Department of Agriculture and Livestock

AGRICULTURAL RESEARCH DIVISION

1984 - 1988 ANNUAL RESEARCH REPORT

DEPARTMENT OF AGRICULTURE AND LIVESTOCK, PAPUA NEW GUINEA

CONTENTS

ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research
AVRDC	Asian Vegetable Research and Development Center
CAB	Commonwealth Agricultural Bureau
CCRI	Cocoa and Coconut Research Institute (PNG)
CRI	Coffee Research Institute (PNG)
CIBC	CAB International Institute of Biological Control
CIP	CAB International Institute of Parasitology
CMI	CAB International Mycological Institute
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAL	Department of Agriculture and Livestock (PNG)
EEC	European Economic Community
HAES	Highlands Agricultural Experiment Station (PNG)
HFSRT	Highlands Farming Systems Research Team
IBPGR	International Board for Plant Genetic Resources
IBSRAM	International Board for Soil Research and Management
IDRC	International Development and Research Center
IITA	International Institute for Tropical Agriculture
IRETA	Institute for Research, Extension and Training in Agriculture (University of the South Pacific)
ISNAR	International Service to National Agricultural Research
LAES	Lowlands Agricultural Experiment Station (PNG)
LFSRT	Lowlands Farming Systems Research Team
OPRA	Oil Palm Research Association (PNG)
PNG	Papua New Guinea
SCCREP	Smallholder Cocoa and Coconut Rehabilitation and Extension Project (PNG)
SMAFSP	Smallholder Market Access and Food Supply Project
SPC	South Pacific Commission
UOT	University of Technology (PNG)
FSR	Farming Systems Research
RRA	Rapid Rural Appraisal
SE	standard error
SD	standard deviation
LSD	least significant difference
*	significant at 5% probability
**	" " 1 % "
***	" " 0.1% "
DMRT	Duncan's multiple range test -- in any table means followed by the same letter are not significantly different at the 5% probability level
a.i.	active ingredient
asl	above sea level (altitude)
DAP	days after planting
K	Kina (1.05 US Dollars)
kcal	kilocalories
ppm	parts per million
od	oven dry weight
km	kilometre
m	metre
cm	centimetre
mm	millimetre
ha	hectare
t	tonne
kg	kilogramme
g	gramme

INTRODUCTION

This consolidated annual report covers a period of rapid and radical change for the Agricultural Research Division.

Prior to 1984 our research programme was instituted along discipline lines with agronomists, pathologists and entomologists working more or less independently of each other. Much of the research was directed towards the major cash crops, coffee, cocoa, coconut and tea, and relatively little towards the subsistence sector.

From 1983 onwards responsibility for the major commodity crops, coffee, cocoa, coconut and oil palm was gradually handed over to semi-autonomous research institutes largely funded by the growers themselves. Since this change was phased, research on some aspects of these crops is still to be found in this report.

A new Crops Research Division was created to conduct research on all crops not covered by the commodity research institutes, with particular emphasis on subsistence food crops. Partly as a result of the visit of an ISNAR review team in 1983, the research method was changed from a discipline orientated approach to multi-disciplinary team work.

Farming systems teams were instituted. The Highlands Farming Systems Team, based at Kuk Research Station in the Western Highlands province, was mandated to conduct research on sweet potato based farming systems.

The Lowlands Farming Systems Research Team, based at Bubia in Morobe Province, was mandated to pursue research on taro, banana and yam based farming systems.

The coffee, cocoa and coconut based farming systems research was initiated because it is now recognised that an increasing number of farmers grow both cash and subsistence crops on the same piece of land. These research programmes are designed to complement research by the respective research institutes.

A lack of focus in some of our research had been evident prior to the period covered by this report. Part of the reason for this has been an initial difficulty in identifying the major problems of the smallholder in producing his crops. The Rapid Rural Appraisals described in some detail in this report were designed to meet this deficiency, giving the research programmes both relevance and direction.

More recently there has also been a tendency to ignore crops not present in the existing farming systems, hence research programmes were initiated to encourage crop diversification.

For example, introduced vegetables are increasingly important as sources of cash income for smallholders taking advantage of the selective import ban. The first results of a research programme on introduced vegetables will be found in this report.

In addition, emphasis is now being placed on alternative cash crops to cocoa and coconut that are currently suffering depressed prices. Our spices research programme reported herein is the response to this demand.

The maintenance of plant genetic resources continues to be a task for all research stations. Many of the national germplasm collections were initiated in accordance with IBPGR protocols.

The efforts of the Crop Research Advisers, Frank Bolton and Richard Viner, in collecting and editing this material from disparate sources are acknowledged. A number of the scientists responsible for the work reported here have transferred out of Papua New Guinea and it has therefore been impossible to consult with those responsible for each and every piece of research. We apologise in advance for any oversights in preparing this report.

The Agricultural Research Division gratefully acknowledges the assistance and cooperation of external agencies, Government organisations and other Divisions of the DAL.

The Director
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A Rapid Rural Appraisal in the Jimi Valley

J Joughin, B Thistleton, R D Ghodake, G Giago, M Gunther, A Iorive, M Jikian, K Kalit, M Kanua, J Kambkai, G Kitikai, P Kokoa, M Kuruma, S Silovo, T Sululo, J J Spencer and L Zimmer

Introduction

The Jimi Valley in Western Highlands Province is a region of fast-flowing streams and rivers, precipitous gorges, and large stands of virgin rain forest from which the local inhabitants collect firewood, building materials and other important resources such as birds of paradise, wild pigs, marsupials and many edible plants and mushrooms.

Located in the north of the province, the Jimi Valley includes the whole of the Jimi District with its three census divisions (Upper, Middle and Lower Jimi) and parts of two other census divisions - Dei and Baiyer - which are part of the Hagen North District.

The Jimi Valley covers an area of 2,382 km^2. It ranges in altitude from about 4,000 m in the northwest where the Jimi River flows into the Yuat River, to about 4,500 m on Mt. Wilhelm. Most of the valley is deeply incised by rivers, except in the lower reaches where the valley floor has been filled and levelled with prehistoric volcanic deposits. Rainfall is high throughout the district (>2,300mm).

The influence of man has modified the ground cover in many areas. Parts of the valley floor and much of the land to the north of the Jimi River are covered with fire-climax grasslands, while much of the land between 1,200 and 1,800 m has been converted to secondary bush as the result of the bush-fallow gardening. Most of the population of the Jimi District is located between 1,200 and 1,800 m. People have tended to avoid lower altitude areas because of higher disease incidence.

According to the 1980 National Census, the population of the Jimi Valley was 28,855 (12 people/km^2). The Jimi District held 9.8% of the total Western Highlands Province population and comprised 10.3% of the rural population. Most of the population live in Jimi District with 10,019 in Upper Jimi, 8,345 in Middle Jimi and 7,379 in Lower Jimi. The remaining 3,112 persons are living in Dei and Baiyer census divisions.

A primary activity of most inhabitants of the Jimi Valley is subsistence gardening. The main crop is sweet potatoes but a wide variety of crops is grown, including taro, yam, manioc, banana, sugar cane, marita and many other fruits and vegetables. In addition to planting gardens, Jimi Valley people also raise pigs, and to a lesser extent chickens and cassowaries.

While the bulk of daily food requirements comes from their gardens and wild forest foods, most Jimi households supplement their diet with tradestore foods such as rice, tinned fish, coffee and sugar. The money to purchase tradestore items comes primarily from the sale of coffee. Other income-earning activities in the Jimi Valley include the sale of timber and small quantities of individually panned gold, government and mission jobs, and the sale of cassowaries, kapul fur and bird of paradise feathers. Another source of cash is urban remittances from relatives working in other parts of the country.

Malnutrition in the Jimi District is identified in the National Nutrition Survey as being higher than the national average and much greater than the provincial average. There are also significant differences within the district as to the degree of development that has already occurred (*ie*, availability of roads, income earning opportunities and access to Government services). This RRA was designed to investigate the causes of underdevelopment, specifically of malnutrition, and to suggest both intervention and further research to alleviate the problem.

The appraisal

The RRA was conducted in two phases. The first phase involved the full team and covered three areas, Kol-Karap, Ambullua and Kwima/Tabibuga with a 24 hour visit to Bubgile. These areas were chosen because they have the highest population densities in the district and because the majority of the Jimi population lives not too far distant. In the second phase, a smaller team walked from Koinambe to Tsendiap in the Lower Jimi, carrying out fieldwork in villages on the way. This area was investigated since it appeared from the work in the first phase that malnutrition rates might be higher there than in the Upper Jimi.

Socio-economics

The people of the Jimi are poor by PNG standards and their poverty is a major cause of malnutrition in the area. Their low cash incomes are largely a function of poor access to markets, inadequate extension and marketing advice and a low level of other business opportunities. The team was not able to show that malnutrition is a result of a shortage of food and indeed subsistence agricultural systems appeared to be broadly stable. Questions of long term dietary inadequacy and the implications of possible seasonal food shortages could not be resolved in a short appraisal such as this.

Migration is also significant in terms of future population densities in the region. At present there appears to be no overall shortage of land and returning migrants experience few difficulties in acquiring suitable land for gardens and cash crops. However, with increasing development, a natural increase in population, a decrease in outmigration and the return of at least some migrants to the region, both individuals and groups may suffer from inadequate supply of land for subsistence purposes as well as cash crops.

The Jimi Valley is a remote area where cash earning opportunities are limited and where per capita incomes are low. Virtually all income earned in Upper and Middle Jimi villages is from agriculture, mostly coffee (90%), but also cardamom, vegetables and pigs.

In the Lower Jimi, coffee is probably the major source of income, although in some villages people earn money by panning for gold. Average income from cash crops is almost certainly below K30 per head, compared with K53 per head for average citizens income from cash crops in 1980. Total annual income in the Jimi Valley probably did not exceed K1,300,000 in 1987. This represents a per capita cash income of around K40. About 60% of this income is accounted for by sales of smallholder coffee. Villagers have a very poor understanding of why coffee prices fluctuate.

Cash income of the Jimi people is almost certainly a support to their nutritional status. Some 60% of trade store expenditure is on food, notably tinned fish (12%), fresh and canned meat (10%), flour and biscuits (13%), oil and dripping (6%) and vitamin enriched rice (13%). The annual pattern of expenditure appears to follow the mid-year coffee flush.

Soils and terrain

There were significant areas under cultivation in both the Upper and Lower Jimi that were above 1,800 m. The RRA team observed gardens at 2,050 m (Ambullua) and estimated that cultivation in this area went up to as high as 2,200 m. About 43% of gardens had slopes exceeding 30°; indeed there were parts of gardens going up to 50°. While there is still cause for concern and further work, it would appear that the situation is not as severe as claimed. Fallow periods average 15 years but are shorter in kitchen gardens. There was no evidence for a general land shortage although there may be unequal access to land in some villages.

Gardens are generally planted with the absolute minimum of tillage beyond that necessary for actual planting. This in itself is a significant soil conservation measure on steep slopes. The structure of the virgin soil gives it a tenacity that resists significant erosion even on very steep slopes. The quick ground cover provided by sweet potato protects the soil before significant degradation of the soil structure. A second crop on the same site would not have this advantage.

Results of soil analyses from the Upper and Middle Jimi collected during phase 1 of the RRA indicate reasonable fertility. However, soil pH was very low, it being a product of the nature of the parent rock and leaching by heavy rainfall. This would suggest that leaching of soil nutrients could accentuate fertility decline as fallow periods become shorter, reducing nutrient accumulation and organic matter build up.

Soil creep is widespread throughout the Jimi Valley. In a number of gardens there were numerous rock fragments on the surface and in the top soil. The major causes of soil creep are harvesting of sweet potato and rooting pigs in gardens that have been abandoned.

This land has been gardened from time immemorial and is still producing. It would seem that the traditional farming techniques that involve zero tillage and long fallows allow long term food production from these very steep slopes.

Agriculture

In the Upper Jimi, sweet potato is the dominant staple crop, followed by taro, chinese taro and banana, although at lower altitudes, cassava and yams become more important. In the Lower Jimi, taro, yams and banana constitute a very significant proportion of production. The greater interplant space of sweet potato in gardens of the Lower Jimi is filled with other crops. At Kwibun (960 m), the five cultivated species of yam that are indigenous to mainland New Guinea were recorded in one garden. These species are *Dioscorea alata*, *D. bulbifera*, *D. esculenta*, *D. nummularia* and *D. pentaphylla*. *D. esculenta* is a lowland species and it was only in the lower altitude areas of Kwibun-Kwima-Yembugena where it was observed. Many crops are represented by a few plants per garden. Production from the garden commences with beans, maize and cucumber. This is followed by sweet potato, then taro, yam, banana and cassava.

In the Upper Jimi, up to twenty varieties of sweet potato were recorded in individual gardens. This was far greater than the eight to ten that were common in the Lower Jimi, and very different from the one to two varieties that were recorded in the Kwima-Kwibun area. The number of varieties of banana represented in the Lower Jimi gardens was very much greater. These differences are indicative of the relative importance of the crops.

Sweet potato, banana and cassava tend to give a reasonably constant supply of food. Taro and yam on the other hand, produce for a limited period only. In the Lower Jimi, continuity of food supply is upset by the restricted production period of taro and yam that constitute a significant component of garden supply. Cash crops tend to compete with food crops for better soil, for plots close to the road and for residential areas.

Pests and diseases

Black Rot and Scab are present on sweet potato in many gardens. The effect on yield is to be assessed experimentally. No comments can be made on nematodes until the samples taken have been examined. Many other diseases were found on other crops, but were of largely minor significance.

Foliage damage to sweet potato by insect pests was not considered serious, although many species of both chewing and sucking insects were widespread. Sweet potato weevil damage was often found on the vines (1-100%). Other crops had minor pests. The only serious pests were the Diamond Back Moth on brassicas and Taro Beetle. Tomato may have serious problems from *Heliothis armiger* and *Spodoptera litura*.

Estimates of the loss in coffee income from the outbreak of Coffee Rust are unknown but are likely to be considerable. This will almost certainly lead to a major cutback in expenditure on store foods with serious implications for general nutrition. Unfortunately, after over a year, the Coffee Development Agency's (CDA) plans for rust control and rehabilitation are still unclear.

Infrastructure and services

Large areas of the Jimi Valley still lack adequate road access and this is a major constraint to the production and marketing of cash crops, to economic development generally and to the delivery of government services (including protection measures against Coffee Rust). New roads are under construction but their continued maintenance will be essential.

There is a general lack of understanding about effective business practices and market forces, a feeling that development is taking place elsewhere but not in the Jimi. The people are also quite aware that government services and support in the area are erratic. In situations where individuals and local groups feel that their interests are being compromised, there is a pronounced tendency for such individuals and local groups to withdraw their support and to allow such development projects to founder.

