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Commercialising cocoa growing in North Queensland

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by Yan Diczbalis

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Foreword

The project, "Commercialising Cocoa Growing in North Queensland" commenced following an initial feasibility study for cocoa production in northern Australia. The project was co-funded by RIRDC, Cadbury and the Queensland Government. The initial planting material supplied to four co-operator growers was financed directly by Cadbury. During the life of the project Cadbury as a company was consumed by Kraft whose vision, although remaining supportive of the project, had refocused to other priorities. RIRDC and the Queensland Government maintained their support for a potential new industry for northern Queensland.

The research and extension support was important because an embryonic industry based on the production of boutique or north Queensland origin cocoa has emerged, despite the devastating influence of a Category 5 tropical cyclone (TC Yasi) in February 2011. One of the four initial grower co-operators has replanted and is now a producer of chocolate and associated products. This has inspired another two producers who commenced self-funded seed imports and planting in early 2013.

This project could support a north Queensland cocoa industry focussed on the production of premium quality fermented dried beans, developing up to 1,000 hectares which could produce up to 3,000 tonnes of dried bean. The raw product value to the region would be in the vicinity of $10 to 12M. This volume of production could be easily absorbed into the cocoa market and would only partially meet the increasing demand for high quality fermented cocoa bean.

The project highlighted a range of issues associated with the commercial production of cocoa. Cocoa, traditionally grown as an understory plant, can be grown in full sun but only with excellent wind protection and precise management of irrigation, nutrient and pest and disease problems, particularly in the first two years of establishment. The project also developed a workable regime for the fermentation and drying of bean, which is fundamental for the production of a profitable crop.

New and existing producers will need to ensure they use only high yielding hybrid or clonal material for the establishment of new orchards.

This project was funded from RIRDC Core Funds, which are provided by the Australian Government and was also supported by the Queensland Government. Industry contributions were also provided to the project by Cadbury Schweppes.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our New and Developing Plant Industries R&D program, which aims to facilitate the development of new and developing industries based on plants or plant products that have commercial potential in Australia.

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

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Yan has worked in the tropics his entire professional career, the last 20 years of which he has worked with the tropical exotic fruit industry. He is currently the leader of the Tropical Fruit Research and Development team, based at the Centre for Wet Tropics Agriculture, South Johnstone, Queensland. His interests include the commercial development of exotic tropical crops based on an understanding of crop production patterns in relation to their growing environment. He has worked with a range of crops including; cocoa, papaya, lychee, longan, rambutan, durian, and mangosteen.

Acknowledgments

The author wishes to acknowledge the inputs of the following;

Cadbury Schweppes Ian Mitchell David Preece	**Growers (Innisfail to Ingham)** Noel Stevenson Gerard Binder Bob and Carolyn Broom Chris and Lynn Jahnke Mark Smith	**University of New South Wales** Prof. Graham Fleet Dr. Hugh Dirk Ms Van Ho Thi Thuy (PhD candidate)
Mars Chocolate Dr Smilja Lambert	**Growers (Mossman region)** Dr Alan Mortimer Daryl Kirk Don Murday Gerard and Angelo Puglisi Carmen White Lister and Bronwyn Pringle	**Zokoko** Dean and Michelle Morgan Gerhard Petzl

Abbreviations

CA	Cocoa Australia,
CCI	Cocoa and Coconut Institute - PNG
CS	Cadbury Schweppes, Australia – now amalgamated into Kraft
DE	Daintree Estates

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Executive Summary

What the report is about

The report is about the commercialisation of cocoa (*Theobroma cacao*) growing, including harvesting, fermenting and chocolate manufacture in far north Queensland.

The work is important because it is another step towards the development of a small and stable cocoa industry of regional importance in far north Queensland.

Who is the report targeted at?

The report is targeted towards government R&D agencies and potential growers/producers of cocoa.

Where are the relevant industries located in Australia?

The industry is located in far north Queensland on the wet tropical coast from Daintree to Kennedy. There are approximately a dozen growers, three in the Innisfail to Kennedy region and the remainder in the area around Mossman.

The study documented the issues involved in establishing and producing cocoa in a Cadbury Schweppes funded seedling scheme initiated in 2007. The project also established protocols for successful fermentation and drying of cocoa bean in a cool wet tropics environment.

New growers entering the industry will benefit from the learning and outcomes of this research.

Background

A cocoa production feasibility study initiated by Cadbury, funded by RIRDC and Cadbury and carried out by three state/territory departments (QDPI&F, NTDPI&F and Ag WA) from 1999 to 2007 showed that yields of PNG SG2 hybrids could reach 3 t/ha by the fourth year after planting in north Queensland (Diczbalis et al., 2010). Production at the Northern Territory and Western Australian sites did not fare so well. Prior to the completion of the feasibility study Cadbury approached the Queensland DPI&F and RIRDC to discuss the prospect of a co-funded project to examine *Commercialising cocoa growing in north Queensland*.

This report details the activities, outputs and outcomes of this current phase of industry development.

Aims/objectives

This research set out to:

1. Facilitate, support and monitor Cadbury Schweppes(CS) linked pilot commercial cocoa plantings
2. Offer support to non CS-linked growers including Cocoa Australia (CA) growers, management and proprietors
3. Support general industry development activities including publication of an Australian Cocoa Growing Guide.

Methods used

The project facilitated the establishment of four pilot commercial cocoa growing blocks on private grower properties. The project organised the import of hybrid cocoa seed from Papua New Guinea and supervised the growing of seedlings to field ready status. The project provided a base level of extension support to growers within the pilot group and to pre-established growers in the Mossman region.

Results/key findings

Pilot growers found cocoa difficult to establish and produce. The importance of intensive management in the initial tree establishment phase was underestimated. Despite initial establishment problems three of the four pilot growers commenced producing and suppling cocoa pods during 2010 to a centralised pod splitting and fermentary established with the assistance of the project and one of the three growers.

Damaging winds linked to Cylone Yasi in February 2011 severely damaged plantings and ended harvesting in the Innisfail region. One producer self-funded the establishment of new cocoa plantings, this time in conjunction with commercial banana production. The producer also initiated investment in small scale chocolate manufacturing equipment and began producing chocolate from bean fermented and dried pre-Cyclone Yasi. The project provided support and monitoring during this process as well as initiating preliminary work on the influence of fermentation vessel type.

The project also assisted Biosecurity Queensland in the identification cocoa pod borer and industry liaison associated with quarantine measures. This pest has been successfully eradicated.

The economic analysis of cocoa production suggested that as a niche crop, production of 2 tonne/ha of dried bean, approximately 2/3 of that which was achieved in the earlier feasibility study is profitable.

Implications for relevant stakeholders

Potentially a north Queensland cocoa industry based on the production of premium quality fermented dried beans could develop up to a 1,000 hectares producing up to 3,000 tonnes of dried bean. The raw product value to the region would be in the vicinity of $10 to 12M. This volume of production could be easily absorbed into the cocoa market and would only partially meet the increasing demand for high quality fermented cocoa bean.

Recommendations

Recommendations for further development of the cocoa industry include:

1. The availability of chemical permits or registrations for the control of a range of pests and diseases relevant for cocoa production. Any further work in this area should be linked to a ICCO publication (Bateman, 2009)
2. Updating the Cocoa Growers Manual first published in 2009 and place the publication on the RIRDC publications web site
3. Providing continued extension and industry development to the embryonic cocoa industry with particular reference to recent new plantings
4. Assisting in the location of new high yielding genetic material and subsequent importation and evaluation
5. Supporting the development of a stand alone budget spreadsheet which perspective growers can use to assess industry profitability based on their preferred inputs.

The recommendations are primarily aimed at R&D agencies.

Introduction

Cocoa (*Theobroma cacao*) is a tropical tree crop originating from the Amazon basin rainforests with a secondary distribution in central America, southern Mexico and the Caribbean, between 20°S and 20°N of the equator. The seedling tree is composed of an orthoropic (vertical growing) trunk and plagiotropic (horizontal angled) branches (Figure 1). The pods borne by cocoa trees contain seeds (beans) which are fermented and eventually used in the manufacture of chocolate and cocoa products.

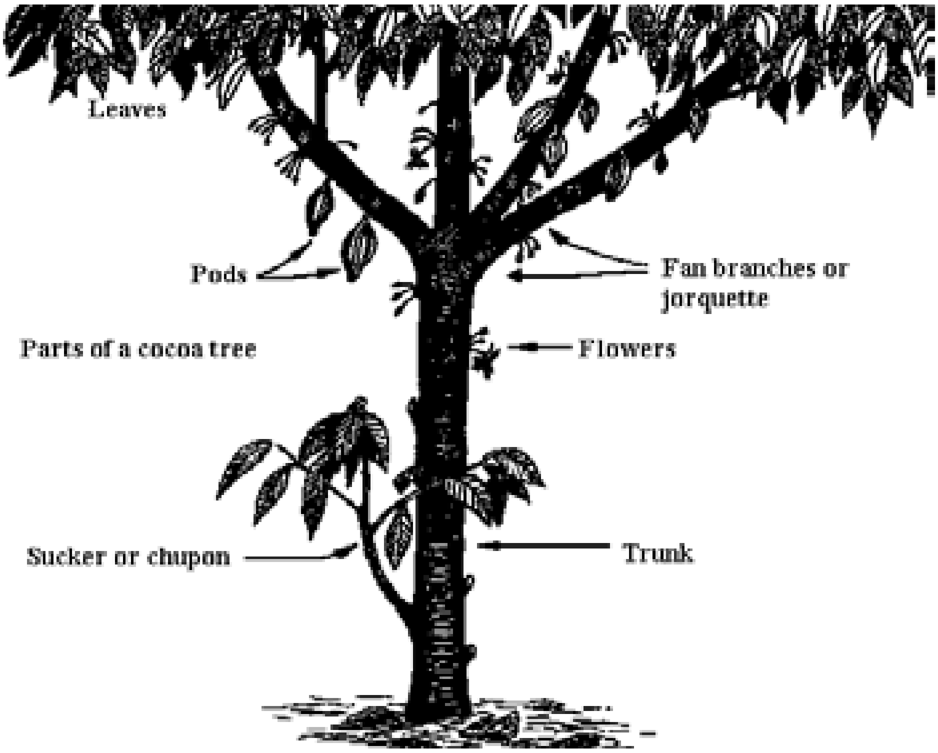


Figure 1. A diagrammatic representation of a seedling cocoa tree with common part names.

Cocoa was cultivated and revered by the Aztecs and Mayas of Central America where the bean was used as a form of currency and for a frothy drink called "chocolatl" in sacred ceremonies. When cocoa was "discovered" by the Spanish in the early 1500's it was already a well-developed, commercial crop (Wood and Lass 1985; Dand 2011). Cocoa beans were taken to Europe by Spanish conquistadors, and during the following centuries, were widely used as a chocolate drink until 1847 when the first block chocolate was produced in the United Kingdom by J.S. Fry & Sons (Coe and Coe 2000).

Cocoa production was rapidly commercialised only in the 20th century after the Swiss developed milk chocolate manufacturing and trees were planted in West Africa. Cocoa is now a major world commodity crop and is the seventh most traded food commodity.

Climatic requirements place cocoa in the tropical regions of the world generally within 15° of the equator. This region is predominantly underdeveloped and densely populated and cocoa production has evolved with access to cheap, plentiful labour. About 70% of world production is grown by smallholders on a low input, low output basis typically using family or village labour at low cost. Trees are individually tended; traditional methods of fermentation are employed and quality is generally good. As a rule of thumb, one person can manage about 2.5 ha of cocoa under traditional production systems. In the last 50 years large-scale production of cocoa been carried out by plantation companies. Cocoa has not offered the advantages of other crops grown under estate style management systems like coffee, oil palm and coconuts. To be competitive with smallholder production, higher yields are required based on higher inputs.

Previous reviews of the potential for cocoa in Australia (Urquhart and Stephens, 1960; Cull 1973; Watson, 1987 and Watson, 1992) suggest that production is feasible and that the crop has potential in north Queensland. In 1999, cocoa trees were growing on private properties in north Queensland from Tully to Daintree (none were commercially cultivated). Additionally, cocoa trees were successfully grown at the Coastal Plains Horticultural Research Farm (CPHRF) about 50 km east of Darwin since 1987. Small plot yield data suggested that yields in excess of 2.5 t/ha dry bean are possible in north Queensland (Watson, 1992). This material is now dispersed (with the closure of Kamerunga Horticultural Research Station), but much of it was accessible through private gardeners and tropical tree fruit producers. At CPHRF, yields from three year old cocoa trees were recorded at 2.0 t/ha dry bean under irrigated conditions with predictions that yields could exceed 2.5 t/ha by year five (Diczbalis and Richards, 1998). Cocoa yields worldwide range from 0.2 to 3.7 t/ha with the bulk of production less than 2.0 t/ha.

A cocoa production feasibility study initiated by Cadbury, funded by RIRDC and Cadbury and carried out by three state/territory departments (QDPI&F, NTDPI&F and Ag WA) from 1999 to 2007 showed that yields of PNG SG2 hybrids could reach 3 t/ha by the fourth year after planting in north Queensland (Diczbalis *et al.*, 2010). Production at the NT and WA sites did not fare so well. Prior to the completion of the feasibility study Cadbury approached the Queensland DPI&F and RIRDC to discuss the prospect of a co-funded project to examine *Commercialising cocoa growing in north Queensland.*

This report details the activities, outputs and outcomes of this current phase of industry development.

Objectives

The project had three main objectives;

1. To facilitate, support and monitor Cadbury Schweppes(CS) linked pilot commercial cocoa plantings

    a. To evaluate existing and new planting material (yield and general performance) in commercial plantings and test the commercial viability for production of ‘commodity cocoa”

2. To offer support to non CS-linked growers including Cocoa Australia (CA) growers, management and proprietors

3. To support general industry development activities including publication of an Australian Cocoa Growing Guide

    a. reduce risk to participants in the emergent industry and increase the likelihood of a viable cocoa industry becoming established in north Queensland for commodity or niche markets

    b. provide on-going engagement with the emergent industry and address technical and structural issues which arise and develop appropriate industry development strategies.

Methodology

New crop development is a challenge with a number of hurdles to challenge the grower. Fletcher and Collins (2004) suggest that commercialisation of a new crop includes 13 steps. Collins (2005) describes a model for new crop development which included four stages; S1 - Hunters and Collectors (a period in which new crops are introduced and evaluated by early innovators); S2 – Quasi-commercialisation (new industry entrants enthusiastic and flushed by the potential for high returns due to the niche nature of the crop); S3 - Dawning of Reality (a period in which increasing production meets market and price realities); S4 – Sink or Swim (the final phase where industry development continues or stagnates)

This project report represents the early stages in the development of a new industry for tropical Australia. The path of development thus far has undertaken many of the 13 step process but not necessarily in the order as stipulated by Fletcher and Collins (2004). Cocoa industry development has been similar to the "Collins" development model but different in key areas.

- The research and development program which preceded the start of the project was initiated by a major commercial company seeking supply stability in a market where long term demand is predicted to outstrip supply

- A comprehensive research and development project (Diczbalis et al., 2010) was carried out across northern Australia with the support of Cadbury, RIRDC and three state/territory governments

- The commercialisation plots were instigated by the commercial partner with co-operator growers to examine the problems and issues related to commercial production of cocoa

- The processing requirements of cocoa bean for downstream chocolate product meant that the participation of growers was not influenced by lucrative returns but by a longer term requirement for diversification and income security.

