On farm

Cassava Study

Project number FLOT.107
Final Report prepared for MLA by:
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ISBN 1 74036 766 9

November 2005

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EXECUTIVE SUMMARY

1. Two possible localities were identified and evaluated for the establishment of an integrated cassava based stockfeed industry which grows the crop and manufactures cassava pellets. The localities considered were:

   - south east Queensland, around Bundaberg/Maryborough - the location of the initial foray into commercial cassava cultivation for industrial starch and ethanol, and

   - the top end of the Northern Territory.

2. This study shows that the 'best bet' factory gate price of cassava pellets, considering fixed and variable costs plus 20% return on capital($6.769 million) before tax, would be:

   - $218/tonne in the top end of Northern Territory;
   - $267/tonne in SE Queensland.

3. These estimates have been based on the following key assumptions:

   - an integrated growing/processing business structure;

   - total plantation area of 1,000 ha of which 400 is planted/harvested each year but as a biennial crop has 800 ha under crop at the commencement of the harvest season each year;

   - whole plantation irrigated;

   - seasonal average yields of a biennially harvested crop, of underground cassava plant parts of <u>92 tonne FW/ha</u> for the NT and <u>63 tonne FW/ha</u> for SE Queensland;

   - growing/harvesting/processing season of 36 weeks and 24 weeks respectively for the NT and Queensland respectively;

   - for the NT, annual fresh weight cassava underground plant part production of 36,800 mt from which 16,394 mt of cassava pellets would be manufactured; for SE Queensland, fresh weight production of 25,200 mt to yield 11,227 mt of pellets;

   - totally mechanised plantation operation;

   - processing based on use of furnace oil as power source for dehydration.

4. In the <u>Northern Territory</u>, cassava pellets at $218/tonne would appear to be competitive against feedgrain which, in the main, commands a premium of $140/tonne over SE Queensland prices. In the current year of low feedgrain prices, grain delivered to the top end of the NT is $260/tonne indicating a margin of $42/tonne in favour of cassava. In most years a premium above this would

apply. The market is, however, small and a cassava factory producing 11,000 tonnes of pellets per year would rely on all intensive livestock industries incorporating some cassava pellets into their ration. Our preliminary analysis suggests there may be a market for 5,000 t in the poultry and dairy industry if it was used to substitute 30% of the grain ration. The other potential market is as an energy 'spike' for low grade locally manufactured hay cubes used for the live export market. This market is presently supplied by both local product and southern lucerne-based product. The size of this market will depend upon how competitive the energy-enhanced locally produced cube is against the cubes imported from southern Australia and the size of the future live export market. At the present depressed live cattle export levels, the market for a cassava flour, or pellets, as an energy enhancer of local hay cubes would be only 2,300 t assuming 75% of the boat market being supplied from locally produced hay cubes. With a return to live export numbers of 450,000 per year ex Darwin, the cassava pellet market, based on 75% supply from local cubes, could rise to around 7,000 t. It is concluded that, given the recovery of the live cattle export market, there is good market potential for an energy dense feedstuff produced from cassava in the top end of NT..

5. At $267/tonne, cassava pellets produced in <u>south east Queensland</u> would not be competitive with feedgrain in any year. The feedgrain price over the past decade in SE Queensland has ranged from around $110/tonne to $240/tonne at feedlot gate. At $267/tonne, ex cassava factory, cassava pellets could not compete with feedgrain, even in the worst case scenario for feedgrain price. Given freight rates to feedlot-gate are likely to be $10 to $30/tonne the competitive position of cassava pellets is further diminished with the present geographic disposition of feedlots in SE Queensland. The conclusion is reached that cassava as an energy dense feedstuff for the intensive livestock industry is unlikely to be viable in this region.