In the Provincial Government HQ, there is clearly inadequate communication within the divisions; the officers in DPI were unaware of the plans and policies of the Coffee Development Agency to combat Coffee Rust in the Jimi area.

The DPI extension service is inadequate. Staff ceilings and operational budgets are well below recommended levels. Villagers are quite aware that they are not receiving the services to which they are entitled.

Nutrition education has been conducted by monthly Family Services patrols and through the influence of many missions in the area. Further nutrition education is needed to identify the reasons for the non-implementation of earlier nutrition education.

Recommendations for action

Team recommendations requiring DAL involvement are:

1. The relationship between crop seasonality and periodic food shortages (taim hangri) should be investigated. In this connection variety trials of sweet potato should be conducted to investigate the possibility of using the varieties with different growing times to spread the food supply.

2. The role of certain crops in the system should be expanded and new crops introduced. Pulses and peanuts, for example, already exist in Jimi gardens but in small quantities and there is much potential to increase plantings. Seed multiplication should begin and the seeds distributed to the villages at low cost.

3. Soil acidity should be studied in relation to possible aluminium toxicity and nutrient availability. This could lead to a better understanding of how production can be sustained despite shorter fallows.

4. The effects of increasing the number of stems per planting station of sweet potato as an alternative to using multiple maturity types should be investigated.

5. The potential of fallow phase plants (yams, *Trema*, *Crotalaria*, *Tephrosia*, Guatemala grass etc.) should be investigated - possibly off site, in conjunction with agro-forestry work at Aiyura.

6. The effect of wet conditions on tuberisation

should be investigated. This was highlighted in the 1985 patrol to investigate food shortage problems in the Upper Jimi. The work would also relate to tuberisation problems in Enga and Southern Highlands Province.

7. The crop loss assessment work on nematodes, Scab and Black Rot should be continued. This is already part of the HFSRT programme, to be instituted at Gumine and probably Upper Mendi. Work in Jimi should be worthwhile.

8. The crop loss assessment experiments for sweet potato weevil should also be continued. These are, again, already part of the HFSRT programme for Kuk and Gumine.

9. Similarly, investigations into the pests of vegetables, particularly brassicas should be continued. The latter were often mentioned in the Jimi as having severe pest problems (Diamond-Back Moth). Further introduction of biological control agents would be desirable.

10. Cocoa and other coastal crops are already growing in some places. The potential for their expansion at the lower altitudes should be investigated.

11. Accurate climatic data in a number of locations is essential if many of the above recommendations are to be fully implemented.

Rapid rural appraisal in Gumine District, Simbu Province

R D Ghodake, P Watinga, M B Kanua, M P Levett, J Bailey and J Kerage

The district has a population of 37,000 and a density of 33/km², 85% live between 1000 and 2600m. Gumine station is 19 km from Kundiawa. The area has high population pressure, low soil fertility, a shortage of food and malnutrition. The steepness of the terrain concentrates the population on accessible and cultivatable land to as much as 430/km². Less than 3% of the land is flat. Annual rainfall is approximately 2000 mm per annum with a distinct dry season in May and August. There are three main zones; Nomane, Yani and Dawa. Yani has the highest population density (202/km²).

In 1986 fourteen scientists and technicians conducted a RRA. In all, 23 gardens and 24 households in fourteen villages were surveyed. Garden areas were from 0.03 to 0.37 ha. A household in the Yani Zone had only half the number of gardens of those in Nomane, and farmers had only 33% of their fields fallow in Yani as against 58% in Nomane. In Yani, 74% of fields were planted with sweet potato, compared with about 50% in Nomane. All Yani farmers grew coffee, compared with only 29% in Nomane. The average fallow was only 4.5 years in Yani compared with 21 years in Nomane. The number of plantings per cultivation was also double in Yani. The result of high population and low soil fertility will be increasingly serious for Yani farmers. In fact 72% of farmers recognised the land shortage. They also recognised the problem of soil fertility decline, reducing productivity by at least half in the second recultivation. In response, new gardens on better soil were planted to taro, yam, banana, sugarcane, pitpit, tapioca, maize and cabbage, whereas older gardens were put to sweet potato. Almost half the Yani farmers used some form of improved management -- fertiliser, seeds, plant protection etc., but few did so in the other zones.

Altogether 101 distinct sweet potato cultivars were grown by farmers. In the 23 gardens surveyed, the most frequent were Bogigi (57%), Morigi and Nilkulangi (52%), Spaği (48%), Ongi (39%), Doleagi (30%), and Tripelangi and Wanmungi (26%). The gardens were at 1620 to 2150 m on slopes of 4 to 35°. Sweet potato was progressively harvested until there was no yield, hence the low yield estimates (0.6 to 10.1 t ha^{-1}); only two farmers reported yields of more than 4 t ha^{-1}. Mound density was uniform, 0.7 to 1.7 mounds/m², typically 20-25 cm high and 45-50 cm diameter planted with three cuttings. No compost or fertiliser was added.

There would be two or three recultivations with sweet potato, and towards the end of the garden life, *Casuarina oligodon* was planted in preparation for a long fallow.

Based on the above observations a series of trials was started to test the response of these soils to improved fertility, use of crop rotation, compost mounding and contour mounding, as well as controlled fallows. Few Casuarina seedlings survived so the the dominant fallow species were *Mischanthus floridulus* and *Imperata cylindrica* (kunai). It was proposed to test two Crotolaria species, Tephrosia, Pigeon Pea and *Casia didymobotrya* as alternatives.

On average, there were three adult pigs per household, with a total value of about K600. Although pig has been important to traditional subsistence agriculture in the highlands its importance is declining. As population increases, the pig's complementary role is changing to one of competition for food, and with food and cash crops for human labour and other resources. While pigs consume about 50% of sweet potato produced, around 20% of it is directly coming from what is suitable for human consumption, yet the pig's contribution to human diet is meagre.

In the Gumine area, many of the roads are impassable during the wet season. Most of the limited extension activity is directed towards cash crop farmers. Credit is almost non-existent. Markets are rudimentary and prices favour the buyers. Some vegetables, cauliflower, cabbage, broccoli, beans etc. are grown but the cost of production is high and again marketing remains a problem. Inputs are not used by most farmers, except for some fertiliser on coffee and purchase of coffee pulpers. Many were not aware of where these inputs could be purchased or how to use them correctly. Tribal fighting creates a strong disincentive for long term investment in agriculture, due to the damage caused to crops and property.

Rapid Rural Appraisal in the Bubia area

Team Members, LFSRT

The Lowlands Farming System Research Team, based at Bubia, conducted a diagnostic Rapid Rural Appraisal in August 1987, to orient future research towards the needs of small-scale farmers. More than 70 farmers in 27 villages were interviewed and over 80 subsistence gardens visited.

The objectives were to describe the farming system, identify constraints and rank the research priorities.

The survey area included the Huon, Kaiapit, and Mumeng Districts. Six social scientists and six biological scientists were on the team, representing nine disciplines.

Problems

Major: Banana Leaf Roller is a recent pest introduction and a severe problem, best resolved - if possible - by biocontrol. The other problems were drought, weak agricultural extension and limited access to credit.

Localised: Taro Beetle was a problem in the yam/ kongkong system. In the banana-based system, *Imperata cylindrica* (kunai) and *Rottboellia* were found to be major weeds. The giant African snail and occasional flooding were also major problems in some villages. Taro leaf defoliators, Leaf Blight and virus diseases were also evident. There was a shortage of taro planting material. Flood damage was an additional problem.

Minor: Fertility, land availability and slope were consistently listed as minor problems by farmers, though researchers ranked them as major. Pig damage to gardens was evident but tolerated.

Problems perceived by both farmers and researchers as major, and that the latter felt could be solved with the minimum of capital and labour, included drought and flooding damage, Banana Leaf Roller, and the weed, Mimosa.

Occasional problems were Black Pod of cocoa, Leucaena psyllids on shade trees and unidentified coffee diseases.

Institutional problems were access to markets, low prices, health, physical location, consumption, education and training, politics and communications.

Researcher perceived problems

The main biological factors affecting banana production appeared to be the Banana Leaf Roller, the Sigatoka complex and low fertility, the latter two unrecognised by farmers. Other problems were bacterial soft rots and possibly nematodes.

Workshop on planning research trials

Team members, LFSRT

A workshop was held at Bubia in March 1988 with the provincial extension service to develop a programme of on-farm and station research. It was attended by staff from Bubia, Labu, the Division of Primary Services, Morobe Province and Unitech.

The agreed priorities were:

Taro Beetle: The three control measures proposed were chemical, trap crop and ash. Labour inputs will be monitored.

Land availability/fertility: On-farm research to include chemical fertiliser, composting, planted fallow and integration of alley cropping with livestock.

Taro Leaf Blight: There will be farmer and researcher managed on-farm varietal trials screening for resistance using at least ten varieties from the Bubia collection.

Sigatoka: The extent to which the disease has reduced farmers' yields will first be determined in trials with and without control by fungicide spray.

Planting density: Monocrops should not be studied as they do not exist in village gardens. Initial trials should be taro+banana or taro+sweet potato.

Banana Leaf Skipper: Biological control using natural parasites is the only feasible means of controlling this insect pest.

Planting material: Expansion of taro production is limited by the lack of planting material. The simplest rapid multiplication technique would be to cut corms into small pieces each with a bud, dust with fungicide or ash and plant in a bed. This technique could easily be used by farmers.

Sweet potato weevil survey in Gumine

R Masamdu and T Solulu

The objective of the survey was to determine whether Sweet Potato Weevil, *Cylas formicarius* (Coleoptera: Cucurlionidae) was an important pest in the Gumine area of the Simbu Province.

This survey was conducted as part of a Rapid Rural Appraisal in South Simbu (Gumine District) in late July 1986. During the appraisal, fifteen sites were surveyed. At each site, 20 sweet potato mounds were selected from which main vines up to 30 cm from the base were assessed for the weevil damage and life stages.

A follow-up survey was conducted in October 1986 when fifteen gardens were surveyed for sweet potato weevil, where tubers were also examined.

Kuale, Goropa Gura, Wara Sua, Dimau and Woruma (1 and 2) sites were heavily infested by weevil (Table2.1). This was attributed to the high population density and consequent land shortage, that in turn led to intense sweet potato cultivation continuously for up to six years on the same land. Weevil populations had therefore built up and fallows were as short as three to four years. In the other areas such as Gomgale, Kilau and Nomane, more land was available, new gardens were more common and fallows longer.

Weevil infestations ranged from 1% to 78% (Table 2.2). This variation was due to age of plants and intensity of cultivation. Local cultivars did not appear to differ with respect to weevil damage.

Table 2.1 Sweet potato weevil assessment, South Simbu.

Village	Damage Vine (%)	Damage Tuber (%)	
Kuale	34	61	
Goropa Gura	35	0	
Wara Sua	60	7	
Nomane	4	-*	tubers not recorded
Ori	7	-	vine borer present
Biri (Bri)	4	0	
Tabai	0	6*	tubers damaged
Kilau	0	0	
Gumine	0	0	vine borer damage
Argigi	0	0	
Dimau	25	10	weevil damage
Woruma 1	75	-	severe weevil damage
Woruma 2	66	13	" " "
Gomagale 1	0	0	
Gomagale 2	6	0	

* new garden

Table 2.2 Sweet potato weevil assessment, Gumine District.

Village	Vine damage (%)	Remarks
Kanadan	61	
Golba	44	
Dingi Dalepa	12	
Boromil (Gubane)	12	
Boromil (Goldimaine)	33	
Kugalen	49+	weevil a problem
Yani	63	
Numakua	78	severe vine damage
Akua	9**	
Malaba	26	
Alkua	18	
Minaiba	1	
Koplekarma 1	38	
Koplekarma 2	3	
Yani	9	

** New garden, damaged vines used as planting material

\+ old garden

Banana production in Amele, Madang Province and the Vanapa River and Kabadi, Central Province

G A King, J Banag, R N Kambuou, K Ovia, A Ovia, P F Heywood and R L Hide

This was jointly researched by nutritionists from the Institute of Medical Research and agricultural scientists from DAL, and was funded by the PNG Biological Foundation.

The objective was to compare production methods and yields, describe the uses of each cultivar, identify constraints and set research priorities.

There were surveys of the gardens, market and consumption (the latter two only in Madang Province).

Diploids are more important in wetter areas. There was no seasonality in banana production. In Madang Province there was no seasonal variation in price and at each survey round over 60% of women reported consuming bananas.

Although 38 banana cultivars were grown by Amele farmers, the average farmer grew only eight. Four diploid cultivars accounted for 64% of all cultivars. A much wider range of cultivars was grown in Central Province gardens but again just a few cultivars dominated.

Potassium and phosphorus are most likely to constrain yields in the Amele area. Fallows were less than six years in 12% of gardens and between six and ten years in 46% of gardens; land is therefore limited. Soil fertility and fallow lengths were adequate in Central Province gardens.

Black Sigatoka and Black Cross were serious diseases. The insect pests, fruit fly and thrips and flying foxes were more important in Central Province gardens, possibly due to the greater importance of triploids.

A survey of cocoa wet bean marketing

B Gaupu and C Gimbol

Cocoa is one of the most important tree crops of Papua New Guinea. First introduced by the Germans in 1900 and grown primarily as a plantation crop until the 1970s, the trend is now for an increasing proportion of production to come from smallholders. After coffee, cocoa is the second most important agricultural export crop and provides income to 70,000 households.

The last survey of smallholder cocoa was conducted in 1973. In 1985 the Queensland Department of Primary Industries, DAL and Cocoa Board of PNG conducted a survey on the cocoa plantation sector. Following this plantation study, the ACIAR reformulated the smallholder component as "Designing Monitoring Systems for Smallholder Agriculture in Papua New Guinea". Out of the main smallholder cocoa and coconut survey, a supplementary study on the marketing of cocoa wet bean was simultaneously conducted.

East New Britain, East Sepik, Madang and Oro were surveyed. In East New Britain surveys were conducted at major buying points. Roadside trading is more common in the other three provinces and data were collected by accompanying the buyers and interviewing farmers as they sold their wet beans (Table 2.3).

Table 2.3. Number of respondents for the wet bean market survey.

Province	Male	Female	Total
East New Britain	36	19	55
East Sepik	32	9	41
Madang	24	11	35
Oro	27	9	36
Total	119	48	167

East New Britain differed in travelling distance and marketing costs. The average distance to market was 10 km and transport cost 10% of sales. Overall, 75% sold their wet bean to the roadside buyers or lived close to the dealers and so did not pay for transport (Table 2.4).

Wet bean sales varied from 15 kg in Madang to 83 kg in East Sepik Province (Table 2.5). Differences in quantity sold and income received in each province can be attributed to number of harvests per month/year. For instance, in Oro and East Sepik, wet beans are harvested once a fortnight while in East New Britain harvesting is more frequent. Prices ranged from a low of 18 toea/kg in Madang to 30 toea/kg in East New Britain. The average income received from wet bean sales during the survey was K14, at 25 toea/kg.