The project methodology was based on supporting new growers to produce cocoa based on learning's from the R&D project. The project facilitated the establishment of several Cadbury-linked pilot commercial cocoa growing blocks on private grower properties. Funded and aided by Cadbury, the then Queensland Department of Primary Industries and Fisheries (DPIF) initially imported hybrid cocoa seed from PNG as available and supervised the growing of seedlings to field ready status. The DPIF supported these growers in establishment and maintenance of the plantings by providing pre-emptive and prescriptive technical advice. In collaboration with the growers, DPI&F also monitored and document production costs and yield/performance under commercial conditions.

The project also provided a base level of support for cocoa industry development to growers and potential growers outside of the Cadbury linked pilot plantings including to what was then known as Cocoa Australia and their linked growers.

A major output was the production of a "Cocoa Growing Guide" compiled as a result of the cocoa feasibility R&D program. A Cocoa Economic Model initially developed in the feasibility study was further developed as a management decision support tool using the expertise of an economist.

Commercial Cocoa Block Establishment

Introduction

Cadbury Schweppes Australia provided initial seed funding for four growers to establish a minimum of 1 hectare. Three growers in the Innisfail region and one in the Ingham region expressed interest. A grower in the Innisfail region requested the option of establishing 6 hectares. This was supported by Cadbury. The Queensland DAFF coordinated the importation of hybrid seed from Papua New Guinea (PNG), seedling establishment in a commercial nursery and plant distribution to growers and planting advice.

Nursery Phase

Initial commercial blocks were established in 2007 due to direct support from Cadbury Schweppes. Hybrid cocoa seed were imported from Papua New Guinea. A total of 20,200 seeds were imported of four hybrids from PNG Stewart Research Station (Madang), Cocoa and Coconut Institute (CCI).

Seed importation dates ranged from January 2007 to April 2007. Imported hybrids included KA2-106 x KEE12 6300 seed, KA2-106 x KEE12 3768 seed, K82 x KEE43 5012 seed and K82 x KEE12 5120 seed.

All seed lots were supplied with a phytosanitary certificate and treated with a combination of Tilt© and Ridomil©. On arrival in Cairns seed were cleared by a customs broker and inspected by quarantine (AQIS).

Seed were planted within 24 hours of arrival at a commercial nursery (Mission Beach Tissue Culture Nursery) in forestry tubes (50 mm x 120mm) and transferred to grower sites at approximately three months of age as plants reached field planting age (Figure 2 and 3).

Figure 2. Cocoa seed germinating in forestry tubes within styrofoam fruit boxes

Figure 3. Cocao seedlings ready for field planting. From left to right; Dr Ian Mitchell (CS Australia), David Preece (Cadbury UK) and Steve Lavis (Mission Beach TC Nursery)

Average germination rates varied between lines, ranging from 32.7% for K82 x KEE43 to 50.9% for KA2-106 x KEE23. Individual lot germination rates were as high as 92.1% but the mean germination rate was poor (40%). This was most likely due to the quality of the seed lots and subsequent handling during transport from PNG. Seed planted and germination rates are presented in Table 1.

Table 1. Hybrid seed imports and germination rates

Seed Planted	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Total
Variety							
KA2-106 x KEE12	750	750	1000	2000	1800	0	6300
KA2-106 x KEE23	362	1150	1500	715	41	1240	5008
K82 x KEE43	256	1186	1379	1621	570	1073	6085
K82 x KEE12	1632	0	879	1500	1109	0	5120
TOTAL Seed	3000	3086	4758	5836	3520	2313	22513
Seedlings germinated							
Variety	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	
KA2-106 x KEE12	154	2	427	541	1188	0	2312 (*36.7%*)
KA2-106 x KEE23	132	67	829	479	34	1008	2549 (*50.9%*)
K82 x KEE43	6	8	394	337	254	988	1987 (*32.7%*)
K82 x KEE12	1263	0	67	66	827	0	2223 (*43.4%*)
TOTAL Plants	1555	77	1717	1423	2303	1996	9071
Germination %	*51.8*	*2.5*	*36.1*	*24.4*	*65.4*	*86.3*	*40.3*

Field Stage

Commercial trial plots of cocoa (three farms in the Innisfail region and 1 farm in the Ingham region) were planted from May to September 2007 as seedlings became ready for field planting. The details are presented in Table 2.

Table 2. Commercial trial cocoa plots, regional location, area planted and tree number

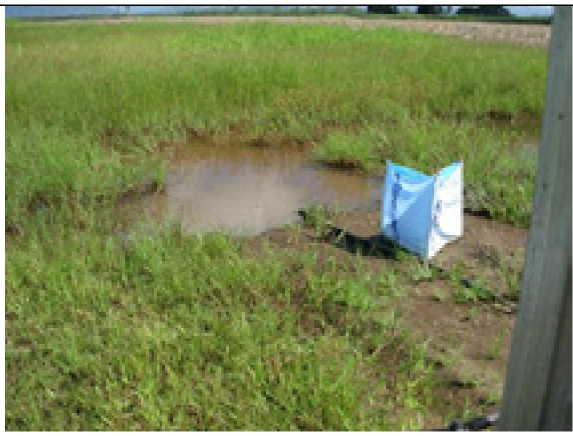
Region	Grower Name	Spacing	Area (ha)	Approximate tree number
Innisfail	Bob Broom	Single row 2.0m in row x 4.0 m between rows	1.0 ha	1100
Innisfail	Gerard Binder	Twin row 2.6m in row x 3.0 m between rows 7m centre to centre	1.1 ha	1100
Innisfail	Noel Stevenson	Single row 2.0 m in row x 5.0 m between rows	6.0 ha	5700
Ingham	Joe Russo	Single row 2.0m in row x 4.0 m between rows	1.0 ha	1100

Commercial trial plots were successfully established with minor loss of plants.

Ingham – Site 1 (481 Lannercost Extension Road)

Key Points

- Successfully established by November 2007
- Low lying areas were subjected to water logging during the wet season in early 2008
- By April 2008, the bulk of plants were struggling in the hard setting soil. Plants were also exhibiting symptoms of nutrient deficiency, low nitrogen
- Low winter temperatures (minimums down to 4^{o}C) caused further tree loss
- By November 2008, the owner had decided to abandon the plot due to financial considerations
- A photographic time sequence record appears in Figure 4.

	
27 Nov 2007	25 Feb 2008
	
1 Apr 2008	1 Apr 2008

	
2 Oct 2008	2 Oct 2008
	
14 Nov 2008	14 Nov 2008

Figure 4. Photographic time record of cocoa establishment at Site 1

Innisfail – Site 2 (Mena Creek Road)

Key Points

- Successfully established by November 2007 in conjunction with Pinto peanut ground cover in the interows
- Small tree guards used initially
- By April 2008, flush swarming beetles (Ryparida sp) were a major problem. Insecticides applied were unable to penetrate the tree guard
- By August 2008, the tree guards were removed and the grower provided wind protection by allowing the weeds and grass on the windward side of the plant to develop
- Trees unaffected by Rhyparida and in the lower portion wind protected parts of the paddock continued to develop through 2009
- The first viable pods were harvested by early to mid 2010
- Poor growth in higher wind exposed sections of the block with continuing problems with flush swarming beetles
- Cocoa and wind break trees severely impacted by Cyclone Yasi in February 2010
- Post cyclone recovery of trees is poor and block abandoned in 2012, after establishing another 4 hectares under bananas
- A photographic time sequence record appears in Figure 5.

	
27 March 2007	12 April 2007
	
23 July 2007	4 September 2007
	

1 Nov 2007 - Rhyparida beetles feeding on new cocoa shoots and soft bark.	4 Aug 2008
	
29 Oct 2008	26 Feb 2009
	
13 July 2009	3 Nov 2009
	

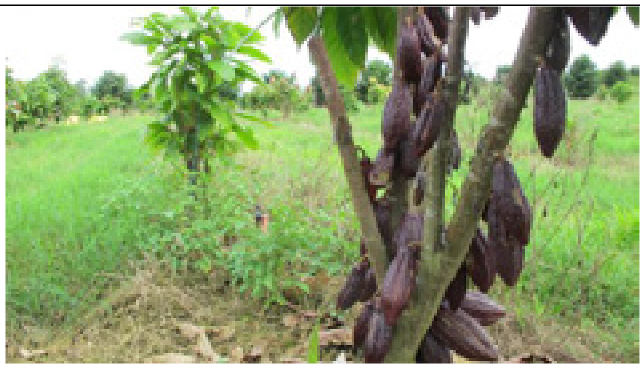
24 March 2010	24 March 2010
	
12 May 2010	20 July 2010
	
1 March 2011	1 March 2011

Figure 5. Photographic time record of cocoa establishment at Site 2

Innisfail – Site 3 (Henderson Road)

Key Points

- Successfully established by November 2007 using a double row planting pattern and drip irrigation (20 l/hr button dripper)
- Banana bunch cover (1/2 length) or shade cloth used as tree guards
- Tree development and growth of excellent partly due to the wind protection offered by the natural windbreak along the creek line
- The first pods were formed by July 2009, two years after planting
- Harvesting commenced by mid 2010 with promising production from lower “wind protected” parts of the block
- The block was severely damaged by cyclone Yasi in February 2011, failed to recover and was abandoned in early 2012
- A photographic time sequence record appears in Figure 6.

25 July 2007

4 Sep 2007

11 October 2007

26 Oct 2007

7 May 2008	21 Nov 2008
	
5 June 2009	13 July 2009
	
15 Oct 2009	28 May 2010
	

21 June 2010	21 June 2010 – Fortnightly havests occurring.
	
3 March 2011 – one month post cyclone Yasi.	6 Sep 2011 – low survival seven months post cyclone.

Figure 6. Photographic time record of cocoa establishment at Site 3

Innisfail – Site 4 (Lidgard Road)

Key Points

- Successfully established by November 2007 using a single row planting pattern and undertree sprinklers
- Shade cloth used as tree guards
- Tree development and growth excellent in parts of the orchard partly due to the wind protection offered by the planted wind break
- Swarming leaf beetle a continuous problem until the use of a Confidor® drench
- The first pods were formed by Oct 2009, two years after planting
- Harvesting commenced by mid 2010
- The block was severely damaged by cyclone Yasi in February 2011 and failed to recover
- A photographic time sequence record appears in Figure 7.

	
11 Oct 2007	11 Oct 2007

	
9 April 2008	9 April – Jorquetting (branching – change of growth from a orthotropic shoot to plagiotropic branches)
	
28 Oct 2008 – severe infestation with leaf case moth.	3 June 2009 – Excellent tree growth near windbreak.
	
15 Oct 2009 – first pods	23 Feb 2010

Figure 7. Photographic time record of cocoa establishment at Site 4

A further 1700 seedlings of an Indian cocoa hybrid secured by Cadbury UK were planted at Site 2 in November 2009. The seedlings were co planted with a commercial papaya crop or as a mono crop on banana row spacings - 6 m between rows (Figure 8). Based on learning's from the original site 2 planting the grower incorporated the following measures:

- Nutrient + insecticide (Initiator®) tablet
- Organic based fertiliser granules (3.5:1.7:1.6)
- Tree guard using a half length banana bunch cover held by 4 bamboo stakes
- Cardboard weed mat

	
3 Nov 2009	3 Nov 2009 Newly planted cocoa with suitable wind break (half length banana bunch cover) and cardboard weed mat.
	
23 February 2010 – excellent early growth	20 July 2010 – trees commence jorqueting
	
1 March 2011 – post Cyclone Yasi	1 March 2011 - post Cyclone Yasi

Figure 8. Photographic time record of cocoa establishment under papaya at Site 2

Cocoa planted in conjunction with papaya performed well, with plants reaching the jorquette stage (branching – change of growth from an orthotropic shoot to plagiotropic branches) within 9 months of planting. Fertiliser and water inputs were as required for the successful production of papaya and hence more than sufficient for cocoa. Unfortunately Cyclone Yasi, which struck 15 months after planting, severely damaged the plants. Surviving plants have since been protected by a follow up banana crop and are responding to improved conditions.

As of June 2013 only one of the four sites (Site 2) is actively growing cocoa. The original plot at site 2 has been abandoned and being prepared for replanting cocoa under banana. Following the cyclone further cocoa seedlings were planted in conjunction with bananas (Figure 9). This method of establishment has proven to be successful and trees have commenced early flowering.

Figure 9. Photographic time record of cocoa establishment under banana at Site 2

Early Yield Observations

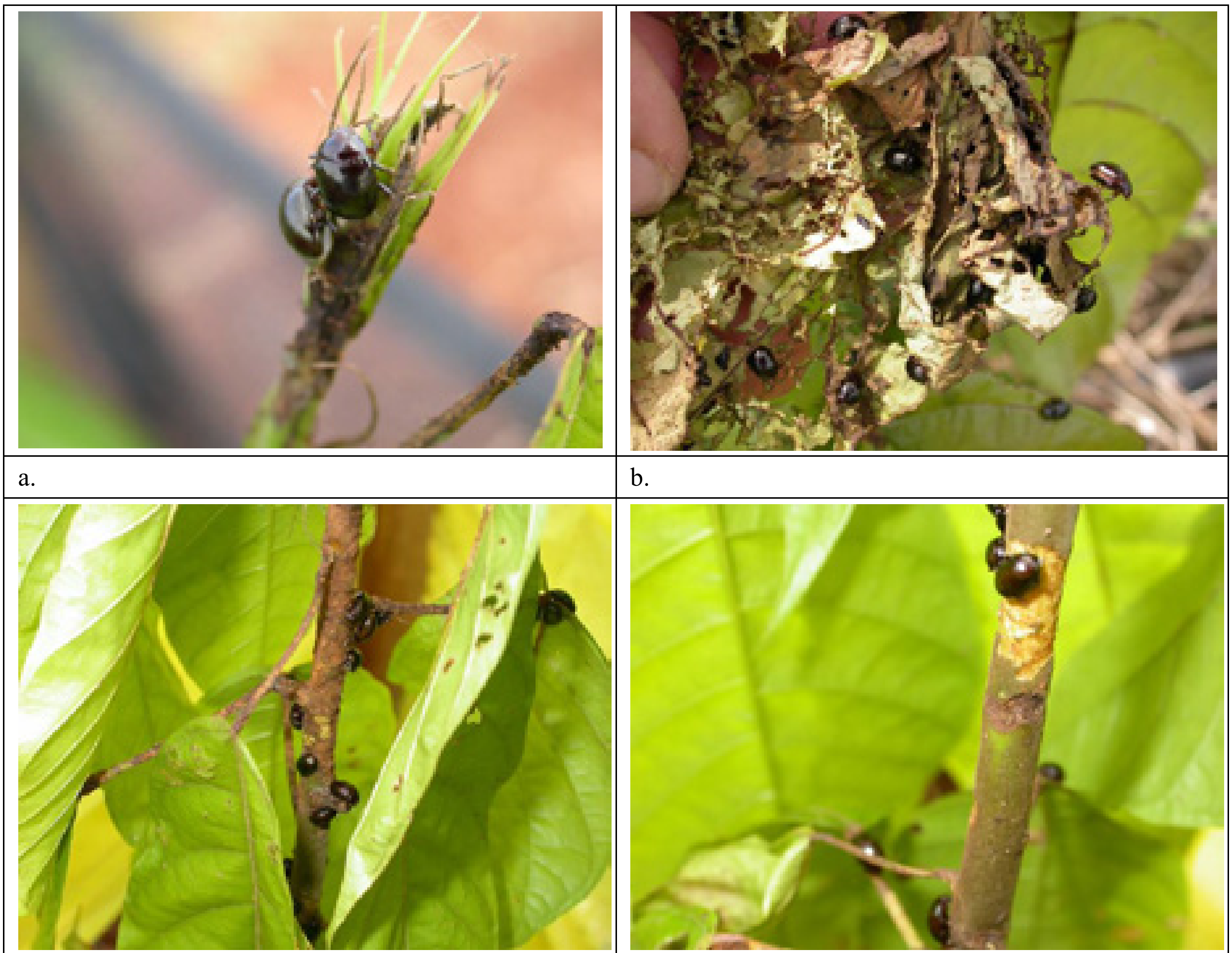
In 2010, cocoa was harvested from the three sites at Innisfail and pods were weighed and accumulated at Site 2 for processing (Table 3). Yields were on the low side for three year old plants (maximum 1,800 kg/ha) and well below the 14,000 kg/ha achieved in the feasibility study (Diczbalis *et al.*, 2010).