6. There are some uncertainties which could enhance, or depress, the prospect of a new cassava based feedstock industry in the top end of the Northern Territory. These are:

- yield assumptions may be depressed by termite attack, particularly for a biennial harvest program, and agronomic solutions to this problem need to be found;

- on the other hand, yield assumptions used here are based on the previous standard variety (M Aus 7) which are conservative relative to the yields which were achieved from new cultivar selections (e.g. ACP444 - 25 to 50% higher) in the late 1980's;

- a satisfactory array of superior cultivars exist in Australia but often in small quantity (e.g. single plant) and it is estimated that it would take up to 4 years to multiply this planting material to enable 400 ha to be planted;

- the availability of land with reliable irrigation potential in the Daly/Katherine region was not investigated in the field by this study and qualifies the basic assumptions made here;

- specialised machinery for mechanised cassava farming developed by Australian Cassava Plantations Pty Ltd during the 1980's solved the key problems, but this machinery no longer exists and would have to be rebuilt from scratch; no documented specifications or plans exist for these machines and its re-development would depend on the knowledge and experience of the very few people who were involved in its original development;

- a purpose-built processor for the manufacture of cassava pellets from mechanically harvested cassava roots has not been developed, to our knowledge, anywhere in the world and further development would be required;

- application of new drying technology (e.g. refrigeration dehydrators or low grade heat) which is now being applied in a raft of other primary industries has the potential to greatly reduce the processing cost; it has been suggested that the cost of drying by oil burning (as assumed in this study) could be reduced by 50%, or $10/tonne; the establishment of a viable cassava based stockfeed industry would necessarily apply such technology;

- feedgrain substitution by cassava in rations for intensive livestock feeding has to also add protein because of cassava's extremely low protein level - the economics of cassava as a feedgrain substitution will be determined by the parallel cost of supplying substitute protein;

- cassava plant tops are high in protein (albeit with some qualification as to its feeding value) and offer a prospect of being harvested as a feedstock for protein meal production where the plant is not deciduous in the dry season - there is some prospect that this could improve the economics of a cassava based industry in the NT but detailed development of this concept needs to be carried out.

7. It is concluded that cassava as a source of an energy dense stockfeed looks promising in the top end of the Northern Territory where the climatic conditions are optimum for its growth, where the opportunity cost of alternative energy dense feedstuffs is high and where there is a limited but, adequate market for the product. Environmental concerns are minimal for an integrated irrigation structure whereby effluent water from the processing operation can be returned to the field and, because of irrigation, the plant can be planted and established before the onset of severe, erosion causing storms.

8. It is proposed that, while there remains some unfinished R&D on cassava as a energy dense feedstuff for the intensive livestock industry in the top end of the NT, the most likely scenario to progress this proposition to fruition would be a joint venture between, say the Northern Territory Government and a private sector feed manufacturer to fill the few remaining knowledge gaps as a precursor to a full scale commercial venture.

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1. INTRODUCTION

1.1 Background

1.1.1 Antecedent MRC Investigations

The Meat Research Corporation (MRC)[1], under its Feedlot Consistency and Sustainability Key Program (FCSKP), commissioned this Phase 2 research into the use of cassava as a possible alternative source of energy dense feedstuff for the cattle feedlot industry following a favourable outcome of Phase 1[2] investigations.

Phase 1, involving an extensive review of alternative crop and byproduct options, identified cassava as one of the few possibilities for supplying a feedstuff with metabolisable energy equal to or greater than 10 megajoules/kilogram and satisfying other selection parameters. However a significant conclusion from Phase 1 was that there appears to be no new feedstuff (cassava included) which is a 'silver bullet' and which could significantly hedge the Australia industry against future feedgrain cost fluctuations which are, in the end, controlled by global supply and demand. Notwithstanding, cassava was considered to have specific potential relevance for, (a) enabling the feedlot industry to expand and develop away from the current predominant grain producing areas (e.g. to provide intensive feed opportunities for northern live cattle export), and (b) enabling improved security of supply of energy dense feedstuffs to the feedlot sector in some localities (e.g. those feedlots which are located at the periphery of feedgrain producing areas and those feedlots which are located in regions which occasionally suffer feed shortages such as in SE Qld). It was this perceived specific opportunity which justified further evaluation of cassava as an alternative energy dense feedstuff in Australia.

