concentrations were relatively high, typical of many Sulawesi soils (Mars soil survey data, and see Table 7.3.1, Section 3.1). Nevertheless, uptake of P and cations could be greatly restricted by the low pH of the soil. Low pH can also lead to high Al toxicity due to its high solubility at low pH; this might have affected in such a dramatic way the treatments with only urea and NPK (see below, Fig. 7.1.4B) that are likely to reduce the pH of an already very acidic soil.

Effect of treatments on soil fertility and leaf nutrient contents:

The mean percentage ratio of sand/silt/clay at the trial site was 68/26/6 indicating a very low clay content at the trial site, consistent with the baseline data. Soil parameters determined from 2012 – 2014 are given in Table 1, Appendix 4. Soil analyses indicated sub-optimal N, base saturation and CEC and Ca in soil. The high sand content, low organic matter content and low concentration of exchangeable cations are indicative of a heavily leached soil, which is likely given the total annual rainfall in BoneBone is high (ca 2800 mm/pa).

Application of organic manure (compost) gave the best response for general plant growth and health (Figure 7.1.4 photos below). Application of inorganic NPK tended to induce Ca deficiency and poor growth, even tree death. Table 2 (Appendix 4) shows the leaf nutrient contents in the 8 treatments for two years, 2013 and 2014. Except for Ca, leaf concentrations for both macro- and micronutrients were consistent between the two years and were largely unaffected by the treatments.

However, it is clear that the organic soil amendments increased nutrient uptake substantially since trees treated with compost were twice the size of control trees, and much larger than trees receiving only mineral fertiliser or lime (see Fig. 7.1.4 photos).). By June 2014 45% of the trees from treatment 2 with urea and NPK were dead probably due to aluminium toxicity and un-availability of nutrients due to low pH, just next to the treatments with compost showing beautiful healthy cocoa trees with high production of pods. Further, yields, determined as number of pods, were much higher in compost-treated trees (Fig. 7.1.2) than the trees receiving other soil amendments, and surprisingly even higher in the compost only treatment than in the treatment receiving all nutrient amendments (compost, mineral fertiliser and lime). However, in older trees addition of NPK seemed more beneficial as in an assessment in June 2014 trees treated with both compost and NPK were showing slightly higher yields compared to compost alone, indicating that for high production in mature trees some nutrient support from mineral fertilisers could be beneficial. In this experiment we were testing compost treatments with 10kg of compost per tree per year as we wanted to prove the concept of importance of compost (and soil organic matter content). However, we are aware that for farmers not enough compost is available for such high rates of application, so the combinations of compost treatments with mineral fertilisers is an important option.

The data support tree growth and yield being mainly limited by nutrient supply, since the site was uniformly managed, viz. with similar shade and tree pruning according to standard practice. Since yields were higher in compost–treated trees, an increased total supply of N, P and K (provided by mineral fertiliser) was clearly not sufficient to maximise the cocoa trees' potential yield in these nutrient-poor soils with very low pH and possibly high Al toxicity. While soil organic matter content was not increased greatly by any of the treatments (see Table 1, Appendix 4) and did not reach the higher levels found under the coconut in the baseline samples (see Appendix 1), it is apparent that compost treatment has overcome some limitation in total nutrient supply and/or availability to plant roots.

While tissue cation concentrations were not higher in compost-treated plants, it is apparent that Ca and Mg uptake was greatly enhanced by compost-treatment due to the greater size, health and yield of these trees. Interveinal chlorosis on both young and old leaves in control and mineral fertiliser-treated trees suggests these trees may have suffered deficiency of both Ca (immobile) and Mg (mobile). Compost apparently increased availability of these nutrients either through an effect on the CEC of the rhizosphere, or by increasing populations and/or diversity of microbial biota, and that this improved availability of cations.

Notwithstanding the supply of N, P and K provided by mineral fertiliser, it is also possible that compost increased pH in the rhizosphere, and therefore, uptake of these elements. In other words, increasing NPK by supplying mineral fertiliser could be redundant if the soil pH is too low. While the topsoil pH did not differ between treatments (Table 1, Appendix 4), it is possible that the NPK + urea treatment decreased pH of the rhizosphere, so that crucial nutrients were unavailable to roots. This (and/or Al toxicity) might explain the high mortality rate among young trees that received only mineral fertiliser.

Fe and Mn are abundant in the BoneBone site, reflected by high soil and tissue concentrations (Appendix 4). Further, uptake of these elements (as well as Al) increases with soil acidity. One possibility might be that the poor performance of the mineral fertiliser-treated trees was exacerbated by increased uptake of these elements due to increased acidity in the soil. However, the data do not support a correlation occurring between the treatments and tissue concentrations of Fe and Mn (Table 2, Appendix 4). It is more likely, as discussed above, that the response to mineral fertiliser applied alone, could be explained by the mineral fertiliser decreasing the already low soil pH, causing Al toxicity. Supporting this, the baseline soil data for the site (Appendix 1) indicate exchangeable Al concentrations of 1.2 to 4.3 cmol/kg in the soil.

Bean quality:

The relatively high bean count generally found in the PBC123 clone is evident in Table 7.1.5 (Column 2). However, treatments 3 and 8, both including compost, appeared to decrease bean count indicating that these treatments caused an increase in average bean size. The proportion of flat beans and waste was also lowered by compost amendment.

Table 7.1.5 Bean quality characteristics of PBC123 cocoa at the Bone Bone trial in mid-2014. No foreign matter or clustering of beans was detected. Quality characteristics were determined for dry beans harvested from each of the 8 treatments in the trial (see 5.1.2).

Treatment	Bean count	Total waste (%)	Flat beans (%)	Placental waste (%)	Broken beans (%)	Bean moisture content (%)	Fat content (%)	Shell content (%)	Moisture of liquor (%)
1	105	1.12	0.90	0.22	-	6.14	45.0	12.7	2.8
2	99	1.02	0.81	0.21	-	6.11	46.5	12.5	2.9
3	83	0.18	0.06	0.12	0.12	5.82	46.4	10.9	2.7
4	108	1.19	1.01	0.18	-	6.91	44.9	13.2	2.9
5	98	0.76	0.32	0.44	0.20	6.72	45.6	13.3	2.9
6	92	0.80	0.66	0.14	-	6.38	45	12.5	2.8
7	105	0.65	0.33	0.32	-	6.67	45.5	14.47	2.8
8	88	0.42	0.07	0.35	0.30	6.66	46.3	12.09	3.1

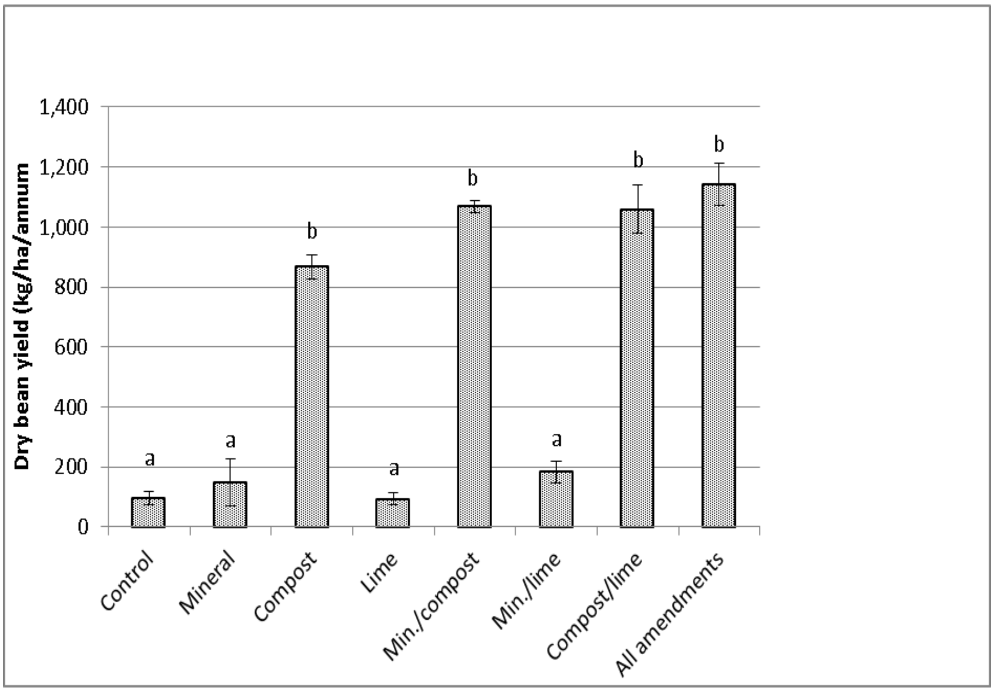


Figure 7.1.1. Yield of dry beans (determined from 2014 to 2015) following soil treatments first applied in May 2012. Data shown are the means of four replicates. Means with the same letter are not significantly different (p = 0.05, Games-Howell test). A, control (no amendment); B, mineral fertiliser; C; compost; D, lime; E, mineral fertiliser/compost; F, mineral fertiliser/lime; G, compost/lime; H, all amendments.

Pod production figures from the trial indicated that while mineral fertiliser increased productivity, compost treatment clearly increased tree productivity to a greater degree with no additive effect if mixed with fertiliser. In fact productivity in the treatment including both mineral fertiliser and compost was not much higher than when mineral fertiliser was added alone, and substantially lower than the cocoa trees supplied only with compost (Fig. 7.1.1). However, these data are for the first harvest year and trees with only mineral fertilisers (treatment 2) still might have some rests of better soil from planting time and therefore better absorption of nutrients. Later during the evaluation, the effects of

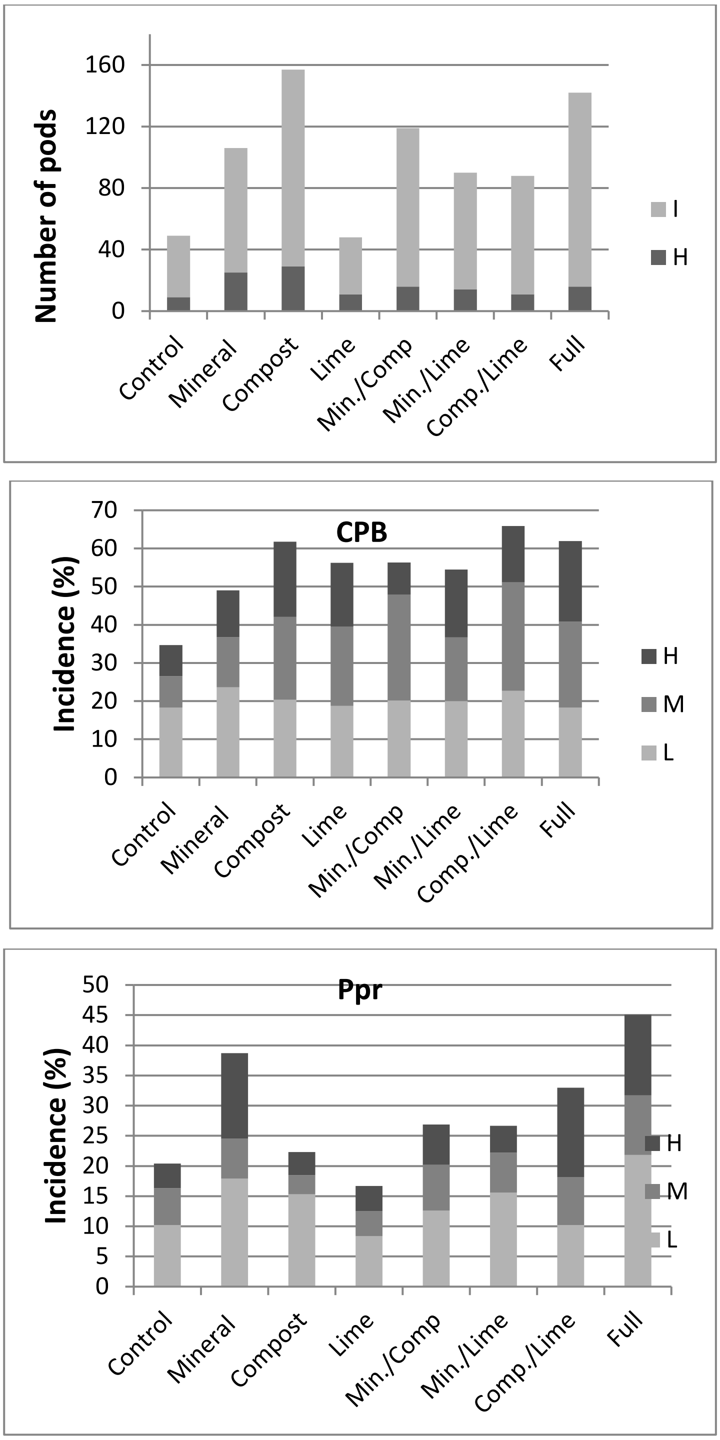


Figure 7.1.2 (a, top) the numbers of healthy (darkly shaded) and infected (lightly shaded) pods harvested from each of the eight treatments (including all plots) in the Bone Bone trial, indicating infection rates were very high regardless of treatment but that pod production was higher in the treatments including compost. Addition of lime had little effect. (b, middle) Incidence (%) of pods with low (in light grey), medium (grey) and high (dark grey) levels of CPB infestation. (c, bottom) Incidence (%) of pods with low, medium and high levels of PPR infection .

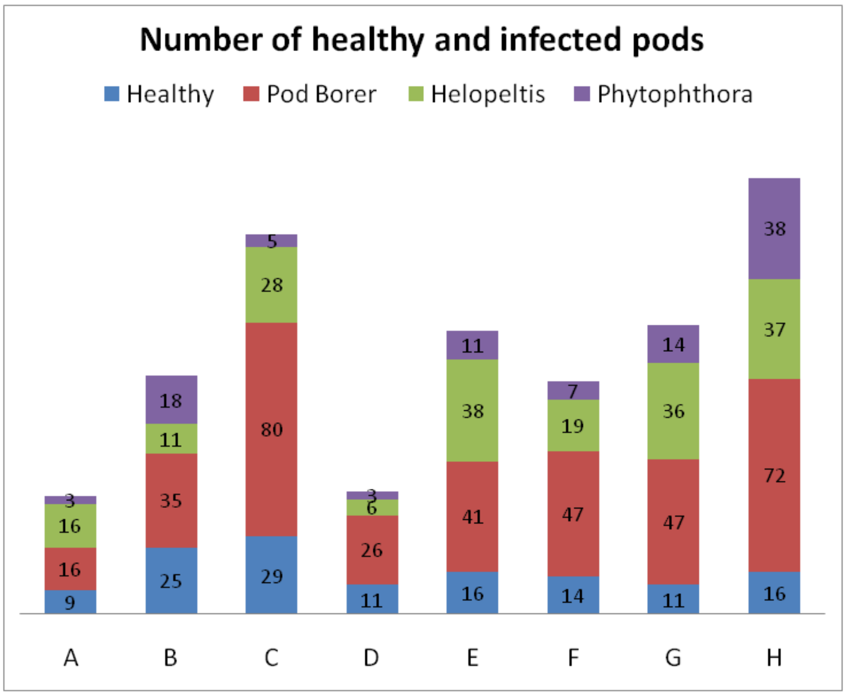


Figure 7.1.3 Number of pods infected with individual pest/diseases as well as healthy pods evaluated in treatments A, control; B, mineral fertiliser; C; compost; D, lime; E, mineral fertiliser/compost; F, mineral fertiliser/lime; G, compost/lime; H, all amendments.

exclusive mineral fertiliser (urea + NPK) were very much negative with 45% of trees dead by June 2014. However, the combination of compost and mineral fertilisers showed more response with older trees maybe because for high productivity of adult trees some additional nutrients might be useful. Microbial activity was substantially greater in the compost than in the mineral treatments (see below 7.3.1).

It was predicted that lime treatment would increase nutrient availability by increasing soil pH and, therefore, productivity, but this was not borne out by the data collected so far (see Fig. 7.1.1). Presumably under these nutrient poor conditions macronutrient availability still limited growth and productivity. Since dolomite contains Ca and Mg, while mineral fertiliser includes N, P and K, possibly the three latter nutrients are limiting productivity. There was no increase in soil pH in the lime treatments (Table 1, Appendix 4), so possibly the lime added was insufficient to overcome the buffering capacity of the soil. Compost in addition to increasing macronutrient supply would also increase organic matter content, and as a direct result, microbial activity, as well as providing a range of micronutrients, one or more of which might be limiting to production in BoneBone. As mentioned above, the very poor health of the trees (photos, Fig. 7.1.4) treated solely with mineral fertiliser indicate that this amendment was detrimental to nutrient uptake, perhaps by increasing acidity in the rhizosphere. Nevertheless, pod production was higher than in the control or lime treatments indicating a high allocation of nutrients to pod production, even though trees receiving these treatments were approximately half the size of those receiving compost treatments. However, when trees were older by June 2014, 45% of trees under treatment with only urea and NPK were dead, indicating that continuous application exclusively of urea and NPK is causing a complete exhaustion of the soil and probably further acidification of soil preventing absorption of nutrients and also increasing aluminium solubility and toxicity effects.

Figure 7.1.4 Cocoa trees in Bone Bone 2.5 years after planting and 2 years after the following treatments were initiated: A (top left), Control; B (top right), Mineral fertiliser; C (bottom left), Compost; D (bottom right), Lime (Dolomite).

Incidence of CPB and Ppr was not markedly different under the various nutrient treatments (Figure 7.1.2 b and c), and in fact the preliminary data suggest the nutrient amendment to the soil increased the total incidence of pest/diseases, especially *Helopeltis* sp. (Fig. 7.1.3). However, since the number of pods produced by the control treatment was under 50, this is inconclusive.

Bantaeng

Results of soil analyses for the Tana Loe compost/fertiliser trial, Bantaeng are given in Appendix 5 (Tables 1 and 2). The control measurements indicate a soil with cation and P concentrations sufficient for cocoa production (see Table 7.3.1) but with low N and C contents. The two measurements per treatment varied too much to draw conclusions about the effect of the soil amendments, although soil pH was slightly higher in the treatments with lime (Appendix 5). This was not found in BoneBone (Appendix 4, Table 1) perhaps because of the higher acidity of the soil there which would buffer the effect of lime; no acidity (or exchangeable Al) was detected in the soil in Tana Loe. Despite soil amendments N and C soil contents remained critically low (Appendix 5, Table 1). However, since productivity was increased by amendment with compost, it is apparent that nutrient uptake was also higher in soils treated with compost (see below).

The high incidence and severity of VSD in Tana Loe, Bantaeng is evident by the average VSD severity scores in Table 7.1.6. The data to date do not indicate that soil amendment with compost, or mineral fertiliser, had an effect on VSD although lime treatment appeared to slightly decrease average severity. This is consistent with experience of the Malaysian Cocoa Board in Pahang where lime is used to alleviate VSD (H. Azmi, pers. comm.).

Table 7.1.6 Effect of soil amendments on VSD (scored from 0-6) in Bantaeng in 2014. Treatments: P0, Control; P1, Lime; P2, Compost; P3, Mineral fertiliser (NPK); P4: 1 + 2, P5: 1 + 3; P6: 2 + 3 and P7 1 + 2 + 3. An increase in VSD severity for all trees occurred during the long dry season of that year but differences between treatments were not observed.

Treatments	March	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean
P0 Control	1.5	2.5	3.0	3.5	4.3	4.8	4.8	4.0	3.3	3.5
P1 Lime	2.5	1.3	2.0	3.0	3.0	4.0	4.0	4.0	3.0	3.0
P2 Compost	1.0	2.0	3.0	3.5	4.0	4.5	4.5	4.3	3.5	3.4
P3 Mineral	2.3	1.7	2.7	3.7	3.7	4.3	4.3	3.7	3.3	3.3
P4	2.5	3.0	4.0	4.0	5.0	5.0	5.0	4.0	4.0	4.1
P5	1.3	2.0	2.0	3.0	3.0	4.0	4.0	4.0	3.0	2.9
P6	2.8	2.0	2.5	3.3	3.5	4.3	4.3	3.3	3.3	3.2

Table 7.1.7 Number of pods harvested in 2014 and average PPR incidence in the soil amendment trial in Bantaeng.

Treatments	Number of pods	PPR incidence (%)
P0 Control	79	11.7
P1 Lime	96	9.0
P2 Compost	219	12.0
P3 Mineral NPK	69	8.6
P4 Compost + lime	164	1.5
P5 Mineral + lime	282	6.4
P6 Compost + mineral	57	5.7
P7 NPK + compost + lime	306	6.4

Productivity was greatly increased with some nutrient amendments of the soil, but not others (Table 7.1.7). In addition, compost with lime appeared to reduce PPR incidence, although with little effect on CPB incidence. Pod production was highest in trees supplied with compost (P2), mineral fertiliser/lime (P5) and all nutrient amendments (P7), but was low in mineral fertiliser treatments without lime (P3, P6, Table 7.1.7). Possibly, mineral fertilisers increased rhizosphere acidity while lime treatment increased nutrient availability by increasing pH (while the data are variable, Appendix 5, Table 1 indicates that soil pH was no higher than the control in the soil receiving mineral fertiliser and/or compost treatments, but was increased by lime).

Populations of soil fungi and bacterial in the control treatment 100,000 cfu/g and 30,000 cfu/g respectively, but soil amendment treatments appeared to have no significant effect, although bacterial populations appeared to be increased by mineral fertiliser (data not shown).

Comparisons of soil analyses by different soil laboratories

Equivalent soil samples were analysed in three soil laboratories at: ICCRI, BPTP Maros and Universitas Gaja Madah (UGM) in 2014 (in November, 2011 equivalent samples were also analysed by the ICCRI and BPTP labs, data not shown). In June 2014, eight samples from plots representing the 8 treatments in the Bone Bone compost/fertiliser trial were collected and sent to ICCRI and BPTP Maros, and three samples (from control, compost and full treatments) were sent to UGM. Results are presented in Appendix 6. Results for the analyses of most nutrients, including C and N content, were consistent between labs (Tables 1 and 2, Appendix 6). The concentration of exchangeable cations (except for Na) and, therefore, base saturation appears to have been underestimated in BPTP Maros. On the other hand, pH (H_2O) estimates were lower in ICCRI than the other two labs (see Appendix 6).