Table 3. Pod yield recorded from the three cocoa plots in the Innisfail area in the third year after planting

Date	Site 3	Site 4	Site 2	Total Pod weight (kg)
10-Jun-10	90	46	70	206
21-Jun-10	13	0	0	13
06-Aug-10	320	0	0	320
27-Aug-10	0	0	100	100
10-Sep-10	300	100	100	500
01-Oct-10	0	0	190	190
08-Oct-10	450	0	0	450
15-Oct-10	0	0	230	230
29-Oct-10	0	0	190	190
12-Nov-10	680	220	220	1120
Total Pod (kg)	1853	366	1100	3319
Pod weight kg/ha	1,853	366	183	
Dry bean equivalent (kg)	***185.3***	***36.6***	***110***	***331.9***

The poor performance was directly attributable to poor tree growth in all commercial sites. Major problems observed were:

- Insufficient protection from wind and sun through poor management of shade covers
- Wind break trees were planted at the same time as cocoa plants and not established 12 months prior as is ideal
- Loss of the growing shoot due to swarming leaf beetle damage and inadequate follow up control (Figure 10)
- Inadequate pruning management, removal of water shoots (choupons) and pruning of the tree post jorquetting
- Inadequate management of irrigation during the short dry season
- Low temperature contributing to tree death of already compromised trees
- Poor weed control at times
- Inadequate fertiliser management.



a. b. c. d.

Figure 10. Rhyparida sp., damage to a. shoot tip; b. new flush, leaf pulvinus (swellings on the proximal and distal ends of the petiole); d. and bark

Cocoa requires a high level of fertiliser and irrigation management particularly when grown in an unprotected environment. In the first 12 months of establishment high levels of inputs are required to ensure tree survival and unimpeded canopy development. Loss of the growing shoot while the tree is in the orthrotropic growth stage results in multiple shoots which, unless removed interferes with subsequent tree development and flowering.

The level of input required was above the expectations of the growers involved and only small portions of the orchard performed at the expected level. The situation may have improved in 2011, due to the growing interest from growers who were starting to see some reward for their inputs to date. However, this could not be monitored as all orchards were severely affected by Cyclone Yasi in February 2011.

Grower perceptions of problems were as follows:

- Poor seedlings provided by the nursery. Pots too small and the mix tended to crumble and fall apart on planting
- Large percentage of planted trees lost or severely affected due to cold weather experienced shortly after planting. Ideally planting should be coordinated for spring or in the early wet season

- Swarming leaf beetle (Rhyparida sp.) is a major pest of young seedlings. Contact insecticides such as Carbaryl or synthetic pyrethrins are needed almost fortnightly to ensure adequate control. This is a large expense. Note: longer control was provided by the use of a Confidor drench. This option is not currently registered for use in Cocoa

- Lack of chemicals, that have permits or are registered, for pest control

- While shade trees become established it was emphasised that other wind break options need to be operational upon planting. Finding affordable alternatives is a problem, e.g. the cost of wooden stakes for traditional three or four stake tree guard is prohibitive.

Discussion and Recommendations

The four pilot growers found the establishment of cocoa more challenging than they anticipated. The cocoa plant is particularly sensitive to wind, high light levels and moisture stress. The young seedlings are susceptible to swarming flush eating beetles, namely Rhyparida sp.

The beetles are attracted to the new flush and young bark of the terminal orthotropic shoot. In cocoa there are two distinct types of shoots and patterns of growth. Young seedlings have an orthotropic phase of growth where the shoot is actively growing vertically. At approximately 1.5 m height the shoot branches naturally (jorquette) and forms five plagiotropic or horizontal branches. Severely damaged orthotropic shoot tips are slow to reshoot and are prone to further attack from subsequent swarms of Rhyparida. Once the shoot bud is damaged the resulting side shoots can be prolific and difficult to manage. Unmanaged shoots create multiple stems which results in a difficult to manage canopy.

Once the tree has jorquetted damage to shoots is less of a problem as the tree is already in a multiple shoot and branching form of growth. Hence management of the juvenile phase of growth is critical to obtaining the classical seedling tree shape with a long single trunk and branches which form at 1.5 m height or above.

A range of other pests were also noted, however they were isolated to particular farms and not responsible for causing severe damage.

During the juvenile phase, seedlings are susceptible to wind. Wind protection as provided by a combination of pre-planted wind breaks and or tree guards is a preferred method of establishment. A large guard as provided by a half length banana bunch cover is ideal. Unfortunately the cost of providing a minimum of three wooden stakes to hold each guard is expensive. Planting sites exposed to regular wind should be avoided.

Water management is also crucial during seedling establishment. Cocoa does not tolerate periods of low soil moisture and this is of particular importance when growing trees in open full sun conditions. The use of high flow button drippers at one site was found to be ideal for tree establishment. Mulching newly planted trees would assist with moisture management.

Managing fertiliser inputs is essential for optimum growth of cocoa in high light conditions. Estimates for nutrient inputs vary depending on soil type and fertility. As a general guide the inputs recommended by Figueria 2008 are appropriate (Table 4).

Table 4. Guide to cocoa nutrient requirements

Nutrient Requirements (kg/ha)								
Plant Stage	Age (mths)	N	P	K	Ca	Mg	Mn	Zn
Seedling (nursery)	5-12	2.4	0.6	2.4	2.3	1.3	0.04	0.01
Immature - field	28	136	14	151	113	47	3.9	0.5
1st year of production	39	212	23	321	140	71	7.1	0.9
Mature	50+	438	48	633	373	129	6.1	1.5

A range of fertilisers are available to provide the inputs above. With the benefit of technology in a north Queensland environment these nutrients can be added in foliar, fertigated and granular forms. Young seedlings trees benefit from regular applications of fertiliser and would most likely benefit from foliar inputs.

Cocoa Developments in the Mossman Area

Regular engagement with Mossman based cocoa growers has also occurred during the project (Table 5).

Prior to the commencement of the current project a private company, Cocoa Australia (CA), was established in 2004. The company, based in Mossman, contracted growers for the production of cocoa pods for feedstock for a primary and secondary processing plant, funded by Federal and State grants to be built in conjunction with Mossman Mill. CA was an off shoot of Horizon Science, involved in Intellectual Property, R&D and Commercialisation, and was linked to a retail company "Farm By Nature". The strategy appeared sound and CA was able to attract government funding to establish six farms in the region. CA is no longer actively involved in cocoa production and processing in Australia.

Daintree Estates (DE) is a new company which has commenced operations in the Mossman area as of September/October 2010. Former CA contracted growers joined DE after their former contracts with CA ended. DE has issued buying contracts to prospective cocoa growers including the three growers based in the Innisfail region. Growers were offered $700/tonne for pods (equivalent to $7/kg for dried bean) if they were prepared to sign up to an exclusive supply agreement. DE has recommenced discussions with DEEDI (now Qld DAFF). The group have requested assistance with agronomic management and fermentation techniques and monitoring. A meeting and farm inspections were held on the 8 March 2012 with four growers supplying pods. Farm visits also occurred on the 21st of March. Planning has commenced for fermentation monitoring, and when the group commence harvesting, to examine the microbiological and flavour differences. Fermentation techniques will include; traditional box, rotating barrel and tray systems.

The project leader has worked directly with CA and DE contracted growers and assisting them with issues related to cocoa production and or fermentation.

On 15 July 2012 the project leader contributed to a DE growers field day at Mossman. Approximately 30 prospective growers attended. The workshop covered aspects of establishment, growth, production, nutrition and irrigation requirements, pests and diseases.

Table 5. Date and extension related activities associated with growers linked to Daintree Estates

Date	Activity
14 Aug 2009	Shed meeting at Angelo Puglisi. Distribution of cocoa growers manual.
21 Oct 2009	Grower visit and diagnostic samples taken
4 May 2010	Grower visits
7 Dec 2010	Grower visits
12 Apr 2011	Cocoa pod borer outbreak field and farm visits
20 Apr 2011	Cocoa pod borer info to Mossman growers
12 May 2011	Cocoa pod borer farm visit
27 June 2011	Cocoa pod borer farm visits
10 Sep 2011	Cocoa farm visits with Dr Ray Schnell

14 Nov 2011	Cocoa farm visits
9 Feb 12	Discussion with Dr Barry Kitchen re extension support for existing and new growers
8 March 12	Drive to Mossman, meet with Gerard Puglisi and Dr Alan Mortimer at Don Murday's farm. Visit existing plots at Don's, Carmel White, Gerard Puglisi, Mill block and Daryl Kirk. Visit potential new grower – Tony Hensler
22 March 12	Drop in on Mill block and discuss management
24 May 12	Phone call from Dr Barry Kitchen re new growers and proposed fermentation work
4 June 12	Set up fermentation monitoring trial with Daryl Kirk at DE fermentary (Box, Barrel and Tray) techniques. Overnight Mossman
5 – 8 June 12	Visit fermentation trial – install button loggers; follow up visits during the week to check temperatures. Sample ferments on Friday 8th June and deliver to microbiology lab in Cairns.
12 June 12	Drive to Mossman, reset temp loggers. Set up tray fermentation.
25 June 12	Drive to Mossman, fermentation logger reset, 100 bean cut tests. Leaf/soil sample Mill and Kirk block. Overnight Mossman
26 June 12	Sample Puglisi, Murday and Goodman block. Meeting with Alan Mortimer
15 July 12	Daintree Estates new grower field day – Mossman
2 October 12	Meetings with Lawrence Marmara, John Goodman and Don Murday. Orchard visits.

Pod Processing, Bean Fermentation and Drying

Introduction

Pod processing, fermentation and drying are essential steps in converting cocoa pods into the foundation material "dry beans" for chocolate making. In most traditional cocoa producing countries, harvested cocoa pods are processed into dried, fermented beans on-farm. This 'primary processing' of cocoa involves three steps:

- opening of the cocoa pods and extraction of the wet bean
- fermentation of wet beans
- drying of fermented beans.

Typically, harvested pods are gathered together and opened in-field. This is done manually by cutting or breaking the pods and scooping out the beans by hand. Pod opening is performed within 0 to 12 days of harvesting. Where pods are opened in field the wet beans are stored in hessian bags and delivered to the fermentary within 24 hours of picking.

Fermentation methods vary considerably from simple in-field heap fermentations with beans wrapped in banana leaves, through to industrial scale, central cascade box fermentaries servicing large production areas (Figures 11 and 12). Depending on the method utilised, fermentation takes 5 to 7 days.

Figure 11. Typical heap fermentation – west Africa. Photo provided by Dr Smilja Lambert.

Figure 12. Cascade box fermentary and bean drying area – PNG

Bean drying is started as soon as fermentation is completed. Drying technology varies from simple sun drying, solar assisted drying to large scale dryers using forced hot-air facilities. Sun drying takes over a week, whereas 'artificial' drying can be achieved in as little as 48 hours.

Fermentation and drying are crucial to developing cocoa quality and small variations in the technique can have a major influence on flavour development. More importantly, for a small niche industry, the process has to be repeatable as there is no opportunity to blend beans as occurs in the production of commodity cocoa.

In this project considerable effort was expended to developing a system that would work for small scale commercial producers in a wet tropical environment where, cool conditions during the winter months interfered with the fermentation and sun drying was a challenge.

Pod Splitting and Bean Removal

Mr. Noel Stevenson (Mena Creek Investments) took up the challenge of supporting primary processing (pod splitting, fermentation and drying) of cocoa beans. The cocoa pod splitting and bean removal equipment developed during the cocoa feasibility project (Diczbalis *et al.*, 2010) was installed at the Mena Creek farm (Figure 13, 14, 15, 16 and 17).

The machinery which had been in storage for several years was repaired where necessary and installed with full consideration to emergency STOP procedures and electrical safety.

Details on the development of the pod splitter and associated bean separator and conveyors can be found in Diczbalis *et al.*; 2010.

Figure 13. Load of cocoa pods ready for processing with the cocoa pod splitter and bean separating unit in the background

Figure 14. Feeding pods onto the pod splitter via a pod elevator

Figure 15. Pod alignment conveyer which feed pods into the pod splitter

Figure 16. Pod and bean separator tumbler

Following the resolution of intellectual property considerations by the parties involved in the North Australian Cocoa Development Alliance (NACDA) the pod splitter and separator were demonstrated to a number of parties, including representatives of Cocoa Australia, Daintree Estates and a private interest from Cote d'Ivoire (Ivory Coast). In the latter case, discussions were held with IBS a local fabricator to determine an approximate cost of manufacture.

Figure 17. Wet bean collection area and pod waste disposal conveyor

The pod splitter was used regularly throughout the latter half of 2010 to process pods which were harvested from the three plots in the Innisfail region. Since Cyclone Yasi the equipment has remained in storage due to the lack of pods. Pod processing is expected to recommence in late 2013.

Fermentation

Fermentations were successfully conducted using Australian grown cocoa beans sourced from the NACDA trials in Queensland, which resulted in acceptable flavour characteristics (Diczbalis *et al.,* 2010). The process involved was more difficult than anticipated to achieve consistent and acceptable cocoa flavour characteristics. This is attributed to inexperience with the method and techniques for fermentation rather than any deficiency in the beans themselves. The primary physical characteristics of beans (bean size, fat content, shell content) met International Cocoa Standards for commercial acceptability and were comparable with cocoa from Ghana and Indonesia. Meeting standards for other attributes such as tolerable levels of defects and chemical residues will depend on the application of good production management practices and appropriate secondary processing technology.

Fermentation is complex and involves the interaction between cocoa beans (sugars in the surrounding mucilage), yeasts and bacteria (lactic acid and acetic acid bacteria) with a rapid rise in temperature and the production of ethanol, lactic and acetic acid. The process is well described in the schematic below (Figure 18 - from Schwan and Wheals, 2004).