1.1.2 Cassava in an Australian and Global Context

A detailed account of the history of cassava's development in Australia and its global importance is provided in a summary prepared by Australian Cassava Products Pty Ltd (ACP) (*Attachment B).*

The 'oil crisis' in the 1970's was a key factor in the awakening of interest by CSR and Bundaberg Sugar in cassava as a possible feedstock for the production of ethanol for use in motor fuel blends. Concurrently Fielder Gilespie were developing interest in the crop as a source of food starch, which has unusual viscosity and dimensional strength characteristics. These three companies eventually joint-ventured as ACP to undertaken cassava research.

However, by the mid 1980's CSR and Bundaberg Sugar had lost interest due to the non competitive price of ethanol blends[3] which was exacerbated by the Government policy of maintaining excise duty on ethanol blended automotive fuels, the fading of the fuel crisis and the opposition to ethanol fuels from the petroleum industry. Finally Fielder Gilespie bowed out, apparently after a change in top management which curtailed R&D into new agricultural

[1] On 1/7/98 the Meat Research Corporation (MRC) was absorbed into a new organisation, Meat and Livestock Australia (MLA).

[2] MRC Phase 1 report (Feb. 1997) prepared by Aquila Agribusiness P/L, Ross Bentley & Associates & IM Wood & Associates

[3] For the best case scenario, cost of production of ethanol from cassava (farm variable & fixed costs + feedstock transport & processing + 15% profit) at the ACP's Torbanlea farm amounted to 56c/litre compared to 36c/litre for petrol ex refinery (free of excise duty) a margin of 20c in favour of petrol at 1984 prices. From Report 627 Harris,N.V (1985)

products. ACP effectively ceased to operate in 1986/87 and with its cessation of operations any further development of a cassava based industry in Australia collapsed.

At its demise, Australian Cassava Products Pty Ltd comprised a shareholding of:

Fielder Gillespie Ltd	40%
CSR Ltd	40%
Bundaberg Sugar Company	20%

The formation of ACP in the 1980's was preceded by a decade of R&D by Fielder Gillespie, and to a lesser extent by CSR and included:

- acquisition in 1975 by Fielder Gillespie of a 250 ha property at Yandaran near Bundaberg on which research into cassava agronomy and pilot processing studies were undertaken;

- lease in 1978 by Fielder Gillespie of 4,000 ha at Torbanlea, near Maryborough intended for commercial development of cassava as warranted by feasibility studies;

- a CSR program of varietal selection and agronomy at other locations in Queensland and New South Wales.

The Queensland Department of Primary Industries and University of Queensland as well as ACP carried out cassava research in the 70's and 80's and was supported by grants from the National Energy Research Development and Demonstration Committee (NERDDC). Some cassava agronomy research was also carried out on the Daly River by the Northern Territory Department of Primary Industries and Fisheries (G. Schultz pers.com.).

Because cassava in most parts of the world is grown as a subsistence crop, the mechanised farming research carried out during the 1982- 1986 period at Torbanlea has been of particular use for the evaluation of future commercial development in Australia. This research involved development and demonstration of, (a) planting and harvesting equipment suitable for Australian conditions, (b) agricultural systems using mechanisation, and (c) the cost of growing cassava on a commercial scale. Area planted here peaked at 500 ha and results of this field work at Torbanlea are presented in a number of summary reports (e.g. Harris, N.V. (1985)- Report Number 627; Harris, N.V. & Tlaskal, J. (1985) - Report Number 445).

Despite two sugar companies investing in cassava R&D, it is noteworthy that cassava R&D did not receive unqualified support from the whole of the sugar industry. It is understood that the interest of the two sugar companies in cassava was heightened due the potential economic benefit of shared infrastructure between existing sugar mills and future starch and ethanol processing plants. The general opposition to cassava by the cane industry was based on concerns about competition for land, which may not have been unfounded, but there is evidence that sugarcane and cassava can be grow in a rotation which is beneficial to sugarcane in some situations.