7.1.3 Testing organic amendments

Soil microbial activity

All treatments using compost (either alone or in combination with chemical fertilizers or lime) consistently shows higher level of microbial activity than that without compost (Fig 7.1.5).

Microbial diversity (using DNA extracted from soil in Indonesia analysed by T-RFLP in Australia) is currently being evaluated at the University of Sydney.

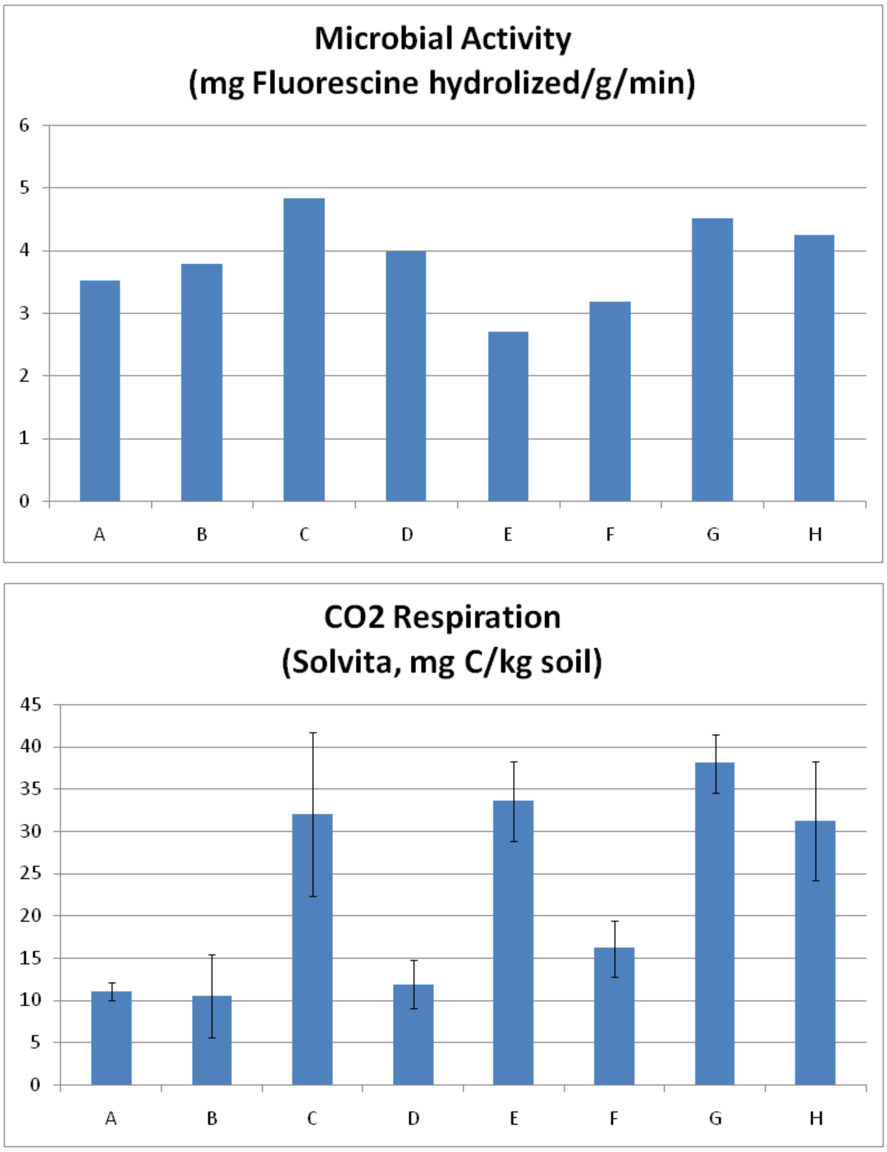


Figure 7.1.5. Effect of nutrient amendments on soil microbial activity in BoneBone determined by fluorescein diacetate hydrolysis (upper plot) and by soil CO_2 respiration (lower plot). Treatments A, control; B, mineral fertiliser; C; compost; D, lime; E, mineral fertiliser/compost; F, mineral fertiliser/lime; G, compost/lime; H, all amendments. Mean activity is indicated by the vertical bars with SEM.

Testing a chelator-based foliar nutrient product

Foliar application of a chelator-trace element-nutrient mix once per week for five months, significantly increased seedling growth in Binuang and Mapilli (Figure 7.1.6). In a complete randomised experiment in Tampanua, Polman the mix applied as a foliar spray once per week and also mixed with biochar and applied to the soil in April 2014 reduced the severity of VSD (Figure 7.1.7). The effect on pod disease remains unknown: replicated tests need to be conducted in the harvest season.

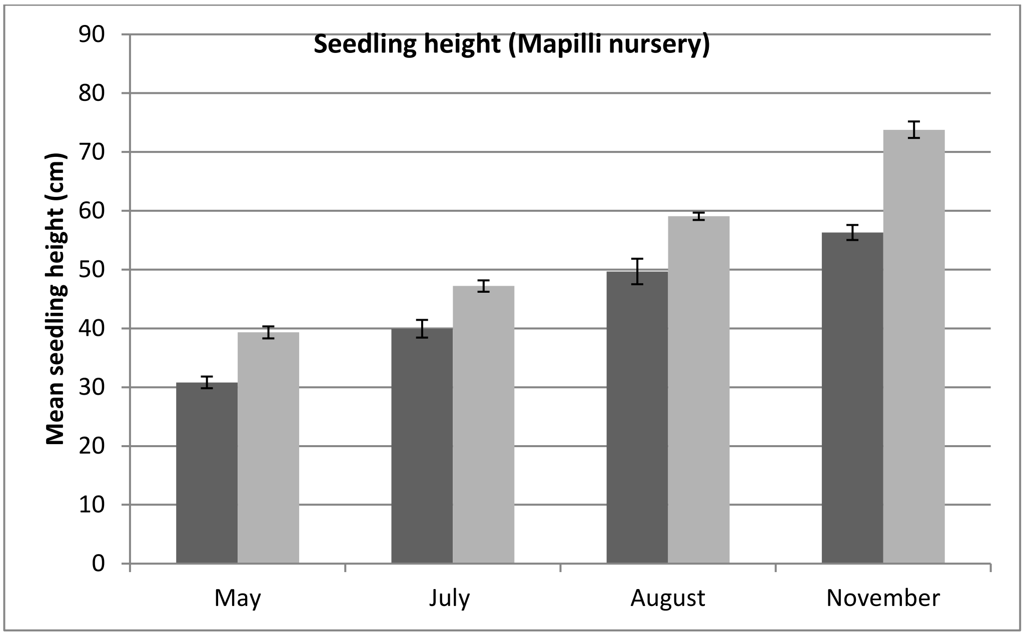


Figure 7.1.6 A chelator-nutrient- trace element mix developed in Malaysia was tested on 1-month old cocoa seedlings. It was applied as a foliar spray once per week beginning in March/April 2014 for six months and by May growth was significantly different between treatments: seedling height of control (untreated) plants indicated by dark grey bars; seedling height of plants treated with the chelator-nutrient mix shown as light grey bars.

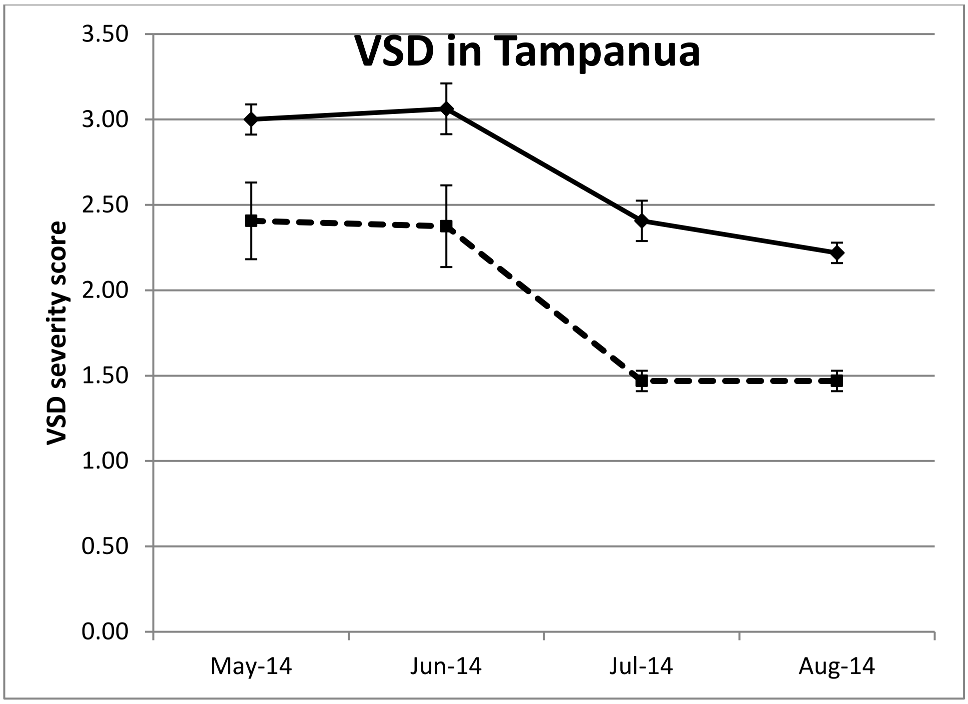


Figure 7.1.7 In an experiment at a river-side farm Tampanua affected by VSD with an average severity of 2.8 in April 2014 based on a scoring system from 1 (healthy) to 4 (severe infection with some dieback evident), trees treated with a chelator-trace element-nutrient product mixed with biochar (applied in April) and by foliar spray once per week had a lower average severity of VSD

(dashed line) than the control trees (continuous line). Each treatment consisted of 8 plots with 8 trees per plot; trees were scored each week for severity. Note that VSD severity declined in all of the trees after June due to alleviation of symptoms in the mid-year rains.

7.2 VSD in relation to changes in severity and new symptoms

7.2.1 Incidence, severity and symptoms of VSD

VSD severity in clones

Two clone trials (established by SMAR/2005/074) comprised the field component of a Hasanuddin University PhD study. Results indicated a clear ranking of VSD resistance among local clones and the predominance of chlorotic or necrotic symptoms in VSD-infected trees in particular clones (Table 7.2.1). No clear correlation between symptom type and severity was shown. Nevertheless, the study found that the newer symptoms now predominate and the increase in their frequency occurred concomitantly with a general increase in VSD severity in the last decade in Sulawesi.

Table 7.2.1 Incidence and severity of VSD with original (chlorotic) or new (necrotic) symptoms in a clone trial at Anreapi, Polman. Means within columns with the same letters are not significantly different (P<0.05).

Clone	Total infections		Necrotic symptoms		Chlorotic symptoms		Mixed symptoms	
	Incidence	Severity*	Incidence	Severity	Incidence	Severity	Incidence	Severity
PB123	37.1^{a}	2.4	32.5^{a}	2.5^{ab}	3.0^{a}	0.8^{a}	1.6^{a}	0.5^{a}
MO5	40.7^{a}	2.7	34.5^{ab}	2.8^{ab}	3.3^{a}	0.8^{a}	2.5^{a}	0.8^{ab}
Geni J	48.3^{ab}	2.8	34.7^{ab}	2.6^{ab}	6.0^{a}	1.1^{a}	1.4^{a}	0.3^{a}
KW523	60.5^{abc}	2.9	57.1^{bcde}	2.8^{ab}	3.2^{a}	0.8^{a}	2.6^{a}	0.4^{a}
KW516	60.6^{abc}	2.9	49.7^{abc}	2.8^{ab}	7.4^{a}	0.9^{a}	2.0^{a}	0.4^{a}
KW617	74.8^{bcd}	2.8	68.7^{defg}	2.9^{ab}	3.6^{a}	1.1^{ab}	2.1^{a}	0.8^{ab}
MO1	74.8^{bcd}	2.9	64.1^{cdef}	2.8^{ab}	7.3^{a}	1.4^{ab}	3.1^{a}	1.3^{ab}
BR25	76.5^{cd}	2.9	44.8^{abc}	3.0^{ab}	22.3^{b}	2.6^{b}	8.9^{b}	1.7^{b}
Muhtar	80.3^{cd}	3.0	73.7^{efg}	3.0^{ab}	4.1^{a}	1.1^{a}	2.5^{a}	0.6^{a}
Nasir R	86.4^{cd}	3.0	79.6^{fg}	2.7^{a}	3.6^{a}	1.1^{ab}	2.7^{a}	0.8^{ab}
Ilham	86.8^{cd}	2.8	82.0^{fg}	2.9^{ab}	2.7^{a}	0.6^{a}	1.6^{a}	0.3^{a}
Husbitori	94.2^{d}	3.0	88.7^{g}	3.0^{b}	2.9^{a}	0.7^{a}	1.7^{a}	0.4^{a}
Average	68.4	2.8	59.2	2.8	5.8	1.1	2.7	0.7

Progress of infection was also followed in both trials showing the time from the appearance of early symptoms to imminent dieback is about 3 months, and that in susceptible clones the infection reached the branch tip.

In the established clone trial in Anreapi, West Sulawesi, nutrient contents of healthy and infected leaves in two clones displaying either chlorotic or necrotic symptoms indicated significantly lower P content in VSD affected than healthy leaves in Sulawesi1 and significantly lower K content in VSD affected than healthy leaves of MO1 (Table 7.2.2), supporting earlier observations by ICCRI in East Java. There was no difference in nutrient contents between leaves with different symptoms, and so the results did not provide evidence of an association of the new symptoms with a nutrient deficiency. The reasons for the necrosis associated with recent symptom changes remains unknown.

Table 7.2.2 Analysis of leaf nutrients from three leaf types (healthy, VSD chlorotic, VSD necrotic) in clones M01 and Sulawesi 1, showing means over four sites (Cendana, Pinrang, Anreapi, Lera). Phosphorus: *Kruskal-Wallis ANOVA identified significant differences between leaf types (df=2, f=6.8, p=.045). Potassium: **ANOVA identified significant differences between leaf types (df=2, f=6.5, p=.018). Values with the same letter are not significantly different.

Nutrient	Clone	Leaf type		
		Healthy	Chlorotic VSD symptoms	Necrotic VSD symptoms
N (%)	M01	1.67	1.70	1.67
	Sulawesi 1	1.72	1.71	1.70
	Mean	**1.70**	**1.70**	**1.69**
P (%)	M01	0.09	0.07	0.08
	Sulawesi 1	0.15* a	0.07* b	0.08* b
	Mean	**0.12**	**0.07**	**0.08**
K (%)	M01	1.18** a	0.60** b	0.65** b
	Sulawesi 1	0.94	0.60	0.58
	Mean	**1.06**	**0.60**	**0.61**
Ca (%)	M01	4.30	6.32	5.65
	Sulawesi 1	4.05	5.70	5.87
	Mean	**4.18**	**6.01**	**5.76**
Mg (%)	M01	0.39	0.44	0.46
	Sulawesi 1	0.41	0.41	0.42
	Mean	**0.40**	**0.42**	**0.44**
S (%)	M01	0.34	0.27	0.25
	Sulawesi 1	0.31	0.27	0.23
	Mean	**0.33**	**0.27**	**0.24**
Zn (ppm)	M01	31.2	30.5	28.7
	Sulawesi 1	43.7	34.2	36.7
	Mean	**37.5**	**32.3**	**32.7**

Sporocarp observations and spore shape and size

Evidence provided both by molecular studies (see below) and microscopic examination indicated that the causal pathogen of VSD, *Ceratobasisium theobromae*, remained unchanged (see Talbot and Keane, 1971) (however, regional haplotypes based on ITS sequences were identified – Samuels et al., 2012). Basidiospores were rare or absent in the basidiocarps collected. In February 2012, although a number of basidiocarps were collected from the Polman clone test site as well as from cocoa farms nearby, no basidiospores were found. In February 2014, basidiospores were observed on basidiocarps in Tarengge, East Luwu. In 2012 and 2014, following microscopic examination of the myclelium of many basidiocarps, hyphae in the advanced stages of basidiocarp development (before sporulation) were revealed (Talbot and Keane 1971) and some basidiocarps also had formed basidiospores.

Most basidiospores observed were detached (Fig. 7.2.1). However, attached spores and sterigmata were also observed and measured. Spore dimensions were within the range described by Talbot and Keane (1971) as typical of *C. theobromae*, ranging from 15 to 20 um in length and 7.5 to 8.0 um in width. Many had a slightly asymmetric shape as described in Talbot and Keane and later in Malaysia. Sterigmata observed were approximately half the length of the spores (consistent with the descriptions of Talbot and Keane). The spore dimensions and shape and their association with sporocarps which developed from *Rhizoctonia*-like hyphae support their identification as *C. theobromae* basidiospores. Whether other *Ceratobasidium* species, particularly *C. ramicola,* were also present (as reported based on DNA evidence by Samuels et al., 2012) is uncertain, as the hyphae of *C. ramicola* and *C. theobromae* are very similar, but small basidiospores with dimensions of approx. 6 x 4 um typical of *C. ramicola* (Kotiranta and Saarenoska 2005) were not found. Also the frequent anastomosis reported in *C. ramicola* (Samuels et al. 2012) was not observed, either in the mycelia collected from sporophores or in mycelium observed growing out from cut petioles and leaf mid-ribs. In 2012, the presence of spores in at least some of the basidiocarps collected in March but not in February is likely to be explained by the heavy daily rainfall over the 4 days that preceded the collection in March. In Tarengge in February 2014, basidiospores were observed to have been formed on sporocarps that had developed on cracks in the main veins of leaves followed several days of near continuous rain (Fig. 7.2.1).

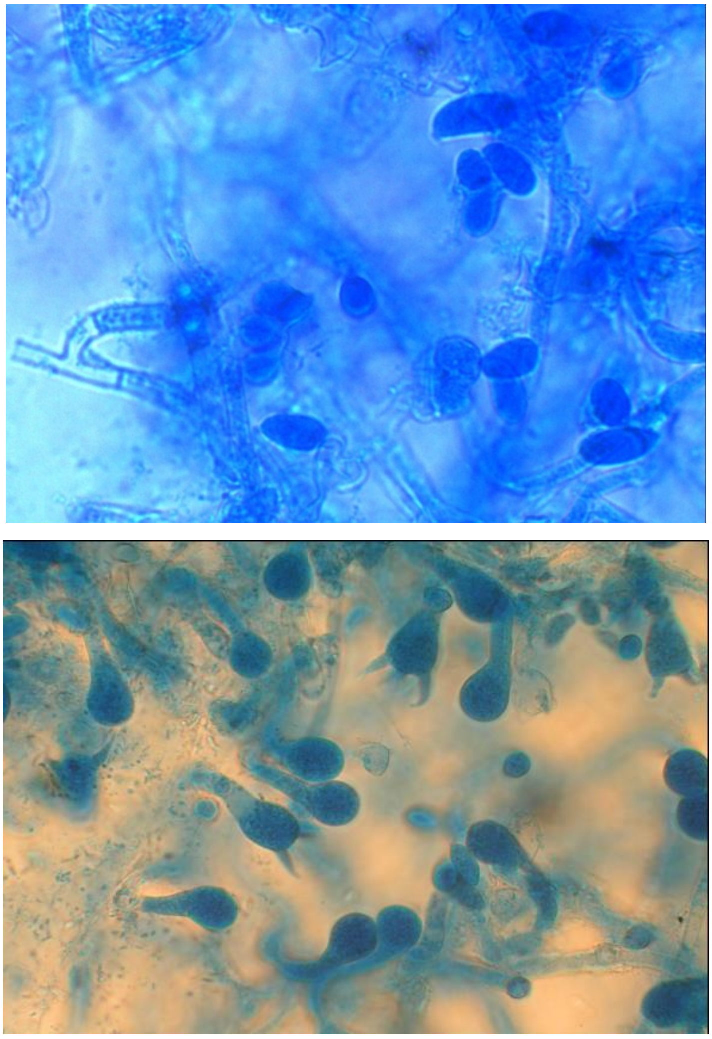


Figure 7.2.1 Photomicrograph showing basidia and basidiospores identical in morphology and size to those described for *Oncobasidium theobromae* from PNG in 1970. Taken from sporocarp formed on leaf lamina adjacent to cracks in the main vein on a leaf showing the new, necrotic symptoms, Tarengge, North Luwu, South Sulawesi Feb 2014.

7.2.2 Isolation of potential pathogens

In VSD-infected cocoa with new (necrotic) symptoms, *C. theobromae* and other fungi were identified by PCR and sequencing was undertaken of isolates from Sulawesi and by direct amplification of infected leaves from plant samples collected in Kerala and Sulawesi. Typical DNA isolation and PCR methods adapted for research in the Hasanuddin University facility are given in Appendix 7.

ITS DNA sequences obtained from isolates grown from VSD-infected tissue or by direct amplification indicated a range of fungi associated with VSD infections (some are shown in Table 7.2.3). *Ceratobasidium theobromae* was identified in samples in Kerala, India (Table 7.2.3) – the predominant symptoms in Kerala were the original (chlorotic) symptoms. Distinctive basidia and basidiospores were observed in a sporocarp formed on a leaf lamina at Tarengge, South Sulawesi. *C. theobromae* sequences in addition to sequences for *Guignardia* sp. isolated from VSD-infected leaves in Kerala and *Ceriporia* sp. in Sulawesi have been submitted to NCBI Genbank.

Table 7.2.3 DNA (ITS region) sequences: some species matches for isolations from VSD-infected cocoa.