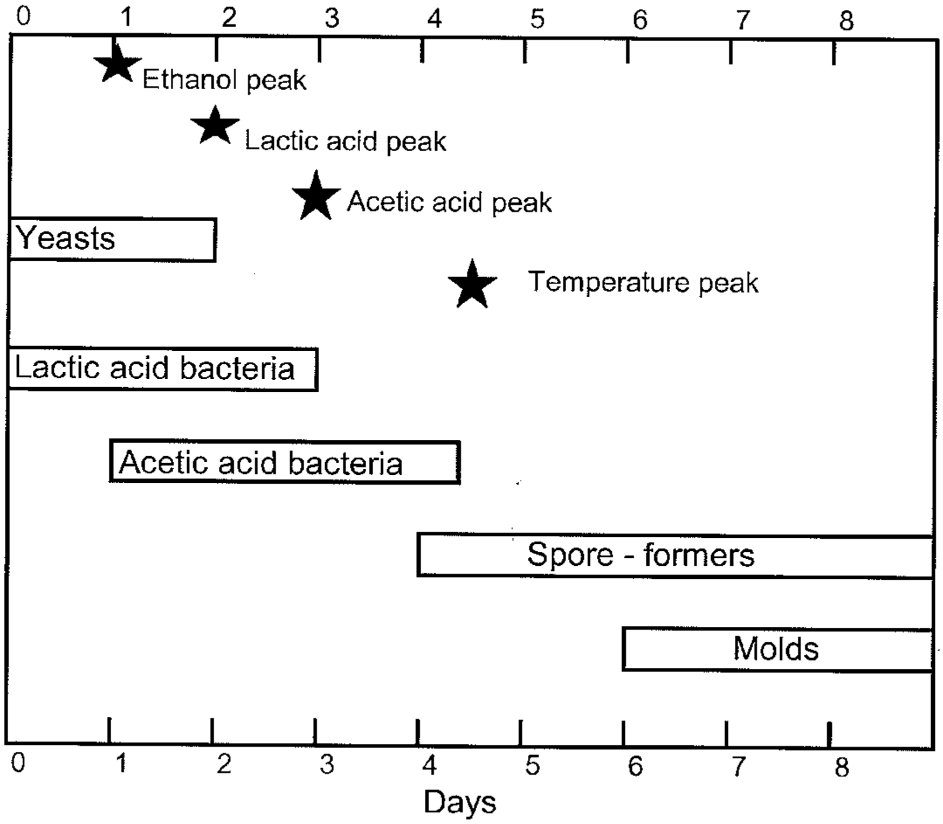


Figure 18. Schematic of microbial succession during cocoa fermentation, the boxes indicate the microbial activity most abundant/important at the time. The stars indicate the timing of the peaks of metabolites and temperature (from Schwan and Wheals, 2004)

Further refinement of fermentation and drying techniques is required to develop proven methods which work under local conditions. The viability of an Australian cocoa industry is dependent on producing a high quality fermented dried bean based on reliable method for fermentation and drying, applying appropriate technology for post-drying processing and successful commercialisation of the mechanised pod splitting and bean separation technology.

The development of a "state of the art" cocoa wet bean processing facility will provide a strong incentive for independent cocoa production in far north Queensland, ensuring strong competition from multiple buyers.

Fermentation is crucial to producing good quality cocoa beans. The process is generally carried out in a relatively unsophisticated environment (eg. heap fermentations) in much of west Africa (Figure 11) by small holder farmers. In plantation cocoa production fermentation is generally carried out in boxes (Figure 12) with beans being turned every 2^{nd} or 3 day in a 6 to 7 day fermentation cycle.

In small scale production as is carried out in north Queensland, fermentation boxes and barrels (modified composting units) have been used in experimental work (Diczbalis *et al.*, 2010).

Materials and Methods

Fermentations were carried out using the barrel technology developed during the NACDA project. The potential advantage of a barrel is that bean turning is a less labour intensive operation with a simple turning action required to thoroughly mix the beans. The modified compost barrels hold in excess of 80 kg of wet bean (Figure 19). The co-operator grower adapted the barrels to a pallet system so that the fermentation barrels could be easily moved (Figure 20).

Figure 19. Fermentation occurring in rotary compost bins in the papaya ripening room set at 29 °C

Fermentations were initially carried out in a papaya ripening room set at 29°C. This proved to be very successful ensuring that the fermentations start quickly and run their course even during the cooler winter months experienced in north Queensland where ambient temperatures can fall below 20 °C.

Figure 20. Bean drying on palletised drying trays occurring in the new high temperature humidity controlled rooms

Nine fermentations, a number with multiple bins, were carried out from July to November 2010 (Figures 21 and 22). The bulk of these fermentations were carried out to establish if there was a level of repeatability in fermentation and the final product. The repeated ferments also allowed a commercial process to be developed with experience from preceding fermentations incorporated into subsequent ferments. By mid November a "system" had been developed which was repeatable and appeared to produce a "suitable" commercial product.

A question remains as to the influence of the frequency of bean turning on cocoa bean quality. Frequent turning improves the aeration within the bean mass and promotes the development of acetic acid bacteria over lactic acid bacteria. This can potentially lead to more acidic beans which are not preferred. For the fermentation conducted on the 12 November, there were sufficient wet beans to allow for a comparison of bean turning frequency. Equal amount of wet beans (approx 85 kg) were loaded into three modified rotating compost bins. Temperatures were monitored using Tiny Talk loggers with the temperature probe inserted into the middle of the bean mass. The beans were fermented over a 7 day period, with fermentation starting on Friday and ending on the following Friday. Beans were turned either **daily** (once per day - 6 turns); on day 1, 3 and 5 (**3 turns**) or day 3 and 6 (**2 turns**). At each turning the bins were rotated a full 360° three times to ensure the beans were well mixed.

At the end of fermentation, beans were removed from the bins and spread on metal grid based trays which were dried over seven days to a defined schedule (Figure 23). Drying operations were initially also carried out in a room set at 29°C with no control of humidity. However, the limited heating capacity of the room and lack of dehumidification capacity meant that successful drying was only possible for small quantities of bean (20-30 kg). Fermentation and drying operations since November 2010 have been carried out in a modified cold room with heating and dehumidification equipment.

Bean moisture contents at the termination of drying were measured using a KPM Aqua-Boy moisture meter specifically calibrated for cocoa. A 1.0 kg sample of dried beans was taken and stored in a calico bag for later analysis of bean colour, physical parameters and pH and titratable acidity (TA).

Results and Discussion

The bulk of ferments conducted were run for 5 to 7 days, with the shed opting for a 7 day turn around period to fit in with other commercial activities.

Fermentation temperature

The maximum bean temperatures during fermentations were generally above 45°C with the maximum temperature recorded at 47.7 °C (Table 6 and Figure 21). Hollywood (undated) suggests that fermentations above 45 °C are required for a good fermentation with temperatures closer to 50 °C being preferable. Observations suggest that the lower maximum temperatures recorded may be related to lower turning frequency. Insufficient ferments were run at lower turning frequencies to allow the data to be quantifiable. Where dual fermentation bins were run at the same time, the temperature profiles were generally similar but temperature peaks were not identical (Figure 20). This is either a reflection of the temperature monitoring, single point per barrel, or subtle differences between individual barrels.

In the last ferment (12 November 2010) where turning frequency was compared, the peak temperature of 46.3°C was reached in the **3 turn** treatment, 45 °C was reached in the **daily** turn treatment and 41.5 °C was reached in the **2 turn** treatment (Figure 21). The temperature peak of the minimal turn treatment was reached at day 4 as occurs in the schematic whereas the temperature in the daily turn treatment continued to rise gradually until the end of the ferment. The 3 day turn treatment had a temperature spike occur subsequent to the last two turns.

Bean quality assessments were carried out on the last five fermentations (Table 7). Results were compared with a commercial sample from PNG. Bean size varied from 0.77 g to 1.07 g and was generally the same as the commercial sample from PNG (0.87 g). Bean colour of fermentation samples ranged from 10.3% to 20.3% fully brown with 79.7% to 89.7% partly purple. There were no purple or slaty beans indicating that beans had been subjected to fermentation. This varied from the commercial sample with 75% fully brown and 25% partly purple beans. Beans continue to darken after drying (Lambert pers comm.), which may account for the difference between freshly dried beans and a commercial sample in excess of 6 months of age.

Table 6. Details of fermentations carried out during the period from June to November 2010

Start Date	Pod Weight (kg)	Bean Turn	Max Temp °C	Finish date (days)	Mean drying temperature	Bean Moisture at removal %
11/6/10	200 (50)	1	40.6	17/6/10 (6)	28 °C	Approx 7%
6/8/10	320 (80)	5	46.9	12/8/10 (6)	28 °C	Approx 7%
27/8/10	100 (25)	7	43.7	3/9/10 (7)	28 °C	Approx 7%
10/9/10-B1	350 (87.5)	5	46.9	20/9/10 (10)	28 °C	Approx 7%
10/9/10-B2	350 (87.5)	5	44.6	20/9/10 (10)	28 °C	Approx 7%
1/10/10	180 (45)	5	45.5	6/10/10 (5)	28 °C	6.1
8/10/10-B1	225 (56)	6	46.8	15/10/10 (7)	28 °C	6.5
8/10/10-B2	225 (56)	6	47.4	15/10/10 (7)	28 °C	6.5
15/10/10-B1	245 (61)	5	47.4	22/10/10 (7)	Drying room; 42°C for 2 days, 38.4°C for 4 days	6.3
15/10/10-B2	245 (61)	5	47.7	22/10/10 (7)	Drying room; 42°C for 2 days, 38.4°C for 4 days	6.3
29/10/10-B1	190 (47.5)	6	46.0	5/11/10 (7)	Drying room; 40°C for 1 day, 38.0°C for 1 day and 36°C for 3 days	6.3
29/10/10-B2	190 (47.5)	6	45.8	5/11/10 (7)	Drying room; 40°C for 1 day, 38.0°C for 1 day and 36°C for 3 days	6.3
12/11/10 - **daily**	350 (87.5)	6	45.0	19/11/10 (7)	Drying room; Day1 36.5 °C, Day 2 35 °C, Days 3&4 34 °C, Days 5-7 33°C	6.1
12/11/10 - **3 turn**	350 (87.5)	3	46.3	19/11/10 (7)	Drying room; Day1 36.5 °C, Day 2 35 °C, Days 3&4 34 °C, Days 5-7 33°C	6.1
12/11/10 - **2 turn**	350 (87.5)	2	41.5	19/11/10 (7)	Drying room; Day1 36.5 °C, Day 2 35 °C, Days 3&4 34 °C, Days 5-7 33°C	6.0

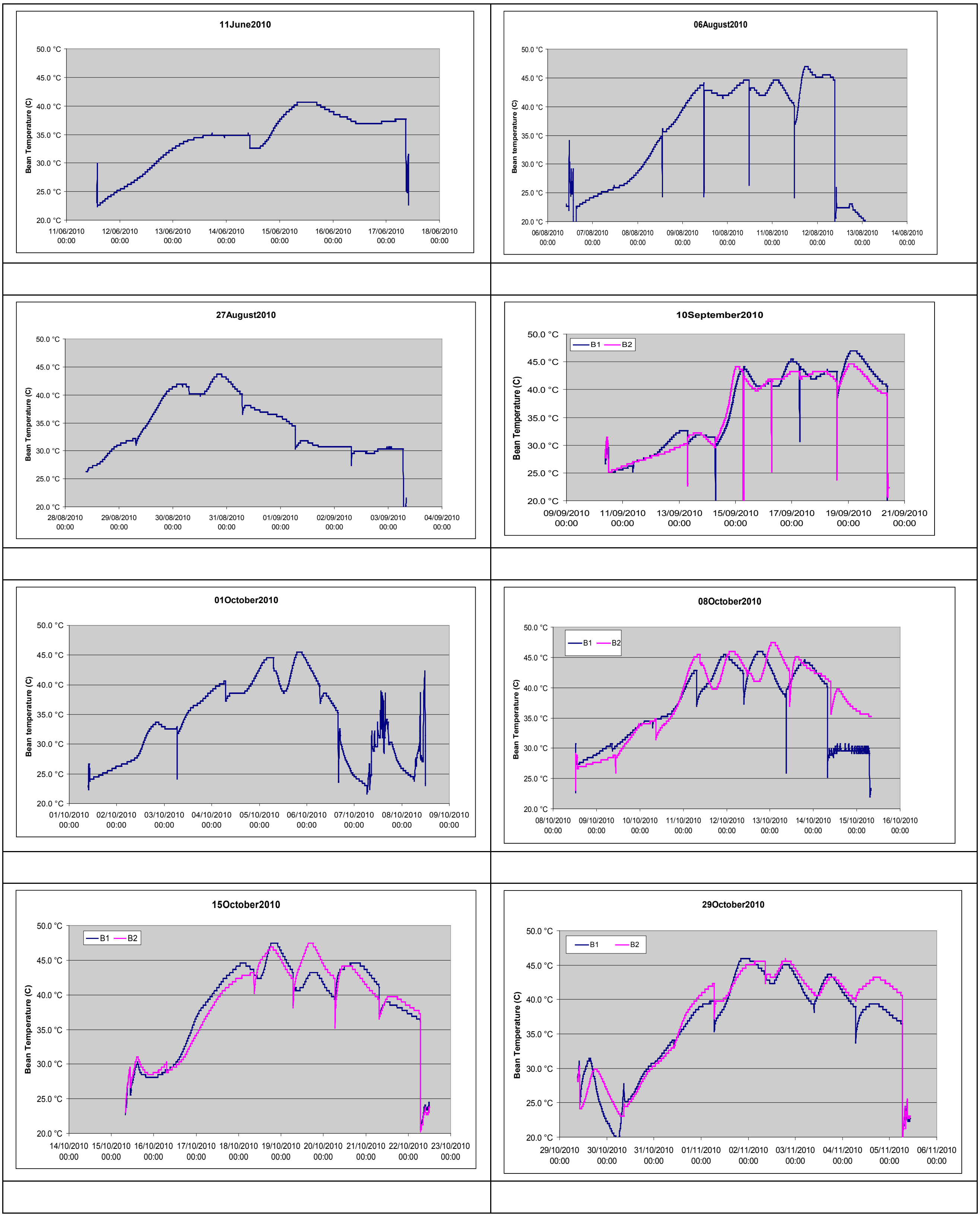


Figure 21. Fermentation temperatures for eight fermentations carried out from June to October 2010 (B1 = Barrel 1; B2 = Barrel 2).