Table 2.4 Distance to the market and transport cost of cocoa wet beans.

Province	Distance to market (km)	Paid for transport Yes	Paid for transport No	Transport cost (t/kg)
East New Britain	10	73	27	2.7
East Sepik	0	2	98	0.1
Madang	0	0	100	0
Oro	0	0	100	0
All respondents	-	25	75	-

Table 2.5 Average quantity sold, price and amount received.

	Quantity sold (kg)			Price (Toea/kg)			Income (Kina)		
	Min	Max	Av	Min	Max	Av	Min	Max	Av
ENB	8	696	67	25	36	30	2	201	20
ESP	0	794	83	15	30	23	0	223	21
Madang	5	27	15	15	26	18	1	5	3
Oro	12	431	45	25	30	29	3	62	13
Mean	6	487	53	20	30	25	2	123	14

Marketing practices and accessibility varied considerably.

East New Britain, particularly the Gazelle Peninsula, has an excellent road network and market access is easy so prices were better at fermentary doors. Transport cost is standardised at 3 toea/kg, irrespective of distance. Roadside buying in the other three provinces reflects, in general, difficult access, poor roads and inefficient transport, resulting in lower prices offered to growers.

Cocoa based farming systems

G Ling

Increased cash cropping has left less land for food gardens and diverted labour away from traditional crops. Of economic necessity the farming system has evolved to combine cash and food crops.

There are seven cocoa farming systems trials reported here, two formal and the rest observation trials, including one off-station.

1. Cocoa intercropped with food crops during establishment

The aim of the trial was to assess the growth, yield and economics of intercropping food crops whilst establishing hybrid cocoa.

In 1985 at LAES, food crops were planted at the same time as Gliricidia, and the cocoa seedlings planted 10 months later, when shade was adequate. The Gliricidia was planted at 4 x 4 m instead of the more usual 2 x 2 m, thus cocoa planting was delayed by 4 months. The intercrop combinations were:

a) Cocoa/Gliricidia/food crops
- Maize
- Snakebean (*Vigna unguiculata*)
- Karakap (*Solanum nigrum*)
- Peanut
- Sweet potato
- Cassava
- Chinese taro (*Xanthosoma* sp.)
- Yam
- Cooking banana

b) Cocoa/Gliricidia/banana/food crops
- Maize
- Peanut
- Cooking banana

c) Cocoa/Triploid banana/Chinese taro
- Chinese taro
- Eating banana

d) Cocoa/Gliricidia (Control)
- None

By 1987 the only food crop left was triploid banana. Cocoa harvests started towards the end of 1988 and full production is expected in 1989.

Weed control. Only the treatment with taro and banana was weed-free for the five crucial months after establishment. Treatments where the annual food crops had been removed were later invaded by weeds, and in the control (cocoa alone) weeds had fully covered the plots and required slashing. These differences, however, evened out with time as Gliricidia shade increased, equalising weed suppression in all treatments.

Gliricidia. Shade tree growth was slower in treatments with mixed food crops or sole-cropped cocoa, principally due to weed competition in the former and inadequate weed control in the latter, wherein weeds were only slashed.

Early cocoa establishment and yield. The triploid banana/chinese taro combination enhanced cocoa growth during the crucial five months after establishment by providing shade and weed control. Cocoa girth and jorquetting height at nine and 15 months were unaffected by intercropping with food crops. In the first year of bearing, however, yields were similar (518 to 555 pods/ha) for all treatments except where cocoa had been intercropped with triploid banana and Chinese taro. In the second year, the control (no intercrops) had more pods (14,726/ha) than plots that had mixed crops or intensively managed annual crops (12,543 and 12,367/ha) and nearly twice as much as plots with banana and taro, wherein the intercrops were of longer duration.

If yields of the main crop in an intercrop combination are noticeably depressed or delayed a cocoa grower is unlikely to intercrop and may be better off with sole crop cocoa and food crops planted separately. If, as is claimed, smallholders must intercrop, then choice of crop, planting time, variety and management must be improved so as not to compete noticeably with the cocoa.

Food crops. The net returns were greatest (K3503/ha) when banana, maize and peanut were intercropped with cocoa, second best was the intercrop with banana and taro (K > 1216/ha). Cocoa with mixed crops alone was only marginally (K520/ha) better than the cocoa sole crop. At least two years of full bearing by the cocoa are needed before a final assessment can be made.

2. Mixed food cropping during cocoa renovation with fruit and nut trees as shade

The objective of these observation blocks was to compare mixed relay and intercropping during cocoa renovation and to substitute shade of Gliricidia by cash earning fruit and nut trees. The cocoa was still good material but canopies of both the cocoa and shade trees were unmanageable. The renovation period provided a fallow from pests and diseases for the renovated cocoa and as such may be preferable to infilling an old stand. Pest and disease riddled trees were removed and misses replanted.

A range of fruit and nut trees will provide permanent shade at the normal 25%, usually provided by Leucaena or Gliricidia, by varying the spacing according to species. Diploid banana and food crops were used as temporary shade.

A. Banana+aibika followed by chilli, undershade of betel, durian, paunut and tulips. Old cocoa was stumped in 1987, old Leucaena was removed, banana suckers, betel nut seedlings and aibika were planted, without tillage. Aibika was replaced by chilli ten months later.

Aibika was tested with and without fertiliser and insecticides. With both fertiliser and insecticide the yield was threefold greater; insecticide alone raised yields 150%. The principal pest was the Leaf Roller. Gross returns were K6924/ha.

Unfortunately the number of recovered stumps was low because the block had been devastated by Pantorhytes and termites and there were already many misses. Where serious pests such as these are present, new development is advisable.

B. Banana+taro+vegetables, under shade of Kalava, Galip, Carambola, Pomelo, Aela, Bukubuk, Breadfruit and mango. Cocoa was stumped in mid 1987 and diploid banana was planted two months later. Taro and vegetables (melon, maize and snake bean) were planted without tillage in September. At the end of 1987 the cocoa replants and betel nut seedlings were planted as the vegetables were harvested. Taro was harvested four months later.

Shade is provided by Galip nut (*Canarium inidicum*), Carambola (*Averrhoa corambola*), Laulau (*Eugenia malacconis*), Pomelo (*Citrus paradisi*), Aela (*Inocarpus fragiferus*), Breadfruit (*Airocarpas altilis*) and Mango (*Mangifera indica*) as well as Kalava (*Ormocarpum senoides*).

A no-till mini-trial was also included. Taro was planted at three densities, 764, 528 and 272 planting positions, with a corresponding increase in vegetable planted positions from 840 to 3342. Yields were low, none exceeding 0.8 t ha^{-1}. Gross returns ranged from K622 to 822/ha, greatest returns being for snake bean (K220 to 315), Xanthosoma (K89 -197) and banana (K100 -152/ha).

Another observation trial, identical to the above, was established on a farm in Viviran village. Cocoa and betel nut seedlings were planted in early 1988. The food crops and cocoa are managed by the farmer.

C. Banana+chilli under Kalava shade. Kalava was the only permanent shade species, and chilli the only vegetable. Cocoa was stumped in August 1987, banana and Kalava were planted one to two months later. At the beginning of 1988, cocoa replants were introduced, at the same time as betelnut was planted. In September 1988 chilli was planted, but yields were low due to infrequent harvesting. Stumped cocoa in the first year yielded 12 times more than replants (917 pods/ha). Banana yielded only 1.5 t ha^{-1}, valued at K293.

3. Intercropping cocoa with pepper under betel nut.

Betelnut is commonly grown in smallholders' cocoa blocks; the extent of the interaction is not known. Betel was planted in 1980 at 4 x 4, 3 x 3 and 4 x 2 m, cocoa and pepper were then intercropped in early 1988:

a) palms and cocoa 4 x 4 m square, one pepper on each palm;

b) palms and cocoa 3 x 3 m triangular planting (no pepper) with good management (fertiliser and herbicide);

c) palms as 4 x 2 m hedges, cocoa 4 x 4 m square and pepper every second palm.

In sub-blocks a) and c) weeds were only slashed and no fertiliser was applied. First and second series hybrids were planted in subplots.

One year after planting, girth was greatest in the cocoa+pepper under betel (a), but well-managed cocoa (b) was the first to flower.

4. Cocoa under Kalava or betelnut shade

Gliricidia requires much labour for pruning, Kalava is being tested because it is less vigorous. Kalava is also a legume and a traditional vegetable. Betel nut is a well established cash crop.

a) Gliricidia 4 x 4 m within cocoa rows (control)

b) Kalava " " " "

c) as b) but with betel nut between cocoa rows

d) as c) but with betelnut as a 4 x 2 m hedge a metre out from the cocoa rows;

e) Kalava as a 4 x 2 m hedge one metre out from the cocoa, betel within cocoa rows; and

f) Kalava planted 2 m square between the cocoa rows.

The Kalava, Gliricidia and banana suckers were planted out at the beginning of 1988, betel and cocoa were planted in October 1988.

By 14 months cocoa girth averaged 10.5 cm, being marginally greater in treatments e) and f) with dense planting of Kalava. Of the three treatments with betel nut (c, d and e), the tallest seedlings, and those with greatest girth, were when the betel was planted as a hedge (4 x 2 m) one metre out from the cocoa row.

COCOA

Most production increases over the last ten years have been from smallholders in North Solomons, East Sepik and Madang Provinces (Table 3.1 and Figure 3.1). Smallholders cannot afford the inputs necessary for crop protection, therefore the breeding programme now concentrates on selection and crossing pest and disease resistant material. Only trials started under DAL management are included in this report. Trials started after 1986 are reported separately by the Cocoa and Coconut Research Institute.

Table 3.1. National cocoa production (1985/86)

Province	Total (t/year)	(%)
N Solomons	16080	49.6
E New Britain	9880	30.5
East Sepik	1909	5.9
Madang	1840	5.7
New Ireland	976	3.0
W New Britain	822	2.5
Oro	516	1.6
Morobe	217	0.7
West Sepik	103	0.3
Manus	86	0.3
Central	50	0.2
Milne Bay	27	0.1
Gulf	3	<0.01
Total	32509	

Breeding

The locally adapted Trinitario (Criollo x Forastero) cocoa was introduced about 1900. It is heterogeneous, varying widely in pod and bean size as well as pest and disease resistance. Some 300 selections have been collected at Keravat. In the 1960s Upper Amazonian types were introduced from Trinidad and Amelonado from Ghana and in the 1970s from Puerto Rico. In 1981 mainly Trinitario material was introduced from Kew. Selected Trinitario cocoa (polyclonal seed) was the first improved material distributed to farmers. Clones were initially selected and propagated as cuttings, this was later replaced by the highly successful budgrafting technique.

The aim of the Cocoa Improvement Programme is to raise yield without sacrificing fat content, flavour or resistance to pests and disease. The first hand pollinated crosses were 21 combinations of seven Trinitario and seven Amazonian from which three parents of both types were chosen for multiplication of hybrid seed in seed gardens.

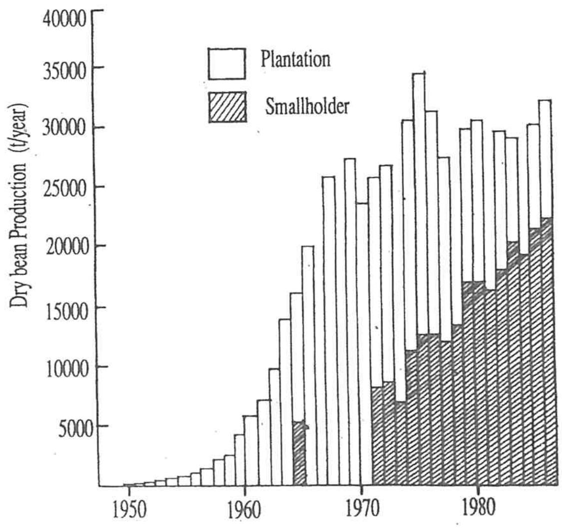

Figure 3.1 Smallholder and plantation cocoa.

The best crosses in the first progeny trial produced outstanding yields in the first 4-5 years(1973-78), in excess of 3 t ha^{-1} even under shade and without fertiliser. However, the yields from this trial fell to 300 kg ha^{-1} by the seventh year due to Black Pod disease (*Phytophthora palmivora*), and possibly genetic factors. Due to the large number of crosses there are now three progeny testing trials aiming for high and early yield with Black Pod resistance. Trinitario parents were selected for high yield and Vascular Streak Die-back (*Oncobasidium theobromae*) resistance and Amazonian for VSD and Black Pod resistance.

In addition there are hybrid clonal trials, a scion/stock interaction trial and trials for crosses of Amelonado with Trinitario and Amazonian.

About fifteen progeny trials and seven clonal trials were in the field during 1984-88:

Table 3.2. Progeny Trial I: Trinitario x Amazonian crosses (kg ha^{-1}). Planted 1973.

Cross	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
K21 x KEE40	177	962	1606	2028	1672	312	386	1361	1307	1667	1344
K21 x KEE51	218	583	734	1420	1469	263	498	1101	1092	1516	1317
K21 x KEE2	310	1257	1698	2506	2617	671	504	1617	1468	2295	1769
K24-103 x KEE40	153	743	870	1451	1812	317	213	1066	1209	1803	1714
K24-103 x KEE34	135	719	983	1427	1495	266	319	1288	828	1339	1055
K24-103 x KEE52	320	1196	1168	1722	1605	148	327	1384	1253	2145	1908
K20 x KEE40	375	1281	1353	2046	1782	778	761	1150	1699	2548	2139
K20 x KEE5*	510	1416	1682	2935	2324	511	247	1503	1135	2117	1973
K20 x KEE19	162	767	497	1754	1206	193	247	903	946	2015	1541
KA1-105 x KEE51	311	877	1220	1564	1438	210	320	1027	8601	421	1106
KA2-195 x KEE34	173	799	1381	1628	1355	239	308	131	973	1762	1508
KA2-105 x KEE5	465	1574	2267	2937	2367	331	358	1932	2004	3046	1889
KA2-101 x KEE51	515	1191	1297	2001	1947	370	268	1272	1266	1906	1430
KA2-101 x KEE52*	475	1422	1587	2500	1909	235	396	1728	1441	2213	2253
KA1-101 x KEE19	300	1385	1606	2535	2086	457	262	1550	1262	2773	2082
KA5-104 x KEE2	101	801	850	1563	1835	224	255	1264	1144	2479	2419
KA5-104 x KEE34	263	781	538	1125	1440	286	442	1492	1505	2261	1484
KA5-104 x KEE19	190	737	349	947	1286	245	197	1079	1049	2179	1653
KA5-201 x KEE2*	540	1198	1677	2908	3026	540	133	1577	1844	3470	2499
KA5-201 x KEE52*	334	902	1338	2044	2004	318	241	994	975	2274	1878
KA5-201 x KEE5*	928	1682	1765	2850	1690	200	244	1414	1629	2356	1902
Local crosses (Trinitario x Trinitario)											
K82 x K26	234	875	755	1242	1143	294	379	940	1164	1591	1030
K6 x K4-101	303	1063	299	528	1004	212	211	974	1069	1236	986
KA2-106 x KA2-201	42	458	569	912	1229	392	249	730	663	1284	768
K24-103 x K60	230	725	834	1365	730	181	381	812	677	1632	1063

* these crosses are distributed for commercial planting

Progeny trials

I Trinitario x Amazonian (KTC 51)

In 1971, 54 hybrids (3456 trees) of Trinitario x Amazonian were planted, with both parents being selected for high yield. Additional requirements were lower susceptibility to Vascular Streak Dieback (VSD) in the Trinitario and Amazonian parents.