Origin	Source	Primers	Species (% identity)	Comments
Anreapi	Fungus isolated from Husbitori	ITS5/ITS4	*Meripilus giganteus* (100)	Basidiomycete; wood rotting
Anreapi	Fungus isolated from Husbitori stem	ITS5/ITS4	*Meripilus giganteus* (100)	Basidiomycete; wood rotting
Anreapi	Fungus isolated from Husbitori	ITS5/ITS4 and ITS1F/ITS4B	*Meripilus giganteus* (100)	Basidiomycete; wood rotting
Anreapi	Fungus isolated from BR (Sul2)	ITS5/ITS4	*Phomopsis sp.* (99)	Or *Diaporthe* sp
Anreapi	Fungus isolated from M01	ITS5/ITS4 and ITS1F/ITS4B	*Ceriporia lacerata* (99)	Basidiomycete; wood rotting
Pinrang	Fungal isolate from petiole	ITS5/ITS4	*Lentinus squarrolus* (97)	Basidiomycete; wood rotting (isolation from Panimbu Red)

Sulawesi	Fungal isolate	ITS5/ITS4	*Eutypella* sp. (100)	
Kerala, India	Direct leaf extraction	ITS5/ITS4	*Guignardia mangiferae* (99)	Leaf pathogen (Monipali)
Kerala, India	Direct petiole extraction	ITS5/ITS4 and ITS1F/ITS4B	*Thanatephorus (Ceratobasidium) theobromae* (99)	Unmanaged cocoa in Monipali
Kerala, India	Direct petiole extraction	ITS1F/ITS4B	*Thanatephorus (Ceratobasidium) theobromae* (99)	Unmanaged cocoa in Vempley
Kerala, India	Direct petiole extraction	ITS5/ITS4	*Thanatephorus (Ceratobasidium) theobromae* (99)	Unmanaged cocoa in Monipali

7.2.3 Student studies

The framework and budget provided by the project enabled students from local universities to undertake fourth year Skripsi projects (necessary for completion of their undergraduate degrees). The provision of cocoa research sites contributed to substantial interest among the students, and some of these were selected to take part in various research studies at ACIAR project locations. Interesting findings resulted. For example, in the CPB study at the Anreapi clone trial, students evaluated the response of clones to egg laying and larval development in six clones, finding a markedly different resistance response in the clones. These studies are related to an interest in the kairomone properties of cocoa in attracting the moth and conferring susceptibility. Collaborative work continues with USDA (Peter Teal) and a Masters graduate has applied for the Borlaug Fellowship to identify and assay volatiles produced by cocoa pods. Most student studies were based in Bantaeng where Hasanuddin University trains and conducts participatory research with farmer groups. A Muslim University study supervised by Ayu Parawansa was conducted at the IPDM site in Wotu.

Other field studies included Honours studies based at La Trobe and Sydney which used these clone tests and other sites (see above). This included a 7-month study through La Trobe University supervised by the project leader and co-supervised in Sulawesi by the project coordinator under an Endeavour Scholarship which required all field work to be done in the target country of the scholarship.

VSD severity at different altitudes in Sulawesi

An Honours study (supported by an Endeavour Scholarship) by Susanna Bryceson included evaluation of VSD severity and symptoms in relation to altitude at two sites in Sulawesi. There was a strong negative correlation between altitude (presumably temperature) and incidence and severity of necrotic (new) symptoms of VSD while there was no relationship between altitude and the incidence of chlorotic (old) symptoms.

Tables 7.2.4 and 7.2.5 shows a selection of results on the relation of VSD and altitude obtained in the Honours study. Clones were evaluated for VSD severity, incidence and symptoms at different altitudes in Central Sulawesi and West Sulawesi.

In Central Sulawesi (Table 7.2.4), incidence and severity of VSD was less at the higher altitude for all three clones. Further, among diseased trees the symptoms changed from being predominantly necrotic at low altitude to predominantly chlorotic at the higher altitude. Results for disease severity were consistent with data on VSD severity collected in East Java.

Table 7.2.4. Severity and incidence of VSD symptoms in 3 cocoa clones (Anton Panimbu, MO6, MO4) grown at low or high altitude in Central Sulawesi *(Susanna Bryceson)*. At each sampling point and for n trees of each clone, the incidence of VSD symptoms (necrotic or chlorotic) was determined. On each tree, scores of severity from 0 (no disease) to 4 (severely infected) were allocated to a random selection of 10 branches. The cumulative score was taken and a mean score determined for the n trees in the sample.

CLONE	**ALTITUDE (M)**	**SEVERITY**		**INCIDENCE**					
		n trees	**mean tree VSD score**	**n branches**	**% trees with necrotic symptoms**	**% trees with chlorotic symptoms**	**% healthy**	**diseased trees: % with necrotic symptoms**	**diseased trees: % with chlorotic symptoms**
AP	**59**	5	14.0	50	52	18	30	74	26
AP	**672**	10	1.8	100	2	16	82	11	89
M06	**59**	7	4.6	70	27	19	54	59	41
M06	**672**	10	0.8	100	0	8	92	0	100
M04	**59**	8	9.8	80	30	10	60	75	25
M04	**672**	10	1.2	100	0	12	88	0	100

The decline in VSD incidence/severity and increase in the relative proportion of chlorotic symptoms with altitude was also shown by data collected from a transect along an altitudinal gradient in Sulawesi 2 cocoa in West Sulawesi (Table 7.2.5). The clone Sulawesi 2 (also known as BR25) has a relatively high frequency of chlorotic symptoms (Ayu Parawansa PhD thesis) but at lower altitudes in the transect in this study necrotic symptoms were equally frequent. These disappeared as the altitude increased along the transect. The highest altitude in the transect was under 200m, yet symptoms at this altitude were exclusively chlorotic. A similar change in the predominant symptom from necrotic to chlorotic with increasing altitude was shown for hybrid cocoa (S. Bryceson, Honours thesis).

Table 7.2.5 VSD severity and incidence in *cocoa* clone BR25 (Sulawesi 2), July, West Sulawesi 2014 (Susanna Bryceson Honours thesis 2014). Disease severity and incidence of symptoms were evaluated as described in Table 7.1.3.

Altitude (metres)	n trees	Severity: mean tree-disease score	Incidence: % of diseased trees	
			necrotic symptoms	chlorotic symptoms
46	14	8.7	23	21
64	8	7.8	27	73
93	8	3.1	13	87
144	8	3.3	0	100
173	8	2.8	0	100
197	8	4.3	0	100

7.3 Improved planting material

7.3.1 Clone evaluation

Data on clone evaluation of the SMAR/2005/74 trials in Pinrang, Polman, North Luwu and North Kolaka was completed and has been reported (McMahon et al., 2015; Purwantara et al., 2015). Two trials continue to be evaluated by Mars Inc. field staff. Soil analyses from Anreapi and Tiwu (Pinrang) trials are given in Table 7.3.1. They indicate the greater fertility of soil in the Pinrang trial site which would account for the more prolific vegetative growth and higher yields in this trial, than the other sites (soil fertility in both the Anreapi – see Table 7.3.1 - and the North Luwu trial sites was low). Identification of the VSD pathogen, the new symptoms and heritability of VSD resistance was also reported (McMahon et al.,submitted for publication).

Table 7.3.1 Soil properties at the clone trial sites in Anreapi, Polman and Tiwu, Pinrang

Soil parameter (unit)	Polman trial	Pinrang trial	* Adequate or normal range
sand/silt/clay (%)	66/28/6	35/48/17	na
pH	5.89	6.76	5.5 – 6.5
N (%)	0.14	0.14	>0.20
Organic carbon (%)	1.45	1.83	>5
C/N	10.3	13.0	8-10
[1]S (total, ppm)	466	540	100 – 500
[2]Available P (ppm)	61.2	38.4	6–10
CEC (cmol/kg)	9.16	19.94	12 – 25
Exch. Ca (cmol/kg)	9.74	25.72	5 – 10
Exch. Mg (cmol/kg)	1.21	2.90	1 – 3
Exch. K (cmol/kg)	0.28	0.55	0.3 – 0.6
Fe (ppm)	6314 (total)	10930 (total)	41.3 (21.6 – 99.3): avail.
Mn (ppm)	237 (total)	460 (total)	19.0 (3.3 – 48.6): avail.
Cu (ppm)	20	30	2.06 (0.53 – 4.62)
Zn (ppm)	40	4	2.34 (0.91 – 4.53)
Co (ppm)	<1	1	na

7.3.1 Establishment of clone tests

The clonal trees were planted in March 2012 in different sites in Sulawesi and evaluated at some of the sites. Early growth results from these tests, as well as average VSD severity, are shown in Appendix 8. VSD severity was consistently lower in clones such KW617 (progeny clone of PBC123, which is well-known for VSD resistance), KW514 and 45 than in more susceptible clones. A high heritability for VSD resistance was established in previous clone trials (Section 7.3.1). Pod production was evaluated when the trees were 2.5 years old.

A number of trees died during the severe dry season of 2014 in the Sumarang collection. The clones with higher survival rates, such as M06, are potentially more resistant to drought although this would need to be confirmed in replicated trials - the clone test was not blocked (replicated) and so local variation in edaphic or microclimatic factors may have played a role in tree survival.

Table 7.3.2 shows the average number of pods produced during the main harvest season (three months) at three sites. Growth parameters determined at the same time are shown in Table 7.3.3 for two of the sites. The difference in total pod production between sites can be attributed to different rates of tree growth as shown by the data on tree height and diameter (Table 7.3.3). No correlation occurred between growth parameters in individual clones at the two sites: it appears that interaction with environmental factors was key to differential growth between the tested clones. When ranked for production (not shown) relative productivity of individual clones was not consistent between sites (see Table 7.3.2). Further harvests would be needed to verify whether the productivity of the tested clones has multi-location consistency, which would indicate reasonable heritability for yield.

Table 7.3.2. Average number of pods produced by trees (2.5 years after planting) during the peak harvest (three months) in multi-location clone trials. There were16 trees of each clone at each location.

Clone	Average number of pods per tree/peak harvest		
	Bone Bone	Wotu	Tampumia
KW 617	19.3	11.4	0.6
KW 516	19.0	6.0	17.4
KB 1	17.2	3.3	2.0
M 01	11.3	1.1	10.1
M 06	11.3	14.0	4.6
45	9.9	5.1	2.6
THR	8.7	4.8	11.7
KW 733	6.8	13.2	1.4
TSH 858	5.9	2.0	-
KW 514	5.3	-	2.5
PR	2.8	2.5	1.4
Sulawesi 1	-	1.0	6.0

Table 7.3.3 Diameter and height of trees 2.5 years after planting in Bone Bone and Wotu.

Clone	Bone Bone		Wotu	
	Diameter (mm)	Height (cm)	Diameter (mm)	Height (cm)
KW 617	75.3	192.8	45.8	171.6
KW 516	72.2	222.5	47.7	267.8
KB 1	73.2	269.8	58.0	230.6
M 01	72.9	223.0	54.6	213.2
M 06	70.7	243.6	59.6	224.0
45	63.1	174.6	62.2	205.4
THR	65.7	194.4	68.2	247.6
KW 733	71.9	210.2	56.6	239.4
TSH 858	60.1	198.4	49.5	198.2
KW 514	29.1	153.0	-	-
PR	68.3	232.8	63.6	255.2
Sulawesi 1	-	-	57.2	187.8

7.4 Extension and Policy

7.4.1 IPDM and extension

As part of a participatory research and extension model, IPDM demonstration trials in West and South Sulawesi and West Papua were located strategically on farms along roads frequented by farmers to demonstrate 4 management options (or 5 in Sumarang) (see Methodology): A - unmanaged (current farm practice); B - improved pruning of shade and cocoa trees and sanitary removal of infested pods; C - B plus fertiliser addition; D - C plus targeted spraying (E – B plus organic manure and insecticide treatment). Only the results from West Sulawesi are presented below as these trials were monitored regularly by project partner staff, especially Dinas Perkebunan Kehutanan (Office of Plantation Crops and Forestry), Polman. The IPDM plots in Wotu were assessed for 6 months for the field component of a Skripsi project at Muslim University (supervisor: Ayu Parawansa).

Key results from IPDM trials:

1. The improved management option involving minimum investment in the form of labour for pruning and sanitation (option B) significantly increased pod production. Further capital investment for addition of fertiliser (option C) significantly increased pod production further. However, further capital investment in pesticide application (option D) did not significantly increase the number of pods, although in Anreapi, the proportion of healthy pods increased slightly (Figs 7.4.1 and 7.4.2).

2. Sanitation of infested pods significantly reduced the proportion of pods with CPB and Phytophthora infestations, but not *Helopeltis* infestation. Application of fungicide reduced Phytophthora incidence, but application of insecticide did not reduce CPB and *Helopeltis* infestations. Possibly the pressure of pests from surrounding plots was so high that the application insecticide in the plots did not have an effect.
3. Similar trends were evident in the Sumarang trial: fertiliser increased the number of pods, but no increase in pod harvest above this plot (C) occurred in the plot with a pesticide (option D) or in the plot with the organic fertiliser/organic pesticide (option E), possibly due to the variability of trees in the plot.

Anreapi: The effectiveness of management, even solely cultural management, in increasing productivity is clearly shown by the data from Anreapi (Figures 7.4.1 and 7.4.2). In addition, application of fertiliser greatly increased production above that of cultural management. However, treatments C and D did not decrease the proportion of infected pods in the total harvest compared to the plot using cultural methods. The relatively high proportion of healthy pods in the sprayed plot (Treatment D) by May 2-14, in the peak harvest, suggests the full treatment was having an effect by this time.

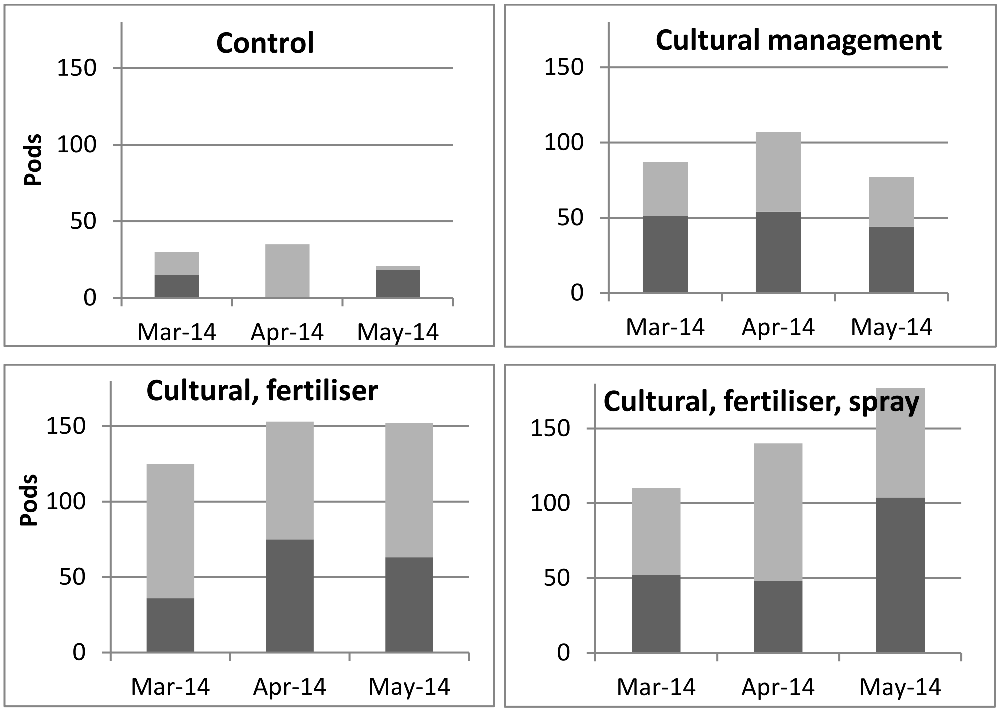


Figure 7.4.1. The 2013 harvest season in four IPDM plots in Anreapi, West Sulawesi showing total number of pods per 25 trees. The four treatments are: upper plots, Control (untreated) and cultural methods of pruning and sanitation, lower plots, cultural methods in addition to fertiliser application and cultural, fertiliser and pesticide treatments. For each monthly harvest, the number of healthy pods (dark shading) and infected pods (light shading) is shown.

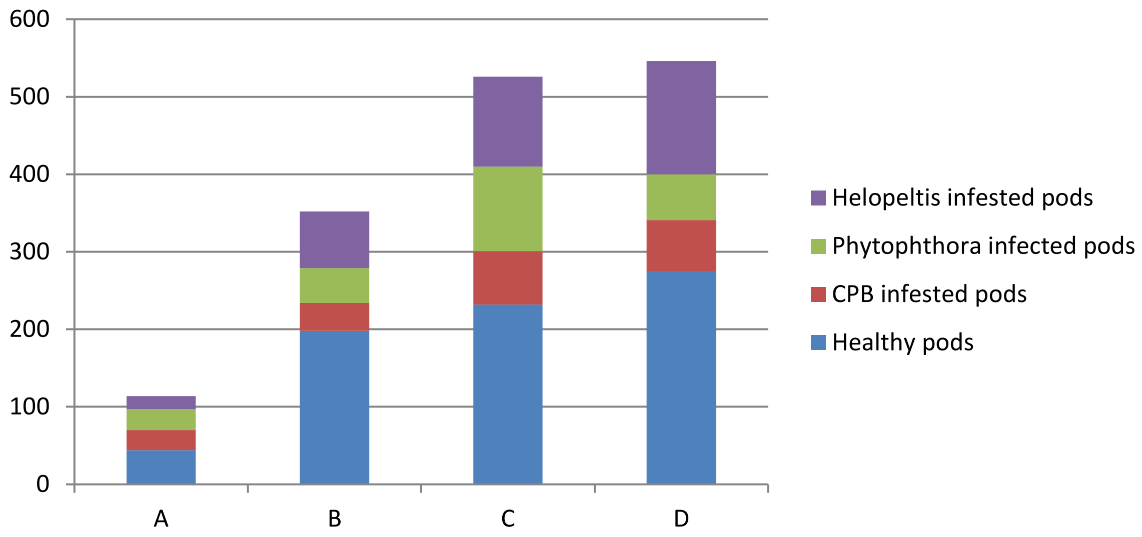


Figure 7.4.2 Number of harvested pods (infected or healthy) per plot in the IPDM trial in Desa Duampanua, Kec. Anreapi, Polman (March-December 2014) in plots with increasing level of management: A, control, B, + cultural management; C, cultural + fertiliser; D, cultural + fertiliser + spray.

Table 7.4.1 Anreapi IPDM trial: incidence of cocoa pod borer (CPB), Phytophthora pod rot (Ppr) and *Helopeltis* sp. in the total harvest (ripe and immature pods) during three months of the peak harvest of 2014 in IPDM plots demonstrating management options (I - IV) ranging from unmanaged (control) to complete (including cultural, fertiliser and targetted spraying) in Anreapi sub-district. The cocoa genotype in the trial was BR25 (Sul2) * also infested with *Helopeltis* sp.

	Incidence (%)								
Treatment	CPB			Ppr			*Helopeltis* sp.		
	March	April	May	March	April	May	March	April	May
A control	50.0*	31.4	38.1	0.0	68.6	100	(50.0)	0.0	14.3
B + Cultural	12.6	9.3	10.4	9.2	14.0	28.6	19.5	26.2	3.9
C + Fertiliser	22.4	6.5	15.1	29.6	22.9	24.3	19.2	21.6	19.1
D Complete treatment	13.6	9.3	15.3	7.3	28.6	6.2	31.8	27.9	19.8

Sumarang: In Sumarang, 5 treatments were included by a roadside near the river on the outskirts of the village.

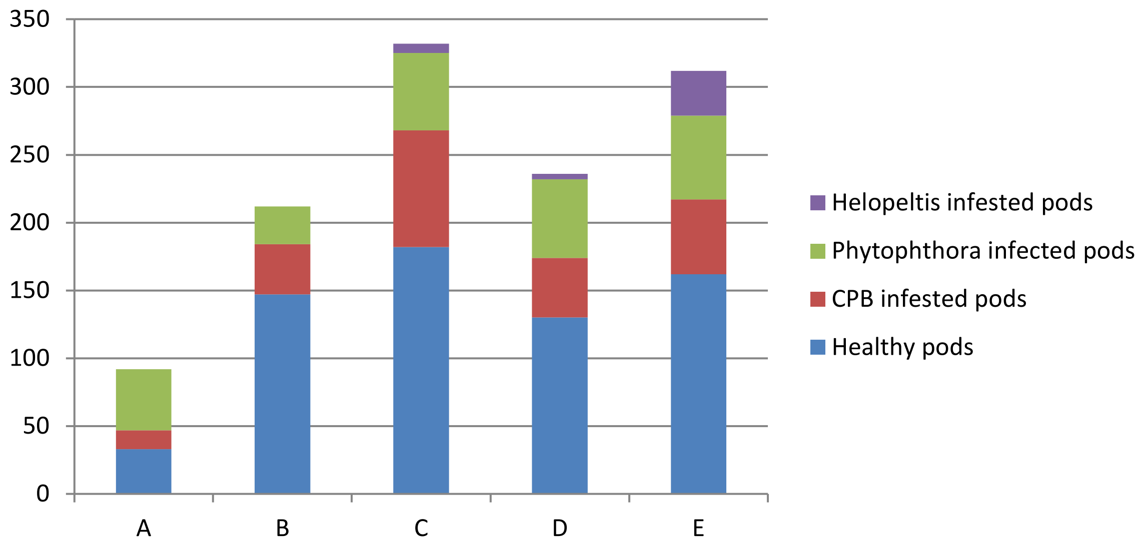


Figure 7.4.3 Number of harvested pods per plot (25 trees per plot) in IPDM trial Desa Sumarang, Kecamatan Campalagian, Polman, 2014 (March-December 2014) in plots with increasing level of management: A - control; B - cultural management; C - B + fertiliser; D - C + spray. In addition, farmers in Sumarang chose another treatment: E, organic amendments as well as cultural management.

From July 2013 to Jan 2014 at the Sumarang IPDM site, pruning and sanitation (treatment B) doubled production, but the sprayed plots had a similar level of pod production and proportion of infected pods (about 40%). The organic plot (treatment E) produced a good yield compared to the control. Cultural management (pruning, sanitation) greatly reduced Ppr incidence (Fig. 7.4.4) but not CPB incidence. *Helopeltis* sp was found at one end of the trial (in treatments C, D and E), suggesting infestation had a site effect. Possibly nutrition (from fertiliser applications) increased the attractiveness of pods to *Helopeltis* sp. *Helopeltis* sp infestation was high in Anreapi (see above) and especially so in the plots receiving fertiliser (see Fig. 7.4.3), but it should be noted that *Helopeltis* damages the surface of pods and does not reduce bean yield at the levels of infestation observed here.