1.2 Study Objectives

The objective of Phase 2, shown in detail in Attachment H, is in summary, as follows:

"To review past research and commercial experience in Australia and overseas and on the basis of this:

(a) compile and collate information available on the use of cassava in cattle feedlot rations and present it in a form of a reference document for use by industry operators,

(b) evaluate the technical and financial feasibility of establishing a commercial cassava production and processing industry in Australia capable of supplying the intensive industries with an energy dense feedstuff, and

(c) make recommendations on the feasibility of establishing a commercial cassava production and processing industry in Australia, outlining the necessary steps for catalysing commercial development, should such development be recommended as feasible."

1.3 Study Approach

A three person team carried out the research: Dr John Doyle (cattle nutritionist), Mr Lincoln Doggrell (cassava agronomist) and Mr Ian Sillar (project analyst).

The adopted study ethos, consistent with the terms of reference, entailed a focus on collating, as a priority, the past 'hands on' field experience with cassava growing in Australia, and on providing a commercial perspective to the feasibility of growing cassava and producing a cassava based feedstuff which could be cost competitive in the intensive cattle industries.

On the cassava agronomy side we have been able to document much of the past experience with the crop in Australia through the input of Lincoln Doggrell who was the operations manager and agronomist with Australia Cassava Products Pty Ltd from 1980 to 1986 and who thereby has had a wealth of practical field experience with cassava growing and processing in Australia. However past commercial forays into growing cassava in Australia were orientated towards producing ethanol and starch for human consumption and therefore required different processing requirements which are discussed in the body of this report.

On the cattle nutrition side, we have undertaken a world literature review from which we have documented the intrinsic feeding value of dried cassava feedstuff products. However specific nutrient analysis of the cassava stockfeed output from mechanised growing and processing of selected high yielding Australian cultivars is not known and may vary slightly from the reported generic feeding values. The point at issue is that for stockfeed, the processing requirements may be less exacting than for industrial starch or ethanol production, and concomitantly different cultivars may emerge, resulting in a different end product with a different feeding value. For a stockfeed-dedicated cassava industry these issues would require further research.

On the project analysis side, the focus has been a comparative analysis of the potential long term returns from cassava benchmarked against sugarcane which is the dominant existing crop in the potential edapho-climatic zone suitable for cassava. Germane to this analysis is the relative trends and volatility of regional feedgrain prices vs sugar and price thresholds at which a grower may shift from one commodity to the other, or indeed, the regional price for feedgrain which would encourage a corporate investor to invest in cassava stockfeed production.

2. CASSAVA - AN ENERGY FEEDSTUFF

2.1 Product Description

Cassava (Manihot esculenta Crantz.) root contains an average of 35 to 40 % dry matter (DM), 82 to 88 % carbohydrate, 0.4 to 4.0 % ether extract, 2 to 4 % crude protein, 4 to 5 % crude fibre 84 % total digestible nutrients (TDN) with comparatively low vitamin and mineral content. The non-structural carbohydrates (NSC) component of the root is approximately 80 %, and the NSC contains 80 % starch, 20 % sugars and amides. Starch content is composed of 20 % amylose and 70 % amylopectin.

Cassava root contains a low quantity of protein and/or nitrogen for animal feeding. The nitrogen content of cassava is composed of 60 % amino acid, and 1 % from nitrates, nitrites and hydrogen cyanide. The remaining 38 to 40 % nitrogen has not been identified. The levels of total nitrogen and non-protein nitrogen are higher in the bark than in the whole root.

Cassava may be fed fresh, but in limited quantities due to potential toxicity. It may also be fed as silage or dry with diminished toxicity, and other parts of the cassava plant (e.g. leaf and stem) can be used for animal forage. However to provide a practical alternative energy dense feedstuff for the Australian cattle feedlot industry a dried root product will be required. Dried cassava product can be manufactured as either chip, meal or pellets. Chips and meal are inferior to pellets because of (a) mechanical handling difficulties, (b) variation in density and size, and (c) inferior nutrient digestibility. The relative merit of pellets, chip and meal are discussed in more detail below but the essential focus of this report assumes that pelleted cassava root is the only feasible form for utilisation by the Australian cattle feedlot industry.