Yield decline set in at year seven, so in 1979 shade was removed and fertiliser applied, but the trend continued to 1982 when the average yield was just 399 kg ha^{-1}. The decline was attributed principally to Black Pod that to date had been inadequately controlled by hooking infected pods and cherelles, and spot spraying trees with more than 10% infection. In 1982 low volume spraying of metalaxyl (Ridomil 250EC) and cuprous oxide (Sandoz) was started to reverse the decline. By 1984 the yield had increased dramatically, the highest yield was 3.5 t ha^{-1} for KA2201 x KEE2 (Figure 3.2).

Production data for the top 21 hybrids is presented in Tables 3.2 and 3.3. A principal advantage of the hybrids is that they come into bearing early. Roughly 100 to 155 pods were produced from each tree, their potential yield (pod production/pod value x no. of trees/ha) was in excess of 3 t ha^{-1}, and all out-yielded the Trinitario standards. High yields may in part be due to the absence of pronounced peaks in production in the early years.

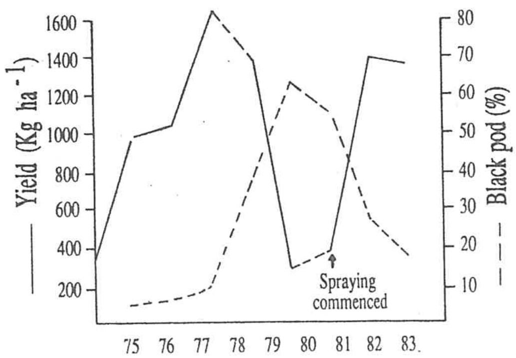

Figure 3.2 Black Pod incidence in KTC51.

Table 3.3 Progeny Trial I (Trinitario x Amazonian), pod values, total yield (1975-85) and stand (1985).

Cross	Pod value	Cumulative yield (t ha^{-1})	Stand (%)
K21 x KEE 40	19.1	12.8	71
K21 x KEE 51	21.3	10.2	56
K21 x KEE 2	21.3	16.7	77
K24-103 x KEE 40	17.1	11.3	87
K24-103 x KEE 34	20.2	9.9	69
K24-103 x KEE 52	15.2	13.2	90
K20 x KEE 40	16.5	15.9	79
K20 x KEE 5*	17.4	16.3	79
K20 x KEE 19	22.1	10.2	63
KA1-105 x KEE 51	24.1	10.3	77
KA2-195 x KEE 34	21.7	11.4	69
KA2-105 x KEE 5	18.5	19.2	77
KA2-101 x KEE 51	28.8	13.5	94
KA2-101 x KEE 52*	17.3	16.2	85
KA1-101 x KEE 19	22.5	16.3	77
KA5-104 x KEE 2	21.8	12.9	77
KA5-104 x KEE 34	23.0	11.6	50
KA5-104 x KEE 19	21.9	9.9	56
KA5-201 x KEE 2*	21.6	19.4	69
KA5-201 x KEE 52*	22.6	13.3	73
KA5-201 x KEE 5*	17.9	16.7	92
Mean	20.6	13.7	75
Local crosses			
K82 x K26	22.3	9.6	69
K6 x K4-101	24.1	7.9	72
KA2-106 x KA2-201	26.3	7.3	90
K24-103 x K60	20.5	8.6	58
Mean	23.3	8.3	72

* these crosses are distributed for commercial planting

Most of the progeny had pod values below 20 and three had values below 15. Butter fat (58.5%) and shell contents (15.4%) are high compared with West Africa (56 and 12.5%), and chocolate flavour poor (>5.4 vs. 2.3), due to high acidity and astringency, but these are the best results ever recorded in PNG (Table 3.4). To improve the taste of PNG hybrid cocoa a small box technique of fermentation was developed, modified from work in PNG and Malaysia. Initial results suggest the problems of acidity in fermented cocoa beans can be solved.

Table 3.4. Cocoa quality characteristics+.

Progenies	Shell (%)	Butter (%)	Value Index	pH	Flavour score*
Hybrids					
TA17	15.5	54.1	91.2	4.7	6.2
TA24	14.0	59.2	101.9	4.7	6.8
TA25	13.6	59.1	101.2	4.8	7.0
TA27	12.6	60.4	105.7	4.8	7.0
TA34	13.9	56.0	96.2	4.8	5.6
TA35	13.2	55.2	95.9	4.8	7.2
Standard clones					
TA29	16.1	57.3	95.9	5.0	5.4
Commercial cocoa					
PNG	17.6	55.4	93.2	-	-
Malaysia	16.0	57.0	95.9	-	-
Brazil	12.8	54.5	94.4	-	-
Ghana	12.4	57.4	100.0	-	2.3

* chocolate score is 1 (excellent) to 9 unsatisfactory (Cadbury-Schweppes, Aust.)
+ Source: Cocoa Industry Company Limited

The trial was terminated in 1987/88, with a complete 12 year record.

The following cocoa breeding trials were conducted by the Cocoa Industry Company Ltd. and cover the period up to 1986 when the CCRI was officially formed and whose reports were then separate.

I Trinitario x Amazonian progeny trial

The trial at the Tavilo Research Centre Keravat was planted in 1981. There are 54 hybrid progenies with both parents selected for high yield, low susceptibility to VSD in the six Trinitario female, lower Black Pod in the nine Amazonian male parents, and yield components (pod and bean, weight and number). The two standard hybrids were TA 21 and TA 29. Management standards were high: 4 x 280 g/tree/year NPK (15:15:15), canopy pruning, Black Pod control with metalaxyl and 10-20% overhead shade from Gliricidia.

From 1983 to 1985 the production from the young trees was uniform and increasing, but from 1986 onwards the bimodal (May and November peaks) production pattern of mature trees set in. About half the hybrid progenies produced more than 2 t ha^{-1} in 1984. After five years production the best eight progenies yielded more than 4 t ha^{-1}, and the best yielded 4.6 t ha^{-1} with a cumulative yield of 18.7 t ha^{-1} by 1988. Mean trial yield declined from a peak of 3.3 t ha^{-1} in 1986, through 2.9 in 1987 to 2.3 t ha^{-1} in 1988, though the latter was a dry year.

II Trinitario x Amazonian Progeny trial

In 1982 the 35 hybrids were planted. The yield reached 3.8 t ha^{-1} for the best cross. Cumulative yields were 1.8 (1984), 5.7 (1986) and 8.9 t ha^{-1} (1988); the best progeny was TA23 with 14.7t ha^{-1} (1988).

III Trinitario x Amazonian Progeny trial

In 1983, 15 hybrid progenies were planted, including two currently grown by growers. By 1984 the cumulative yield was 2.7 t ha^{-1}, reaching 8.1 in 1986 and 12.5 t ha^{-1} by 1988. The best progeny, TA3 produced 18.3 t ha^{-1} by 1988.

IV Reciprocal testing, Trinitario x Amazonian and Amazonian x Trinitario

The trial was not sprayed for Black Pod. No differences have been reported in field performance between hybrid progenies and their reciprocals.

V Trinitario x Amelonado and Amazonian x Amelonado

Amelonado is a more compact tree suitable for high planting densities, but highly susceptible to VSD, though less susceptible to Black Pod and Canker. The habit of bearing pods on the trunk is a desirable characteristic. Some of the unselected trees from the 1962 import from Malaysia have resistance to VSD.

Three Amazonian selections highly resistant to VSD were crossed with six Amelonado. Eight hybrid crosses of Trinitario x Amelonado and 15 Amazonian x Amelonado crosses were planted in 1983, but they proved less vigorous than the Trinitario x Amelonado control cross. All Trinitario x Amelonado crosses produced less than the control. Six Amazonian x Amelonado produced more than the control.

VI Trinitario x Amelonado

This progeny trial included 32 crosses, with parents as outlined in progeny trial V above. Tree size was smaller, requiring less pruning and other management, but long term yields will determine whether they are precocious. They may be appropriate for smallholders.

VII Diallel crosses of Trinitario

The PNG Trinitario material originated from a natural hybridization between Criollo and Forastero types in Trinidad; they were genetically heterogeneous so a wide range of material exists for crossing. The purpose of this crossing trial is to evaluate the yield and economically important characters for the less vigorous Trinitario crosses alongside the currently recommended hybrids; suitable for smallholders.

Ten Trinitario clones from the local population selected for high yield and disease resistance were crossed in all combinations (without selfing and reciprocal crosses). The resultant 43 crosses were planted in 1985. The promising crosses are to be used either for commercial planting material and/or breeding. The trial was planted in 1985; by 1988 cumulative yield of the best progenies (T49 and T67), barely equalled the lesser of the two control yields of 2.9 t ha^{-1}. The other control yielded 4.2 t ha^{-1} and the trial mean was barely 1.8 t ha^{-1}.

VIII New Trinitario x Amazonian Black Pod resistance (1)

The incorporation of Black Pod resistance into high yielding clones is one of the highest priorities. Currently only two Trinitario clones are rated as truly resistant. Using artificial inoculation of attached pods, 200 trees in an old cocoa block were screened, 12 have been selected as pollen parents to cross with 6 Amazonian female tester parents in all combinations. The resultant 72 hybrid crosses were planted under coconut in two blocks (42 and 32 crosses, one standard cross) at Raulawat plantation in January 1986. Interest is in their combining ability and incidence of Black Pod and canker.

IX New Amazonian Black Pod resistance (2)

The objective is to select new Amazonian parents with good combining ability. The trees are from a twenty year old block of Amazonian material from Peru, which may have different genetic composition to the existing selections (KEE series). Thirty Amazonian x Trinitario crosses were included, with a commercial mixed hybrid as a control. Trees were selected for resistance to Black Pod based on inoculation tests and field performance.

X Trinitario x Amazonian Black Pod resistance (3)

Four standard Trinitario clones (two resistant, one moderately resistant and one susceptible) were used as female testers with the 12 Amazonian males. The resultant 25 hybrids were planted at the end of 1986 with a commercial mixed hybrid as control. The trial was planted in late 1986, with the same objectives as VIII and IX above.

XI Trinitario x Amazonian Black Pod resistance (4)

Planted in late 1986, identical in structure to the progeny trial above, with 29 crosses of Trinitario X Amazonian and parents with a commercial mixture of Trinitario x Amazonian hybrids as control.

XII Ex-Sabah Amelonado (1)

The PNG Amelonado originated from six pods introduced in 1962, and presents a narrow genetic base (Progeny trials V and VI). In 1985 ex-Sabah Amelonado were collected from Dodo Creek Research Station near Honiara, Solomon Islands. The first trial was set up at Kurwina, North Solomons Province with 48 open-pollinated ex-Sabah Amelonado and two standard crosses.

XIII Ex-Sabah Amelonado (2)

In the second trial 54 open pollinated and one cross were planted at Kurwina. The crosses are also being tested at LAES for VSD and Pantorhytes resistance.

XIV Open pollinated ex-Sabah hybrids

The well known Sabah hybrids were tested against PNG hybrid cocoa. Ten thousand seeds of the open pollinated F_2 progenies of the Sabah hybrids were collected from the Solomons, where yields in excess of 3 t ha^{-1} have been reported. These hybrids were planted in 1985 at Kurwina and LAES.

XV Kew introductions

Twenty-one clones were introduced in 1981. Fourteen clones of the ex-Kew Gardens cocoa collection will be reintroduced, and some introductions from Miami are being kept at Laloki. The trial was planted in 1988. The aim is to evaluate hybrids from three local Trinitario and two Amazonian crossed with material introduced from Kew.

XVI Ex-Kew x Amazonian

Planted in late 1988, being 22 crosses of material imported to PNG from Kew in 1981 with four Amazonian selections from Keravat.

Seed garden I

From progeny trial I, 15 combinations of Trinitario and Amazonian were selected for high yield and resistance to VSD and Black Pod. Second generation cocoa hybrid seed gardens were set up at both Tavilo Plantation and LAES, each will produce in excess of 12 million seeds per year from 1987 onwards.

Clonal trials

G Y Tan

I hybrid selection (Trinitario x Amazonian)

The best 20 hybrid progenies (1188 trees) were first selected in 1982 from progeny trial I. They were placed in a replicated (6) trial to further evaluate their yield performance against the checks, KA2-101 and K82 to identify superior hybrid clones that will be recommended for commercial planting or further hybridisation. Thus far, several clones have yielded more than the controls and TAC4 is consistently producing high numbers of pods.

Pod values of all hybrid progenies ranged from 13.3 to 31.8 but 62.5% were in the acceptable range of 13 to 20. Bean weight was greatly improved (10 to 40%) by crossing small bean Trinitario parent K82 with any Amazonian line. However shell content of the hybrid progenies (14.7%) remained higher than the Ghanaian (12-13%), though butter fat content was comparable (56% vs. 54%). Progeny TA27 produced the highest butter fat content (60.4%) and lowest shell content (12.3%). High acidity (pH 5.2) and astringency, however, still limit chocolate flavour.

II Hybrid selections (Trinitario x Amazonian)

The second trial was to provide budwood; it includes 20 selections and was planted in 1982; VSD was recorded for individual trees. By 1988 average cumulative production was 9.0 t ha^{-1}, with TAC4 producing 18 t ha^{-1}, versus4.4-6.4 t ha^{-1} for the controls.

III Scion/rootstock interaction

Dwarfing rootstocks would permit high density planting. At present clonal material is grafted on unselected stock to produce budwood for distribution to growers. Seven clones (2 Trinitario, 3 Amazonian and 2 hybrids) were budgrafted on five rootstocks (seedlings of Trinitario, Amazonian, Amelonado and Trinitario x Amazonian hybrids) and fields were planted in1982. The material included individual selections from F_1 high yielding progenies. Pod production was more influenced by scion. Two rootstocks, K82 and Amelonado, were superior to the rest, but both had relatively low vigour. By 1988 TAC4 yielded 8.3 t ha^{-1} on K82,7.9 on Amazonian and 9.0 t ha^{-1} on Amelonado.