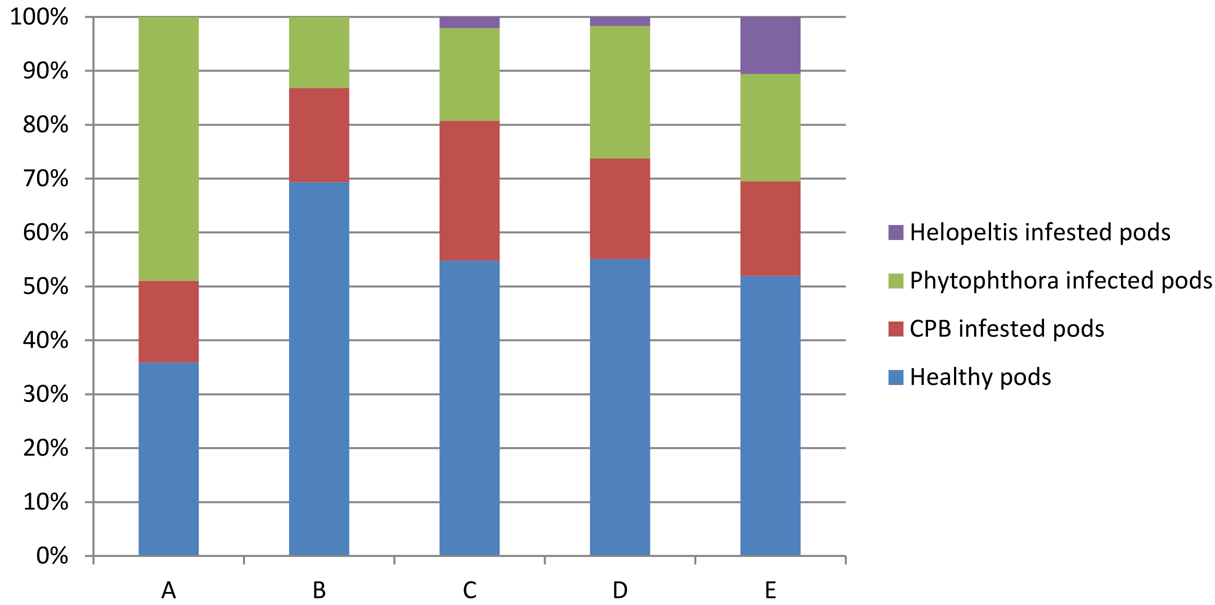


Figure 7.4.4 Incidence of Phytophthora, CPB and Helopeltis sp. in pods harvested at the IPDM trial in Desa Sumarrang, Kecamatan Campalagian, Polman, 2014 (March-December 2014). Treatments are given in the legend of Fig. 7.4.3.

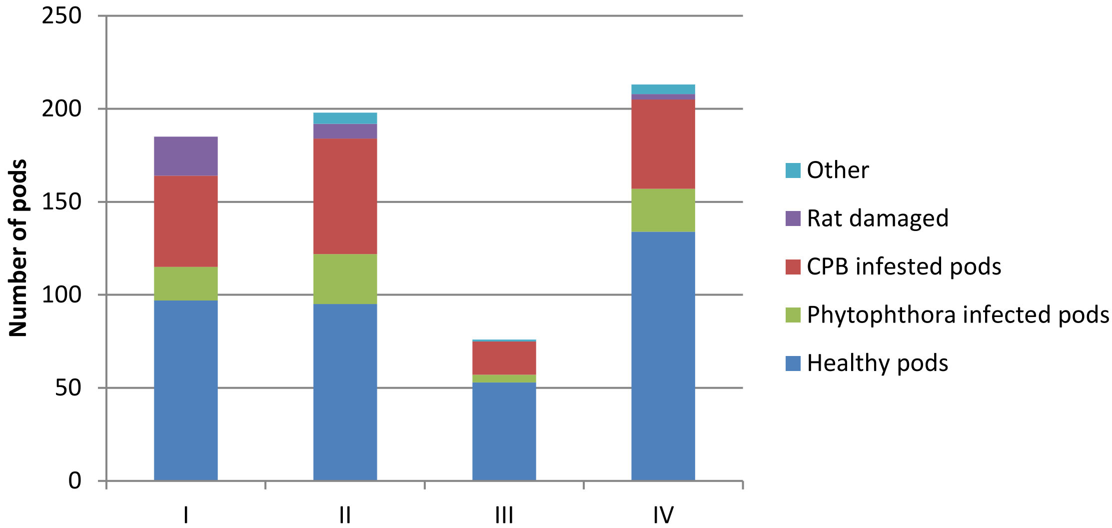


Figure 7.4.5. Results for 6 months evaluation from the IPDM plots (25 trees per plot) at Desa Cendana Hijau, Wotu, Luwu Timor. The number of healthy and diseased or damaged pods per plot are shown (almost half of the trees in Treatment III were killed during an extended dry season. Note: I - control (usual farmer management: light pruning, no weeding); II - cultural management including sanitation, pruning and weeding; III similar to II as well as application of inorganic fertiliser: IV similar to III as well as application of organic fertiliser and targeted spraying.

Wotu IPDM: This trial differed from that in Anreapi, West Sulawesi in that the control treatment (I) was usual farmer management (the farmer conducted light pruning of these trees) and the complete treatment (IV) included application of a combination of organic and inorganic fertiliser. In Treatment III, 12 trees died during the dry season accounting for the low yield of this plot. *Helopeltis* sp. was not detected (demonstrating the extremely localised distribution of this pest). However, rat damage was common. An increase in the total number and proportion of healthy pods was detected in treatment IV (Fig. 7.4.5).

Applying a participatory extension model

With the help of the project team in formal and informal discussions, a farmer group in Desa Duampanua, Kecamatan Anreapi, Kabupaten Polman was able to identify their 3 main problems in growing cocoa: 1. Aging cocoa trees, 2. Scarcity of chemical fertiliser, and 3. Pest and disease problems, mainly Cocoa Pod Borer and Phytophthora Stem Canker and Pod Rot. To address these problems, the farmer group established a nursery with plastic cover to raise seedlings and graft the seedlings with high yielding, pest and disease tolerant clones. They also set up demonstration plots to demonstrate the effect of organic fertiliser and to demonstrate pest and disease control. The project provided UV resistant plastic film for the nursery, polybags for raising seedings, and provided training and assistance for demonstration plots. At the first round of seedling establishment, 2500 seedlings were grafted and were planted in the farms of 8 members of the farmer group. With the skill on nursery management including grafting technique, the farmer group is now keen to grow grafted cocoa seedlings for commercial purposes.

Following the experience of the Anreapi group, in 2013 several farmer groups from different subdistricts (kecamatan) showed interest to be involved in similar work to that carried out in Anreapi. A farmer group in Kelompok Tani Andau, Desa Landi Kanusuang, Kecamatan Mapili (25km from Anreapi) established a cocoa nursery for 5000 seedlings. A second farmer group in Kelompok Tani Gema Desa, Desa Kuajang, Kecamatan Binuang (15km from Anreapi) also established a cocoa nursery for 5000 seedlings. Seedlings were also raised in Kec. Tampanua. The ACIAR project provided UV resistant plastic cover for the nursery and polybags, assistance in building plastic covered nurseries, and training on nursery management and grafting techniques.

In Feb 2014, during a project field visit, farmer training was held in Kelompok Tani Gema Desa, Desa Kuajang, Kecamatan Binuang with 4 main topics: 1. Nursery management and planting materials, 2. Pruning and maintaining cocoa, 3. Fertilising and making organic fertiliser, and 4. Management of pests and diseases. Training was officially opened by the Vice Regent of Polman, Mr. HM Natsir, and attended by 80 farmers from 5 subdistricts in Polman. On this occasion, the vice Regent and Head of Forestry and Estate Crops Division, Mr. Abdul Salam, officially spoke of the urgent need on the farms for high yielding, grafted cocoa plants.

A Girl Grammar Boarding School (Pondok Pesantren) Al Ihsan at Desa Katapang, Kecamatan Tapango, Kabupaten Polman showed interest in establishing a cocoa nursery for their school farm and for commercial purposes. In line with our program to promote cocoa for the young generation, the ACIAR project provided assistance and training in establishing a cocoa nursery, grafting seedlings and maintaining seedlings. As for other farmers groups, ACIAR provided UV tolerant plastic cover and polybags for the nursery sufficient for 2000 seedlings.

To fulfill the need for an on-farm extension location for Kabupaten Polman, Dinas Kehutanan dan Perkebunan (Division of Forestry and Estate Crops) established an agreement with one of the farmer members of Kelompok Tani Andau, Desa Landi Kanusuang, Kecamatan Mapili, Kabupaten Polewali Mandar to use their 6 hectare cocoa farm as a ”training centre/field school” for cocoa farming and other related activities. The farm can be used for formal and informal (peer learning: farmer-to-farmer) training on various topics, including 1. Cocoa farming including nursery management, planting, pruning, fertilising/manuring, fermentation, rehabilitation with side grafting; 2. Horticulture, such as banana, papaw, pineapple and vegetables, as supplementary income; 3. Goat, cow, and duck farming with prunings from shade trees such as *Gliricidia, Leucaena, Crotalaria* and *Kaliandra*, and cocoa pod husks as feed; 4. Organic fertiliser (compost) from manure and cocoa wastes; 5. Fish farming with fish feed made from cocoa wastes. A farmer hut (Saung Kakao, 4 m by 10 m) was built on the farm to facilitate trainings and discussions among farmers. Facilitator training on ”CacaoSafe” was held in this farmer hut, organised by ICCRI Jember, ICCO London, and CABI Malaysia, on 11-13 January 2015, attended by 20 participants from selected farmer groups in Kabupaten Polewali. Apart from that, almost every week, farmers from surrounding areas visited the farm to ask for advice and to discuss various aspects of cocoa farming.

In June 2014, ACIAR reviewers from Canberra (Dr. David Pearce and Dr. Amir Jilani), accompanied by the ACIAR representative in Jakarta, visited and interviewed farmers at 5 locations, including 1. Dusun Beluak, Desa Duampanua, Kecamatan Anreapi, 2. Dusun Duampanua, Desa Duampanua, Kecamatan Anreapi, 3. Dusun Pulludung, Desa Landi Kanusuang, Kecamatan Mapilli, 4. Dusun Kampung Baru, Desa Landi Kanusuang, Kecamatan Mapili, 5. Desa Kuajang, Kecamatan Binuang. Generally, they found farmers involved in the projects had a positive view of ACIAR project activities in the district and that the presence of expert technical ACIAR project staff ensured well maintained demonstration and trial sites, in addition to providing participating farmers with the opportunity of feedback and training.

The extension and rollout model adopted included interaction between farmers from different areas. One of the project roll out activities in Desa Duampanua, Kecamatan Anreapi, Kabupaten Polman is described in Appendix 9. This is a report of a farmer-interactive activity where farmers from Polman visited well-managed farms (guided by partners Mars Inc. and BPTP) and the Mars Centre in Luwu and East Luwu. Farmers expressed enthusiasm to apply on their own farms some of what they had learned during the five days of exchange.

Survey on uptake of technology following training

Results of two surveys (see 5.4) indicated farmers exposed to participatory training increased efforts to rehabilitate their farms by grafting, replanting and the adoption of better clones. The first study compared two groups from one village, each with 25 farmers: a target group exposed to training facilitated by the project (including visits to the IPDM plots in the same village) and a non-target group or control of farmers who had not been so exposed. Results (shown in Table 7.4.2) demonstrate that a significant difference in adoption of improved management methods occurred between the two groups, with a greater proportion of the target group adopting improved technologies on their farms. In particular, all of the farmers in the target group had replaced their existing trees with superior cocoa clones (i.e. more productive and/or more resistant genotypes) compared to about half of the non-target group. Farmers involved in training were also more interested in constructing nurseries than those in the control group. Table 7.4.3 indicates clear increases in the level of skill that farmers demonstrated in various farm activities related to improved cocoa production.

Table 7.4.2. Adoption of farm technologies by cocoa farmers including a target group (25 farmers, receiving participatory training) and a non-target group (25 farmers, control): 1, do not wish to adopt; 2, would like to but have not yet adopted; 3, have adopted (Kartika Fauziah, Masters thesis).

Technology	Target farmers						Non-target farmers						Chi-square test
	1	%	2	%	3	%	1	%	2	%	3	%	
Side-grafting	0	0	0	0	25	100	3	12	1	4	21	84	0.114
Top-grafting	0	0	17	68	8	32	10	40	13	52	2	8	0.001
Propagate better clones	0	0	0	0	25	100	4	16	9	36	12	48	0.000
Nursery	2	8	21	84	2	8	15	60	9	36	1	4	0.001

The second study included 36 farmers who participated in a training workshop in December 2015 at the Saung Kakao training centre, Mapili (see 5.4). Table 7.4.4 indicates that following the workshop farmers worked to rehabilitate their farms by replanting some of their farm (less than 50% of the area). This is in line with extension training provided by ACIAR project partners: farmers are recommended to rehabilitate a part of their farm and compare production on this part with that on the rest of their farm, and then to increase the area rehabilitated if they consider it successful. However, farmers side-grafted most of their trees following the workshop (this method enabled them to maintain some pod production during rehabilitation).

Table 7.4.3. Skill level among target and non-target farmers: 1, unskilled in method/technology; 2, have some skill; 3, skilled.

Skill/method	Target farmers						Non-target farmers						Chi-square test
	1	%	2	%	3	%	1	%	2	%	3	%	
Nursery management	1	4	10	40	14	56	19	76	5	20	1	4	0.000
Top-grafting	0	0	10	40	15	60	11	44	10	40	4	16	0.000
Side-grafting	0	0	1	4	24	96	3	12	7	28	15	60	0.008
Control of pest/diseases	0	0	4	16	21	84	5	20	8	32	12	48	0.012
Preparing compost	1	4	6	24	18	72	18	72	3	12	4	16	0.000

Changes in farm maintenance following the workshop were not substantial (Table 7.4.5) but some increased farm sanitation was found in the survey, with a slightly higher proportion of farmers practising sanitation (removal of diseased pods) following the workshop. Slight increases were seen in other activities, especially pruning (which is important to maintain aeration and adequate light in the canopy). An unexpected outcome was that while only 19% farmers applied organic fertilisers to their cocoa trees prior to the

Table 7.4.4. Proportion of farm area rehabilitated by farmers by side-grafting or replanting before and after a farmer training workshop in December 2015. In the study, 36 farmers were interviewed before the workshop and 7 months later (following the main harvest season).

Method of rehabilitation	Before		After	
Side-grafting	Farmers	%	Farmers	%
- 0 – 50%	25	69	21	58
- 51 – 100%	11	31	15	42
Replanting				
- 0 – 50%	34	94	34	94
- 51 – 100%	2	6	2	6

workshop, this was increased to only 22% following the training. Since the workshop included presentation of data on the benefits of added organic matter in cocoa production and methods to prepare compost this was a surprising result. Possible reasons are that that purchasing organic fertiliser is expensive, and compost preparation requires group cooperation, for example in purchasing pod shredding equipment, compost sheds and so on. In addition, some of the farmers (who were selected randomly for this survey) grew their cocoa in areas with fertile soils: the soils in sub-district Tapango, for example, are generally more fertile than those of Anreapi sub-district.

Table 7.4.5. Farm maintenance before and after the farmer training workshop.

Maintenance activity	Before		After	
	Farmers	%	Farmers	%
Light pruning				
- No	5	14	2	6
- Yes	31	86	34	94
Heavy pruning				
- No	32	89	29	81
- Yes	4	11	7	19
Control of pests/diseases				
- Light control	1	3	3	8
- Moderate control	34	94	32	89
- Heavy control	1	3	1	3
Sanitation				
- No	13	36	10	28
- Yes	23	64	26	72

7.4.2 Knowledge transfer

As part of Objective 4.2, ICCRI have developed an SMS platform, called ‘likeCocoa’, for Android phones to access user-friendly information on smallholder cocoa production (see 8.4 Communication and Dissemination Activities). This can be downloaded and used by farmers and extension staff in Indonesia. A web-site has been prepared by UNHAS in cooperation with the CSP, with a link for ACIAR project activities, as a platform to provide standardised and consistent information to extension services, researchers and farmers (see http://unhas.ac.id/lppm/cocoainfo/?p=10).

7.4.3 Market incentives, value chain and farmer responses

A report on the 2012 study which includes preliminary observations on the impact of certification on farmer livelihoods is available at: http://www.geosci.usyd.edu.au/documents/cocoa2.pdf

Participating farmers were generally satisfied with the certification schemes, although it was not possible to identify direct benefits on farmer livelihoods resulting from the programs. This does not mean that there are no benefits, but that a causal relationship was difficult to establish. Certification has been associated with the enhanced upstream engagement with farmers by large cocoa firms, and this has led to several direct-buying programs that benefit farmers and that have opened up avenues for knowledge exchange along the value chain. The benefits to farmers appear to be linked more directly to this engagement rather than certification *per se*, and several cocoa companies now appear to be exploring new methods beyond certification for achieving sustainability goals. Most importantly perhaps, the research has field-tested methodologies and indicators for impact evaluation of certification programs in Indonesia, and has provided insights now being applied in larger impact evaluations funded by UTZ, ISEAL and COSA (Jeff Neilson).

7.4.4 Policy and government engagement with the cocoa sector

Export tax

This empirical study has not identified a noticeable downward impact of the tax on farm-gate prices as predicted through modelling. While these are preliminary results and the assumptions regarding moisture levels of beans and price transmission between international markets and farm-gate prices require further examination, subsequent refinement of the analysis is unlikely to fundamentally alter the key findings. We present two key possible reasons to explain these findings: i) the emergence of marketing channels direct to exporters and processors has diminished the profits of middle-men over the same period, and these savings have been transmitted to farmers by way of higher prices; and ii) local cocoa markets are kept tightly competitive due to a significant volume of cocoa production not being taxed due to illegal trade networks. From a policy perspective, the apparent benefits from the tax in terms of the development of industrial capacity, off-farm employment generation, revenue generation and value-retention need to be assessed against the minor observable farm-level effects of the tax. It is also important to assess any effects on farmer prices against the much greater fluctuations in the international cocoa market, ranging from a low of 1900USD in April 2007 to a high of 3500 USD in January 2010 (Figure 4). These price fluctuations are far greater than the price effect would be even if the full tax was passed on entirely to farmers.

Gernas

Many farmers, scientists and cocoa stakeholders indicated that cocoa trees produced by Somatic Embryogenesis (SE) and planted in Sulawesi and Flores did not perform well in the field and that this has significantly affected farmer's income. The objective of this survey was to evaluate the actual present conditions of SE trees, planted between 2009 and 2011, to record actions taken by the farmers on the farms that have SE tree problems and to evaluate their success.

The results of the survey show that 74% of all SE cocoa planted between 2009 and 2011 suffer from poor root structure and development, leading to weak trees with a tendency to fall over, while only 26% are considered healthy. These problems were observed in all places where SE cocoa was surveyed, and is entirely consistent with observations and reports from Flores and other areas that have SE cocoa trees. The 26% of apparently healthy trees had produced pods at a relatively normal time and with pod abundance per tree comparable to that of non SE cocoa of the same clone. SE trees were found to be heavily infested by VSD (68%) and other pests and diseases. It was also observed that the large majority of productive SE cocoa produces green pods indicating that they are not S1 or S2 clones, and therefore the mix of clones in the survey area is not in proportion to what was originally anticipated.

Many farmers have taken action on their own initiative, including side grafting, chupon grafting, replacing the trees with either SE or non-SE cocoa seedlings, to try to solve the problems but the issues observed with SE cocoa trees will likely extend for several years to come, before being fully resolved. Five percent of cocoa farmers who received SE trees have so far abandoned their cocoa to plant other crops.

8 Impacts

8.1 Scientific impacts – now and in 5 years

Encouraging field studies by university, research and extension staff:

Government of Indonesia partners in the project have undertaken long-term field studies. Training under the project prepared technical staff to critically evaluate potential interventions with field experiments designed and analysed in a systematic manner. The project has emphasised the importance of conducting practical, empirical studies, as opposed to more esoteric investigations. This approach was applied in a PhD study by Ayu Parawansa conducted through Hasanuddin University and co-supervised by the project leader. Her study on VSD disease was based on close and regular field observations of infected trees of a range of cocoa clones in the project clone trials in Polman and Pinrang. This included monitoring infected branches over time. Other students, including 4th year students, have taken up this approach with regular evaluations at the same sites. The fertiliser experiments established and monitored by Hasanuddin University and BPTP Sulsel are a case in point: staff are now involved in longer term experiments which can also be accessed by students for short-term studies (Objective 2.3). Two students from Universitas Muslim Indonesia (UMI) based their research on *Phytophthora palmivora* at the IPDM plots in Wotu, East Luwu, and a number of Skripsi studies are being conducted at ACIAR field trial sites in Bantaeng. The importance of microscopic observation has also been emphasised in the project. Masters students (for example from Kendari and UMI) integrated microscopic observations of pathogens into their study, using the microscope provided by the project. A problem is the poor condition and maintenance of microscopes in research institutions, and so students and extension staff often have little chance of observing microorganisms under high power.

Using molecular methods for studies in plant protection:

A PCR facility established under the project has been popular among post-graduate students and staff in enabling them to integrate new informative methods into their studies. A research assistant employed by the project with funding from Mars Inc. has developed protocols suitable for a lab in Sulawesi (where, for example, liquid nitrogen is unavailable) and has been actively involved in teaching and assisting researchers to use these applications: for example, plant viruses (which can be identified with molecular methods, *Ceratobasidium theobromae* in infected cocoa for studies in Kendari and a Borlaug Fellowship study in the USA, identification of *Colocasia esculenta* (taro) varieties to establish whether local varieties in Sulawesi are the same as those distributed by companies and government departments, and a study on genetic variability between selected cocoa genotypes using RAPDs. An important contribution of the project has been to make (expensive) reagents available, although researchers have also contributed from their own budgets where possible. The facility will continue to apply new molecular methods to research in the agricultural faculty and to other visiting students and staff for years to come. An important limitation will be availability of operational funding for further studies.