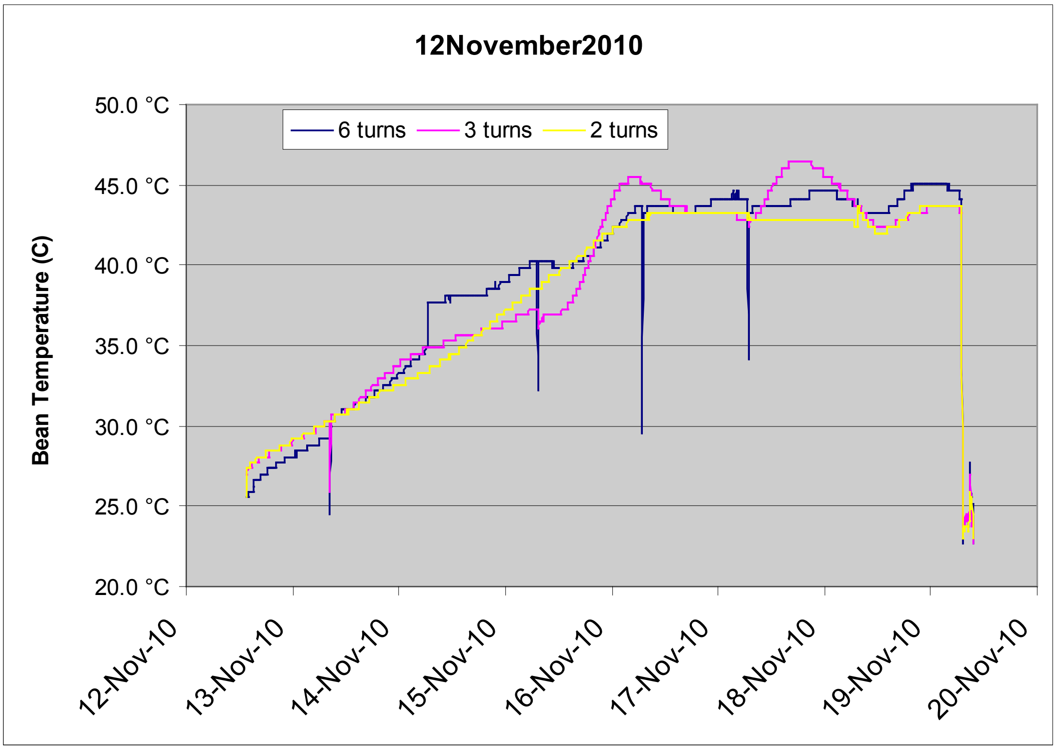


Figure 22. Fermentation temperatures for a comparison of bean turning frequency

Table 7. Mean (of 3 replicate samples), cut test results, bean moisture content, and pH and TA of fermented dried cocoa beans

Sample	6 day ferment, daily turn 01Oct10	7 day ferment, daily turn 08Oct10	7 day ferment, daily turn 15Oct10	7 day ferment, daily turn 29Oct10	**Daily** - 12Nov10	**3 Turn** - 12Nov10	**2 Turn** - 12Nov10	PNG bean sample
Bean Colour								
Fully Brown	14.0	15.3	20.3	17.7	13.7	10.3	10.3	75
Partly Purple	85.3	84.3	79.7	81.0	85.0	89.7	89.7	25
Purple	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Slaty	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0
White	0.0	0.0	0.0	1.3	1.0	0.0	0.0	0
Bean Quality								
Germinated Beans	1.7	2.0	0.0	0.3	1.7	1.0	2.3	0
Flats	13.3	11.0	10.7	12.7	29.0	15.3	26.3	10
Mouldy	22.0	27.3	5.7	13.3	6.0	8.3	13.7	100
Bean acidity, TA and moisture								
pH	6.0	5.7	na	6.0	5.5	5.3	5.2	6.22
Titratable Acidity	0.7	1.8	na	0.6	0.5	0.6	0.7	0.47
Moisture	6.1	6.5	6.3	6.3	6.1	6.1	6.0	na
Bean Size								
100 bean weight (g)	107	89	99	91	77	80	89	87
Bean wt g (by calculation)	1.07	0.89	0.99	0.91	0.77	0.80	0.89	0.87

All samples were affected by mould, including the PNG commercial sample where 100% of beans were mouldy. Mould percentage on the fermented samples ranged from 6 to 22%. Final bean moisture content for the bulk of the beans was 6% which is ideal. This indicated that mould may have occurred during the drying process. The occurrence of mould is not ideal, due to the threat of mycotoxins and highlights the importance of drying and subsequent bean storage (Copetti *et al.*, 2013; Anon, 2012). The percentage of mould affected beans decreased following the installation of the heating and dehumidification equipment in the modified cold room. Room temperature and humidity data for fermentation and drying can be seen in Figure 23.

Conclusions

A successful fermentation and drying regime was developed which was suited to the Wet Tropics in far north Queensland. Although there is continued room for improvement, the combination of an artificially warmed environment for fermentation and a low humidity drying facility allowed a successful fermentation and drying to occur. Fermented dried beans were successfully used for the production of chocolate with favourable consumer responses.

Based on a number of international fermentation studies (Schwan and Wheals 2004, Ardhana and Fleet, 2003, Nielsen, 2006) and the opinion of fermentation experts the current fermentation period being used

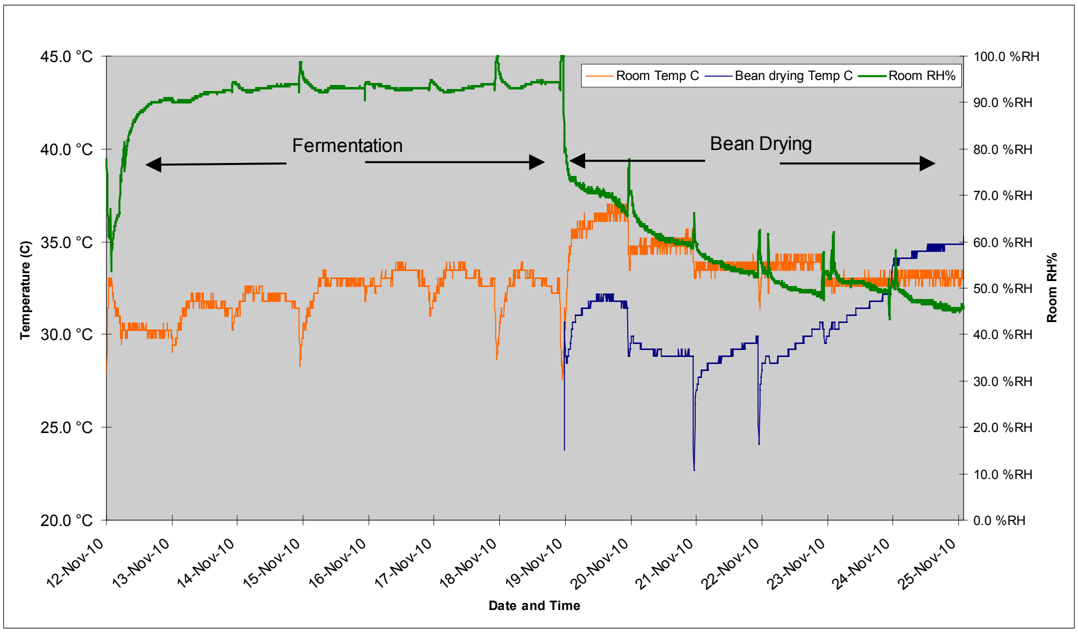


Figure 23. Ambient temperature and humidity (RH%) during bean fermentation and drying and bean temperature during drying

is too long and based on commercial operational requirements rather than what is ideal. Issues to consider for determining the fermentation finishing point are:

- five to six days with the temperature over 40^{o}C is sufficient
- one to two turns during fermentation is generally considered sufficient
- If a temperature drop occurs earlier than day three consider remixing the beans to aerate and stimulate bacterial activity and a subsequent temperature rise
- after three days if the temperature drops below 40^{o}C consider ceasing the ferment and drying the beans
- many fermentations are adequately completed by four days. A good sign of the end of fermentation is:
    - open cotyledons
    - purple/brown liquid present under the testa (seed coat)
    - beans are dark brown in colour on the outside but purple/red/bleached colour internally (Figure 24)
    - greater than 50% of the beans have the above appearance.

Day 5	Day 6

Figure 24. Based on bean colour the end of the fermentation could be judged as early as day 5 (details for Fermentation 6 August 2010 in Table 6 and Figure 21).

Fermentation in excess of five to six days allows purification bacteria (eg. Bacillus species, spore formers) and moulds to develop which are responsible for the development of off flavours.

Issues which need to be incorporated into commercial drying operations include:

- ensuring wet beans are thinly spread on the dry racks
- turning beans frequently during the first 48 hours of drying to ensure good air circulation and evenness of drying
- Monitoring bean moisture and aiming for a final moisture content of 6 to 7%
- Store bagged bean in hessian or cloth bags in a low humidity moderate temperature environment.

New single layer fermentation trays were built at the end of 2010 and were ready for use in the 2011 season when cocoa processing commenced again. The single layer tray offered an interesting alternative to box or rotary bin fermentations. Work conducted by a Danish chocolate manufacturer (Mikkelsen, 2010; Toms, 2010) in Ghana suggested that tray fermentation offers a number of benefits. These include no need for turning and improved quality of the fermented bean.

Tray fermentation has received renewed attention partly because bean turning over the period of fermentation is not required and secondly because of reported improvements to cocoa flavour, aroma and quality (Nielsen, 2006; Owusu, 2010). The trays are approximately 1.2 m in length, 0.9 m wide and 12 cm high, suited to pallet and forklift operations. The floor of the tray is made using a porous material, in west Africa a raffia matt, in Australia a stainless steel mesh. Wet beans are loaded into each tray to a height of 10 cm and multiple trays are stacked on top of each other. The top tray is covered and fermentation is allowed to take its course.

The ability to test this at Site 2 in the Innisfail region was curtailed by Cyclone Yasi in February 2011. An opportunity to test the trays occurred in June 2012 with the assistance and cooperation of the Daintree Estate growers.

Comparison of Fermentation Vessel

Materials and Methods

Cocoa bean fermentations carried out by Daintree Estates are centralised at a fermentary on the outskirts of Mossman in far north Queensland. Box fermentations, (approximate dimensions 100 x 100 x 80 cm), have been the preferred method.

A small trial was proposed to compare bean samples following fermentation using three different fermentation vessels; box, barrel and trays (Figure 25).

		
Box – capable of holding in excess of 200 kg of wet bean	Barrel – capable of holding approximately 85kg of wet bean	Tray – capable of 50 kg of wet bean per tray. The system can incorporate up to 12 trays at a time.

Figure 25. Fermentation vessels utilised in the experiment. From left to right; box, barrel and tray

Fermentation vessels were filled on Monday 4th June, 2012 at approximately 3.00 pm. The ambient shed temperature ranged from 13.4 to 28.8 ^{o}C during the fermentation period. Due to the cool night conditions, the vessels were covered in a tarpaulin, following bean loading, (Figure 26) to help maintain internal heat.

The tray ferment consisted of two trays with 50 kg of wet bean per tray. An empty tray was placed below and above the loaded trays. The beans in the tray were not turned for the duration of the fermentation. A temperature logger probe was placed in the centre of the beans in the upper tray. Fermentation was ceased on the 10 June.

The barrel was loaded with 50 kg of bean which approximately half filled the barrel. The barrel was rotated (beans tumbled) on the 5th, 6th and 8th of June. A temperature probe was inserted mid load from outside the barrel. Fermentation was ceased on the 10 June.

The box ferment consisted of 150 kg of beans. A temperature probe was located in centre of box. Beans were turned by hand on the 6th, 8th and 10th June. The temperature data probe was either mis-inserted or not inserted into beans after the 10 June. Hence an incomplete temperature record is available. Fermentation was ceased on 12th June based on the experience of the fermentation manager.

Figure 26. Fermentation vessel's covered in a tarpaulin to aid with heat retention

A summary of turning operations and fermentation end dates are presented in Table 8.

Table 8. Summary of events for the fermentation vessel comparison trial

Event	Box	Barrel	Tray
Fermentation start	4 June	4 June	4 June
Turn 1	6 June (2 days)	5 June (1 day)	Not applicable
Turn 2	8 June (4 days)	6 June (2 days)	Not applicable
Turn 3	10 June (6 days)	8 June (4 days)	Not applicable
Fermentation end	12 June (8 days)	10 June (6 days)	10 June (6 days)

Following cessation of fermentation the beans were laid out on a drying tray and sun and forced air dried to 7 to 8% moisture. Fermented dried beans were packed and sent to the Daintree Estates laboratory for chemical, physical, microbiological and sensory analysis.

Results and discussion

Temperature profiles of the box, barrel and tray fermentations are shown in Figure 27. The last two days of the box ferment reflect ambient conditions due to a misplacement of the temperature probe. Despite the low ambient temperatures all treatments were in fermentation "mode" by day two. The highest temperature peak was achieved in the barrel container (47.9 ^{o}C) while both the box and tray reached a peak temperature of approximately 44 ^{o}C (Table 9). Ambient temperature ranged from a minimum of 13.4 to 28.8 ^{o}C.

Table 9. Maximum and min temperatures recorded during the fermentation period 4 to 10 June

Temperature	Ambient	Box	Barrel	Tray
Min	13.4 °C	20.6 °C	16.3 °C	20.2 °C
Max	28.8 °C	43.2 °C	47.9 °C	43.7 °C

Fermentation was ended on day 6 for the barrel and tray fermentations due to signs of a decline in temperature (Figure 26). The box fermentation was continued for another two days based on the experience of the fermentation manager. Unfortunately the temperature profile data was not collected due to a misplaced temperature probe.

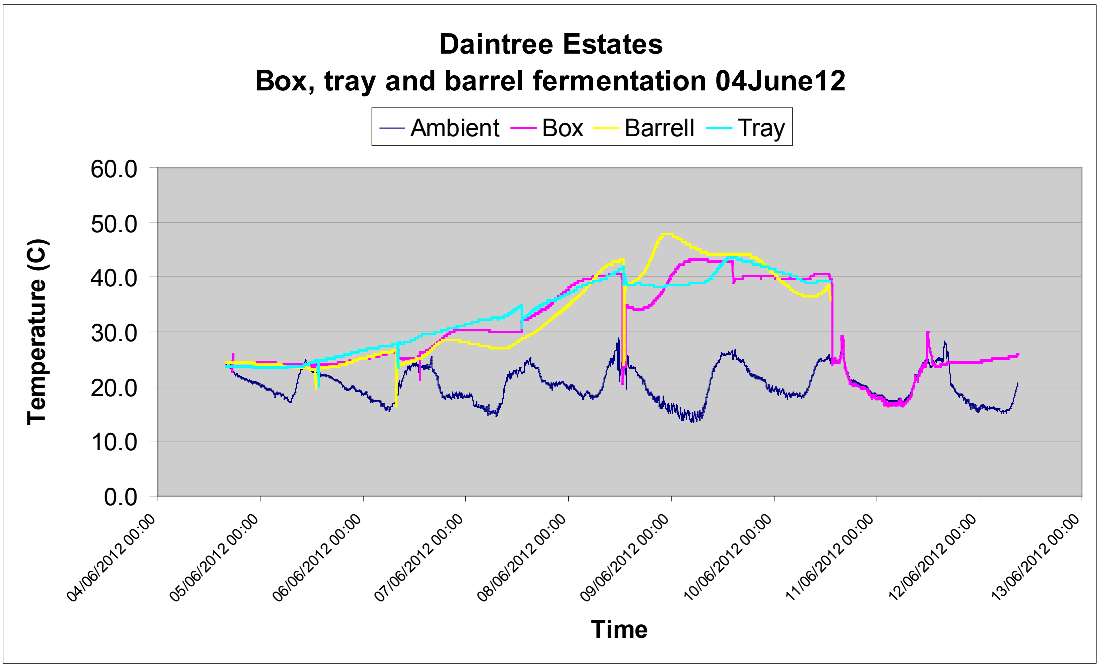


Figure 27. Temperature records for ambient, box, barrel and tray fermentations

Bean samples were taken at 24 and 48 hours after the start of fermentation to measure total yeast and bacterial counts with the assistance of UNSW. At 24 hours the counts for yeast and bacteria were considered to be similar, however, by 48 hours the tray system were showing higher yeast to bacteria ratios than the barrel and box fermentation systems (Table 10). Further sampling at day 6 was unfortunately not able to be quantified due to sample dilution issues.