IV Material possibly resistant to Pantorhytes

A trial was established in 1983. It contained 21 Trinitario clones derived from Block 108 of LAES planted in the 1960s that had been devastated by Pantorhytes.

V Kew introductions

Established in 1984, were 20 clones from many origins introduced from Kew included to expand the genetic base. A standard Trinitario has been included as control. By 1988 yield was not promising, 1.8-2.6 t ha^{-1}.

VI Black Pod resistance (1)

Established in 1984 with eight Amazonian and nine Trinitario clones from Block 405 of LAES planted in 1958, and selected for possible above-average resistance to Black Pod. Three Trinitario clones were included for comparison. High yielding material will be used in future progeny trials. KEE6 is the highest yielder upto 1988.

VII Black Pod resistance (2)

Planted in 1985 and contains 12 Trinitario clones, with the objective of VI above.

Fertiliser response

G Ling

Unshaded cocoa. The currently recommended three-monthly applications of nitrogen originate from trials between 1958 and 1976, where it was found that the most economic application was 100 g N per tree every three months and that frequency was more important than rate. The superiority of three over six month application is already established. The present trial was started in 1985 with unshaded cocoa. Rates of N were from 20 to 240 g per tree at frequencies of one to three months. There was no ($P > 0.05$) response to fertiliser in the first two years of application (Table 3.5).

Table 3.5 Yield response of mixed hybrids to fertiliser N. Field planted 1980.

Fertiliser* Rate (g)	Interval (months)	Yield (kg ha-1) 1982[1]	1983[1]	1984[1]	1985	1986
Nil		82	597	1374	1436	1737
20	1	144	532	1578	1547	1384
30	1.5	71	390	1391	1844	2032
40	3	50	442	1195	1330	1234
50	1	42	444	1277	1665	1489
60	1.5	30	418	1449	1412	1635
120	3	51	402	1565	1773	1778
60	1	33	284	1143	1388	1718
90	1.5	83	471	1393	1744	1737
180	3	80	444	1224	1362	1435
80	1	76	444	1497	1763	1530
120	1.5	43	450	1431	1278	1714
240	3	63	520	1389	1453	1850

* g/plant ammonium sulphate
[1] Pre-treatment yields

Shaded cocoa. It is recommended that smallholders retain some shade to minimise damage from Pansepta and Pantorhytes. When the canopy is complete a shade density of one Gliricidia or Leucaena per four of cocoa is recommended. The fertiliser response under such shade is not known. In a trial with cocoa under shade, ammonium sulphate was applied at 150 or 300 g per tree followed by three half doses at three month intervals and compared with an unfertilised control. On the LAES soil, addition of fertiliser did not raise pod yields in the year following application, but may be of longer term benefit on less fertile soils, where the response may be significant.

Growth regulators

P Jollands

Paclobutrazol (PP333, ICI) and daminozide (Alar, Uniroyal) are broad spectrum growth retardants that reduce vegetative growth in perennial plantation crops. Use of such growth regulators reduces the pruning requirement, controls intertree competition and enhances fruit bud development leading to higher yield.

In earlier trials where young cocoa was sensitive to paclobutrazol, plants were stunted, girth was reduced and there was severe leaf deformation at 5 to 45 mg ai/plant. Early jorquette formation was reported but there was no effect on yield.

Daminozide is recommended commercially on cocoa in Malaysia where it reduces shoot emergence and increased fruit set and yield. These chemicals were applied to 18 month old (prebearing) cocoa as soil drench, strip or circular sprays of PP333, at 2 or 8 l ha^{-1} (8 and 3.2 g/tree). Alar was foliar sprayed at 360 g ha^{-1}. Applications were 1 litre per tree for soil drench, 168 l ha^{-1} strip spray and 250 l ha^{-1} foliar sprays (Table 3.6).

With paclobutrazol there was severe leaf deformation but enhanced yield, particularly using the soil drench at 8 l ha^{-1} applied in a circle around the tree. Alar gave no increase in flower production or yield.

Table 3.6 The effect of PP333 and Alar on flower production and yield.

Retardant application	Rate (l ha^{-1})	Flowers (no./week)	Yield (pods)
PP333			
Soil drench	2	47.9	128
" "	8	34.4	143
Strip spray	2	5.6	47
" "	8	2.3	23
Foliar "	2	3.4	11
" "	8	5.8	20
Circle "	2	14.3	38
" "	8	15.6	94
Alar	(g ha^{-1})		
Foliar spray	360	5.2	1
Control		19.2	19
"		3.8	6

Weed control in cocoa

P Jollands

Herbicides are increasingly used by large plantations and smallholders. The most widely used chemicals are paraquat (paraquat/ametryne +/ - sitrazine) and glyphosate. In a survey, up to 75% of young cocoa plants were damaged by paraquat, and large scale wastage by misapplication was observed.

Method. In trials, slashing, herbicide, ring weeding and weed sheets all affected early cocoa growth in like manner. By 17 months, however, girth of trees with weed sheets was greatest (18.4 cm, $P<0.05$) and slash-weeded trees the least (16.9 cm). Weed weights were 18.7 g with weed sheets, 92.5 g with ring weeding, 71.9 g with herbicide treatment and 592 g m^{-2} for the slash-weeded.

Herbicides. Selective herbicides tested were quizalofop, fluazifop and sethoxydim. Herbicides tested for woody species were fluoroxypyr, 2,4,5-T, 2,4-D + picloram. Residual herbicides tested were: simazine and terbumeton and glyphosate based herbicides (+/- pichloram or 2,4-D). Herbicides in current use, ametryne (+/- simazine) and paraquat, were used for comparison.

Surfactants were ineffective in reducing the required dose of glyphosate below 1.5 l ha^{-1} for at least 90% kill.

Spray nozzles and applicators. Technical advances in herbicide application are now commercially available: Cooper Pegler VLV nozzles, the Micron Herbi and rope wick applicators. All could reduce labour and cost through using reduced volumes. In earlier trials 0.15 kg ha^{-1} ai glyphosate applied with the VLV nozzles and the Micron Herbi had acceptable weed control in 1.2 m swathes either side of cocoa rows.

A range of weed wipers are available. All operate on the principle of wiping herbicide onto weeds using a rope, wick or pad kept wet with herbicide solution from a reservoir in the handle. The machines are simple with no moving parts and easy to use.

In the trial a hockey stick shaped machine was used (Donaghys Weed Wand , Box 342, Auckland, NZ). Each fill of the wiper (500 ml) was sufficient for about 5000 trees. Wick life was only four to six weeks and wicks are rapidly soiled by dust.

Hand weeding of young clonal cocoa was compared with weed wiping using an 11.9% solution of glyphosate on an area dominated by *Paspalum paniculatum* and *Urochloa panicoides*. Each fill of the weed wiper was sufficent for 50-60 trees at 20-30 seconds per tree and treating a circle 2.5m in diameter.

Weed wiping controlled weeds for 8-10 weeks, four weeks longer than hand weeding, but at K31/ha the cost was 50% more than handweeding. Over a year, however, the cost will be 13% less due to the longer period of control with glyphosate. The other advantage is that the weed wiper does not need calibration, however the wicking rate did decline as the reservoir emptied, resulting in a reduced delivery rate, from 14 to 8 ml/tree with a full and half-full tank, respectively.

Taro control. Taro is a common weed in cocoa blocks. As an alternative to paraquat/ametryne, which causes only scorch, 2,4,5-T and glyphosate were tested and completely killed weeds within 30 days, without damage to cocoa. The wiper was relatively safe even with a translocated herbicide such as 2,4,5-T, (phytotoxic to cocoa). 2,4,5-T is more cost effective than glyphosate but the latter has lower mammalian toxicity (oral LD_{50} 300-1700 mg kg^{-1} vs 5600 mg kg^{-1}).

Herbicide tolerance of cocoa. At the recommended 0.5 kg ai ha^{-1} it is unlikely that glusinate (Basta 20EC) could be safely used around young cocoa unless a spray shield was used, since foliar spray killed plants. Penetration through bark and soil did not occur so the chemical can be safely used on trees older than one year.

COCONUT

F_1 Hybrids

M G Woruba, T Ovasuru and R. Brook

PNG coconut consumption is about 300 million nuts/year valued at K58 million from about 265,000 ha or 3.21% of the world planted area. In the early 1960s, half of PNG coconut palms were over 50 years old, senile and unproductive and yields were declining. Superior material was needed to rehabilitate the industry. A trial was therefore laid out at Kapogere in Central Province in 1967 to test 16 tall varieties. It was found that Rennell Island Tall from the Solomons yielded best, followed by Karkar Island Tall and Markham Valley Tall.

In 1974 a seed garden was established at Omuru from which specific F1 hybrids were produced for testing. The overall aim was to increase yields through faster growth, early bearing, uniform endosperm weight, higher oil content and more nuts. The seed nuts obtained were from the following F1 crosses:

1. MRD x Rennell Is. Tall - MARE
2. MRD x Markham Valley Tall - MAMA
3. MRD x Karkar Island Tall - MAKA
4. MRD x West African Tall - MAWA
5. Local Tall - Tall

Fourteen such trials were planted in each of 14 coastal provinces. Differences between ($p<0.05$) locations were because the Amele block was on a heavy clay soil, Hawain on alluvium and Natava on volcanic soil (Table 3.7). There were significant differences between talls and hybrids but none amongst hybrids and none between locations and varieties at four years. The Hawain block was more precocious than Natava and Amele.

In the Hawain block, MARE led with 88.2% precocity followed by MAMA and MAKA with 81.1% each, MAWA (79.9%) and local talls (22.5%). MAWA had the most nuts per palm (47.1), followed by MAKA (38.3), MARE (33.6), MAMA (25.6) and Local tall (3.7) with the lowest. The most probable reason why MARE, being very precocious, came third in nut production is that some of the bunches snapped off because they carried too many nuts. This problem disappears as the palms become older. Hybrids are still the superior material, but farmers may not accept MAWA because it bears small nuts. MARE is the best hybrid for non - Scapanes beetle infested areas. Further breeding work is required to produce a hybrid for beetle infested areas.

Table 3.7 Growth and yield of coconut.

	Height (cm)			Prod.n/palm		Precocity
	'82*	'83+	'84+	fronds	nuts	(%)
Amele	519	25	61	15.7	7.1	32.8
Hawain	655	70	130	16.9	29.7	70.6
Natava	640	82	154	13.7	13.3	37.4
Mean	605	59	115	15.4	16.7	46.9

* Seedling height + trunk height

TEA

M Gunther

Improved prices of tea in the early1980s resulted in increased demand for clonal planting material.

Clonal selection. The last 27 clones of the W series (Assam type) were planted out in the Clonal Field Trials (CFT) in 1984. In 1986 the CFT 1978 series and 1980/4 were not assessed as the trials had been pruned. The remaining trials were assessed for vigour (1-4,2 being equivalent to the control 1/222). Eleven clones rated higher than the control and two had the best score of 1. Eighty-four clones in the 1978-80 CFT series had better performance than the standard 1/222; the number for further evaluation will be reduced after taste tests.

Fertiliser. The trial was pruned back in January 1984 and brought back into plucking in August.

From August to December six fertiliser treatments were superimposed (Table 3.8). The effect of zinc oxide applied with NPK was significant from 1974-79, but between 1984 and 1987 the effect was only apparent over the 1985 and 1986 period. Also in this period, zinc oxide with sulphate of ammonia had no effect. There was a response ($p<0.05$) to 175 kgN ha^{-1} only. Additional N or Zn did not raise yields further. There was a 12% increase advantage to NPK over N alone as ammonium sulphate.

In 1986 the NPK treatments produced 22% more than the corresponding ammonium sulphate treatment. Zinc oxide provided a 10% gain in yield when supplementing the NPK treatment.

The treatments provide insufficient P and K to meet the needs of the crop and this is limiting the ability of the crop to respond as previously to additional N and zinc oxide.

Table 3.8 Fertiliser response of tea and yield of green leaf. Kuk, 1984-1987.

gN ha^{-1}	Yield (kg/plot)				
	1984	1985	1986	1987	74-79
NPK					
175	33.8	87.7	93.9	74.6	4812
350	33.5	103.0	103.7	85.1	5418
350 + ZnO*	35.9	111.2	114.2	82.2	5861
Ammonium sulphate					
175	31.8	80.7	81.5	68.3	4656
350	29.8	88.2	89.2	76.2	5275
350 + ZnO*	30.3	86.5	85.5	71.7	5510
Control (nil)	21.7	57.4	54.7	54.5	3546
LSD$_{(P=0.05)}$	3.8	10.7	11.7	9.3	388

* 25:5:5

In a long term NPK factorial trial at Tibi Estate there was a significant response to N, raising plot height by 3-4 cm (ns at $P=0.05$), and a response to K raising heights by 14-15 cm ($p<0.05$), but no response to P.

BANANA

Banana variety trial

This trial at Laloki started in 1983 and was completed in 1985. The ten superior varieties included Tall and Dwarf Cavendish, Gross Michel and Unu 2 (imant type). These are triploids (AAA) with potential for use in the banana industry. The six other varieties were cooking types.

The high management treatment had fertiliser, nematicide, fungicide, irrigation, sucker pruning and bunch cover. The low level treatment received irrigation only. Both treatments were hand weeded and sprayed with recommended herbicides.

The banana suckers with high management were all treated with phenamiphos (Nemacur 10G) at 25 g per stool. A complete fertilizer (12:12:18) was applied at 500g/hole before planting and a basal dressing of 40 g N and 80 g K was applied. Fungicide treatment was applied once a month to control Sigatoka disease and other fungal diseases of banana. Irrigation was applied to both blocks once every week for three hours (30 mm). Suckers were pruned regularly allowing only one follow-up at a time.

The high level of management increased yields substantiallly (Table 3.9), especially for the Cavendish cultivars and Unu.

Table 3.9 Variety and management of banana.

	Crop yield (t ha-1)		
	First	Second	Third
Management			
High	11.6	14.5	12.0
Low	7.6	7.8	7.6
Mean	9.6	12.0	9.8
LSD $_{P=0.05}$	3.2		

SWEET POTATO

Genotype x environment interactions

M B Kanua and C N Floyd

A feature of the subsistence production of sweet potato in the highlands is the number and diversity of the cultivars. An average of 34 sweet potato cultivars are grown by individual groups in the highlands.

The reasons for the diversity of varieties include (1) the adoption of new cultivars derived from the spontaneous germinations of seeds, (2) the cultural isolation of growers, (3) taste preferences of the growers, (4) the need to produce sweet potato for both humans and pigs and (5) an apparent suitability of varieties to specific environments, *ie,* genotype x environment interactions.

Some cultivars are grown throughout the Southern Highlands, yet each locality has certain varieties that are perceived to do particularly well in that locality.