An important on-going aspect of all the ACIAR cocoa projects has been the facilitation of studies in the main cocoa growing region of Sulawesi by ICCRI staff, based in Jember, East Java. For example, now ICCRI staff are able to interact with the Mars staff at the enlarged cocoa research station at Tarengge and some ICCRI trials have been established at this site.

Two cocoa clones (M01 and 45, now called MCC01 and MCC02) that were identified by Mars Inc. staff and also tested in the ACIAR project were recognised as recommended cocoa clones by the GOI Ministry of Agriculture, after application from ICCRI.

One of clones that was identified and additionally tested in the ACIAR projects as CPB resistant (Aryadi 2) is being used as a parent clone in the Mars cocoa breeding project in Tarengge with a total of 45,000 hybrid progeny being evaluated.

8.2 Capacity impacts – now and in 5 years

Research facilities at Hasanuddin University

The Hasanuddin University Cocoa Research Group (CRG) povided a laboratory facility on their old campus. The facility included a glasshouse and was established by the project as a field lab equipped with a benchtop 10 ml tube centrifuge, sample tubes and other consumables and microscopes. At first this lab was to be developed into a facility with PCR capability but this was later moved to a laboratory in the agronomy department of the main campus. The CRG facility is used for glasshouse experiments and processing field samples.

For the molecular research facility (see Scientific Impacts) a microfuge, PCR machine, gel trays, power pack and general laboratory materials such as tubes, bottles etc. were provided by the project. The project also provided reagents and consumables necessary for the project research and other research projects taken up by post-graduate students. Methods developed by project staff were adopted for other research in the university and by visiting researchers (from Kendari and Bogor, for example). In particular, various DNA extraction protocols at room-temperature were applied (including kit-based and CTAB-based protocols). The laboratory was developed with substantial equipment being provided by the GOI Department of Education (DIKTI) but much of this equipment was based in another laboratory and was destroyed by a fire in November 2014. Fortunately, the laboratory facility developed by the project and agronomy department escaped damage.

A research assistant employed by the project with funding supplied by Mars Inc. (see above, Scientific Impacts) was trained in PCR techniques, which she disseminated to students and staff who wished to apply molecular methods to their own research. Having a trained researcher in the laboratory, working protocols and the consumables necessary for PCR ensured that this laboratory has been active, in contrast to a number of laboratories in the university in which advanced equipment is mainly unused, due to lack of technical expertise and/or lack of the necessary consumable materials. In Indonesia, public universities such as Hasanuddin University have access to budgets to purchase equipment, but little material support for running research projects or the technical expertise necessary to put the equipment to good use.

A high power microscope Nikon E100, dissector microscope, second-hand PCR machine, gel trays, powerpack and laboratory consumables were provided to university partners in Sulawesi.

Extension

In Polman a small nursery was constructed by farmers using their own resources apart from the plastic film roofing materials and polybags (see Section 7.4). In Tampumia cows provided to the farmer group by the project have calved. Also a facility was built (designed with the advice of BRIEC) for collection of biourine. Dinas Kehutanan and Perkebunan

(Office of Forestry and Plantation Crops) have built a farmer meeting house at the extension centre established by the project.

Partner institutions continue to work with farmer groups. Their work on farmer group strengthening and training has been partly initiated by project activities. For example, Dinas Kehutanan and Perkebunan in West Sulawesi work with farmer groups who have established IPDM plots and clone tests under the project. Their staff help evaluate IPDM and clone sites. In addition, the organic manuring trial established with the Harapan Farmer group in Luwu, South Sulawesi is evaluated by staff from BPTP Sulsel as well as Mars Inc. field staff. Hasanuddin University staff have been working with farmer groups in Bantaeng, South Sulawesi including a number of project activities and Skripsi (third year) student studies.

Web-site and access to information:

ICCRI and UNHAS were jointly responsible for this activity (under 4.2). A preliminary website was developed but under UNHAS logo – it would be preferable if this was a CSP resource. It is expected that the site will have a telephone sms link but an unresolved issue is the expense per text message. ICCRI have developed an Android phone information transfer application, named “likeCocoa”, while CSP and the University of Sydney collaborated on the communication system with BRIEC (Arief Iswanto) as consultant. Because of the prior experience of the Cocoa Innovation Project (CIP) funded by WCF, the project aimed to work through CSP, drawing upon CIP developments in this area – this is still in progress.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

Costs of inputs have been recorded in the IPDM plots in the project – the highest cost is for hired labour. Since the average age of farmers is increasing around Sulawesi as their children seek education or work in larger towns, labour availability and cost is becoming an increasing issue in the relative profitability of cocoa farming. While increased productivity is demonstrated by intensified management in the IPDM plots, farmers need to be convinced that higher yields more than compensate for the increased cost of the labour required.

Following training of two farmer groups in Luwu, South Sulawesi on tree management by pruning and generating *in situ* compost in trenches for feeder roots to access, project staff member Arief Iswanto returned to the sites in early 2014 to check the progress made by the farmers in the two groups. He found most of the farmers had pruned the trees well on their farm: pod setting on the trees (mainly Sulawesi 2) was high, indicating a good harvest potential. Farmers in the other group were less active. They reflected the discouragement many farmers are facing with cocoa farming which is causing some to change to other crops. National cocoa production has not been able to meet the demand of domestic processors in the last few years with only 450,000 tonnes of dry beans being produced in the last year (Askindo data). The imposition of an export tax has stimulated the industry to construct processing plants in Indonesia but they have to import a substantial proportion of the beans required (mainly from West Africa).

However, some groups such as the one in Toangkajang have shown that with soil improvement (using compost especially), rejuvenating farms with younger clonal trees such as Sulawesi 2, and proper management as demonstrated by Arief Iswanto and Agus Purwantara from BRIEC, it is possible to at least double the annual production of a previously poorly managed farm. The pruning of the trees in Toangkajang increased the flowering rate substantially and therefore the number of pods. Now is a good time to encourage farmers to continue cocoa farming with more intensive methods because the cocoa price is high, often exceeding 2300 USD per tonne, and at this level cocoa farming can generate a good income.

The average production by farmers was around 600 kg or less per ha per year and even if this was increased by half then the additional 300 kg/ha/yr would have a value of 1050 USD per ha for the farmer who improved his/her management. In Indonesia, farmers receive a much larger proportion of the international commodity price of cocoa than farmers in West Africa (in Ghana the proportion received is only 45% although other services are provided to farmers by the government) so that such an increase in yield could generate about 700 USD/ha/yr for the farmer. But such impacts depend on the response of the farmer.

8.3.2 Social impacts

In Kanusuang, Kec. Mapili, West Sulawesi a cocoa extension centre was established with cooperation of the local farmer group. A field technician employed by the project was stationed there permanently. A large nursery with UV-resistant plastic covering has been established and used to raise the seedlings for top-grafted clones. Project partner, Dinas Kehutanan dan Perkebunan (Ofice of Forestry and Estate Crops), has built a meeting house at the location. The site is a focal point for the local community who receive training in various aspects of cocoa farming. The centre has raised the awareness of the local community about the benefits of managing cocoa properly and the returns it can provide.

In a farmer meeting with Australian project staff in Polman, West Sulawesi in mid-2013, feedback from the group indicated strong support for this style of extension. Farmer groups in Polman have generally requested better nurseries (with good protection from VSD disease) and training on the propagation of clones by grafting rootstock seedlings. Four nurseries have been constructed under guidance from project staff and on-going training is provided (a project field technician is permanently stationed there). The extension model followed (tested initially by Fiona McKenzie and Agus Purwantara, University of Sydney), is based on farmer consultation and regular feedback from farmers following the implementation of improved farming practices, especially pruning and weekly sanitation harvesting of infested pods, and the adoption of new clones.

Health extension program

The project participated in a pilot study of the feasibility of imparting public health awareness through agricultural extension services. The study included a visit to Sulawesi in 2013 by senior medical personnel from University of Sydney and the Chancellor, Dame Marie Bashir. They were accompanied by medical staff from Hasanuddin University. A field meeting was held with the Anreapi farmer group as well as spouses and children, with interviews on health awareness, access to medical facilities and experiences among farmers and their families. As a result of this preliminary visit, it became evident that the isolated cocoa-growing communities suffer a serious lack of health services and that this is a factor contributing to perceived labour shortages for good cocoa management. A later follow-up visit by senior medical epidemiology staff from the University of Sydney, Professor Merrilyn Walton and Dr Grant Hill-Cawthorne, came to the same conclusion after taking part in discussions with a farmer group at Anreapi and visiting health clinics.

8.3.3 Environmental impacts

With greater intensification of cocoa production on existing farms, the tendency to expand cocoa productioninto new areas of natural forest are mitigated but other environmental impacts, particularly due to the increased use of farm chemicals, may be increased. Therefore, testing integrated or organic methods of cocoa production becomes increasingly important. Results from the IPDM demonstration plots established by the project in four locations (including West Papua) and the fertiliser trials indicate substantial increases in production are possible with no inputs other than increased labour hours for pruning, sanitation, burial f organic waste and compost production. Therefore, in the short term a farmer can increase production substantially through application of labour and good management alone.

A trial commenced on 1.3 ha in Toangkajang aims to be completely organic. Therefore, no chemical inputs (fertiliser or pesticides) have been applied since November 2013. The trial is evaluated by BPTP Sulsel and Mars Inc. field staff. Also, for more than three years, compost has been used to fertilise the farm, rather than inorganic fertilisers. However, the farmer has experienced a high infestation rate of Cocoa Pod Borer in the main harvest season of 2014. Frank Mars, who initially proposed that the trial be added to ACIAR project activities with the assistance of Mars company field staff, has suggested that the farmer use plastic sleeving to protect pods from CPB, although the high infestation rate may be due to the poor application of sanitary harvesting of infested pods. In addition to this organic trial, the IPDM demonstration plot in Sumarang, West Sulawesi is treated organically. This will potentially demonstrate that methods of cocoa production are possible without substantial use of chemicals.

Project partner, Disbun Kehutanan dan Perkebunan (Department of Forestry and Agriculture) is of the view that the periodic nature of the cocoa harvest (with most pods harvested mid-year) is linked to illegal logging activity in Polman (which borders a mountainous forested region) since the harvest only provides income for a certain proportion of the year. The other problem is that farmers move in to natural forest both to open new farms (which remain largely unmanaged) and obtain income from the trees logged. The project encouraged raising goats in conjunction with cocoa farming since selling these (Kalimantan being a major market) can provide a more regular income, evening out the intermittent income from cocoa, and they are a source of manure for compost production. The cocoa centre in Mapilli raises goats of good pedigree: their kids fetch high prices of 200 USD or more. Some farmer groups working with the project have built housing to raise goats. In Toangkajang (in Luwu) a farmer group working with the main project partner, BPTP Sulsel, raises cows.

8.4 Communication and dissemination activities

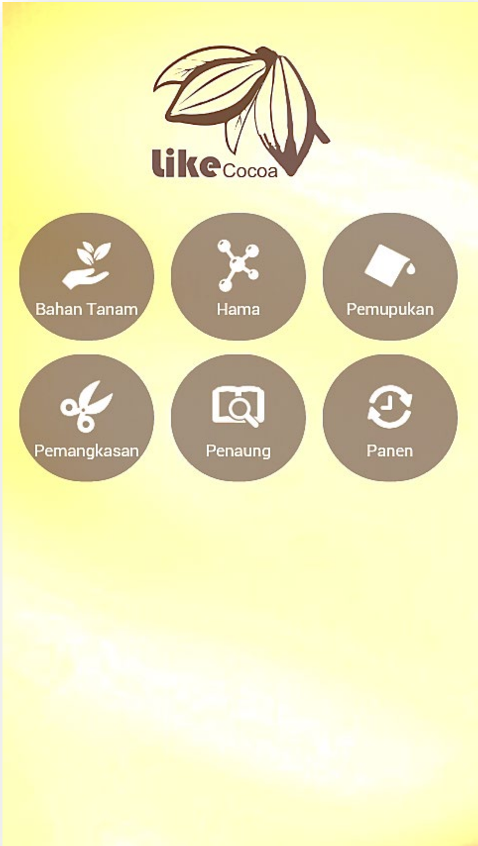
A completed handbook written in Bahasa Indonesia on all aspects of cocoa management co-authored by two Indonesian project staff, Agus Purwantara and Arief Iswanto, was submitted to ACIAR for publication in early 2014. The handbook is relevant to the Indonesian situation of cocoa farmers and emphasises minimising expensive inputs by the use of cocoa waste on the farm as compost, integrated with goat husbandry, and basic cocoa management methods to decrease losses from pests and diseases and increase productivity. It covers a range of topics including clone selection and propagation, nursery construction and management, regimes of pruning according to the season, composting using farm waste and other organic materials, IPDM and post-harvest management.

A major arena of dissemination of appropriate agricultural practices, certification standards and perceived priorities in the market chain is the Cocoa Sustainability Partnership (CSP) which has grown from humble beginnings largely initiated by Mars Inc. and Hasanuddin University to a large forum that includes the major cocoa stakeholders in Indonesia, served by a well staffed office in Makassar that produces a highly valued and attractive extension magazine ‘Cokelat’, published in both English and Bahasa Indonesia. The ACIAR project has participated in the development of this forum as a member, financial contributor and through regular participation of staff in meetings and seminars. Project staff attend the regular general assembly and task force meetings and have contributed to the CSP publication, Cokelat (see below).

A website to provide information to the cocoa sector in Indonesia has been designed as part of project Objective 4.2 for interactive use by stakeholders under the responsibility of

Hasanuddin University (Daniel Uteng); this website is designed in collaboration with the CSP. For Objective 4.2, a handphone-based information system, “likeCocoa”, has been developed for Android technology by ICCRI project staff. The app can be downloaded from http://iccri.net/aplikasi-like-cocoa/

LikeCocoa consists of a number of modules providing information on cocoa fertilizer requirements, pests and diseases, pruning methods, harvesting and shade requirements (see below).



Dr Ayu Parawansa presented papers on her VSD research to the International Plant Pathology Congress, Beijing and the Pakistan Plant Pathology Society meeting in Karachi supported by the project. Her paper was entitled: *Incidence, severity and symptom development of vascular-streak dieback.* A poster paper: *A widespread and substantial change in the symptoms and phenology of vascular-streak dieback of cocoa in Southeast Asia and Melanesia* was presented by David Guest at the Australasian Plant Pathology meeting in Auckland, New Zealand in September 2013.

Jeff Neilson, Hiswaty Hafid and Fiona McKenzie released a discussion paper on the effects of certification on farmer livelihoods (April 2013), which was presented at workshops hosted by CP (April 2013) and by ASKINDO (December 2013). Jeff Neilson and Fiona McKenzie published an article in *Cokelat (July-Sept 2013)* on ‘Evaluating the impacts of sustainability schemes in the Indonesian Cocoa Industry’. Other project partners have contributed articles, including Arief Iswanto, or their experiences in interviews with the magazine.

Jeff Neilson and Kartika Fauziah published their research on the effects of the export tax on farm-gate prices at the Malaysian International Cocoa Conference, October 2013. Jeff Neilson presented a paper on *People and Environmental Considerations* to the 2014

Askindo Indonesian international cocoa conference in Bali (Empowering smallholders for a sustainable cocoa industry, 15-16 May, 2014). Jeff Neilson and Fiona McKenzie were competitively selected to publish project research under a global FAO initiative on ‘Innovations in linking sustainable agricultural practices with markets’. Their paper was submitted to the FAO in February 2014 with the title, “Sustainable solutions in the Indonesian cocoa sector: farmer-driven innovation and business-oriented outreach programs”. Jeff Neilson has co-authored a book chapter with Niels Fold on “Sustaining supplies in smallholder dominated value chains: Corporate Governance of the global cocoa sector”, in a publication on the global cocoa industry by Oxford University Press (submitted to the editors in March 2014).

Peter McMahon and Agus Purwantara have co-authored a chapter on VSD in ‘Cacao Diseases’ ed. Bryan Bailey (2015), and co-authored with project partners three paper manuscripts, one in press with Crop Protection. Philip Keane and Peter McMahon authored chapters for a 2012 Intech publication, ‘Plant Pathology’. Peter McMahon presented results from clone tests to the Cocoa Symposium and National Expo of Cocoa and Chocolate, Padang, Nov 2012, Sulawesi International Seminar on Cocoa (SISCO), Makassar, July 2013 and the EU-Indonesia Trade Support Programme II (TSP2) Improving Cocoa Bean Quality in Indonesia, Makassar, September, 2014. Agus Purwantara presented results of soil and microbe tests from the compost/fertiliser trial in BoneBone, North Luwu to the Asian Congress of Plant Pathology, Chiang Mai, Nov 2014.

9 Conclusions and recommendations

9.1 Conclusions

Objective 1: To investigate the effect of improved soil management on cocoa production, quality and damage caused by cocoa pod borer, Phytophthora diseases and vascular-streak dieback

A well conducted experiment at Bone Bone on the fertilisation of cocoa with compost, inorganic fertilsers and lime clearly demonstrated the value of compost for increasing pod production at this site. A similar experiment at Bantaeng and another at Mapili gave similar results. The results clearly support the move to encourage smallholders to bury in the field the husks of harvested healthy cocoa pods (as well as all pods damaged by Phytophthora pod rot or Cocoa Pod Borer removed during sanitation harvesting) and also to exploit local sources of organic manures and composts for maintaining soil fertility. This can be combined with the method developed and demonstrated during the project by project collaborators involving burial of husks and damaged pods and other organic matter in shallow trenches dug between the rows of cocoa. This links in with the trend to encourage farmers to diversify into goat production as a way of exploiting cocoa wastes (e.g. prunings from cocoa and *Gliricidia,* thus providing an extra incentive for vigorous pruning, pod wastes) and giving manure to assist in composting.

The main impact of improved soil fertility is on pod production. Detailed DNA-based studies at The University of Sydney showed that biological activity was greatly enhanced by application of compost and this is an important aspect of soil fertility that is now becoming the focus of attention rather than measuring simple concentration of nutrients and trying to address deficiencies with the application of inorganic fertilisers.

The trials at Bone Bone and Bantaeng showed that much more detailed study is required to show the efficacy of mineral fertilisers like NPK. From these trials it would appear that the current blanket recommendations to apply NPK are likely to result in much waste of fertiliser.

Unfortunately the major trial at Bone Bone was established with a VSD resistant clone in an area with a very low incidence of VSD and so one of the aims (investigating whether the change in VSD incidence and symptoms was linked to declining soil fertility) could not be addressed in the trial. The trial at Kaliwining showed that the addition of compost decreased the severity of VSD, but unfortunately the effect of nutrition on the incidence of new necrotic symptoms of VSD was not addressed.

Analyses of foliar nutrient concentrations failed to support the hypothesis that the necrotic VSD symptoms may be linked to a nutrient deficiency – the hypothesis was developed because the necrotic symptoms on leaves are similar to those of K deficiency, but there was no significant difference between leaves with chlorotic or necrotic symptoms in the concentrations of any of the leaf nutrients analysed.

Objective 2: To investigate the causes of the changed symptoms and severity of vascular-streak dieback in cocoa

During the project, repeated observations, both morphological and DNA-based, provided strong evidence that the VSD showing the necrotic leaf symptoms is essentially the same disease, caused by the same pathogen *Ceratobasidium* (*Oncobasidium) theobromae*, as reported in 1969 and 1970 in PNG and Malaysia, except that the response of the cocoa plant to the infection is different. Instead of leaves turning yellow, with clean spots of green tissue remaining, they tend now to turn yellow with less distinct patches of remnant green, or they don't turn yellow but develop irregular dark necrotic areas on the green leaves. Originally leaves abscised neatly at the abscission zone and readily as soon as they became fully yellow; necrotic leaves tend not to abscise easily and remain attached to the branch for an extended period, a response to leaf necrosis in cocoa reported previously from Brazil (Zaparoli et al.2009, Mycological Research 113, 61-72). These necrotic symptoms are still first evident on the second or third flush behind the growing tip, a distinctive characteristic of the disease as first described, indicating a similar infection court and incubation period. The hyphae of the invading fungus are found only in the xylem vessels, regardless of the leaf symptoms, again a unique and distinctive feature of the disease as first described. An important feature of the new symptoms, associated with the fact that necrotic leaves tend not to abscise easily, is the rarer occurrence of sporulation on leaf scars – in all observations of the disease throughout the region until about 2004, sporulation was observed only on leaf scars formed when chlorotic leaves abscised during periods of wet weather. With the necrotic leaf symptoms, the adhering infected leaves develop cracks in the main vein (and sometimes the petiole) through which the fungus can emerge and sporulate on the lamina, something never reported from leaves that turn completely chlorotic and abscise rapidly. In fact, during the current project this was overwhelmingly the most common form of sporulation observed on infected branches. It was apparent during the project that this change in pathology allows the fungus to sporulate much more commonly than when the only avenue for emergence of the hyphae from the xylem was via leaf scars freshly formed by the abscission of chlorotic leaves. The sporocarps on leaf laminae are likely to be more easily wetted to induce basidia formation (perhaps even by dew on the laminae) than the larger sporocarps that typically formed on leaf scars and required heavy late-afternoon rains to become sufficiently wet to induce basidia. This may explain the apparently increased incidence of VSD associated with the occurrence of the changed symptoms since 2004. Another important change in the symptoms associated with the necrosis on leaves is that the vascular streaking after which the disease was originally named is now more intense, being black rather than brownish. The spots found on the diseased petioles cut or pulled off the tree, often used to confirm the presence of VSD, are now much blacker than seen originally with the chlorotic symptoms. The general impression is that, in expressing the new symptoms, the plant is reacting in a more resistant fashion, expressed as tissue necrosis which is commonly associated with resistance to disease in many other plants. This is supported by the observations made commonly during the project, and confirmed by detailed observations by Sue Bryceson in her Honours project in 2014, that in most infections in actively growing cocoa, the infected branches keep growing vigorously beyond the infection and that very few branches are now killed by the disease. Thus we have the paradox that the cocoa in general appears to be reacting in a more actively resistant way to the pathogen invasion, but the disease has become more common through the change in the sporulation court. Through all this, the resistance of particular cocoa clones such as PBC123, first selected more than 4 decades ago, remains unchanged and this was confirmed repeatedly in the clone trials in the project. On many trees there is a mix of old and new symptoms, sometime on adjacent branches, and sometimes on adjacent leaves on the same branch. The Ph.D. study by Ayu Parawansa through Hasanuddin University showed that the ratio of new to old symptoms differed between clones, and that some clones had distinctive forms of the new symptoms. For example, BR25 tends to have more old than new symptoms whereas most of the clones have more new than old symptoms. The clones Husbitori and TR01 have characteristic forms of new symptoms (Husbitori with large necrotic blighting and twisting of leaves; TR01 with only a slight paling of the leaves and slight marginal necrosis).