Table 10. Total yeast and bacterial counts after 24 h and 48 h (Van Ho pers com, 2012)

Sample	At 24 h		At 48 h	
	Total yeasts [log10 (CFU/g bean)]	Total bacteria [log10 (CFU/g bean)]	Total yeasts [log10 (CFU/g bean)]	Total bacteria [log10 (CFU/g bean)]
Box	6.9	7.0	7.6	8.5
Tray	6.5	6.9	8.2	8.2
Barrel	7.0	7.1	7.7	8.6

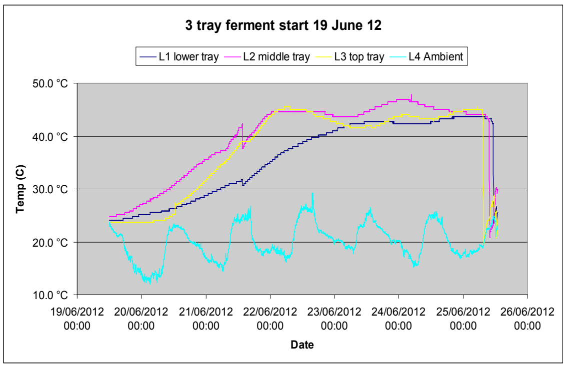
Final fermented and dried bean samples sent to UNSW were analysed for pH, total yeast and bacterial counts. The pH increased from 2.54 for the box through to 4.93 for the barrel to 5.01 for the trays indicating less bean acidity for the tray method. Correspondingly the total microorganism count decreased from box to tray (Table 11).

Table 11. Fermented, dried cocoa bean pH value and total microorganism count (Van Ho pers com, 2012)

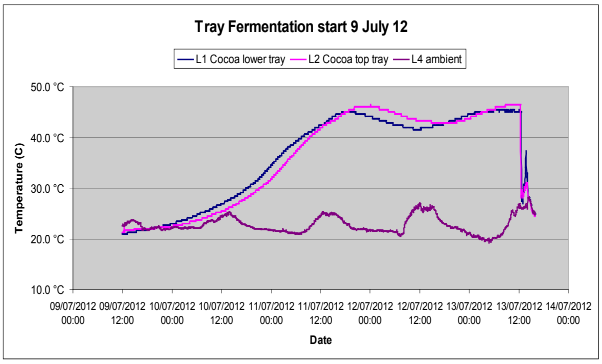
Sample	pH	Total counts (yeasts and bacteria) [log10 (CFU/g bean)]
Box	4.54	4.3
Barrel	4.93	3.2
Tray	5.01	2.7

The tray system produced a bean with a higher pH and lower microbial load which is preferred by bean buyers. The low pH is typical of box ferments as is the higher microbial load for fermentations in excess of 6 days (Nielsen *et al.*, 2013). Sensory panel data was unfortunately not released by Daintree Estates, however, it is anticipated that tray fermentations have the potential to lead to preferable fermentation outcomes.

A further two tray fermentation were carried out with Daintree Estates, the temperature data for booth suggests a favourable outcome (Figure 28).



Three tray ferment



Double tray ferment

Figure 28. Temperature profiles for a further 2 tray fermentations carried out with the assistance of Daintree Estates

Zokoko Chocolate - Visit

Introduction

In the latter half of 2010 concerted effort has been focused towards the development of cocoa fermentation and drying techniques which will result in an acceptable "commercial" grade cocoa bean.

In early October three lots of fermented beans (approximately 50+ kg) were forwarded to Zokoko – Premium Artisan Chocolate, a small but relatively new chocolate producer, for evaluation. Zokoko is one of only a few chocolate producers in Australia that is able to manufacture chocolate from fermented dried bean.

A visit to Zokoko was requested to discuss:

- The production process for chocolates from fermented dried bean with the view to showing cooperating growers how the process occurred
- Discussion on the quality of north Queensland produced bean with direct feedback from the chocolate maker
- Discussion about the market potential for north Queensland beans.

The contingent of two from north Queensland (Yan Diczbalis, Principal Horticulturist, QDAFF and Noel Stevenson – Cocoa grower) were accompanied by Professor Graham Fleet, Microbiologist University of New South Wales.

The Chocolate Making Process

Zokoko is owned and operated by Dean and Michelle Morgan. The facility is located in a small industrial complex on Old Bathurst Road, Emu Heights on the outskirts of western Sydney (Figure 29).

Figure 29. Zokoko shop front and chocolate factory

The facility incorporates a café and chocolate retail outlet to complement the Morgan's other business of coffee roasting. Dried beans are sourced from Papua New Guinea, Uganda, Panama, Bolivia, Ecuador and Peru for the production of premium origin chocolate bars and truffles. Prior to roasting a sample of 100 beans is guillotined and evaluated for internal quality. A Magra cut testing unit speeds up the cut test process considerably (Figures 30 and 31).

Figure 30. A Magra “Cut Test” guillotine

Figure 31. Fermented dried cocoa beans ready for roasting

The beans are roasted in a restored Barth Sirocco ball roaster (Figure 32). Alternatives such as oven roasting or coffee roasters can be used. Roasted beans are broken into small pieces in a crusher and the shell is removed from the cocoa nibs (small pieces of crushed and roasted cacao) by winnowing (Figure. 33).

Figure 32. Barth Sirocco ball roaster (restored)

Figure 33. Cocoa bean cracking and winnowing machine. Note, in the foreground, the small winnowing unit from Kimberly Seeds

Small test samples of beans are cracked using a simple Crankandstein mill (Figure 34) purchased via the web site “Chocolate Alchemy” - http://www.chocolatealchemy.com. Winnowing of small samples is carried out with a seed winnowing machine manufactured by Kimberly Seeds.

Figure 34. Crankandstein mill side on and top view and Crushed beans from a north Queensland batch ready for winnowing

The separation of the nibs from the shell (seed coat) is followed by a grinding and refining process to produce chocolate mass (liquor). The nibs are crushed with sugar in a granite roll mill. For small bean volumes a mill manufactured by Santha in India is used (Figure 35) while for large samples (250 kg) the restored melanger machine is used (Figure 36). After a prolonged grinding session (24 hours +) the paste begins to resemble liquid chocolate, this is then further refined using a ball mill conch (Figure 37).

Figure 35. The Santha granite roll mill used for grinding cocoa nibs and sugar for small volumes of beans (1-2 kg) chocolate batches

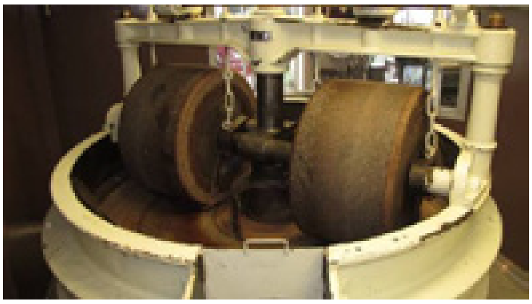


Figure 36. The restored melanger (granite rollers) used for grinding cocoa nibs and sugar for large scale (250 kg) chocolate batches

Following the refining process the chocolate mass is stored or can be tempered, a process in which the crystal structure of the cocoa mass is set to a uniform crystal type to stabilise the cocoa butter and give the final product its "snap", sheen and mouth feel. Tempering is traditionally done by hand but has also been mechanised and a number of small to large devices are available. At Zokoko, small batches of cocoa are hand tempered (Figure 37) whereas larger batches are tempered using a "Selmi Plus" tempering machine (Figure 38).

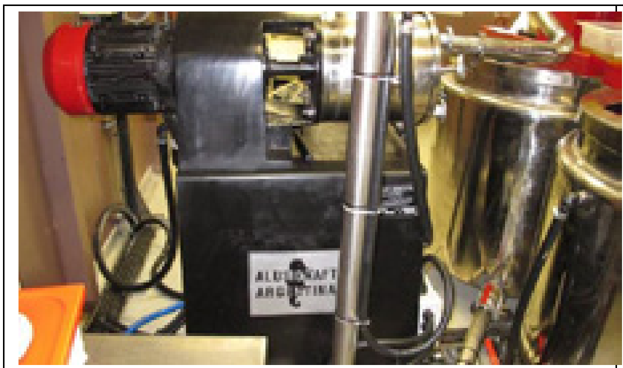


Figure 37. Ball mill conch used for final refining of the cocoa and sugar mass

Figure 38. Hand tempering demonstration by chocolatier Gerhard Petzl (left of picture)

Figure 39. Selmi Plus mechanical tempering devise used for larger batch sizes

Molten cocoa mass is then poured into moulds or used for the production of chocolate truffles.

General Comments on Queensland Produced Beans

Dean Morgan presented an optimistic outlook on the quality of north Queensland fermented and dried cocoa beans. The flavour, taste and mouth feel of the chocolate product made from Queensland beans was excellent.

General comments referred to:

- the need for consistency of bean size, excluding undersized or flat beans which may occur in a batch
- Reducing the amount of surface mould, which requires good drying and post drying storage practices.

Market Potential for North Queensland Beans

The Morgans suggested that they would be interested in receiving product from north Queensland. The issue of price was not directly negotiated and would be an issue for growers to follow up directly.

Price paid for bean currently imported by Zokoko range from $4,000 to $6,000 per tonne. The ICCO commodity price for the 28th October 2010 was $2936.28 per tonne. The ICCO commodity price at 17 July 2013 was $2508 per tonne.

Useful Web Sites

www.Zokoko.com – Zokoko

www.teserba.ch – Supplier of Bean cut test guillotine

www.brooklyncacao.com - Suppliers of cocoa manufacturing equipment.

www.kimseed.com.au – supplier of small scale winnowing machine

www.chocolatealchemy.com – Site detailing methods and equipment for small scale (home made) chocolate making

www.ohcf.us/ - Original Hawaiian Chocolate site

www.alumcraft.com.ar - Alumcraft Argentina, manufactures of the ball mill conch used by Zokoko

www.selmi-group.com/eng/ - Tempering equipment used by Zokoko

www.donveita.com/en/cocoa-glossary.htm - Cocoa glossary of terms

www.grenadachocolate.com/tour/process1.html - View and learn about the cocoa process by clicking on the flow chart

www.tazachocolate.com – Interesting specialist chocolate producer from the USA

www.foreverart.at - Gerhard Petzl chocolate sculptures

www.icco.org – International Cocoa Organisation price and information service

Development of a Chocolate Making Facility at Mena Creek

Introduction

At a grower meeting in August 2010, growers were introduced to chocolate making and a range of small scale chocolate making equipment. Following a visit to Zokoko in October 2010, the managers of Mena Investments visited Florida in April 2011 to inspect small scale chocolate making equipment manufactured by “Cacao Cucina” (www.cacaocucina.com) and to attend a chocolate making course.

Chocolate making is a science within itself and well documented (Beckett, 1999). For the home hobbyist or small scale chocolate maker an introduction to the art is provided by Bittenbender and Kling, 2009. In late 2011, equipment was privately purchased and delivered to Mena Creek, thereby starting another chapter in “Commercialising cocoa in north Queensland”. To date all chocolate manufactured by Cocoa Australia and Daintree Estates has been manufactured under licence in Victoria.

Equipment Overview

Chocolate making, from dried fermented bean involves a range of steps. These include roasting, cracking and winnowing, cocoa nib grinding, chocolate making (concher) and tempering.

Figure 40. Bean roasting unit with a drum roller (behind glass doors) and bean cooling tray (left) and a 15 kg/hr bean cracking and winnowing unit (right)

Following roasting, cracking and winnowing (Figure 40) the nibs need to undergo a grinding process. Equipment to undertake this can be as simple as the Santha granite roll mill shown in the previous chapter or a hammer type mill with 3 stage grinding screen as shown in Figure 41. Following course grinding, a longer grinding, known as conching, process is carried out on the cocoa liquor along with additions of sugar, vanilla and lecithin to reduce the particle size to less than 20 microns (Figure 42). This process takes 8 to 12 hours depending on ingredients.

Figure 41. Nib grinder and the consistency of the cocoa mass (liquor) after it has passed through the final sieve

Figure 42. Programmable chocolate maker (ball grinder) with heated water jacket. A view of stainless balls used to reduce particle size

Following the conching period the chocolate is all but ready to poor. The chocolate mass is decanted into the tempering unit. A tempering unit involves precise heating, cooling and reheating of the chocolate mass to stabilise the crystal type. The tempering process is vital to chocolate feel and appearance. The process of tempering involves converting the six different chocolate crystals which are part of untempered chocolate in to a uniform beta crystal type. For dark chocolate, heated uncrystallised chocolate mass at approximately 45-48°C is allowed to cool while stirring to 28 °C to commence the formation of stable crystals. The mass is then slowly heated to and held at 31-32 °C which supports the development of the preferred crystal type. Chocolate can then be poured into moulds (Figure 43). This action gives chocolate it's unique snap and prevents bloom. Bloom occurs when the fat crystals migrate to the surface giving the chocolate a milky streaky appearance. A simple test to check if tempering has been successful is to place a thin portion on a plate or foil at $20\,^{\circ}C$. If the chocolate sets quickly with a good gloss it is likely that the temper is near optimum (Becket, 1999; McGee, 2004).

Figure 43. Pouring chocolate into the mould from the tempering machine (left) and removing trapped air in the moulds prior to cooling

Stevo's Super Chocolate Product Range

Figure 44. Range of products being produced and sold by Stevo's Super Chocolate

Currently Mena Creek Investments produces a range of products which are available via a vending machine at the companies fruit stall (Figure 44). Products include fermented roasted beans, cocoa nibs, Koko Samoa (cocoa liquor - popularly used by Samoans and other Pacific Islanders for the preparation of chocolate drinks) and dark chocolate.

Recent Developments

Introduction

In mid to late 2012, two new grower/investors sought information on importing hybrid cocoa seed and developing production orchards. Both groups intend to have a whole of chain approach from growing cocoa through to chocolate making and retailing.

Both groups have been provided with advice, including:

- Stage 1 project report and copy of the Cocoa Growers Manual
- Assistance in obtaining SG2 hybrid seed from CCI in PNG
- Supply of *Erythrina variegata* (Wiliwili) cuttings for windbreaks
- Support advice for sowing and planting

A trellising trial has been initiated by QDAFF under the Cyclone project.

The Australian Chocolate Company

Owners and initiators Chris and Lynn Jahnke, own 162 ha in the hinterland west of Mission Beach. They have a strong background in direct selling with mail order and internet shopping components. Following a recent sale of their former business they are interested in developing a cocoa based series of businesses for the Mission Beach region.

Their plan, with the assistance of investors, is to develop a business based on;

- 20 ha of cocoa plantation
- Established infrastructure for harvesting a processing of beans
- Establish a chocolate manufacturing facility
- Commence selling chocolate
- Establish a “chocolate tourism” facility near Mission Beach.

To date the company has imported 4,000 hybrid seed from PNG. Over one thousand trees have been planted, from the first batch of 2,000, following a failure of 600 seeds to germinate (Figure 45).

Figure 45. Newly planted hybrid cocoa trees. Note; use of large size tree guards

The Australian Chocolate company plan to produce beans which will be supplied to "Charley's Chocolate Factory". Chocolate sales will occur via "The Chocolate Club.com.au" and link in with "The Australian Chocolate Centre" (Figure 46).

Figure 46. Proposed intra business connectivity for the Australian Chocolate Company

To date the company has followed agronomic advice closely and experienced successful seed germination and tree establishment.

Mackay Estates

The third generation Mackay family have five properties totalling 3,500 ha south of Tully (mackays.com.au). Their principal business is bananas, producing approximately a third of the Australian production. Other agricultural streams include sugar cane, papaya and cattle production.

In late 2012, the business decided to trial cocoa following introductions to Noel Stevenson. Four thousand SG2 hybrid seeds were imported from CCI in PNG in March 2013. All seed lots had near 100% germination and are now ready to be planted out (Figure 47).