Varieties were evaluated at six contrasting sites in three administrative districts (Mendi, Pangia and Tari) of the Southern Highlands Province. Two sites were at a higher altitude (2170 m) than the other four (1560 - 1650 m); four were on airfall volcanic ash soils, one was on a mudflow soil and another on an alluvial soil. Sites also differed in cropping history and climate; two, Pomiorine and Piwa, were on land managed as experimental stations, and the remaining sites were in village subsistence gardens.

Nine varieties were evaluated at all sites and can be classified into four groups. One popular local variety from each of the districts (Goroka from Pangia, Kariap from Mendi, and Mamme from Tari), and one popular variety (Wanmun) common to all three districts, were included. Of these varieties, only Mamme had been recently introduced. Two varieties, Markham and NG 7570, recommended by the National Department of Primary Industry (now DAL) for the highland region, were included. Markham is a variety originally collected in Papua New Guinea and NG 7570, a variety selected from germplasm imported from Nigeria. Two varieties, K1 and K6, were recently selected for improved yield and resistance to sweet potato leaf scab (*Elsinoe batatas*) from a sweet potato polycross seed nursery in the Southern Highlands. They were respectively maternal half-sibs of Mamme and Markham, mentioned above. The remaining variety evaluated was Mundawana, recently introduced to the Southern Highlands from elsewhere in the highlands.

Two explanations for the difference in response between variety types are suggested. The first is that the established varieties have been selected in response to the major problem of sweet potato production in the area, that of declining soil fertility. This selection results in varieties giving a similar yield over a range of sites.

Established varieties have lower regression coefficients, *ie*, less variation in yield across sites, and higher regression intercepts -- an ability to give some yield at poor sites, than do introduced varieties.

The second explanation relates to the presence of viruses in the sweet potato crop in this area. Differences in varietal regression coefficients may reflect differences between varieties in virus tolerance or infection.

In terms of variety selection, an ideal variety would be one that was both responsive (high regression coefficient) and give some yield at low yield potential sites (positive regression intercept). Amongst the varieties tested, established varieties were less responsive but had some yield at poor sites. Although the introduced varieties were more responsive, only two, NG 7570 and Markham, combined this with an ability to give some yield at poor sites.

Declining soil fertility is the fundamental problem for subsistence sweet potato production and established varieties may have advantages at poor sites. However, agronomic methods to improve soil fertility have been identified, particularly the increased use of traditional composting techniques. On inherently fertile sites, introduced varieties will perform better.

Although multi-location sweet potato variety trials are commonly reported, results seldom lend themselves to the analysis described here because all varieties, particularly the local or check varieties, are rarely tested at all sites.

Leaf scab incidence. The effects of site and variety on leaf scab incidence were most marked at the last monthly assessment before harvest. Leaf scab infection was high in the Tari district sites (Kugu, Piwa and Wabia) and low at other sites. This probably reflects not only the lower temperatures at Egari and Karel but also the more intensive cultivation of sweet potato in the Tari district. For all varieties, leaf scab infection increased with increased level of site infection and there was a significant ($P<0.05$) positive correlation between the variables for all varieties.

Leaf scab is the most prevalent disease of sweet potato in the Southern Highlands. In these experiments, incidence was high, with over half the plants in the more susceptible varieties being affected by the pathogen. Although a yield loss of 57% has been attributed to leaf scab infection, there was no relationship in these experiments between variety yield and leaf scab incidence.

This lack of relationship suggests that although varieties may have considerable tolerance to leaf scab, the method of assessing leaf scab infection may not have been sufficiently sensitive to detect the effects of leaf scab on yield.

The suggestion that leaf scab incidence is lower in varieties lacking purple pigment in their leaves was examined using these results. Leaf samples of the nine varieties taken from the Kiburu nursery were ranked by the depth of purple pigmentation in their leaves. This ranking was then related to the mean variety leaf scab incidence across sites, there was a significant ($P<0.01$) positive linear correlation between increasing depth of purple pigmentation in leaves and varietal susceptibility to leaf scab. Further work is necessary to establish the usefulness of this relationship as a diagnostic criterion in identifying leaf scab resistance in sweet potato

The relative performance of maternal half-sib material from a polycross nursery for improved yield and leaf scab resistance suggests a limited effectiveness in this selection. Only in one of the half-sib comparisons, between K6 and Markham, did polycross selection lead to a significant improvement, namely a reduction in leaf scab incidence. In terms of yield, both siblings performed less well than their maternal lines.

Varietal trials in East New Britain and New Ireland

R Croydon

About 90 accessions of sweet potato are held in the Keravat collection. Off-station test sites are at Gaulim, Pomio and on Manus. In earlier trials K101, K143, K142, K168, K153, K145 and K161 yielded 16.7 to 24.8 t ha^{-1}, in excess of the standards K9 (10.9 t ha^{-1}) and K130 (7.0 t). At Gualim (ENB) in 1982/83, K44 (20.4 t/ha^{-1}), K4 (20.9 t) and K9 (20.3 t) were the best yielders. In a trial at Palmalamal, Pomio, ENB, K44 (12.3 t ha^{-1}) and K9 (11.1 t) were at least as good as the local varieties on a heavy clay soil.

In 1984 at Kabil in the lowlands of New Ireland, there was a drought and the local variety Kimadan did poorly although it is the preferred variety. In contrast, on the Lelet plateau it is a most promising variety and the recommended variety K9 failed. At Lunga lunga in East New Britain the recommended variety K9 produced the highest total yield but K9, K4 and K101 had a high percentage of unmarketable tubers; K9 also had the most severe weevil damage. K47 had a high percentage of reject tubers due to cracking. At Vunapalading the soil is very fertile and yields were high; K4, K142 and K101 produced high yields, 45%

above the control (K9). The low percentage recovery is responsible for poor performance (Table 3.10).

Table 3.10 Sweet potato variety trials 1984.

Variety	Total yield (t ha^{-1})	Marketable tubers (%)
Kabil (New Ireland)		
K9	9.0	100.0
Sonoma	8.4	92.0
K47	8.4	90.7
K130	8.1	94.1
K101	7.3	96.0
K44	8.4	82.5
K4	7.9	84.5
K142	7.6	84.9
K49	6.6	82.1
Kimadan	5.1	75.9
Lungalunga, East New Britain		
K9	26.1	57.1
K101	21.2	48.1
K47	18.7	62.6
K142	14.8	75.0
K49	9.0	61.1
K130	7.6	85.5
K4	7.1	59.1
K44	6.7	61.2
Local	2.6	-
Mean	11.9 (1.8)	59.7
Vunapalading		
K101	32.1	51.3
K142	29.5	62.7
K4	23.1	77.6
K9	22.5	44.7
K47	21.7	47.6
K153	21.1	32.8
Local	18.7	56.9
K44	14.0	56.7
K49	12.7	62.5
K130	6.6	75.3
Mean	20.3 (2.9)	56.9

( ) SE (difference), P<0.01

Fertiliser response. In a 1984 trial there was a strong quadratic response, and a rate of 100 kgN ha^{-1} gave the highest yield for K9, K44 and K47 at Vudal Agricultural College near Keravat (Table 3.11).

Table 3.11 Fertiliser N response of three sweet potato cultivars. 1984.

Fertiliser (kgN ha^{-1})	Yield (t ha-1) total	mrktble	Unmarketable (%) Stock feed	Damage Weevil	Rat
K9					
Nil	40.4	15.7	46.3	7.4	7.4
100	37.3	19.2	32.4	4.6	11.5
200	43.0	21.5	33.3	5.5	11.2
K44					
Nil	19.3	7.2	45.1	15.0	2.6
100	22.8	13.7	29.0	5.7	5.2
200	20.9	8.9	40.2	12.4	4.8
K47					
Nil	29.4	14.6	26.9	12.2	11.2
100	42.7	24.4	25.1	9.6	8.2
150	32.0	20.7	15.3	12.2	7.8
200	31.6	12.4	45.9	8.5	6.3
250	33.9	11.9	46.6	11.5	6.8

Planting density. With mounds at 0.9 x 0.9 m apart, up to four sweet potato cuttings were planted in each. Yield increased with number of cuttings up to three per mound, both the number and weights of tubers increased. There was a significant (P<0.05) increase in non-marketable tubers, rotten tubers and total number of tubers with increase in planting density.

On-farm fertiliser trials in the highlands

M B Kanua and G Liripu

In 1987 an inorganic fertiliser trial was set up on a typical volcanic ash soil in a farmers field where sweet potato had been grown previously and had been under a grass fallow for less then a year. N, P and K were applied as urea, triple superphosphate and muriate of potash (Table 3.12). The cultivars were local: Ongi, Tripalangi and Spagi.

Application of N in the absence of applied P decreased yield ($p>0.05$). Similarly, in the absence of P and increasing K, there was no yield increase above the control. Application of P in the absence of both N and K increased ($p<0.05$) yield.

Table 3.12 N x P and P x K interactions for marketable tubers of the sweet potato varieties.

kgK ha^{-1}	kgN ha^{-1}			kgP ha^{-1}		
	0	75	150	0	75	150
100	11.6a	13.1a	14.9a	5.1a	16.7a	17.7a
50	9.5a	15.0a	16.6b	5.2a	12.9b	17.0a
0	4.4b	2.0b	1.9c	1.4b	3.4c	5.3b

Increasing both P and K rates gave better yields, and yields were greatest with the highest rate of P.

Cultivars Ongi and Tripalangi responded more to inorganic fertilizer than Spagi (Table 3.13). Tripalangi outyielded Spagi at the 50 and 100 kgP ha^{-1} and 75 and 150 kgK ha^{-1}. Overall yields were improved due to a clear P effect on Ongi and Tripalangi but limited effect on Spagi.

Reduced response to fertiliser may be an adaptation mechanism to a nutrient depleted soil where sweet potato is regularly cropped, or perhaps to presence of viruses and nematodes.

Table 3.13 Variety x fertiliser interaction on marketable tuber yield (t ha^{-1}) of sweet potato varieties.

	kgP ha^{-1}			kgK ha^{-1}		
	0	50	100	0	75	150
Ongi	5.5a	15.5a	16.5a	5.6a	15.1a	16.8a
Tripalangi	2.0b	12.9a	4.5a	3.8a	11.5b	14.2a
Spagi	0.9b	6.7b	8.5b	2.4a	6.4c	7.2b

Yields followed by different letter significantly different ($P<0.05$).

Sweet potato growth studies

M B Kanua and G Liripu

In Gumine farmers plant 20 or more varieties of sweet potato in a single garden. The farmers classify these varieties on the basis of their times to maturity and/or their relevance to human and pig nutrition.

Crop growth and development of varieties Markham (early maturing) and Tiki (late maturing) were compared to further understand varietal behaviour in farmers' fields.

Dry matter of leaves and vines for variety Markham was 32%, and 49% for Tiki (20th to 24th fortnightly sampling). Tuber dry matter contents were 26 and 37% respectively.

The vegetative growth curves for both Markham and Tiki follow a similar pattern (Figure 3.3). The vine growth for Tiki increased almost exponentially from the seventh sampling and had two distinct peaks, the first at tenth sampling and the second at the fifteenth. Vegetative growth of Tiki declined thereafter.

Vegetative production of Markham peaked at the tenth sampling and remained at the same level to the sixteenth sampling, then declined sharply. The behaviour of the late variety Tiki is one of continuous increase, although at a reduced pace. At about the 23rd to 25th sampling there is a distinct point where the yields of Markham fall below those of Tiki.

In general, the growth curves of tops for Markham and Tiki follow the typical sigmoid pattern of many other crops.

The vegetative growth of Markham peaked at the 10th sampling (147 days) and then declined, while variety Tiki starts a decline in vegetative growth after the 15th sampling. Formation of tuberous roots started for Markham at 35-49 DAP (3rd sampling). Growth and bulking increased almost linearly till maturity. For Tiki, tuberous root formation started at 91-105 DAP (6th sampling), though further growth and tuber bulking continued for longer than with Markham.

The early maturing variety Markham had a clear cut-off point when marketable tuber production declined, whereas Tiki had no clear cut off points within the first 12 months.

Tiki continued to produce some marketable yield and may continue for a further 8-12 months at a low level of production, as against early maturing variety Markham which has a distinct peak production, declining sharply thereafter.

It is apparent variety Tiki produces a lot more vegetative matter than Markham, and therefore is inefficient in converting assimilates into storage roots. The prevalence of varieties such as Tiki in the farmers' fields, suggests that farmers select varieties not only for high yield, but for high turnover of vegetative matter for livestock feed. Conversely, Markham would be preferred for human nutrition.

Seasonality

M B Kanua and G Liripu

The objective of this study was to investigate the effect of rainfall on the production of four sweet potato varieties. The study was based on recommendations from the Rapid Rural Appraisal findings in Gumine.

At Kuk Research Station (1630 m), Western Highlands Province, the site had a crop of sweet potato two years previously but was over grown with weeds and mixed grass fallow. The soil was a well drained clay loam mineralised peat, with a deep dark top soil, a common soil type for sweet potato production in the Wahgi Valley. Four sweet potato cultivars (NG7570, Munduwana, Naveto and Markham) were planted monthly for one year. No fertiliser was applied.

Both total and marketable yields were highest between July and November plantings when rainfall was lowest for all varieties tested. The somewhat higher yields for the March/April 1987 plantings were possibly due to a soil moisture lag from rainfall a few weeks immediately preceding planting.

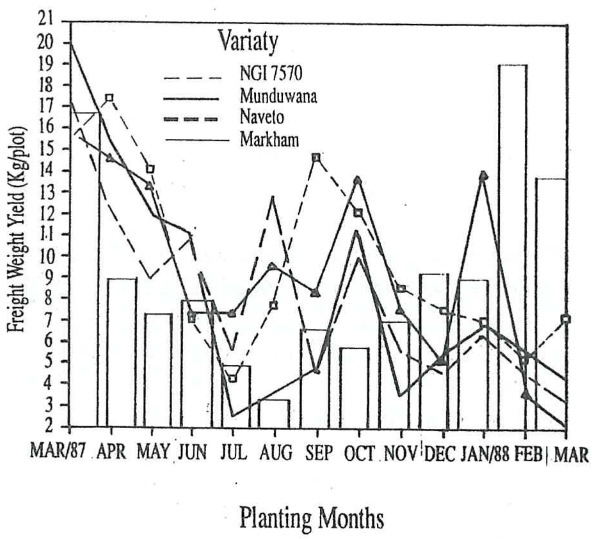

Figure 3.3 Sweet potato growth curve

Preliminary evaluation of sweet potato cultivars for yield and some yield determining characters under dry season conditions (LIB31, 32).

This work comprised two trials of equal size planted in July. Trial design was identical with that of LIB28 and recordings were the same.

In both trials yields were low despite regular irrigation, indicating that cultivars were not adapted to the dry season conditions at Laloki.