So the question still remains – what has caused the change in symptoms, reported from Kerala and Vietnam, through Malaysia, Java, Bali, Sulawesi, Indonesian Papua, and Papua New Guinea? A region-wide change in climate or CO_2 concentration, is one of the few possibilities to explain such a region-wide effect. The observation by Sue Bryceson in the project that with increasing altitude (= decreasing average daily temperature) the necrotic symptoms become rarer while the chlorotic symptoms persist provides some evidence for such an effect.

Objective 3: To continue on-farm testing and dispersal of improved planting material

During the project the two important clone trials from SMAR/2005/074 (at Anreapi and Pinrang) continued to be assessed, providing valuable information on the yield, quality and resistance to CPB, VSD and Phytophthora diseases. The multi-location testing of selected clones provided further testing of a range of clones likely to be deployed more widely on farms, and established sources of budwood in several localities for propagation by local farmers. An important development in the on-going selection on farms and testing of clonal cocoa, promoted through all three ACIAR projects, has been the progress made in the breeding program at ICCRI and the massive cross-breeding and progeny testing program initiated by Mars Inc. at Tarengge, one of the truly impressive developments in cocoa breeding worldwide. One of the clones that was identified and re-tested in the ACIAR project is used as a CPB resistant parent clone in this breeding program, extending over the long term the impact of the ACIAR project. The idea, promoted throughout these projects, of involving farmers in the search for improved planting material among the great genetic diversity of cocoa on their own farms has certainly borne fruit. Additionally, two farmer-selected clones that were tested also in the ACIAR project were recognised as recommended clones by the Indonesian Ministry of Agriculture. One of these is important in the ongoing breeding programs at ICCRI and the Mars Tarengge site.

An important development at the Anreapi trial site (Pak Sukyur) is that the trial has become a source of budwood for commercial propagation of the best clones by a local farmer.

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Objective 4: To improve the extension systems and policy settings that affect sustainable cocoa production in Indonesia

The IPDM demoplot sites, as well as allowing farmers to see for themselves the differences between the levels of treatment, showed the benefit of cultural measures for increasing yield of cocoa and reducing the incidence of CPB and PPR. It was shown that these demplots, combined with demplots of genetic planting material, are an effective way of engaging farmers' interest. Thus it was evident that such plots can have a demonstration (extension) role, a resource role (in providing a local source of improved planting material), and also a scientific role in providing multi-site testing of methods and genetic material.

The demonstration effect of rows of different cocoa clones growing side by side cannot be overestimated and it was evident that farmers exposed to these plots improved their management methods more than farmers who were not exposed. The role of nursery establishment and the development of skills in bud grafting of seedlings were particularly important in stimulating farmers' interest. The ACIAR project provided UV-resistant plastic sheeting to cover the nurseries (constructed by the farmers out of local materials) and the necessary training in grafting. The farmers groups at Anreapi and Mapili, in Polman district, were especially important in showing how good farming methods could spread through group-to-group contact. The project has left a legacy of farmer groups in this district which should carry on into the future.

Socio-economic studies involving farmer interviews and assessment of government policy were crucial in demonstrating some important higher level effects on cocoa production in Sulwesi. These have global implications. For example, it was evident from farmer interviews that they considered that the financial return from growing cocoa was often not enough to allow them to implement the best agricultural practices, especially as labour costs are increasing. Preliminary studies showed that the imposition of an export tax on cocoa beans did not depress farm-gate prices greatly, contrary to expectations, and had a positive effect in promoting within-country processing. This requires further detailed analysis, especially in relation to the great fluctuations in world cocoa prices (from a low of 1500USD per tonne in January 2006 to 3500 USD in January 2010, 2200 in January 2012 and 3400 in December 2015) that have been typical of the industry.

The study of the multiplication of cocoa by somatic embryogenesis under the GERNAS program of the Indonesian Government, directed at a massive rehabilitation of cocoa farms to counter the decline in cocoa production over the last decade, showed important deficiencies in the method, including its tendency to favour clones that behaved well in tissue culture rather than the agronomically best clones, and the problem of deployment to widely scattered farmers of a huge number of plants from one central facility (in this case located in Java). Indeed, the program highlighted the unfortunate tendency of governments, both donor and recipient, and global structures to favour 'high-technology' aid rather than expansion of technologies that have been tried and proven in the local environment. In this case, the large amount of money allocated by the Indonesian Government would have had a far greater impact, both immediate and long-term, if it had supported the establishment of many nurseries across Sulawesi producing and distributing the best available clones by the well-developed grafting of seedlings. This would have had an immediate impact in dispersing the best available clones to be planted at the correct stage of development, and would also have left a network of small nursery businesses able to distribute new clones as they become available from the breeding programs at ICCRI and Mars Inc.

9.2 Recommendations

The main limitation on intensification of cocoa production on existing farms is the exhaustion of the natural soil fertility that had built up under the rainforest that was replaced by cocoa. Further studies of fertiliser and compost application are required at different sites, with different soil types and pest and disease incidence, to develop firm recommendations for the use of organic amendments, supplemented where necessary with inorganic fertilisers. Before inorganic fertilisers can be recommended, much more study of rates and combinations is needed. Measurements of leaf nutrient concentrations are not very helpful in cocoa (the leaves are very fast growing and mature leaves are very thin) and so studies will require the type of field trials, in which effects on growth and yield are measured, shown to be useful in this project.

The integration of cocoa farming with animal production (especially goats and chickens) linked to recycling of cocoa wastes such as pod husks, infested pods, and cocoa and shade tree prunings, and to production of organic manures for incorporation into composts, is an important development being driven by farmers and requires support with further study. The production of organic composts and manures on farms is important in ensuring correct disposal or Phytophthora and CPB infested pods as part of the sanitation component of IPDM. Linked to this, the method for disposing of organic waste in shallow trenches dug between the rows of cocoa in the field deserves further study of its efficacy of *in-situ* manuring and labour use.

The search for improved cocoa clones, involving farmers identifying their best trees among the great genetic diversity on farms, should be an on-going task. The involvement of the government extension service, promoted in these ACIAR projects, has so far been minimal in comparison with the highly productive work of Mars Inc. linked to these projects. Further work is required to embed the process demonstrated so effectively by Mars staff in the government extension service culture.

The Anreapi and Mapili farmers' groups showed the effectiveness of group-to-group interaction, based around some initial demonstration plots of cultural methods and improved genetic material. More effort should be put into establishing such groups in many more districts, to help develop self-sustaining and naturally-expanding groups. This can be done by bringing farmers' groups from other districts to observe and train for a few days with currently active groups.

The DNA- and microscopy-based laboratory work at Hasanuddin University deserves further support. While much sophisticated equipment has been donated to the university over the years, much of it is little used; the ACIAR project was able to support strong activity in a particular laboratory by supplying consumables, expertise and concrete scientific objectives in addition to useful items of equipment. It was important that the ACIAR input was used to supplement the laboratory of an active staff member (although not a pathologist) who will certainly have an on-going role within the university. The laboratory has become a focus for work in plant virology and crop diversity, as well as the work on VSD. An extremely able technician was trained in the project. The study of the PCR amplification and diversity of the VSD pathogen is just coming to fruition after many frustrations and needs further work, especially to support a young UNHAS staff member who has just begun a JAF supported study at The University of Sydney.

The system to disseminate extension and commercial information through a digital system is just starting to be developed after problems and disagreement about the best system. This will be a valuable system but requires further development to achieve its full potential as an extension tool.

Further study needs to be done on the actual extent of climate and CO_2 change in the region from Vietnam and southern India through to Papua New Guinea in relation to the hypothesis that this may have driven the change in VSD symptoms. There is much anecdotal evidence of a change in climate, including a substantial change in the seasons for rice growing. There are reports of rainforest being overwhelmed by lianes through the region, again hypothesised to be due to climate and CO_2 change. Meteorological research into this could have very wide implications.

The socio-economic situation of cocoa farmers and government policy and development settings will benefit from on-going study and analysis to ensure that farmers are well supported and encouraged to continue developing existing farms.

10 References

10.1 References cited in report

Nelson, P. N., Webb, M. J., Berthelsen, S., Curry, G., Yinil, D. &C., F. (2011). Nutritional status of cocoa in Papua New Guinea. Canberra: Australian Centre for International Agricultural Research

Fahmy, F. N. (1977). Soil and leaf analyses in relation to the nutrition of tree crops in Papua New Guinea. In *Proceedings of the conference on classification and management of tropical soils*, 309-318 Kuala Lumpur: Malaysian Society of Soil Science, Kuala Lumpur.

Ruf, F. and Yoddang (2000). Cocoa migrants: from boom to bust. *In* Agriculture in crisis: people, commodities and natural resources in Indonesia 1996-2000, 97-156 (Eds F. Gerard and F. Ruf). Richmond: Curzon Press.

Ruf, F. and Yoddang (2004). Adoption of cocoa. *In* From slash and burn to replanting - Green Revolutions in the Indonesian uplands? (Eds F. Ruf and F. Lancon). Washington D.C.: World Bank.

Curry, G.N., Koczberski, G., Omuru, E. and Nailina, R.S. (2007). Farming or Foraging? Household Labour and Livelihood Strategies Amongst Smallholder Cocoa Growers in Papua New Guinea. Studies in Australia, Asia and the Pacific. Black Swan Press, Perth.

10.2 List of publications produced by project

Fauziah, K. (2013). Women in the Cocoa World , *Cokelat*, (March 2013)

Fold, N. and Neilson, J (2015). Sustaining supplies in smallholder dominated value chains: Corporate Governance of the global cocoa sector, The Economics of Chocolate Cocoa, (eds M. P. Squicciarini, and J. Swinnen) Oxford University Press, Oxford.

Gusli, S. (2013). Cokelat, Improving cocoa productivity and farming through micro-finance facilitation, *Cokelat*, (March-May) CSP, Makassar

Gusli, S., Samsuar, Useng, D.,Darmawan, Sarisi, L. (2012). Field Performance of cocoa trees produced by somatic embryogenesis, Sulawesi, Pusat Penelitian dan Pengembangan Sumberdaya Alam, Hasanuddin University, Makassar (JAF)

Hafid, Hiswaty, 3 years PhD on Cocoa certification and impact of government policy on smallholders, University of Sydney, Supervisor: Dr Jeffrey Neilson

Hafid, H., Neilson, J., Mount, T. and McKenzie, F. (2013). *Sustainability Impact Assessment of a Certification Scheme in the Indonesian Cocoa Industry: 2012 Pilot Survey Results*. University of Sydney, Available at www.geosci.usyd.edu.au/documents/cocoa2.pdf

Hafid, Hiswaty and Fiona McKenzie (2012). Understanding farmer engagement in the cocoa sector in Sulawesi: A rapid assessment *Draft report* 3 may 2012

Iswanto, A. (2013). Compost for Soil Sanitation, Soil Biota Life and Production of Cocoa, *Cokelat*, (March-May) CSP, Makassar

Keane, P.J. (2012). Horizontal or Generalized Resistance to Pathogens in Plants, Plant Pathology, Dr. Christian Joseph Cumagun (Ed.), InTech, DOI: 10.5772/30763. Available from: http://www.intechopen.com/books/plant-pathology/horizontal-or-generalized-resistance-to-pathogens-in-plants

McKenzie, F. (2013). Fostering Farmer Driven Innovation in Sulawesi, *Cokelat*, (March-May) CSP, Makassar

McMahon, P.J., Agus Purwantara, Ayu Parawansa, Amanda Firmansyah, Susanna Bryceson, Agung W. Susilo, Nurlaila, Sahardi Mulia ,Hussin bin Purung, Smilja Lambert, Philip Keane, David Guest. Testing local cocoa selections in Sulawesi: (iii) vascular streak dieback. Submitted 2016 Crop Protection.

McMahon, P.J. and Purwantara, A. 2016. Vascular Streak Dieback: *Oncobasidium theobromae* -History and Biology, *in* Cacao diseases ed. Bryan Bailey. Springer.

McMahon, P.J. 2012. Effect of nutrition and soil function on pathogens of tropical tree crops, *in* Plant Pathology ed. Christian Joseph R. Cumagun, InTech pp 241-272

McMahon, Peter J., Hussin bin Purung, Smilja Lambert, Sahardi Mulia, Nurlaila, Agung W. Susilo, Endang Sulistyowati, Sri Sukamto, Muhajir Israel, Ashar Saftar, Arman Amir, Agus Purwantara, Arief Iswanto, David Guest, Philip Keane, 2015. Testing local cocoa clones in three provinces in Sulawesi: i) productivity and resistance to cocoa pod borer and Phytophthora pod rot. Crop Protection, 70, 28-39.

Meekin, A. (2013). Hot Chocolate! `Cocoa Industry Development' in Indonesia, *Honours Thesis at the University of Sydney*

Mount, T. (2012). Peak Chocolate? Unpacking Sustainability in Indonesia's cocoa Industry*, Honours Thesis at the University of Sydney*

Neilson, J. and McKenzie, F. (2015). Sustainable solutions in the Indonesian cocoa sector: farmer-driven innovation and business-oriented outreach programs, Innovations in linking sustainable agricultural practices with markets, FAO, Rome (Accepted by the editors in February 2014).

Neilson, J., Meekin, A. and Fauziah, K. (2014). Effects of an Export tax on the farm-gate price of Indonesian cocoa beans, Proceedings of the Malaysian International Cocoa Conference, 7-8 October 2013, (ISBN:978-983-2433-25-5), Malaysian Cocoa Board, Kota Kinabalu. Pp. 295-300.

Neilson, J. and Palinrungi, R. (2011). Cocoa Certification: What are the actual benefits for farmers? *CSP News*, Vol I, p. 6

Neilson, J. and Hafid, H. (2012). Fertilizer policy and cocoa farming in Indonesia, *CSP News*, July-September 2012.

Neilson, J. and McKenzie, F. (2016) Business-oriented outreach programmes for sustainable cocoa production in Indonesia: an institutional innovation. pp.17-36 In ‘Innovative markets for sustainable agriculture. How innovations in market institutions encourage sustainable agriculture in developing countries’, Edited by Allison Loconto, Anne Sophie Poisot, Pilar Santacoloma. FAO, Rome 2016

Neilson, J. and McKenzie, F. (2013). Evaluating the impacts of sustainability schemes in the Indonesian Cocoa Industry’, *Cokelat*, (July-Sept) CSP, Makassar

Parawansa et al. Progress of infection of vascular-streak dieback (submitted Sept 2014 and re-submitted in 2015)

Purwantara, A., Peter McMahon, Agung W. Susilo, Sri Sukamto, Sahardi Mulia, Nurlaila, Hussin bin Purung, Smilja Lambert, Philip Keane, David Guest. Testing local cocoa selections in Sulawesi: (ii) resistance to stem canker and pod rot (black pod) caused by *Phytophthora palmivora*. Crop Protection 77, 18-26.

Purwantara, Agus and Arief Iswanto, 2014 Pengelolaan Tanaman Terpadu pada Kakao Booklet submitted for publication ACIAR

Sahardi, Fadjry Djufry, Peter J. McMahon, Agus Purwantara, Hussin bin Purung, David I. Guest, Philip J. Keane and Smilja Lambert. Effect of organic and inorganic amendments on productivity of cocoa on marginal soils in Sulawesi (2016). Submitted to Experimental Agriculture

Samuels, Gary J., Adnan Ismaiel, Ade Rosmana, Muhammad Junaid, David Guest, Peter McMahon, Philip Keane, Agus Purwantara, Smilja Lambert, Marianela Rodriguez-Carres, Marc A. Cubeta, 2012. Vascular Streak Dieback of Cacao in Southeast Asia and Melanesia: In Planta Detection of the Pathogen and a New Taxonomy. Fungal biology, 116, 11-23.

<u>Conferences with ACIAR project presentations</u>

Sulawesi International Seminar on Cocoa (SISCO) June 26-28 2013, Makassar

Padang Symposium Expo Kakao, 6-9 November 2012, Padang, West Sumatra

Promoting Rational Pesticide Use and Improving Management of CPB. A regional workshop organised by Mars, ICCRI, and ACIAR, Denpasar, Bali, Indonesia, 10th and 11th July 2012. Amartha 2 July 2011Opening workshop

‘Effects of an Export tax on the farm-gate price of Indonesian cocoa beans’ Malaysian International Cocoa Conference, Kuala Lumpur, October 8, 2013 (Neilson).

‘Resource-Based Industrialisation in Indonesia and the effects of an export tax in the Indonesian cocoa sector’, Indonesia Study Group Seminar at the ANU, December 11, 2013 (Neilson)

‘People and Environmental the Environment in a sustainable cocoa industry’, ASKINDO 6th International Cocoa Conference, Denpasar, Bali, 15 May, 2014 (Neilson)

‘Cocoa Certification: the challenges of farmer behaviour, SKINDO Certification workshop (Gusli and Neilson), Jakarta, December 2013

Ceratobasidium spp. associated with Vascular-Streak Dieback (VSD) disease of Cacao. International Mycological Congress, Edinburgh August 2010 (Guest et al.)

Helping cocoa farmers manage disease and improve productivity. Sulawesi International Seminar on Cocoa (SISCO). Makassar, June 26-28 2013 (Guest)

Biology and management of Phytophthora diseases in tropical horticulture in the post-gnomic era. International Congress of Plant Pathology, Beijing, August 2013 (Guest)

Integrated management of Phytophthora in the tropics. 5th International Oomycetes Workshop, Bejing, August 2013 (Guest)

The Yield Gap: Why farmers don't achieve potential yields and what we can do about it. International Conference of Plant Physiology, Bali August 2014 (Guest)

The Yield Gap: Why farmers don't achieve potential yields and what we can do about it. 5th Asian Conference of Plant Pathology, Chiang Mai. November 2014. (Guest)

11 Appendices

11.1 Appendix 1:

Baseline soil data from BoneBone and West Papua:

Table 1. Topsoil properties determined at Bone Bone prior to trial establishment: in July 2011, three soil samples (0-5 cm depth) were collected from an old cocoa plantation at the top of the north slope (now the clone test site) and three at the bottom of the north slope on fallow land under coconut.[a] see Section 3.1 ,after Nelson et al. 2011, Fahmy 1977

Soil property		Old Cocoa site			Fallow land under coconut			Adequate or normal range[a]
		1	2	3	1	2	3	
Sand/silt/clay (%)		64/27/9	67/26/7	73/16/11	82/11/7	85/9/6	80/12/8	-
pH (water)		4.4	4.2	4	5.01	4.59	4.82	5.5 – 6.5
Omc indicators	C (%)	2.04	1.82	1.34	3.22	3.84	2.14	>5
	N (%)	0.19	0.17	0.14	0.16	0.15	0.1	>0.2
	C/N	11	11	10	20	26	21	8 – 10
TotalS ppm		33	33	80	74	57	48	100 – 500
Exchangeable cations (cmol/kg)	Ca	0.95	0.36	0.88	3.1	0.47	0.02	5 – 10
	Mg	0.12	0.05	0.12	1.1	0.77	0.21	1 – 3
	K	0.18	0.16	0.13	0.33	0.2	0.1	0.3 – 0.6
	Na	0.27	0.40	0.20	Negl	Negl	Negl	-
	CEC	7.96	8.30	7.92	17.37	19.31	9.18	12 – 25
BS %		19	12	17	26	8	4	-
Soil acidity cmol/	Acidity	7.9	8.7	8.9	1.3	3.8	7.8	-
	Al	1.2	4.3	4.1	0	0	0	-
	H	6.6	4.3	4.8	1.26	3.82	7.77	-
25% HCl mg/ 100g	P2O5	71	19	33	26	22	18	-
	K2O	25	8	12	28	22	7	-
	P2O5	99	49	102	7	6	8	6 – 10

Olsen-Bray ppm	K2O	84	75	61	152	91	47	-
Micronutrients ppm	Fe	38,849	25,088	16,088	22,143	25,620	15,100	22 – 99
	Mn	18	18	40	136	91	30	3 – 49
	Cu	nd	2.6	nd	5.4	5.4	nd	0.5 – 4.6
	Zn	16	13	7	18	21	39	0.9 – 4.5
ppm	Co	5.2	6.2	18.6	4.2	4.2	6	-
Other	Pb	22	19	18	25	22	13	-

Table 2. Baseline soil properties at IPDM Plot I of Pravhi-Manokwari. The data shown are for six samples (soil collected at two depths) analysed prior to establishing treatments. Both omc and CEC are higher in the 0-20cm samples (topsoil). Available P and micronutrient concentrations are adequate for cocoa at both soil depths. However, base saturation was low, indicating cation availability as possibly the main limiting factor. (note that this IPDM plot was later replicated on another farm).