Figure 47. Germinating seeds and developing seedlings at Mackay Estates this year

The company is considering establishing trees on trellis as a method of providing insurance against cyclones which have been relatively frequent in the recent past.

To date the company has followed agronomic advice closely and experienced successful seed germination and establishment.

QDAFF & RIRDC Cyclone Project Planting

As part of the recently funded cyclone project funding, cocoa is being used as a model tree representing cauliferous and ramiflorous species in a trellising trial.

Cocoa seedlings have been recently (June 2013) planted out on three different trellis structures, Tatura, Espalier and T-trellis along with a free form row. Three tree forms will be trialled on each trellis type:

- Single leader with horizontal branches
- Single leader with angled branches
- Twin leader with angled branches

Tree growth and production will be monitored and data collected shared with growers.

Intellectual Property History of North Australian Cocoa Development; Pod Splitter, Bean Separator and Ancillary Equipment

***Text** by* Garry Fullelove (QDAFF)

At the outset of the North Australian Cocoa Development (NACDA) project it was acknowledged that the primary processing of cocoa would pose a significant challenge to viable production in Australia. Indeed the laborious nature of pod processing had in all likelihood been a historical factor inhibiting any development of an Australian based industry. Because the uncertainties about the performance and suitability of previous pod splitting technology from overseas, independent design of a NACDA pod splitter commenced in early 2001 with first tests of the prototype machine in about August 2001.

Once the prototype machine had been successfully tested and its potential confirmed, other development work was undertaken. This was aimed at techniques and machinery for mechanised delivery of pods to the pod splitter and subsequent separation of the pod husk, beans and placental material.

The project partners had taken the decision to protect this project IP via patent. An Australian patent application was lodged with IP Australia with a filing date of 4th April 2006 (Application Number: 2006901746).

The pod-splitters designer and NACDA project leader (Craig Lemin) left DPI&F for alternative employment on 13th February 2007 and his skill set was not directly replaced in the cocoa project. This presented a point at which a commercial partner with design and engineering skills may be brought into the pod-splitter's development. In order to find a commercial partner that may help commercially develop the pod-splitter and co-fund the patent application an Expression of Interest for a commercial partner to develop the pod-splitter was published with a closing date of 23rd March 2007. No bids were lodged.

In order not to let the patent process expire, on the 4th April 2007 a International Patent Cooperation Treaty (PCT) application was lodged to expand the Australian patent application to a broader international territory (International Application Number: PCT/AU2007/000453).

An opportunity arose during late 2007 to lease the prototype pod-splitter to Cocoa Australia (based in Mossman, Far North Queensland) for semi-commercial trialling. The machine was returned in December 2008 to DPI&F.

On 26th September 2008 following discussions with Yan Diczbalis (DPI&F Regional Industries Development Officer) and Bob Williams (DPI&F Science leader) and the DPI&F Intellectual Property Commercialisation Unit (IPCU), the decision was made to proceed with national phase entry applications in the countries of Australia, Indonesia, and Malaysia being territories that may have some use for such an invention and that we had some ability to securely manage and commercialise the IP within the patent.

On that basis three PCT National Phase Entry PCT applications have been made under PCT/AU2007/000453:

Australia – Patent Application Number: 2007233586

Indonesia – pending

Malaysia – Patent Application Number: PI20083951

Discussion with the project partner, Cadbury UK has explored the reason for patent protection being sought for the pod-splitter as the cost of continuing the patenting process was not small and the likelihood of finding a commercial partner to further develop the pod-splitter was fading.

David Preece (Cadbury UK - Cocoa Group Technical Manager) indicated that Cadbury's main goal was to protect the design so that it could not be tied-up by any other entity. By doing this he was of the opinion that on-going broad access to the design would be available for any cocoa grower both in Australia and possibly overseas.

Garry Fullelove (DPI&F Horticulture and Forestry Science Business Manager) then indicated that a patent was only possible on an invention that was novel – that is one that has not been publically disclosed prior to a patent application. DPI&F could ensure that no entity could monopolise the pod-splitter design by publishing the design and photos of the machine either in a project publication and/or on the DPI&F web site. This public disclosure would then preclude any other person/company/entity from lodging a patent and trying to monopolise the design.

The meeting then agreed to seek wider opinion from other project partners on their stance in regard to proceeding with the patent applications and possible commercialisation of the pod-splitter or simply publishing the design and allowing operatives within the cocoa industry to use and modify the design to suit their individual needs.

Such publication and cessation of the patenting process appeared to meet all of the requirements Cadbury had of the pod splitter, ie. available to all cocoa growers and not able to be monopolised by any single entity as well as to allow for continued innovation and equipment development through commercial use.

Cocoa Pod Borer

Text *by Rebecca Sapuppo, Incident Response Coordinator, Plant Biosecurity and Product Integrity Biosecurity Queensland*

The cocoa pod borer *(Conopomorpha cramerella)* was detected on a commercial cocoa plantation in far north Queensland in 2011.

The owner of the infested property contacted the Department of Agriculture, Fisheries and Forestry (QDAFF) in April of 2011 to report unusual damage he was observing whilst processing mature cocoa pods; up to 60% yield loss had been sustained in some areas of the plantation. The damage observed was consistent with that caused by cocoa pod borer in overseas production systems. As the pest was suspected of being an emergency plant pest, the matter was referred to Biosecurity Queensland (part of QDAFF) for further investigation.

A confirmed identification of the pest was not able to be obtained until June of 2011 when three separate taxonomic specialists confirmed the identity of the pest as *Conopomorpha cramerella* using both traditional morphological and molecular techniques. The Australian Chief Plant Protection Office (ACPPO), a part of the Australian Department of Agriculture, Fisheries and Forestry was notified of the detection on the 18 June 2011.

Although a pathway for the entry of the pest into Australia could not be determined, delimiting surveillance conducted by Biosecurity Queensland on commercial cocoa and rambutan properties, plant nurseries, botanical collections and residential properties in the district indicated that the pest appeared to be confined to one property only and had not established more broadly.

On the 4 July 2011 the Consultative Committee for Emergency Plant Pests (CCEPP) confirmed that the pest met the requirements for a nationally cost-shared eradication response and Biosecurity Queensland initiated a program to eradicate the pest from the infested property and to minimise the risk of the pest establishing in Queensland.

The operational phase of the eradication program was active from June 2011 until May 2013. The elements of the eradication program included:

- Property quarantines and on-farm biosecurity measures
- Delimiting surveillance on nearby commercial and residential properties
- The establishment of a district-wide pheromone trapping network
- The maintenance of a four-month long "pod free" period on the infested property
- An insecticide treatment program on the infested property
- Canopy thinning, crop hygiene and destruction of host material on the infested property
- Monitoring of first two crop harvests on the infested property.

As of May 2013 all the operational elements of the response program are now complete and monitoring data indicates that the pest has been eradicated from Queensland.

Biosecurity Queensland is preparing an area freedom proposal which will be submitted to the CCEPP for consideration at the end of July 2013. Once the CCEPP are satisfied with the technical aspects of the proposal, they will make a recommendation to the National Management Group that eradication has been achieved. The International Plant Protection Convention will then be advised that cocoa pod borer has been eradicated and Australia will be declared free of the pest.

Informal Extension Leaflet: Sent to cocoa growers in far north Queensland – Yan Diczbalis

Cocoa Pod Borer (*Conopomorpha sp.*) as seen in the Mossman area. Identification to the species level has not been confirmed as of 19 April 2011 (Figure 48).

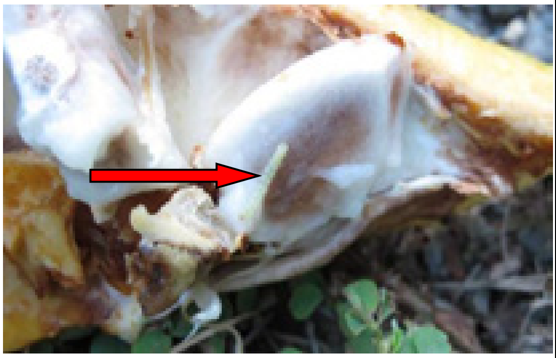
	
Signs of internal damage.	Signs of internal damage to musilage surrounding the beans
	
Severe damage and associated rot.	Moth larva (caterpillar) which causes the damage inside the pod. Length 10 – 12 mm long
	
Pupae on pod	Hatched pupal case
	
Adult moth (photo supplied by Biosecurity Qld)	Adult moth (approx 10 mm in length). (photo supplied by Biosecurity Qld)

Figure 48. Cocoa pod borer images sent to growers by email

Recommendations for Purchasing Seed from PNG Cocoa and Coconut Institute

1. Communicating with PNG

Communications with PNG can be slow so one needs to be patient but persistent. Email and phone systems at the research stations are often not working. CCI contacts are often best approached using their private emails or mobile phone numbers. Please respect the fact that they are using their private communication tools to deal with you.

2. PNG CCI contact details for ordering seed

Keravat Research Station	**Stewart Research Station – Madang**
PNG Cocoa Coconut Institute Keravat Research Station, East New Britain, PNG. Ph. (675) 9839131 Fax. (675) 9839115 CEO: Dr. Eric Omuru Email: ccipng@datec.net.pg	PNG Cocoa Coconut Institute Stewart Research Station – Madang, PNG. Phone: (675) 4221651/4221653 Fax: (675) 4221657 Email: admin_srs@datec.net.pg
Contact: Jeffrie Marfu – Cocoa Breeder Private Mobile: 675-73976388 Private email: marfuj@yahoo.com	Contact: Alfred Kembu Private mobile: (675) 7286 1921 Private email: kembua@ymail.com

Recent discussions with Jeffery Marfu (CCI cocoa breeder based at Karavat) suggest that hybrid seed is readily available.

3. Approximate seed cost?

Cost depends on exchange rate. At the current listed exchange of $1 = Kena 2.16 (Dec 2012)
Seed: K0.50 per seed - approx $0.23/seed

Note a recent seed import (2000 seed) cost $640.96 with a bank exchange rate of 1.851 and additional bank fees.

Additional costs include; Customs Broker and AQIS Fees

4. AQIS Quarantine

You will need to notify AQIS duty officer in Cairns prior to the import with details of your intended seed import and the expected time and date of arrival and flight details.

AQIS duty officer in Cairns. Email: cdo@daff.gov.au Phone 40307852

You can check import details on The AQIS web site using ICON their import data base.

In "Icon", write Theobroma for commodity. This will take you to a different set of links which includes seed for sowing. This link may take you there directly

http://www.aqis.gov.au/icon32/asp/ex_casecontent.asp?intNodeId=8772762&intCommodityId=26841&Types=none&WhichQuery=Go+to+full+text&intSearch=1&LogSessionID=0

You are importing *Theobroma cacao*. It is on the list of permitted species. The document clearly states that an import permit is not required. However, the seed still needs to be labelled with the scientific name "*Theobroma cacao".* A phytosanitary certificate from the exporter will also be helpful.

You may have to pay an inspection fee.

5. How long can seed be retained upon receival in Australia before planting and any special storage requirements?

Try and arrange for seed to be dispatched on Tuesday/Wednesday so they are in Cairns by Friday.

Seed will need to be planted as soon as possible following clearance from AQIS and customs. It is suggested that seed be washed/rinsed prior to planting and directly seed into pots. A forestry tube is an absolute minimum size. A 67mm olive pot or similar is preferred. See link.
http://www.gardencityplastics.com/Propagation/SquareTubes/P67OPX#

6. Customs agent used by the grower?

QDAFF and the recent importers have used;

TACS International,19 Industrial Avenue, Strathford, Qld, 4870; Phone: 40581590

7. Suggested hybrid seed to order?

The four hybrids used in our experimental work were;
KA2-106 x KEE12 - SG2-small
K82 x KEE5 - SG2-small
KA2-106 x KEE23 SG2-small
K82 x KEE12 - SG2-small
A mix of these is suggested to avoid self incompatibility.

8. How were the germination rates? Were there any problems?

Germination rates are generally good with seed often commencing germination during transport. From a recent importation (early November 2012), three of the seed lots had a germination rate in excess of 95%. One lot of seed was less than 10%. The grower has negotiated replacement seed from the Cocoa and Coconut institute.

Economic assessment of cocoa production - A preliminary report

Jim Page, Senior Agricultural Economist, Maroochy Research Facility, DAFF, Nambour with inputs and support from Yan Diczbalis, Principal Horticulturist, Centre for Wet Tropics Agriculture, South Johnstone. Note: the economic model utilised was developed by Bill Johnston, Senior Principal Agricultural Economist, QDAFF.

Introduction

Cocoa is a relatively new industry in Far North Queensland, generally grown as a sideline with other crops. This assessment was conducted to gain an understanding of the profitability of cocoa production in Far North Queensland. Cocoa production is considered as an additional activity on an already established farm with some existing machinery suitable for the production of cocoa.

Objective

The objective is to review the establishment and operating costs and returns of cocoa over the life of a cocoa plantation to determine its profitability.

Method

A spreadsheet developed by and populated by Bill Johnston was used. The data in the original spreadsheet was reviewed and adjusted to fit with the views and experience of those currently producing the cocoa crop.

In this assessment cocoa was considered to be an additional component of an established farming operation. This meant that many of the capital costs associated with cocoa were shared with other farm activities, thereby greatly reducing the capital outlay associated with establishing a cocoa enterprise.

Most labour costs are included in the cost of contracted activities with the exception of harvesting costs- hence allowances for on-farm labour is minimal

The capital costs of the project are listed in Table 12. Most of these costs are incurred at the commencement of the project with some being delayed up to 4 years. Some capital items are replaced during the assumed life of the project. The estimated capital cost of establishing 2.5 ha of cocoa is $82,395 or $32,957/ ha. Details contained in the table show that some of the capital outlays have been halved on the assumption that they are shared with other farm activities. Some may believe that they could further reduce the capital outlay apportioned to cocoa as it may be a very small component of the farm operation, requiring minimal additional investment. This would increase the bottom line significantly if some these capital outlays were covered by other farm activities.

The gross margin (Year 6+) summarises the production assumptions underpinning the assessment (Table 13). It shows the yield, price and details of the costs of inputs and operations. These are presented as an example only and should not be viewed as a recommendation or guidelines as to how cocoa should be produced. Calculations suggest a Gross Margin per hectare of $8,824/ ha after the cocoa plants achieve maximum/ mature yield.