Average yields in the two trials at 110 DAP were 0.23 and 0.13kg/m² respectively. At 135 DAP yields were 0.35 and 0.18kg/m² respectively.

Cultivars L49 (1.49kg/m²), L46 (1.42kg.m²), L18 (1.12kg/m²), L9 (1.03kg/m²), L43 (0.99kg/m²), L96 (0.98kg/m²) and L167 (0.92kg.m²) were the best performing entries in terms of yield.

With the exception of L30 (5.8 tubers/plant) and L49 (3.7 tubers/plant) the average number of tubers produced by cultivars in the two trials was low and this probably contributed to the low yields recorded.

Evaluation of different planting methods on yield and infestation by sweet potato weevil under dry season conditions (LIB34).

A complete factorial trial design with five replicates was used. The factors were:

1) Cultivar: L22 and L44.
2) Days to harvest: 108 DAP and 133 DAP.
3) Method of planting:

a) one cutting per station each with two nodes buried vertically.
b) two cuttings per station each with two nodes buried vertically.
c) one cutting per station each with four nodes buried vertically.
d) two cuttings per station each with four nodes buried vertically.
e) one cutting per station each with four nodes buried horizontally.
f) two cuttings per station each with four nodes buried horizontally.

Terminal 25-30cm cuttings were used for all treatments. Within row spacing was 25cms and between row spacing 1.315m. A split-split plot design was used with cultivar as the main plot and days to harvest as the sub plot.

At harvest sweet potatoes were separated into marketable and unmarketable tubers and assessed for sweet potato weevil damage. Total yield (kg/m²), mean marketable tuber weight (g), percentage unmarketable tubers and percentage by weight of tubers with no weevil damage were recorded.

Total yield was higher for L44 (1.5kg/m²) than for L22 (0.88kg/m²). The time of harvest and method of planting did not significantly affect the total yield although there was an observed non significant trend for higher yield where two cuttings per station were used.

Mean marketable tuber weight was markedly higher for L44 (312g) than for L22 (186g) and method of planting significantly affected marketable tuber size with smaller tubers being produced when two cuttings were planted at each station compared to a single cutting. There was also a non-significant tendency for tubers to be smaller when cuttings were planted horizontally rather than vertically.

The percentage of small tubers was very highly significantly ($P<0.001$) lower (6.7%) for L44 than for L22 (16.8%). There was a small but significant increase in small tubers from 108 DAP (10.5%) to 133 DAP (13.0%) suggesting that tubers initiated between 108 and 133 DAP developed into smaller tubers.

There was no significant difference in sweet potato weevil damage between L44 (91%) and L22 (89%) but there was a highly significant decrease in tubers with no sweet potato weevil damage between 108 DAP (97%) and 33 DAP (83%).

There was no significant effect on the method of planting on tuber damage by sweet potato weevil.

Evaluation of selected cultural methods on sweet potato production under wet season conditions (LIB37).

Sweet potato cuttings were planted on 10.7m² plots using the following five cultural methods.

1) planted on ridges.
2) planted on ridges and staked.
3) planted on mounds without mulching.
4) planted on mounds with polythene mulch.
5) planted on mounds containing 30 tonnes/ha fresh grass cuttings.

For each cultural method an early maturing (L44) and a late maturing (L11) cultivar was used with two harvest dates (114 and 135 DAP).

A randomised complete block design was used with two replicates. Planting density was the same for all treatments (33,645 cuttings/ha). Cuttings were planted vertically with 2-4 nodes beneath the soil.

Percentage survival, total and marketable tuber yield (kg/m²), fresh vine yield (km/m²), number of tubers per plant and mean marketable tuber weight were recorded.

L11 produced significantly greater fresh vine weight than L44. Vine weight increased for L11 between the first and second harvests and decreased for the early maturing variety L44. Vine weight was generally greater on ridged compared with mounded plots. Staking had no effect on vine weight although mulching with polythene and grass cuttings both significantly increased fresh vine weight over the unmulched mounded control plots.

L44 produced significantly higher average total yield (1.27) marketable yield (1.18 vs 0.51kg/m²), number of tubers per plant (1.68 Vs 1.29) and mean marketable tuber weight (318 vs 220g) than L11. L44 also produced a significantly lower proportion (8.6%) of unmarketable tubers than L11 (23.7%). There was no significant difference in the survival rates of the two cultivars.

The total yield of tubers was significantly higher from ridges (1.16kg/m²) than from mounds (1.16kg/m²) with a trend of increased yield with staking (1.61kg/m²). Marketable yield followed the same trends as total yields.

Mulching with 30 tonnes/ha grass cuttings led to higher total (0.91kg/m²) and marketable (0.84kg/m²) yields than for unmulched mounds (0.80 and 0.73kg/m² respectively). The total number of tubers per plant (1.54) was lower in mulched plots than unmulched plots (1.60) whilst the mean marketable tuber weight was greater (272g vs 254g).

Total yields of polythene mulched plots (0.33kg/m²) were significantly lower than for other mound treatments (0.8-0.91kg/m²). Marketable yield (0.27kg/m²), number of tubers per plant (0.83), and mean marketable tuber weight (192g) were all significantly lower than those for other treatments. The percentage of unmarketable tubers (35.3%) was also significantly greater using polythene mulching than for other treatments (8-17%).

It is likely that the polythene mulch impeded gaseous exchange between the soil and atmosphere resulting in decreased soil oxygen with a resultant partial suppression of tuber development.

Evaluation of nine sweet potato cultivars in an advanced yield late wet-season trial (LIB38).

A complete factorial design was used to compare nine sweet potato cultivars (L11, L13, L22, L30, L49, L431 and K40) and two harvest dates 135 DAP and 150 DAP.

The field layout was a split plot design with five replicates arranged as randomised complete blocks. Main plots were for cultivars and sub plots for harvest dates. The gross plot size was 20.0m² and harvested area comprising a single 7m long ridge was 8.4m². Plots were planted with 25-30cm tip cuttings at 25cm within row spacing and 1.2m spacing between ridges.

The following parameters were assessed: 1) plant survival (%) 2) vine yield (kg/m²), 3) total yield (kg/m²), total number of tubers per plant, 5) mean marketable tuber weight (g) and percentage (by weight) of marketable tubers.

There was a significant effect of cultivar on plant survival which ranged from 78% for L30 to 92% for L49. Plant survival was generally high and there was no reduction between 110 DAP and 133 DAP.

Vine yield did not differ significantly between cultivars (range 2.6-3.6kg/m²) but there was a highly significant effect of harvest date and a significant cultivar x harvest date interaction.

There was a wide range in total tuber yields between cultivars (0.44-1.26kg/m²) and a highly significant increase in yield from 135 DAP (0.79kg/m²) to 150 DAP (0.99kg/m²). The highest yielding cultivars at 133 DAP (L44, L135, L431, L49, L11) were also the highest yielding at 110 DAP. For L44 and L135 there was relatively little change in yield between the two harvests. The other high yielding cultivars (L431, L49 and L11) gave large increases in yield between the two harvest dates. Cultivar L431 (1.35kg/m²) was the highest yielding at 150 DAP.

There was a highly significant difference in total number of tubers between cultivars but no significant change between 135 DAP and 150 DAP. With the exception of L44 (1.9 tubers/plant) the highest yielding cultivars generally had the highest number of tubers per plant (L431-3.9 tubers/plant; L49-3.2 tubers/plant; L135-2.9 tubers/plant).

The mean weight of marketable tubers for L44 (294g) was significantly higher than that for any of the other cultivars tested.

The proportion of crop that was marketable was generally high (80-95%) with L44 having the highest proportion of marketable tubers (95%) whilst the high yielding cultivars L49, and L431 had relatively low percentages of marketable tubers (80 and 82% respectively).

Damage by sweet potato weevil was negligible for all cultivars at both harvest dates. This may be related to the season of production and planting towards the end of the wet season may be a useful means of avoiding sweet potato weevil damage.

Evaluation of yields and components of yield of ten sweet potato cultivars grown on land previously cropped to the same cultivars (LIB38.2).

The trial was planted on the site of trial LIB38 and laid out in the same way. The same parameters were recorded as in trial LIB38 and the same sweet potato cultivars were used.

The purpose of the trial was to assess ten sweet potato cultivars previously evaluated under wet season conditions, in the dry season. The trial was planted in mid dry season in August 1985.

Plant survival was good for all cultivars tested. The most promising cultivars for total yield were L44 (1.38kg/m²) L135 (1.54kg/m²) and L431 (1.44kg/m²). However, L431 produced a relatively high proportion of unmarketable tubers, and tubers of this cultivar were severely damaged by sweet potato weevil.

Cultivars L44 (460g) and L46 (488g) produced very large tubers compared with the other cultivars tested. The number of tubers produced per plant was low with a range of 1.1 to 2.7 among the ten cultivars tested. L11 (1.25kg/m²) and L46 (1.16kg/m²) with intermediate yields were selected for further evaluation along with L44. L135 and L431.

Evaluation of effect of wide plant spacing in promoting early maturity and minimising damage by sweet potato weevil (LIB39.2).

A complete factorial design with two cultivars (L11 and L44), three spacings (25,50,100cms) and six harvest dates (9,11.5,14,16.5,19 and 21.5 weeks after planting) was used giving a total of thirty-six treatments. The experiment was laid out in a split-split plot design with cultivars comprising the main plots and spacings the subplots. Each harvest plot was a single ridge 10m long. This design was adopted in order to minimise inter-row competition. Parameters recorded were the same as for trial LIB38.

The yield of L44 (0.78kg/m^2) was substantially greater than that of L11 (0.46kg/m^2) but since cultivar was used as the main plot the statistical comparison lacked sensitivity and the difference was not significant. For L44, total and marketable yield increased upto 19 WAP whereas for L11 total and marketable yield increased upto the termination of the trial at 21.5 WAP. L11 is known to be a later maturing variety than L44.

Mean marketable tuber weight was much greater for L44 (367g) than for L11 (197g). From the harvest at 11.5 WAP, mean marketable tuber weight increased in successive harvests linearly with weight of L44 increasing much more rapidly than that of L11. The increase in mean marketable tuber weight was also more rapid at wider spacing.

Total and marketable yield were not significantly different at different spacings. However, for the 16.5 WAP and 19 WAP harvests there was a trend to higher marketable yields of L44 at 50cm and 100cm spacing compared with 25cm spacing. A similar trend was seen at 21.5 WAP for the later maturing cultivar L11 for which the 100cm spacing may be superior due to the vigorous vine growth and spreading habit of this cultivar.

Between 14 WAP and 16.5 WAP sweet potato weevil began to damage the flesh of both cultivars with a trend to greater damage to the earlier maturing cultivár L44 at 16.5 WAP. At 16.5 WAP there was also a trend to greater tuber damage at the close spacing (25cm), although this trend was reversed at 19 WAP. It is possible that in the early stages of crop growth, the greater amount of foliage and, therefore, ground cover at the closer spacing was more conducive to weevil attack.

The data indicate that in order to avoid substantial weevil damage harvesting must take place 15-17 WAP and slightly earlier for L44 than L11.

Overall trial results indicate that a moderate yield of L44 (about 1.0kg.m^2) of tubers relatively free from weevil damaged can be obtained using wide plant spacing (approx. 0.8-1.0 plant/m^2) and harvesting approximately four months after planting. For the later maturing variety L11 avoidance of weevil damage by adjusting planting density and harvest time does not appear to be practical.

TARO

Evaluation of Varieties

W L Akus

In 1986 at Bubia, thirty taro varieties were harvested at five, six or seven months after planting. Metalaxyl at 0.3% (Ridomil Plus 72 WP) and Ambush were used to control leaf blight and defoliating insects until the plants were established.

Corm, cormel and total (corm + cörmel) yields differed with variety ($P<0.001$). The yields varied from 0.69 t ha^{-1} (BC22) to 5.53 t ha^{-1} (BC30) and dry matter content varied from 14.6 (BC22) to 31.9% (BC126[1]). Sucker (cormel) production varied widely ($p<0.001$) with the highest in BC30 with 30444 plants/ha (Table 3.14).

Yield and dry matter increased but crude protein content declined as harvesting date was progressively delayed from five to seven months (Table 3.15).

Table 3.14 Fresh yield, dry matter content and number of suckers for taro varieties. Bubia, 1984

Variety	Fresh yield ($t\ ha^{-1}$)	Dry matter (%)	Suckers produced ($x10^3\ ha^{-1}$)
BC 30	5.53	21.6	13.0
BC 42	5.40	17.1	5.5
BC126(2)	5.13	19.0	9.7
BC 21	4.49	26.6	20.5
BC 64	4.42	21.4	10.7
BC 16	4.39	28.4	25.0
BC 32	4.34	19.8	10.0
BC 25	4.20	18.8	8.9
BC 29	3.53	25.6	17.3
BC 26	3.36	18.4	7.3
BC 40	3.20	20.4	10.5
BC 13	3.02	23.1	14.0
BC 18	2.90	14.9	2.6
BC 44	2.87	24.6	14.5
BC 17	2.87	26.8	21.2
BC 33	2.16	17.1	3.9
BC 3	2.11	25.8	17.5
BC 12	2.00	22.1	13.2
BC 15	2.00	18.6	18.0
BC 82(2)	1.90	18.7	8.0
BC 53	1.88	28.2	21.3
BC 31	1.87	17.6	5.5
BC 4	1.87	21.6	11.4
BC 85	1.79	25.7	17.4
BC126(1)	1.49	31.9	30.4
BC 63	1.47	30.9	28.9
BC 81	1.29	19.6	10.0
BC 5	1.05	29.9	25.6
BC106	0.89	29.6	25.2
BC 22	0.69	14.6	21.7
Mean	2.80	22.6	13.9
$LSD_{(P=0.05)}$	1.27	7.6	1.5

The early maturing varieties were BC42, BC30, BC25 and BC44 (<5 months). Five varieties - BC33, BC15, BC85, BC31 and BC106 - took seven months or more. Thirteen percent were early maturing, 17% late and 70% intermediate maturing.

Table 3.15 The influence of time to harvest on taro characteristics. Bubia, 1986.

	Harvest (months)			
	Five	Six	Seven	Mean
Dry matter (%)	20.6	21.8	25.4	22.6
Crude Protein (%)	10.0	8.8	6.7	8.5
Maturity score*	1.7	2.9	2.7	2.4
Sucker number	9805	16916	15050	13924

* 1 - 4, late (>7 months) to early (<5 months)

Varieties ranged from very watery soft (BC33) to very good smell, taste and firm (BC44). Papua New Guineans prefer the latter. Several varieties were not attacked by Taro Beetle.