Soil Properties	Plot/Soil Depth					
	1		2		3	
	0-20	20-40	0-20	20-40	0-20	20-40
Texture Class	Silty Loam	Silty Loam	Silty Loam	Silty Loam	Silty Loam	Silty Loam
pH (1:2.5)	4.61	5.01	5.82	6.04	5.12	5.09
C-organic (%)	1.71	1.51	2.10	1.51	1.87	1.47
N-Total (%)	0.12	0.14	0.15	0.14	0.13	0.16
P-Total (HCl 25%) (mg/100g)	44	39	49	34	22	51
P-Available (Bray I) (ppm)	30	23	31	21	23	26
K-Total (HCl 25%) (mg/100 g)	121	115	149	122	122	127
Exchangeable Base (me/100 g or cmol/kg)						
Ca	2.00	3.39	6.08	4.85	1.49	2.02
Mg	0.16	0.27	0.22	0.35	0.14	0.19
K	0.04	0.01	0.10	0.05	0.01	0.01
Na	0.01	0.01	0.01	0.01	0.01	0.01
Cation Exchange Capacity (CEC) (cmol/kg)	17.20	8.37	12.24	8.86	12.25	11.05
Base Saturation (%)	16	44	52	59	13	20
Micronutrients/trace elem.						
Zn (ppm)	47.10	43.25	43.25	50.06	41.25	49.26
Fe (ppm)	146.43	136.15	171.95	14.831	136.13	151.91
Mn (ppm)	233.37	302.82	208.56	311.28	233.23	375.89
Cu (ppm)	25.23	23.32	33.01	29.57	20.87	23.05
Co (ppm)	trace	trace	trace	trace	trace	trace
Cd (ppm)	trace	trace	trace	trace	trace	trace
Pb (ppm)	1.05	1.46	1.23	2.10	2.45	2.71

11.2 Appendix 2. Longitudinal VSD survey of ten sites in East Java

Table 1. Altitude, number of dry/wet months and average VSD severity at 10 cocoa sites in East Java

Location	Altit-ude (m)	Annual Rain (mm)	No. of months		Average VSD severity score													
			Wet	Dry	Apr-12	June-12	Sep-12	Jan-13	Apr-13	May-13	Jul-13	Oct-13	Jan-14	Apr-14	Jul-14	Sep-14	Oct-14	Mean
Gn Raung-JTN	490	2532	8.6	2.5	0.31	1.13	1.31	0.98	nd	nd	nd	nd	nd	nd	nd	nd	nd	**0.93**
Sumber Baru-JTN	410	2532	8.6	2.5	1.30	2.02	1.46	1.05	0.52	0.51	0.99	0.98	0.74	0.55	1.12	0.65	0.64	**0.96**
Pager Gng-Kembu	262	2167	7.3	3.3	1.12	1.88	1.02	0.62	0.39	0.43	1.16	1.4	0.89	0.69	0.82	0.92	1.14	**0.96**
Kaliputih-Kembu	130	2167	7.3	3.3	1.43	2.38	nd	0.86	0.915	0.73	1.78	2.7	1.4	0.76	1.36	0.99	0.89	**1.35**
Pacauda-Sule	4	2233	6.5	4.2	1.68	0.98	nd	0.96	0.92	0.92	2.9	nd	0.57	0.51	0.89	0.93	1.25	**1.14**
Antokan-Bjs	232	2161	6.4	5	3.12	2.56	0.44	0.62	nd	nd	nd	nd	nd	0.49	0.9	0.79	0.42	**1.17**
Banjarsari-Bjs	104	2161	6.4	5	1.70	1.51	0.56	0.89	0.79	0.79	1.22	nd	1.22	1.85	0.98	1.52	1.23	**1.19**
Gerengrejo-Bjs	38	2161	6.4	5	2.33	1.3	1.00	0.94	0.88	0.88	1.23	nd	1.03	1.45	1.78	1.36	1.31	**1.29**
Kaliwining	45	1891	6.6	4.4	1.50	1.07	2.35	0.13	0.22	0.32	1.06	1.92	0.47	0.17	0.75	1.00	0.59	**0.89**
Sumber Asin	580	2302	8.5	3.5	nd	0.04	0.05	0	0	0	0	0	0	0	0	0.08	0	**0.01**

11.2.1 Appendix 3 Helopeltis incidence in the Kaliwining compost trial

Clone	Treatment	Incidence (%)			
		Preliminary	1st	2nd	3rd
KW 422 (KKM 22)	PK 10 l/p/th	83.33	48.38	66.22	58.33
	PK 20 l/p/th	87.50	49.10	55.77	50.00
	Kontrol	87.64	52.09	47.22	31.57
KW 426 (KC 1)	PK 10 l/p/th	54.17	68.47	58.99	62.96
	PK 20 l/p/th	78.96	49.97	49.31	58.33
	Kontrol	81.45	60.96	52.39	100.00
KW 427 (KC 2)	PK 10 l/p/th	91.67	49.41	49.79	72.22
	PK 20 l/p/th	85.17	43.94	59.24	80.56
	Kontrol	73.96	60.66	55.73	63.01
KW 425 (KJ 1)	PK 10 l/p/th	52.59	22.20	28.89	54.17
	PK 20 l/p/th	37.50	17.01	40.48	48.56
	Kontrol	31.60	2.47	25.17	38.89
KW 423 (KJ 2)	PK 10 l/p/th	89.58	55.25	15.85	75.36
	PK 20 l/p/th	96.62	54.04	53.70	77.76
	Kontrol	79.17	42.67	31.05	63.97
KW 059 (GC 7)	PK 10 l/p/th	26.00	0.00	20.00	0.00
	PK 20 l/p/th	25.00	25.00	16.67	11.11
	Kontrol	37.50	37.56	10.42	25.00
KW 062 (GS 29)	PK 10 l/p/th	33.33	19.30	16.67	41.67
	PK 20 l/p/th	53.65	25.78	25.25	47.22
	Kontrol	58.33	33.01	8.33	46.67
KW 084	PK 10 l/p/th	83.13	56.70	49.64	81.06
	PK 20 l/p/th	66.67	30.61	46.46	60.39
	Kontrol	71.44	51.01	42.22	62.78
KW 094 (KEE 2)	PK 10 l/p/th	12.36	23.43	43.91	28.33
	PK 20 l/p/th	26.72	25.50	40.19	61.11
	Kontrol	12.05	38.63	33.80	47.22
KW 162 (PBC 123)	PK 10 l/p/th	59.17	62.98	50.80	87.61
	PK 20 l/p/th	58.37	39.24	45.45	72.22
	Kontrol	64.23	40.29	45.76	64.58
KW 163 (BR 25)	PK 10 l/p/th	57.64	22.89	66.94	89.43
	PK 20 l/p/th	72.33	44.63	81.07	47.22
	Kontrol	56.18	39.67	31.50	55.69
KW 165 (BAL 209)	PK 10 l/p/th	82.55	53.41	40.51	73.33
	PK 20 l/p/th	90.74	51.72	38.58	81.11
	Kontrol	84.64	58.57	58.84	50.00
KW 215 SAUSU PIORE)	PK 10 l/p/th	89.12	52.79	43.39	86.58
	PK 20 l/p/th	63.95	60.24	50.09	83.33

	Kontrol	92.69	75.56	55.19	75.00
KW 219 (DR 38 NEGRO)	PK 10 l/p/th	17.71	8.58	28.87	41.67
	PK 20 l/p/th	8.33	21.53	18.88	36.11
	Kontrol	0.00	8.33	0.00	49.56
KW 235 (JTC 5A)	PK 10 l/p/th	20.83	18.75	12.59	8.33
	PK 20 l/p/th	41.96	25.33	18.92	50.00
	Kontrol	38.71	7.17	11.11	33.33
KW 236 (JTC 5B)	PK 10 l/p/th	56.08	24.03	55.37	77.78
	PK 20 l/p/th	83.97	41.24	66.08	90.00
	Kontrol	71.93	37.82	49.94	87.04
KW 264 (KPC 1)	PK 10 l/p/th	31.25	0.00	21.63	60.94
	PK 20 l/p/th	12.50	0.00	4.91	11.11
	Kontrol	30.65	12.50	3.70	33.33
KW 265 (KPC 2)	PK 10 l/p/th	25.00	25.00	33.33	21.67
	PK 20 l/p/th	35.35	30.15	41.67	37.85
	Kontrol	16.67	0.00	22.22	16.67
KW 005 (TSH 858)	PK 10 l/p/th	65.86	0.17	4.17	18.43
	PK 20 l/p/th	51.03	20.83	50.67	18.33
	Kontrol	35.56	12.04	44.84	29.83
KW 292 (UF 667)	PK 10 l/p/th	40.28	7.30	19.44	45.71
	PK 20 l/p/th	70.38	41.61	13.24	50.95
	Kontrol	48.08	24.98	23.62	61.60

11.2.2 Appendix 4 Effect of soil amendments in the BoneBone trial

Table 1. Soil properties. For each treatment (control etc), data in lefthand column is for Dec 2012 (upper row) and Sept 2013 (lower row), and data in the righthand column for Jan 2014 (upper row) and Jun 2014 (lower row). na, not available

Soil property		Control		Mineral		Compost		Lime		Min/comp		Min/lime		Com/lime		Full	
		2013	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
pH (water)		5.76	5.02	5.03	4.87	5.68	4.70	5.64	4.72	5.80	4.94	5.76	4.95	5.40	4.87	5.61	4.94
		5.13	4.95	5.18	4.91	5.50	4.77	5.20	5.24	5.34	4.99	5.14	5.07	5.13	5.27	5.07	5.01
Omc indicators	C %	1.66	1.66	1.74	1.4	1.40	1.32	1.68	1.28	1.16	1.68	1.50	1.60	1.60	2.31	1.82	1.70
		2.17	1.35	1.74	1.39	1.58	1.52	2.46	1.67	2.67	1.62	2.07	1.53	2.28	1.66	3.14	1.70
	N %	0.16	0.13	0.15	0.14	0.11	0.14	0.13	0.14	0.13	0.15	0.12	0.13	0.13	0.14	0.13	0.13
		0.14	0.11	0.15	0.11	0.14	0.13	0.14	0.15	0.14	0.14	0.15	0.09	0.14	0.16	0.15	0.17
	C/N	10	13	12	10	13	9	13	9	9	11	13	12	12	17	14	13
		16	12	12	13	11	12	18	11	19	12	14	17	16	10	21	10
S ppm	Avail	na	114	na	8	na	86	na	5	na	8	na	1	na	132	na	13
	Total	na	233	na	433	na	100	na	33	na	567	na	1266	na	766	na	133

Soil property	Control	Mineral	Compost	Lime	Min/comp	Min/lime	Com/lime	Full

		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Exchangeable cations (cmol/kg)	Ca	0.95	0.36	0.88	0.71	1.08	0.97	0.78	1.49	0.74	0.81	0.82	1.12	0.63	1.33	0.58	1.39
		0.96	0.34	0.78	0.34	1.04	1.75	0.51	2.07	0.58	1.36	0.65	0.14	0.46	4.22	0.78	1.05
	Mg	0.12	0.05	0.12	0.08	0.09	0.11	0.09	0.06	0.07	0.08	0.08	0.06	0.04	0.12	0.03	0.21
		0.05	0.08	0.05	0.06	0.12	0.09	0.04	0.10	0.05	0.13	0.08	0.06	0.04	0.17	0.11	0.12
	K	0.18	0.16	0.13	0.47	0.12	0.22	0.12	0.17	0.12	0.51	0.12	0.40	0.14	0.16	0.17	0.21
		-	0.14	-	0.14	-	O.12	-	0.12	-	0.11	-	0.11	-	0.14	-	0.10
	Na	0.27	0.40	0.20	0.39	0.26	0.40	0.19	0.42	0.17	0.42	0.16	0.38	0.24	0.41	0.17	0.36
		-	0.26	-	0.28	-	0.35	-	0.29	-	0.22	-	0.35	-	0.20	-	0.34
	CEC	7.96	8.30	7.92	8.06	6.91	3.70	7.96	6.26	7.77	8.70	8.08	7.17	7.87	3.68	8.08	8.43
		7.73	7.05	8.84	7.44	7.61	7.73	8.66	6.17	8.57	7.37	8.64	8.02	8.45	8.30	8.83	7.23
BS %		19	12	17	20	22	46	15	34	14	21	15	27	13	54	12	26
		-	12	-	11	-	30	-	42	-	25	-	8	-	57	-	22
Soil acidity cmol/	Acid-ity	7.9	8.7	8.9	8.1	7.4	8.8	9.0	9.4	6.5	6.8	8.4	9.1	5.6	8.3	9.3	8.3
		-	4.2	-	5.8	-	4.5	-	4.8	-	5.5	-	6.9	-	5.4	-	6.0
	Al	1.2	4.3	4.1	4.3	1.9	4.7	3.5	5.5	0	6.1	4.2	6.0	0	4.3	3.2	4.1
		-	3.5	-	3.8	-	2.7	-	2.4	-	3.4	-	4.5	-	2.9	-	3.8

Soil property	Control	Mineral	Compost	Lime	Min/comp	Min/lime	Com/lime	Full

		2013	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**		**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**
	H	6.6	4.3	4.8	3.8	5.5	4.0	5.6	3.9	6.5	0.7	4.2	3.1	5.6	4.0	6.1	4.2
		-	0.7	-	2.0	-	1.8	-	2.4	-	2.1	-	2.4	-	2.5	-	2.2
Fertiliser equivalent	P2O5 (HCl)	71	19	33	61	18	18	15	16	11	32	14	57	17	19	13	38
		-	34	-	76	-	56	-	45	-	77	-	72	-	59	-	69
	P2O5 (Olsen)	99	49	102	41	85	43	131	37	78	46	132	34	126	56	118	116
			33	-	115	-	39	-	19	-	95	-	62	-	61	-	9
	K2O (HCl)	25	8	12	26	12	12	13	11	13	24	14	20	15	12	16	11
			13	-	13	-	16	-	14	-	13	-	13	-	13	-	12
	K2O (Olsen)	84	75	61	222	57	104	54	78	56	237	54	185	63	77	77	97
		-	67	-	66	-	58	-	56	-	54	-	53	-	65	-	45

Table 2. Nutrient content of cocoa leaves in the BoneBone trial in Feb 2013 and April 2014. The lower Ca concentrations in 2013, compared to the following year, might reflect the age of leaves collected since Ca is immobile . Cadmium and lead were not detected. na not available; bd, below detection limit

Nutrient		Control		Mineral		Compost		Lime		Min/comp		Min/lime		Com/lime		Full	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Macronutrients (%)	N	1.5	1.6	1.4	1.6	1.4	1.6	1.4	1.6	1.6	1.6	1.6	1.7	1.5	1.6	1.6	1.6
	P	0.29	0.29	0.21	0.27	0.27	0.26	0.22	0.23	0.28	0.13	0.30	0.24	0.29	0.25	0.31	0.33
	K	2.4	2.7	1.9	2.5	2.6	2.3	2.1	1.8	2.8	2.0	2.2	1.7	2.8	2.3	3.2	1.9
	S	na	0.07	na	0.07	na	0.05	na	0.05	na	0.1	na	0.05	na	0.07	na	0.06
	Ca	0.3	2.1	0.25	2.1	0.24	3.4	0.45	2.5	0.27	2.3	0.35	2.4	0.56	1.7	0.53	2.3
	Mg	0.28	0.41	0.22	0.48	0.26	0.45	0.18	0.5	0.34	0.52	0.21	0.49	0.32	0.38	0.35	0.36
Micronutrients (ppm)	Fe	191	11,277	693	400	872	257	2554	2198	668	200	805	228	4894	285	4734	1028
	Mn	88	380	75	79	70	109	49	93	76	157	46	49	86	53	83	115
	Cu	bd	44	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd
	Zn	29	38	23	36	27	46	28	42	30	32	27	31	37	30	30	39
	Co	na	7	na	4	na	3	na	bd	na	bd	na	bd	na	bd	na	bd
Other (ppm)	Na	300	892	700	192	600	71	700	101	700	85	900	81	1500	86	1500	70

11.2.3 Appendix 5. Soil analyses from the trial in Tana Loe, Bantaeng

Table 1. Texture, pH and organic matter in soil samples (two per treatment) in the composts/fertiliser trial in Tana Loe. Samples were analysed at the BPTP Maros Soil laboratory in 2014. S content of the soil was not determined. Treatments: P0, control; P1, Lime; P2: Compost; P3, NPK mineral fertiliser; P4, lime/compost; P5, lime/mineral fertiliser; P6, compost/ mineral fertiliser; P7, lime/compost/ mineral fertiliser.

Sample	Texture			pH (1 : 2,5)		Organic Matter			Extract HCL 25%		Olsen/Bry-
	Sand	Silt	Clay	H_2O	KCL	Carbon	Nitrogen	C/N	P_2O_5	K_2O	P_2O_5
	%					%			mg/100gram		ppm
P0-1	42	44	14	5.99	5.58	1.61	0.10	16	91	101	51
P0-2	38	51	11	5.62	4.78	1.21	0.12	10	126	92	172
P1-1	47	45	8	7.12	6.18	0.98	0.10	10	106	45	58
P1-2	44	51	5	6.26	5.15	1.66	0.09	18	129	94	113
P2-1	41	51	8	6.01	5.37	1.81	0.12	15	111	77	52
P2-2	38	44	18	5.98	4.48	0.86	0.13	7	120	42	36
P3-1	40	47	13	5.99	5.62	1.21	0.13	9	97	26	212
P3-2	37	51	12	6.34	5.26	0.98	0.18	5	151	82	120
P4-1	38	54	8	6.82	6.21	1.12	0.12	9	117	60	54
P4-2	30	55	15	6.65	6.09	1.76	0.14	13	122	86	89
P5-1	43	49	8	6.78	5.67	1.41	0.13	11	124	93	93
P5-2	34	59	7	6.8	6.25	1.25	0.14	9	113	79	115
P6-1	35	48	17	5.65	4.57	1.73	0.17	10	165	53	184
P6-2	32	48	20	5.84	4.61	0.84	0.10	8	127	109	198
P7-1	34	55	11	6.02	5.59	1.19	0.12	10	101	26	122
P7-2	38	50	12	7.05	6.28	1.52	0.10	15	220	169	76

Table 2. Exchangeable cations, P and K (total, available) in soil samples (two per treatment) in the composts/fertiliser trial in Tana Loe. Samples were analysed at the BPTP Maros Soil laboratory in 2014.

	Exchangeable Cations	CEC	BS	Extract HCL 25%	Olsen/Bry-I

	Ca	Mg	K	Na	Total			P_2O_5	K_2O	P_2O_5	K_2O
	cmol/kg						%	mg/100gram		ppm	
P0-1	20.76	1.50	0.22	0.41	22.89	11.39	100^{+}	91	101	51	101
P0-2	27.57	0.88	0.20	0.38	29.03	12.83	100^{+}	126	92	172	357
P1-1	26.66	0.36	0.10	0.27	27.39	17.46	100^{+}	106	45	58	314
P1-2	47.18	1.63	0.20	0.24	49.25	15.53	100^{+}	129	94	113	234
P2-1	42.69	1.54	0.16	0.24	44.63	11.95	100^{+}	111	77	52	335
P2-2	17.77	0.62	0.09	0.18	18.66	10.27	100^{+}	120	42	36	223
P3-1	24.89	0.67	0.06	0.22	25.84	10.95	100^{+}	97	26	212	163
P3-2	44.45	0.90	0.18	0.27	45.80	14.41	100^{+}	151	82	120	306
P4-1	32.36	1.60	0.13	0.26	34.35	14.76	100^{+}	117	60	54	244
P4-2	22.59	1.79	0.18	0.29	24.85	11.00	100^{+}	122	86	89	293
P5-1	25.02	0.61	0.20	0.23	26.06	11.69	100^{+}	124	93	93	320
P5-2	21.67	1.18	0.17	0.21	23.23	11.73	100^{+}	113	79	115	266
P6-1	30.41	1.06	0.11	0.25	31.83	14.62	100^{+}	165	53	184	190
P6-2	17.65	0.29	0.23	0.22	18.39	13.45	100^{+}	127	109	198	339
P7-1	33.90	1.17	0.06	0.24	35.37	13.62	100^{+}	101	26	122	122
P7-2	32.06	2.04	2.04	0.19	34.65	15.37	100^{+}	220	169	76	375

Appendix 6. Comparison of soil analysis results provided by three certified soil laboratories: ICCRI, BPTP (Maros) and Universitas Gaja Madah (UGM). Soil samples were collected in June 2014 from plots receiving eight treatments in the project compost/fertiliser trial in Bone Bone (Section 5.1.2) and sent to the three laboratories (eight samples to ICCRI and BPTP and three samples to UGM) for analysis of soil properties, including macronutrients (in all three labs) and micronutrients (in two labs). Soil amendments, listed in column 1, had commenced in May 2012; na, not available, extr., extraction; [a]cmol/kg = me/100g; [b]ICCRI and BPTP labs used different methods to analyse soil content of S and Fe.

Table 1. Macronutrients, Base Saturation and pH

Treatment	C (%)			N (%)			C/N		
	ICCRI	BPTP	UGM	ICCRI	BPTP	UGM	ICCRI	BPTP	UGM
Control	1.44	1.35	1.54	0.14	0.11	0.13	10	12	12
Mineral	1.33	1.39		0.13	0.11		10	13	
Compost	1.56	1.52	1.38	0.13	0.13	0.14	12	12	10
Lime	1.4	1.67		0.14	0.15		10	11	
Min/Comp	1.4	1.62		0.15	0.14		9	12	
Min/Lime	1.38	1.53		0.14	0.09		10	17	
Lime/comp	1.65	1.66		0.13	0.16		13	10	
Full	1.55	1.7	1.48	0.14	0.17	0.17	11	10	9

Table 1 (cont.)