Table 12. Capital costs of project – 2.5 ha planting

Item	Number Items	Total Cost
Land - Initial purchase	-	$0
Land - preparation (spray, rip, drain and lime)	-	$625
Sheds		
Workshop	-	$0
Machinery shed	-	$0
Other	-	$0
Tractors & Vehicles (50% shared with other farm activities)		
4WD utility	1	$7,500
Quadbike	1	$0
60 HP Tractor	1	$0
40 HP Tractor	0	$0
Second-hand Orchard Tractor (40 HP)	1	$15,000
Implements (50% value, assumed shared with other farm activities)		
Slasher	1	$2,000
Boom Spray	1	$0
Mister	1	$5,000
Fertiliser Spreader	1	$3,000
Pneumatic Secateurs	1	$1,250
Mechanical Pruner (1 per 100 ha)	1	$0
Sundries - Secateurs & Tensiometers	1	$250
Forks for tractor	1	$2,500
Other	0	$0
Harvesting Equipment- 100% cocoa		
Secateurs & poles	1	$500
Harvest aid	1	$0
Field bins	6	$1,500
Field bin trailer	1	$3,500
Other	0	$0
Waste Handling		
Mulch spreader	1	$0
Irrigation- 100% cocoa		
Bore	1	$3,500
Pump and filtration	1	$5,000
Fertigation	1	$5,000
Controller	1	$700
Irrigation lines and associated equipment	-	$5,920
Shade		0
Materials	-	$1,383
Labour – planting	-	$282
Windbreaks		
Materials	-	$0
Labour – planting	-	$0
Cocoa Establishment		
On-farm nursery	-	$0
Planting material	-	$12,308
Dig and plant	-	$4,821
Replace field mortality	-	$615
Replant - dig and plant	-	$241
Total cost / ha		$32,957
Total Initial Capital Outlay 2.5 ha		$82,395

Table 13. Year 6+ Gross margin

Yield per Hectare	1.90	tonnes
Expected Price	$7,000	
Gross Income	$13,283	/ ha

Pre-Harvest Costs					
General Machinery Operations (FORM)		Operat-ions	Hours / Ha	$ / Hour	$ / Ha
Slashing		3	0.51	$20.00	$30.60
Fertiliser spreading		4	0.50	$18.00	$36.00
Spraying insecticides (mister)		16	0.40	$20.00	$128.00
Spraying herbicides (boomspray)		4	0.44	$6.50	$11.44
Total					$206.04
Fertiliser	Applications	Rate/ App	L, Kg / Ha	$ / L or Kg	$ / Ha
CK554 (spread)	4	100.00	400.00	$0.80	$320.00
Urea (fertigate)	24	63.00	1512.0	$0.47	$710.64
Other	0	0.00	0.00	$0.00	$0.00
Other	0	0.00	0.00	$0.00	$0.00
Total					$1,030.64
Lime	Applications	Rate/ App	L, Kg / Ha	$ / L or Kg	$ / Ha
Lime spreading (contract) - once every 2 years	1	500.00	500.00	$0.10	$50.00
Total					$50.00
Herbicide	Applications	Rate/ App	L, Kg / Ha	$ / L or Kg	$ / Ha
Roundup	0	3.50	0.00	$10.00	$0.00
Basta	2	4.40	8.80	$18.70	$164.56
Other	0	0.00	0.00	$0.00	$0.00
Total					$164.56
Insecticide	Applications	Rate/ App	L, Kg / Ha	$ / L or Kg	$ / Ha
Confidor	16	0.05	0.80	$0.80	$0.64
Carbaryl	0	2.65	0.00	$15.00	$0.00
Bulldock	0	1.00	0.00	$24.85	$0.00
Endosulfan	0	1.00	0.00	$10.00	$0.00
Maverick	0	0.00	0.00	$0.00	$0.00
Total					$0.64
Fungicide	Applications	Rate/ App	L, Kg / Ha	$ / L or Kg	$ / Ha
Phostech	2	5.00	10.00	$3.75	$37.50
Dithane	0	0.00	0.00	$7.30	$0.00
Copper	0	0.00	0.00	$5.00	$0.00
Metalaxyl	0	0.00	0.00	$90.00	$0.00
Other	0	0.00	0.00	$0.00	$0.00
Total					$37.50
Irrigation			ML/ Ha	$ / ML	$ / Ha
Water usage			6.00	$0.00	$0.00
Pumping cost				$15.00	$90.00
Total					$90.00
On-Farm Tree Maintenance					
Irrigation		Operations	Hours / Ha	$ / Hour	$ / Ha
Sprinkler or drip line maintenance		1	3.00	$0.00	$0.00
Shade Trees		Operations	Hours / Ha	$ / Hour	$ / Ha
Shade tree pruning - manual secateurs		1	1.00	$0.00	$0.00
Windbreaks		Operations	Hours / Ha	$ / Hour	$ / Ha
Mechanical hedging - windbreak		1	0.10	$75.00	$7.50
Bamboo pruning		1	1.40	$0.00	$0.00
Tree pruning		1	1.40	$0.00	$0.00

Canopy Management - Cocoa Plants	Operat-ion	Hours / Ha	$ / Hour	$ / Ha
Chupon removal - hand secateurs only	0	0.00	$0.00	$0.00
Structural - hand / pneumatic secateurs	1	20.00	$3.00	$60.00
Height - pnematic secateurs	1	10.00	$3.00	$30.00
Mechanical hedging	1	2.50	$75.00	$187.50
Total				$285.00
Unspecified costs		Hrs/Ha	$/Hour	$ / Ha
Unspecified casual labour		0.00	$0.00	$0.00
Sundries and contingencies				$0.00
Total				$0.00
Total Pre-Harvest Costs				$1,864.38

Harvesting Costs			
Harvest Machinery Operations - FORM	Hrs/ Ha	$ / Hour	$ / Ha
Harvest aid	128.49	$4.00	$513.94
Tractor and trailer - transport to processing point	5.51	$27.50	$151.59
Total			$665.53
Harvest Labour	Hrs/Ha	$/Hour	$ / Ha
Pod harvesting	128.49	$7.50	$963.64
Pod transport	5.51	$0.00	$0.00
Total			$963.64
Total Harvest Costs			$1,629.17

Post-Harvest and Marketing Costs			
Pod Processing			$ / Ha
Splitting - contract			$322.60
Waste spreading			$92.25
Total			$414.84
Bean Processing			$ / Ha
Freight to fermentary ($ per tonne)	1.90	$0.00	$0.00
Fermentary - contract			$550.31
Commissions		0.00%	$0.00
Levy ($ per tonne)		$0.00	$0.00
Total			$550.31
Total Post-Harvest and Marketing Costs			$965.15

Total Variable Costs per ha	$4,458
Gross Income per ha	$13,283
Gross Margin per ha	$8,824

It should be noted that there is minimal allowance specifically for labour. This is because most of the labour is included as contract payments with the exception of harvest labour.

This gross margin may appear to be attractive but it has to be related to the capital costs incurred to earn it before a conclusion can be drawn. This is done in the investment analysis that follows in Table 14 - Summary Sheet.

Results

Table 14 - Summary Sheet presents the results of the key investment criteria ie Net Present Value (NPV) and Internal Rate of Return (IRR) for the project. It also provides estimates of the Equivalent Annual Return of the project as a whole as well as per tonne, per tree, per hectare and for the whole farm as well expressing all of the project costs as a percentage of the total costs.

Discounting procedures are used to calculate the NPV. This means that future cash flows are discounted to take account of the opportunity cost of money. For example, if we have the option of $100 in a year's time or $95 now we would be indifferent (if interest rates are 5%) because we know that we could invest the $95 at 5% and know that it will be worth $100 in 1 year. Hence $100 in 1 year's time has a present value of near $95 today. As the period is extended, the discount factor applied increases so that after 15-20 years the worth of promised income has a very low present value- perhaps $10- 20, depending on the interest rate used as the discount rate.

The net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over the life of the project. If the NPV is positive the project is said to be profitable. When the NPV is converted to a yearly figure it becomes annualised. In this report the annualised return is called the equivalent annual return. It is a measure of equivalent annual returns generated over the life of the project expressed in today's dollars.

The Equivalent annual return (EAR) is calculated by determining the annual payment required to repay a loan equivalent to the NPV, over the same term and at the same rate of interest. In affect it takes a series of uneven positive and negative cash flows and converts them to a constant but equivalent periodic (annual) sum.

The Internal rate of return (IRR) is the discount rate at which the project has a NPV of zero. The IRR represents the maximum rate of interest that could be paid on all capital invested in the project. If all funds were borrowed, and interest charged at the IRR, the borrower would break even, that is, recover the capital invested in the project.

The body of the table displays the Annual Equivalent of all the costs incurred in the project again expressed as per tonne, per tree, per hectare and for the whole farm.

Both the Total NPV per 2.5ha, @ 0.05%, for 20 years of $61,041 and an Internal Rate of Return of 10.24% reported at the bottom of Table 3 indicated a profitable outcome.

Table 14. Cocoa production IRR summary sheet

	$ per Tonne	$ per Tree	$ Whole Farm	
Equivalent Annual Gross Receipts	$7,000.00	$8.34	$25,677	
Equivalent Annual Farm Costs	$ per Tonne	$ per Tree	$ Whole Farm	% Total Costs
Variable Costs				
FORM	$149.42	$0.18	$548	2.64%
Fertiliser & Lime	$926.00	$1.10	$3,397	16.35%
Herbicide	$131.63	$0.16	$483	2.32%
Insecticide	$4.09	$0.00	$15	0.07%
Fungicide	$19.97	$0.02	$73	0.35%
Irrigation	$50.63	$0.06	$186	0.89%
Tree Maintenance	$161.98	$0.19	$594	2.86%
Sundries	$0.00	$0.00	$0	0.00%
Harvest	$985.29	$1.17	$3,614	17.39%
Process	$508.61	$0.61	$1,866	8.98%
Total Variable Costs	$2,937.63	$3.50	$10,776	51.86%
Fixed Costs				
Repairs and Maintenance	$0.00	$0.00	$0	0.00%
Sundry Fuel & Oil	$0.00	$0.00	$0	0.00%
Electricity	$81.78	$0.10	$300	1.44%
Other Fixed	$572.49	$0.68	$2,100	10.11%
Permanent Hired Labour	$0.00	$0.00	$0	0.00%
Manager	$0.00	$0.00	$0	0.00%
Capital	$2,072.83	$2.47	$7,604	36.59%
Total Fixed Costs	$2,727.10	$3.25	$10,004	48.14%
Total Costs	$5,664.73	$6.75	$20,779	100.00%
Total NPV / 2.5ha, @ 0.05 %, for 20 years			$61,041	
Equivalent Annual Return	$1,335	$1.59	$4,898	
Internal Rate of Return (%)	10.24%			

The Equivalent Annual Return (also reported at the bottom of Table 3) is $1,335/ tonne, $1.59/ tree and $4,898 per hectare.

Reviewing the table reveals the significance of fertiliser, harvest and capital costs- around 70% of all costs.

Projected Discounted Cash Flow (Figure 49), indicates the breakeven point, the bar graph represents the nominal (undiscounted) cash, and the line graph shows the discounted cumulative cash flow. The breakeven point is achieved when the cumulative cash flow exceeds zero- i.e. where the line graph intersects the horizontal axis at year 12. Year 12 is indicated as the year when project returns exceed the sum of all previous capital and other costs. The final point on the discounted cumulative cash flow is the NPV of the project.

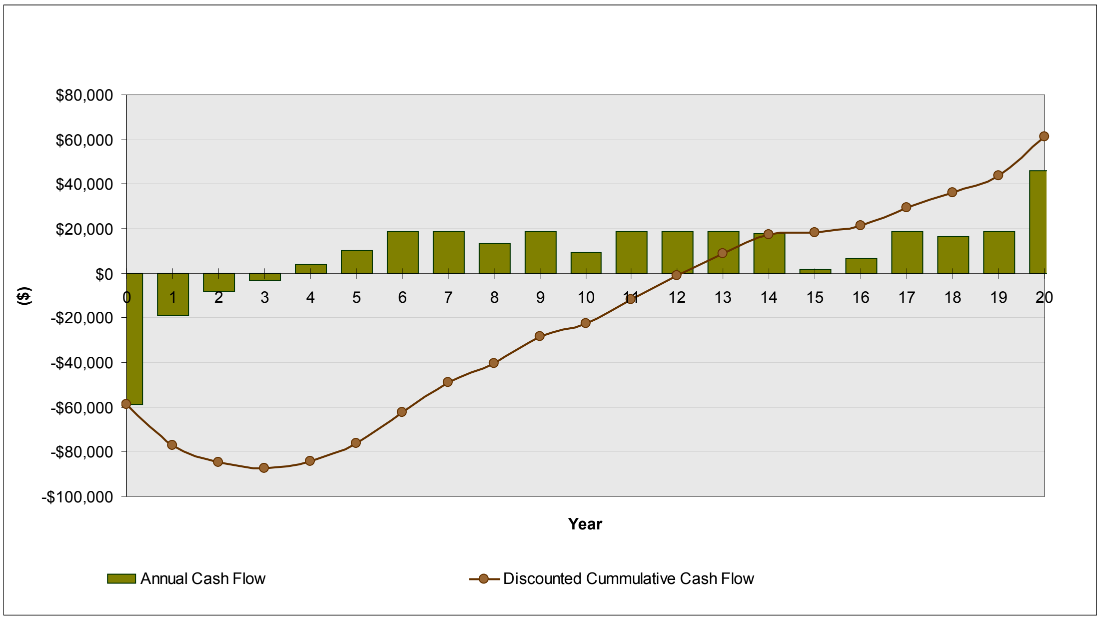


Figure 49. Projected discounted farm cashflows, showing breakeven point

Discussion and Conclusion

The key investment criteria suggest that cocoa will be a profitable activity when grown as an adjunct to other profitable farm activities. The most important determinants of profitability are generally yield and price but producers need to be mindful of the significance of fertiliser, harvest and capital costs.

This study has many limitations, perhaps the most important being that most producers will follow different establishment and production strategies. Never-the- less the study provides a useful indication that cocoa may be a profitable sideline on some FNQ farms but growers should always do their own sums first to be assured that cocoa really is for them.

Acknowledgements

To cocoa growers in the Innisfail and Mossman region who contributed input data and feedback on the budget.

Implications

The project has added further support to the development of a new prospective industry for northern Queensland.

The project has experienced a number of disappointing outcomes with three of the original four project supported growers no longer producing cocoa. The departure of two of these growers was in part due to the occurrence of Cyclone Yasi in February 2011 which destroyed a large proportion of standing trees with further loss of surviving trees in the six months post cyclone.

However, one grower has despite all odds continued to plant following the destruction caused by the cyclone and expanded, commenced fermentation and produced chocolate. This has in some part helped promote the entry of two new growers since late 2012.

Four growers in Mossman originally aligned to Cocoa Australia and now Daintree Estates continue to produce, ferment and dry cocoa bean for shipment to a specialist interstate chocolate manufacturer. They were relatively unaffected by Cyclone Yasi and have continued to produce product. The project personnel have maintained a regular dialogue and support with this group.

Potentially a north Queensland cocoa industry based on the production of premium quality fermented dried beans could develop up to a 1,000 hectares producing up to 3,000 tonnes of dried bean. The raw product value to the region would be in the vicinity of $10 to 12M. This volume of production can be easily absorbed into the cocoa market and only partially meet the increasing demand for high quality fermented cocoa bean.

Recommendations

Issues which still require further work and resolution include;

1. The availability of chemicals (permit or registered) for the control of a range of pests and diseases. Any further work in this area should be linked to a ICCO publication (Bateman, 2009)

2. Updating the Cocoa Growers manual first published in 2009 and place the publication on the RIRDC publications web site

3. Providing continued support and industry development to the embryonic cocoa industry with particular reference to recent new plantings

4. Assisting in the location of new high yielding genetic material and subsequent importation and evaluation

5. Supporting the development of a stand-alone budget spreadsheet which perspective growers can use to assess industry profitability based on their preferred inputs.

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Commercialising cocoa growing in North Queensland

By Yan Diczbalis

Pub. No. 13/114

This report is about the commercialisation of cocoa including growing, harvesting, fermenting and chocolate manufacture in far north Queensland. The work is important because it is another step towards the development of a small and stable cocoa industry of regional importance in far north Queensland.

The report is targeted towards government Research and Development agencies and potential growers and producers of cocoa.

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