The following varieties were recommended for further testing:

BC 30	BC 25	BC 29	BC 26
BC 42	BC 44	BC106	BC126(1)
BC126(2)	BC 5	BC 16	

Table 3.16 Yield, dry matter and marketable yield of taro varieties. Bubia 1987.

variety	Taro yield (t ha^{-1})	Dry matter content (%)	Marketable yield (%)
BC126(2)	10.22	25.3	68.7
BC 64	9.86	27.6	77.9
BC 42	9.33	23.9	62.9
BC 85	8.25	33.1	90.5
BC 4	7.85	27.5	77.8
BC 21	7.23	26.4	72.4
BC 30	6.97	27.1	76.9
BC 29	6.86	31.7	83.0
BC 40	6.70	19.8	54.5
BC 25	6.34	21.6	57.3
BC126(1)	6.22	31.9	88.3
BC 82(2)	5.88	23.7	61.3
BC 26	5.81	27.8	64.2
BC 16	5.54	26.9	76.8
BC 13	5.40	27.7	78.6
BC 12	5.06	28.1	78.8
BC 53	4.72	26.7	76.7
BC 15	4.56	21.1	56.2
BC 17	4.49	30.4	81.4
BC 44	4.37	30.7	81.7
BC 63	4.23	30.8	82.4
BC106	4.15	33.0	88.4
BC 32	4.07	26.5	75.3
BC 81	3.99	28.7	79.8
BC 3	3.81	24.6	62.9
BC 33	3.61	25.4	68.8
BC 31	2.35	25.7	70.9
BC 18	2.27	22.6	60.0
Mean	5.75	21.5	73.4
$LSD_{(0.05)}$	3.13	0.9	10.4

In a follow-up trial (1987), fresh yields ranged from 2.3 t ha^{-1} (BC18) to 10.2 t ha^{-1} (BC126[2]) (Table 3.16).

Only dry matter content was influenced by time to harvest, and there was no interaction ($P>0.05$) between variety and time of harvest.

Corm, cormel and total yield increased with late harvest, especially between the first and the second harvest. Marketable percentage yield declined as time to harvest increased but there was no definite trend in the dry matter content (Table3.17).

Table 3.17 The main effect of harvest time on the taro fresh yield, dry yield, marketable yield (t ha^{-1}) and cormel number.

Yield	Harvest (months) five	six	seven	mean
Fresh				
Corm	3.11	4.34	4.74	4.06
Cormel	1.07	1.08	2.11	1.66
Dry				
Corm	0.87	1.12	1.24	1.07
Cormel	0.29	0.46	0.55	0.44
Market able (%)	76.4	71.7	72.0	73.4
Cormels/ plant	34.6	40.9	36.6	37.4

BC26 was the earliest maturing variety, taking less than six months. The following varieties were promising for testing in farmer's fields:

BC126(2)	BC 30	BC 21	
BC 64	BC 85	BC 17	
BC 42	BC126(1)	BC 33	BC 26

Variety x staking x mulching trial

In Central Province yams are grown with or without stakes, whereas the literature suggests a positive effect on yield due to staking. It was decided to investigate the effect of staking on *D. esculenta*. Mulch was also included as a treatment to control weeds and conserve soil moisture.

Trial 1 was planted in October 1983 and harvested in August 1984. Trial 2 was planted in November 1984 and harvested in September 1985. The varieties used were L4, L33 and L34.

Results obtained in trial 1 were similar to those in trial 2 except that mulching in trial 2 had no effect at all on any of the varieties (Table 3.18 and 3.19).

Staking caused a significant increase in both the yield and the mean tuber weight. Mulching caused a significant increase in tuber number per plant and percentage dry matter in trial 1 but not in trial 2.

Table 3.18 Staking and mulching *D. esculenta*. Trial 1.

	Tuber (no./plant)	Tuber wt. (g)	Yield ($t\ ha^{-1}$)	% Dry matter	% Crude protein
Variety					
V4 (L218)	4.85	400	21.8	26.8	9.75
V33 (L247)	7.99	188	17.9	27.6	9.01
V34 (L248)	7.13	228	16.8	31.1	8.60
Not staked	6.53	243	16.6	28.0	8.93
Staked	6.78	301	21.0	29.0	9.30
No mulch	6.18	268	17.2	27.8	9.32
Mulch	7.13	276	20.4	29.2	8.92
Mean	6.66	272	18.8	28.5	9.12

Table 3.19 Interactions between variety and staking. Trial 2

	Tuber no./plant			Tuber weight (g)		
	Unstaked	Staked	Av.	Unstaked	Staked	Av.
Variety						
V4	4.81	4.89	4.85	321	478	400
V33	7.35	8.63	7.99	176	201	188
V34	7.44	6.82	7.13	233	223	228
Mean	6.53	6.78	6.66	243	301	272

Staking x mulching

Staking is not a common practice in the Central Province as timber is not readily available. Plant densities are low and weed competition is a serious problem. From this point of view, and the results of the above trials, it was recommended that on-farm research was needed to determine whether yams grown in a village garden with minimal inputs respond to staking and mulching. The four villages were Maba, Pari, Gabagaba 1 and Gabagaba 2.

Staking and mulching did not significantly affect the yield (Table 3.20). The only significant difference was between villages. At Maba *D. esculenta* is the only species grown, whilst both D. esculenta and, *D. alata* were grown at Gabagaba.

Table 3.20 Effect of stakes and mulch on village yams.

Village	Yield ($t\ ha^{-1}$)	Tuber no./plant	Tuber (g)
Maba	30.6	15.4	364
Gabagaba 1	16.0	8.14	283
Gabagaba 2	22.0	4.19	595
Mean	22.9	9.24	414
SE (difference)	2.48	0.69	53.4

CASSAVA

Variety trials

Cassava was introduced to Papua New Guinea some time between 1500 and 1870 and although recent it has become a significant co-staple especially in those areas with strongly seasonal rainfall. Cassava is an important staple in subsistence gardens along the dry Central Province coast. In this area cassava is planted at the beginning of the wet season (December - January) as a border around the yam garden and is harvested gradually from September to February or March. Cassava has taken the place of sago in the seasonal food supply pattern of the Motuan people. There are two main types of cassava grown, white and yellow fleshed. In this series of four variety trials the two local varieties were compared with those obtained from LAES, Kerevat.

All four trials were planted at Laloki. Ten varieties were selected from the 28 accessions held in the Laloki collection on the basis of single plot yield.

Table 3.21 Tuber yields (t ha^{-1}) of six varieties of cassava in four trials.

	Trial				
Variety	1	2	3	4	Mean
L12	25.9	-	42.9	124.3	64.4
White	25.6	17.6	41.3	119.1	50.9
L23	17.3	21.3	39.1	106.0	45.9
Yellow	16.8	22.7	29.6	98.0	41.8
L4	23.7	17.1	44.2	81.5	41.6
L16	23.1	19.5	33.3	75.6	37.9
Mean	19.6	19.6	38.4	100.8	47.1

The only significant pest in the trials was *Amblypelta* spp. Damage was assessed by a count of dead stem tips.

In trial 1, L16 had lower ($p<0.001$) specific gravity. The six highest yielding varieties were selected for inclusion in trial 2, however planting material of L12 was insufficient and it was omitted. In trial 2, L16 had greater stem and leaf yield ($p<0.05$). L23 is a very tall variety and tends to lodge in strong winds. This variety also has a significantly greater plant stick yield ($p<0.001$). White had a significantly greater level of *Amblypelta spp.* damage than any other variety ($p<0.001$).

In the third trial, although tuber yields were not significantly different, L23 had significantly greater dry matter content than L4, L12 and White ($p<0.05$). This trial was planted on land with better drainage than the earlier trials.

Yields in the fourth trial were exceptionally high (Table 3.21). The previous crop grown on this site was tomato which had received 500 kg ha^{-1} 12:12:17 fertilizer at planting and a side dressing of muriate of potash (50 kg ha^{-1}). L12 and white had significantly greater yields than L4 and L16 ($p<0.001$). Percent dry matter content of the tubers was exceptionally high and although there were no significant differences between varieties, L23 again had the highest value.

The highest yielding varieties were L12 and White. However cassava White is very susceptible to damage by *Amblypelta* spp.. Yield losses caused by *Amblypelta* are not known. L12 had the smallest canopy of all the varieties tested and hence has a low multiplication rate. However, this variety is potentially useful for inter-cropping whereas L23 with a very tall canopy could not be so used. L23 is possibly the most suitable variety for processing as it has a large top that can be used for fuel and has higher plant stick yields which also have a high starch content.

Varieties with yellow flesh are generally preferred as they are sweeter than white fleshed varieties. However, the yellow fleshed varieties included in this trial series; L19 and Yellow, are lower yielding. Further work is required to select high yielding yellow fleshed varieties and to test these varieties and L12 (white fleshed) on subsistence farms.

AIBIKA

L Kurika

Variety. There were 41 accessions at LAES in 1984, including some duplicates. The weight of tips harvested ranges from 0.6 to 11.3 kg/plot. The accessions producing in excess of 10 kg tips/plot being K11, K34, K52 and K16. In a preliminary trial K22, K38, K50 and K51 were promising, yielding 7.6 to 9.5 t ha^{-1}, whereas in a second trial K69 (10.2 t) and K80 (9.4 t) both yielded higher than K51 (8.4 t ha^{-1}).

Fertiliser response. In a 1985 trial 50 kgN ha^{-1} was applied at planting (1), at one month (2), at planting and at one month (3) or at one and two months (4). Growth, leaf colour, and plant height were unaffected but the number of tips harvested decreased ($P<0.05$) at the first harvest (seven weeks) if fertiliser N was applied at planting and at one month. By the 15 week harvest the treatments having fertiliser N at both four and eight weeks also had increased tip weight at harvest. By 17 weeks tip weights increased with all fertiliser treatments, therefore on fertile soils the fertiliser response may be delayed. Applying fertiliser too close to the cuttings injured the plants and hindered early growth.

In a second fertiliser trial (1986), 50 and 100 kgN ha^{-1} were applied as urea, ammonium sulphate or NPK (15:15:15). There was no significant yield response to applied N, even though there was a trend to higher yield with 100 kgN ha^{-1} for all characters assessed. There was similarly no statistically significant advantage from NPK compared with N alone. Fertiliser N applied as ammonium sulphate had the lowest absolute yield of 11.8 kg/plot.

In 1987, the third trial in this series tested the response of four varieties (K29, K34, K46 and K47) to 50 and 100 kg N ha^{-1}. There was a non-linear response ($P<0.05$) only on canopy diameter: from 70 cm with 50gm N to 67 cm with 100gm N and 65 cm for the control. K46 and K29 were the most promising varieties with the greater number of harvestable tips (246 and 229 respectively), the latter having the larger canopy. K46 yielded 13.1 and K29, 12.1 kg/plot, 11% more than the other two varieties.

Where soils were marginal (0.27%N) there was a fertiliser response, though aibika remains a crop that is efficient in nutrient uptake.

ADZUKI BEAN

R N Kambuou

Twenty introductions of adzuki bean spp. were assessed in a preliminary trial at Bubia in 1977. The 10 best lines were tested in formal variety trials in the Markham Valley during 1978-79 at Bubia and Rumion.

At Bubia the soil is heavy whereas at Rumion it is a very light sandy loam. The site at Rumion also has less bright sunlight, this causes reduced plant height.

Lines A4, A10 and A19 were the best with the greater and more evenly distributed rainfall at Bubia. (Table 3.22). Each line yielded over 1.3 t ha^{-1}.

Table 3.22 Adzuki bean varietal testing. Markham Valley.

Line	Grain yield (kg ha^{-1})	
	Bubia	Rumion
A 4	1597	685
A19	1402	472
A10	1378	534
A18	1289	686
A13	1285	758
A 3	1268	666
A 9	1267	619
A 8	1216	369
A16	1174	192
A12	-	552

The yields from lines planted at Rumion were poor, plants were short and stunted as only 670 mm rain fell during the season and it was evenly distributed.

Table 3.23 Lines and suggestions for planting.

Soil type	Suggested lines	Seed (kg ha^{-1})	Spacing (cm)	Yield (t ha^{-1})
Light alluvial	A13, A18 A4, A3	25-30	70 x 4	0.7-0.8
Medium-heavy	A4, A19, A10	25-30	70 x 4	1.3-1.6

Adzuki beans will grow in light sandy loam soils provided there is enough rain throughout the growing season. To produce good sized grains, water is needed especially at pod filling stage. Adzuki beans will grow best in medium to slightly heavy soils, with good drainage. Adzuki beans also need high insolation. Currently recommended lines are given in table 3.23.

The lines of adzuki beans tested are not suitable for commercial production because they mature unevenly. The adzuki bean is, however, an ideal pulse crop for subsistence gardens since farmers do not have storage. It is also a good rotation crop with staple root and tuber crops and green leafy vegetables.

PITPIT *Saccharum edule*

The collection at Keravat was planted in 1984 with 14 accessions to test the seasonality of production. Production ranged from 0.19 to 20.25 kg/plot, the most promising accessions (K4, K14, K1, K2 and K3) having in excess of 15 kg/plot. K1, K3 to K6, K11 and K14 started production 7-8 months after planting whilst others started as late as 19 months. Peak harvest was December to June for most cultivars, with K2, K3 and K5 having the highest yields during this time, whereas K4 and K5 had greatest production during the rest of the year.

TRADITIONAL LEAFY GREENS FROM TREE SPECIES

In 1980 the following were planted at LAES:*Ficus wassa* (kumumosong), *F. copiosa* and *F. tincturia*, *Gnetum gnemon* (tulip). *Omacarpum orientale* (kalava) and *Polyscias verticillata* (valangur) were planted in September 1986. The Ficus was the only species to propagate well from seed, whereas *G. gnemon* had a low success rate from seed or cuttings.

CABBAGE

R Croydon

In November 1984, English cabbage varieties were tested in the wet season on the Gazelle Peninsula, ENBP for yield and Soft Rot resistance. The varieties were KK, KY, Leo, Princess, YR Summer 50 and Express Cross 60. Only the latter two had satisfactory yield and Soft Rot tolerance (Table 3.24). In the dry season all varieties produced good yields. Express Cross 60 and YR Summer 50 had the highest plant survival (84-86%) as well as the greatest percentage marketability (60-68%). For the larger cabbages such as YR Summer 50 and Express Cross 60, a wider spacing (50 x 50 cm) may be more appropriate, as would a closer spacing for Leo and Princess. Varieties KK Leo and Princess suffered more from Soft Rot damage. Pakrite suffered from Diamond Back Moth (*Plutella xylostella*). Green Star, Rampo Improved, Princess, Eureka and No.4-88 needed numerous replants, whilst YR Summer Cross, Green Star and Eureka had weak seedling growth.

In 1987 on the Vunakanua plantation near Keravat, ENBP, commercial cabbage production was started with a trial plot of KK Cross cabbage to provide continual crops for the retail market in Rabaul, but the dry season and Diamond Back Moth reduced yield. Agrochemicals, tools, sprayers and seed made for a cash cost of K704/ha with labour costing K2874/ha.