Treatment	P_2O_5 25% HCl extr. mg/100g			P_2O_5 Olsen-Bray ppm			CaO 25% HCl extr. mg/100g		
	ICCRI	BPTP	UGM	ICCRI	BPTP	UGM	ICCRI	BPTP	UGM
Control	52	34	30	30	33	13	2	na	12
Mineral	108	76		91	115		3	na	
Compost	67	56	60	45	39	21	7	na	27
Lime	51	45		24	19		11	na	
Min/Comp	90	77		78	95		2	na	
Min/Lime	91	72		72	62		3	na	
Lime/comp	72	59		63	61		6	na	
Full	80	69	80	67	9	45	2	na	16

Table 1 (cont)

Treatment	K_2O 25% HCl extr. mg/100g			K_2O Olsen-Bray ppm			MgO 25% HCl extr. mg/100g		
	ICCRI	BPTP	UGM	ICCRI	BPTP	UGM	ICCRI	BPTP	UGM
Control	52	34	30	65	13	17	14	na	10
Mineral	108	76		86	13		18	na	
Compost	67	56	60	47	16	20	11	na	13
Lime	51	45		54	14		6	na	
Min/Comp	90	77		47	13		14	na	
Min/Lime	91	72		43	13		13	na	
Lime/comp	72	59		40	13		11	na	
Full	80	69	80	49	12	16	7	na	10

Table 4. Table 1 (cont)

Treatment	CEC cmol/kg[a]			Exch. Ca cmol/kg			Exch Mg cmol/kg		
	ICCRI	BPTP	UGM	ICCRI	BPTP	UGM	ICCRI	BPTP	UGM
Control	7.37	7.05	na	2.09	0.34	1.35	0.68	0.08	0.30
Mineral	8.28	7.44		0.98	0.34		0.66	0.06	
Compost	8.88	7.73	na	3.39	1.75	3.92	0.75	0.09	0.39
Lime	8.33	6.17		1.78	2.07		0.66	0.10	
Min/Comp	8.71	7.37		1.17	1.36		0.72	0.13	
Min/Lime	8.48	8.02		0.74	0.14		0.65	0.06	
Lime/comp	8.31	8.30		1.78	4.22		0.89	0.17	
Full	8.49	7.23	na	1.18	1.05	1.44	0.74	0.12	0.33

Table 1 (cont)

Treatment	Exch K cmol/kg			Exch. Na cmol/kg			Total exch. cations		
	ICCRI	BPTP	UGM	ICCRI	BPTP	UGM	ICCRI	BPTP	UGM
Control	**0.48**	**0.14**	**0.23**	**0.10**	**0.26**	**0.36**	**3.35**	**0.82**	**2.24**
Mineral	**0.59**	**0.14**		**0.08**	**0.28**		**2.31**	**0.82**	
Compost	**0.46**	**0.12**	**0.22**	**0.13**	**0.35**	**0.36**	**4.73**	**2.31**	**4.89**
Lime	**0.42**	**0.12**		**0.08**	**0.29**		**2.94**	**2.58**	
Min/Comp	**0.56**	**0.11**		**0.09**	**0.22**		**2.54**	**1.82**	
Min/Lime	**0.39**	**0.11**		**0.07**	**0.35**		**1.85**	**0.66**	
Lime/comp	**0.22**	**0.14**		**0.08**	**0.20**		**2.97**	**4.73**	
Full	**0.55**	**0.10**	**0.20**	**0.12**	**0.34**	**0.33**	**2.59**	**1.61**	**2.3**

Table 1 (cont)

Treatment	Base saturation (%)			pH (water)			[b]S available, [b]total ppm		
	ICCRI	BPTP	UGM	ICCRI	BPTP	UGM	ICCRI[a]	BPTP[b]	UGM
Control	**45**	**12**	**na**	**4.2**	**4.95**	**4.60**	**201**	**1879**	**na**
Mineral	**28**	**11**		**4.1**	**4.91**		**176**	**1845**	
Compost	**53**	**30**	**na**	**4.4**	**4.77**	**4.96**	**128**	**1845**	**na**
Lime	**35**	**42**		**4.4**	**5.24**		**157**	**1780**	
Min/Comp	**29**	**25**		**4.1**	**4.98**		**151**	**1767**	
Min/Lime	**22**	**8**		**4.2**	**5.07**		**106**	**1712**	
Lime/comp	**36**	**57**		**4.4**	**5.27**		**171**	**1832**	
Full	**30**	**22**	**na**	**4.2**	**5.01**	**4.59**	**149**	**1897**	**na**

Table 2. Micronutrients and Al

Treatment	[b]Fe ppm		Mn ppm		Cu ppm		Zn ppm	
	ICCRI (NH_4-ac.)	BPTP (AAS)	ICCRI (acid)	BPTP (AAS)	ICCRI (acid)	BPTP (AAS)	ICCRI (acid)	BPTP (AAS)
Control	**42**	**10432**	**41**	**11**	**1**	**3**	**2**	**6**
Mineral	**38**	**10879**	**33**	**11**	**1**	**1**	**2**	**5**
Compost	**33**	**11516**	**40**	**16**	**1**	**1**	**2**	**6**
Lime	**33**	**10436**	**28**	**13**	**1**	**1**	**2**	**5**

Min/Comp	**45**	**12000**	**12**	**16**	**1**	**1**	**2**	**7**
Min/Lime	**47**	**11788**	**10**	**12**	**1**	**1**	**2**	**9**
Lime/comp	**34**	**9447**	**20**	**15**	**1**	**1**	**3**	**8**
Full	**36**	**11797**	**16**	**13**	**1**	**1**	**5**	**5**

Table 2 (cont)

Treatment	**B ppm**		**Cl ppm**		**Al exch. cmol/kg**		**Pb ppm**	
	ICCRI (acid.)	**BPTP (AAS)**	**ICCRI (acid)**	**BPTP (AAS)**	**ICCRI (acid)**	**BPTP (AAS)**	**ICCRI (acid)**	**BPTP (AAS)**
Control	**57**	**na**	**80**	**na**	**2.28**	**3.53**	**na**	**20**
Mineral	**53**	**na**	**74**	**na**	**3.32**	**3.83**	**na**	**32**
Compost	**56**	**na**	**76**	**na**	**2.20**	**2.69**	**na**	**32**
Lime	**62**	**na**	**67**	**na**	**2.29**	**2.42**	**na**	**32**
Min/Comp	**55**	**na**	**80**	**na**	**2.70**	**3.41**	**na**	**27**
Min/Lime	**57**	**na**	**70**	**na**	**2.90**	**4.51**	**na**	**30**
Lime/comp	**62**	**na**	**101**	**na**	**2.28**	**2.88**	**na**	**34**
Full	**55**	**na**	**73**	**na**	**2.69**	**2.22**	**na**	**32**

11.2.4 Appendix 7. DNA isolation and PCR protocols adapted for Hasanuddin University facility

A) DNA extraction at room temperature from infected plants using an adapted CTAB method based on Carlson lysis buffer – (the DNA of pathogens or other microorganisms is then amplified using specific primers) – Amanda Firmansyah

1. Prepare reagents including Carlson lysis buffer (pH 9.4) which is stored at room temperature; start water bath
2. Weigh 80-100mg fresh weight (leaves, petioles) for each sample; for petioles removed the outer epidermis with a scalpel, remove any mucus using filter papers, leaving the white cambium; chop into small pieces with sterile laboratory scissors, mix with sterile sand then grind in mortar and pestle.
3. After grinding into smaller pieces, add about 500µl of CTAB buffer (containing 2µl mercapthoethanol from a total volume of 750 µl CTAB buffer pre- heated in a waterbath (65^{o}C) for 15minutes) into mortar and continue grinding until the samples becomes a paste.
4. Put the paste into a sterile 2ml tube. Add the remaining 250µl buffer into the mortar in order to wash out the remains and pour into the tube. Mix the contents of the tube using a vortex for 5 seconds. Place all the tubes into waterbath (65^{o}C for 30minutes). Invert the tubes every 5 minutes.
5. After 30minutes, centrifuge (14000 rpm/room temperature/15minutes).
6. Avoid the pellets, transfer the supernatant into a new 2ml sterile tube. Measure the amount of the supernatant. Add an equal volume of chloroform:isoamylalcohol (24 : 1) to the supernatant. Invert gently until it blends.
7. Centrifuge (14000 rpm/roomtemperature/15minutes).
8. Remove tubes; you may see three layers in the tube. Take the liquid (supernatant) in the top very carefully with a pipette and transfer to new 2ml sterile tube. Determine the volume of the supernatant. Add an equal volume of cold isopropyl alcohol to the supernatant.
9. Centrifuge (12000 rpm/4^{o}C /10minutes).
10. Remove the tubes from the centrifuge, remove the supernatant keeping the pellet.
11. Add 220µl cold 70% ethanol to the pellet, centrifuge (10000 rpm/4^{o}C /1minutes).
12. Remove the ethanol then repeat step 10 (Add 220µl cold 70% ethanol, centrifuge (10000 rpm/4^{o}C /1minutes).
13. Remove the ethanol and air dry the tube for 60 minutes (to do this place at an angle upside down on tissue paper).
14. Add 50µl TE buffer, flick the tube to dissolve the DNA and store the tube in a refrigerator or, in the long-term, in a freezer.

B) PCR Protocol

1. Prepare sterile tubes on a small tray for PCR. In a laminar flow cabinet, combine Go Taq Green master mix (7µl) with primers forward and reverse (ITS4/5, ITS1F/4B, ITS1/2, specific primers, 1.5 µl), and sterile ddH2O (2µl).
2. Set the PCR cycle: start with denaturing in 95^{o}C for 15 minutes, 94^{o}C for 30 seconds, primer annealing at 55^{o}C for 30seconds, 72^{o}C for 1minute; these steps are repeated for 35 times, then extension at 72^{o}C for 10 minutes, and 4^{o}C for 30 minute.
3. To check the PCR products, mix 1g agarose with 50ml TBE 1x then heat in microwave. After the mixture has boiled, let it cool then pour it into a gel tray with a comb. After approximately 45 minutes, take out the comb from the gel, in preparation to load the samples.
4. Mix 2 µl of loading dye, 2 µl gene ruler (1 kb) and 3 µl sterile water and, with an autopipette, load the marker lane.
5. For each sample, mix 2 µl loading dye and 5 µl PCR product, mix with pipetting and load individual lanes.
6. Run on electrophoresis at 90 volts for 30-45minutes.
7. Check under UV light for PCR products, determine size of the fragment and photograph if necessary.

11.2.5 Appendix 8

Growth data recorded at multi-location clone tests in March 2013: Campalagian, Polman, W. Sulawesi, Tampumia, Luwu, S. Sulawesi, BoneBone, North Luwu, S. Sulawesi, Wotu, East Luwu, S. Sulawesi.

Site	Clone	Stem ht (cm)	Stem girth (mm)	Flowering (%)	VSD score
Campapalagian	**45**	30.0	107.8	0.0	2.0
	THR	30.3	102.6	38.9	2.3
	PR	34.2	117.6	16.7	2.5
	M 01	31.2	130.0	72.2	2.7
	M 06	26.0	124.8	44.4	2.5
	SUL 1	31.2	129.4	38.9	2.6
	KB 1	28.4	138.0	27.8	2.5
	KW 514	26.0	81.8	5.6	1.5
	KW 617	29.3	91.4	0.0	1.5
	KW 733	34.6	114.0	11.1	2.4
	KW 516	38.0	140.0	22.2	2.1
	TSH 858	31.7	104.8	0.0	1.3
	Mean	**30.9**	**115.2**	**23.1**	**2.2**
Tampumia	**45.0**	30.3	77.4	11.1	1.7
	THR	25.6	83.2	0.0	2.0
	PR	36.2	114.4	0.0	2.0
	M 11	30.4	99.2	0.0	1.8
	M 16	31.9	109.8	0.0	2.4
	SUL 1	29.6	90.6	0.0	2.1
	KB 1	24.2	84.2	0.0	2.1
	KW 514	22.9	77.4	0.0	1.2
	KW 617	20.0	67.4	0.0	1.4
	KW 733	30.4	91.8	0.0	2.0
	KW 516	28.9	101.6	0.0	1.9
	TSH 858	-	-	-	-
	Mean	**28.2**	**90.6**	**1.0**	**1.9**

Bone Bone	**45.0**	32.5	125.2	0.0	1.8
	THR	30.5	114.4	0.0	1.8
	PR	40.9	148.2	0.0	2.8
	M 11	39.2	144.0	44.4	1.9
	M 16	39.7	166.4	50.0	2.9
	SUL 1	-	-	-	-
	KB 2	36.5	151.2	22.2	1.7
	KW 514	20.1	73.2	0.0	1.4
	KW 617	25.3	105.4	0.0	1.4
	KW 733	30.4	126.2	0.0	1.6
	KW 516	40.4	148.4	0.0	1.7
	TSH 858	31.7	122.8	22.2	1.8
	Mean	**33.4**	**129.6**	**12.6**	**1.9**
Wotu	**45**	146.6	43.6	72.2	2.8
	THR	142.0	33.5	55.6	2.8
	PR	151.6	38.2	22.2	2.6
	M 01	154.6	35.1	55.6	2.9
	M 06	146.4	29.6	33.3	2.8
	SUL 1	148.4	41.2	44.4	3.0
	KB 1	157.2	32.6	38.9	2.9
	KW 514	-	-	-	-
	KW 617	140.4	38.3	0.0	2.9
	KW 733	151.0	39.6	33.3	2.8
	KW 516	151.0	29.8	5.6	2.7
	TSH 858	147.4	38.0	16.7	2.6
	Mean	**148.8**	**36.3**	**34.3**	**2.8**

11.2.6 Appendix 9. Farmer-farmer interaction as part of rollout

POLMAN COCOA FARMERS GO TO LUWU AND EAST LUWU

This comparative study began on 17 April 2013. The event was attended by 16 farmers from farming groups Bina Remaja and Tunas Harapan and accompanied by 3 extension and staff of Dishutbun Polman and 2 people from BPTP South Sulawesi. The Comparative Study Group was released by the Secretary of the Department of Forestry and Plantation Kab. Polman. Secretary of the Department hopes that participants learn skills that can be applied after returning from the comparative study. On the first day the group arrived at the Buah Harapan farmer group, Toangkajang hamlet, village Salu Paremang Selatan, District Kamanre, Luwu. They were received at the sanggar of Buah Harapan farmer group and welcomed by the head of the group Baramang, and Mr. Arief Iswanto from ACIAR.

Activities on the first day began with introduction of the participants of the comparative study group to members of the Buah Harapan farmer group as host, followed by a brief presentation about the benefits of using organic fertilizer on cocoa crops by Mr. Arief Iswanto. It was proposed that the state of the soil and plants that are damaged due to the continuous use of chemicals. It is time for farmers to use natural ingredients that come from their own garden such as twigs and leaves, former prunings, and husks of fruit crop residues; these can be collected and further processed into compost. Most members of the Buah Harapan farmer group have long used organic fertilizer in their gardens because the group gets help from the husk shredding machine provided by PT.MARS with supporting advice. Most of the gardens have been certified by RA (Rainforest Alliance) leading to a reduction in the use of plant-based pesticides and chemical weed control to control pests and diseases. In further discussion sessions, participants asked questions related to the formation of the farmer group Buah Harapan and how to manage the cooperative to be successful as it is today. Baramang (the farmer group leader) explained that the group formed in 2003 when under Success Alliance but changed to an autonomous group in 2007 when Baramang was elected as chairman until now. Managing groups and cooperatives requires all members of the group to be in a spirit of cooperation in building the group.

On the second day of April 18, 2013, the group headed to the composting site is managed by farmer groups Buah Harapan. This demonstrates how to compost materials from cocoa waste and animal manure (cow). They proceeded to the next orchard farmer where the group leader (Baramang) which has been using organic fertilizers for 3 years. Organic fertilizer uses waste such as cocoa shells, cocoa pods after harvest, litter and remnants of prunings and manure from cow dung. This organic fertilizer is made directly in the garden by digging a trench in between tree rows as deep as 30 cm in which the waste is placed with the addition of a solution of microbial decomposers, after which it covered with soil. Over time the material will compost itself leaving space for more organic waste additions stacked on top of the rotted material and so on. For weed control, manual methods with weed strimmers are used. For the control of pests and diseases a biopesticide based on biourine is used.

Further discussions took place between participants and the Buah Harapan group of ways of gardening cocoa. The Polman participants were enthusiastic to find out more and really amazed about the cleanliness of the gardens and the ability of farmers in Luwu to manage their gardens. Shortly before noon, the group returned to the sanggar and continued discussing the new gardens they visited. The average farmer Polman expressed admiration and regarded their gardens in Polman as being far behind. This was raised by Mr. Arifin, chairman of the Tunas Harapan group in Anreapi, Polman. Pak Baramang suggested there are three things you need to do in the Polman gardens: intense fertilization, pruning and good sanitation to match the state of Pak Baramang's and other Luwu gardens; for the gardens are located in the mountain it is better to use organic fertilizer because it can be made in local gardens, while chemical fertilizers must be transported from outside to the garden. Mr. Fattah, chairman of the group Bina Remaja from Sumarrang Polman reminded the meeting of the different land conditions in Polman which consist of mostly mountainous highlands while in Luwu the farmlands are generally flat. He added that what needs to be replicated is the Buah Harapan group morale. Mr. Badu raised the issue that their trees have an average height of over 3 meters so are difficult to maintain and also that there are a number of other crops in their farms. Comments from Mrs. Raodah and Mr. Faisal as a companion of the Plantation Office District, Polman suggested that they should emulate the skills of farmers in Luwu; the average farmer in Polman has a large garden but is less enterprising. He added if there are many other crops other than cocoa in the garden do not cut them all down but provide sufficient fertilizer using compost to provide better results. Compost will improve the soil structure and just needs a little longer than chemical fertiliser to see results. At the end of the discussion Mr. Baramang provide motivation to farmers expecting that they love their profession, and do not stay at home. They should focus on the areas of operation in order to work more seriously. Do not always wait for outside help, he advocated, but rely on yourself and then help will surely come from outside. At 12:30 pm, discussion was closed, followed by lunch after which the study participants said goodbye as they were moving on to the District, East Luwu.

The third day of April 19, 2013 at 08:00 pm, the group left the hotel to the MCDC (Mars Cocoa Development Center) Tarengge PT. Mars. MCDC is a research and training center that is supervised by a PT cocoa Mars and has a lot of farmers, extension workers, high school and university student internships at MCDC. For example, when the group arrived there was ongoing training for participants from the Food Security and Guidance organisation, Gorontalo Province, interns from SMK (secondary school) Bone-Bone and Tomoni, and 3 Mars staff from Vietnam who will be the coordinators of another MCDC in Vietnam. The Polman participants were received by the staff at the Mars MCDC, Mr. Muhajir and Mr. Jasi. An overview for the study participants was introduced on the MCDC and its programs, one of which is the Cocoa Doctor program. Cocoa Doctors are farmers who have completed training on cocoa for 2 weeks at MCDC with the expectation that he or she would later become a pioneer in his/her village. Furthermore, the cocoa doctor will be directed to do local business, such as raising seedlings in a way that business can be sustainable. Until now MCDC has had 60 Cocoa Doctors spread across Indonesia.

After introductions, the group was invited to tour MCDC. The first visit was to see clones, where a trial is being conducted on 12 types of clones, followed by a fermentation demonstration, and then cocoa hybrid crosses that have been produced by hand pollination to get one or a few kinds of the cocoa with superior production, quality and general performance characters. There are 15 thousand trees from crosses screened to select the best clones with resistance to pests and diseases, a high production, and high fat content. After the tour, the group was taken to the wet cocoa bean processing plant owned Mars in Tarengge within 1 km of MCDC. While visiting the factory, the group were invited to tour with boots and a hard hat according to the safety standards of the plant. The local staff at the wet cocoa processing plant explained to the farmers the fermentation process until the drying of fermented beans. After completing the tour of the factory, the group was taken to one of the gardens of a Cocoa Doctor who is not far from the factory. The on-site orchard farmer showed results of side-grafting and grafting shoots that have been fruitful. In the garden there are several types of clones, namely M01, M04, and 45. In an area of 1 ha farmers get results at harvest of 1.8 tons. Finishing in the garden, the group returned to MCDC and were shown the research site testing inter-tree spacing. There are 4 models with spacing of 3m x 3m, 3,5 m x 3,5 m, 3m x 4m, and 4m x 4m. For the first year of highest production was obtained from a spacing of 3m x 3m, the second highest production was obtained from a spacing of 3.5 m x 3.5 m; the plants have now entered their third year.

With the visit to MCDC completed the group continued to a garden in Pendolo in Central Sulawesi province to see one of the best Cocoa Doctors, namely Sir Robin. Initially he only had an area of 0.5 ha of cocoa and then visited Noling and Palopo, seeing the enormous potential of cocoa; this stimulated his interest so he often wondered about cocoa. He then went to the MCDC Palopo for training and was eventually trained as Cocoa Doctor. After he returned, he applied the training and practices learned in Pendolo, starting from nursery to business services as oculator (grafter); he trained young men around his house to be oculators as well; turnover eventually reached 45 million rupiah. Now he has a cocoa land area of 12 ha and can build a house for his parents. Here the visiting farmers from Polman could see garden conditions in the mountains, because Pendolo is also in mountains and also they could observe how the Pendolo farmers had successfully developed the side-grafting and grafting seedlings to rehabilitate their farms. The motivation given by Sir Robin is that farmers need to be diligent in the garden and to their profession well, farmers must treat their cocoa crop in terms of standards of maintaining their crop well, then surely the plant will respond back with a lot of results. After discussing a while, the group returned to the hotel arriving at 20.00 pm for dinner and a rest.

The fourth day of April 20, 2013 at 8:00 pm, the party prepared to return to Polman but first stopped to farewell staff at MCDC. The delegation was received by Pak Muhajir and Pak Jasi, asked the opinion of farmers having seen and visited in the region of Mars, what is gained and can be brought back to their homes. One of the group, Mr Alimin, commented that the study this time was a very memorable trip and will not be forgotten throughout his life. During the decades of gardening, he said, he never fertilizes, prunes and sprays his garden; only harvest activities are carried out. He is one who did not believe that continued attention to the cocoa crop will gain results, but after looking at himself, and hearing the discussions since arriving in Luwu and later Tarengge to Lutim, his eyes have been opened and he now believes that with side-grafting he can succeed and sincerely promises will manage the garden with good standards in order to be successful as farmers in the districts, Luwu and Kab. Lutim. Mr Badu also commented that he had felt with an area of 4 ha garden with the results of 1 ton he felt he was the most great in the Polman, but after the visit to Luwu and Lutim he could not say any more because it turns out his garden is nothing when compared to the gardens they have seen during the study.