2.2 Cassava Pellet Nutrient Analysis

The nutrient feed value of cassava pellets compared to dry rolled barley, as compiled from National Research Council[4] data and from analysis provided by various Australian feed laboratories, is shown in Table 2.1. Barley is used to benchmark the feeding value of cassava because of its comparable net energy value which is considered more important in high energy ration compilation than other measures of energy in the feedstuff (e.g. gross energy, digestible energy and metabolisable energy).

Table 2.1

Item	**Cassava (pellets)**	**Barley (dry rolled)**
Dry matter (DM) (%)	88.00	88.00
Neutral digestible fibre (NDF) (%)	8.00	18.10
Acid detergent fibre (ADF) (%)	5.00	5.78
Fat (%)	0.80	2.20
Ash (%)	3.00	2.40

[4] “Nutrient Requirements of Beef Cattle” (1996) 7th revised edition

Item	**Cassava (pellets)**	**Barley (dry rolled)**
Total digestible nutrients (TDN) (%)	84.00	84.00
Starch (non structural carbohydrate) (estimated for Cassava) (%)	68.00	90.00
Metabolisable energy (Mcal/kg)	3.04	3.04
Metabolisable energy (MJ/kg)	12.72	12.72
Net energy (NE m Mcal/kg)	2.06	2.06
Net energy (NE g Mcal/kg)	1.40	1.40
Crude protein (CP%)	3.10	12.00
Degraded intake protein (DIP) %CP	56.11	66.93
Undegraded intake protein (UIP) %CP	43.89	33.07
Soluble protein (Sol P) %CP	25.00	17.00
Non protein nitrogen (NPN) % Sol P	45.00	29.00
Neutral detergent insoluble protein (NDFIP) %CP	30.00	8.00
Acid detergent insoluble protein (ADFFIP) %CP	5.00	5.00
<u>Carbohydrate Digestion Rate</u>		
Rumen rate of sugar digestion (A kd^a %/hr)	300.00	300.00
Rumen rate of starch digestion (B1 kd^a %/hr)	40.00	30.00
Rumen rate of available fibre digestion (B2 kd^a %/hr)	8.00	5.00
<u>Protein Digestion Rate</u>		
Rumen rate of digestion of the rapidly degraded protein fraction (B1 kd^b %/hr)	300.00	300.00
Rumen rate of digestion of the intermediately degraded protein fraction (B2 kd^b %/hr)	12.00	12.00
Rumen rate of digestion of the slowly degraded protein fraction (B3 kd^b %/hr)	0.35	0.35
		<u>Mineral</u>
Calcium (%)	0.28	0.05

Item	Cassava (pellets)	Barley (dry rolled)
Phosphorus (%)	0.19	0.35
Potassium (%)	0.26	0.57

The noteworthy points from the comparative nutrient analysis for cassava and barley are:

- similar energy profile
- very low crude protein of cassava
- higher calcium for cassava but lower phosphorus and potassium

In the literature there are numerous reports of feeding trials evaluating cassava as an energy substitute for grain combined with the addition of various protein sources. Many of these trials fail to equate net energy values of the rations with and without cassava and when fed in high energy feedlot diets do not accurately reflect the cassava substitution value.

the inclusion of cassava as a grain substitute is approximately 15 - 25 % on a dry matter basis (DMB) for growing medium frame cattle (i.e. < 2 years, < 300 kg) diets. Mature medium frame cattle (i.e. > 2 years, > 400 kg) have a lower dietary protein.

2.3 Processing as it Affects Cassava Utility and Feed Value

2.3.1 The Utility of Pellets, Chips and Meal

Cassava pellets have the preferred physical characteristics which make it 'user friendly' for mechanical handling (eg.conveyor, auger) and transport systems. This is achieved through superior durability, size configuration and pellet density (optimum = 66.0 kg/hectolitre[5]). Cassava chips, on the other hand, lack uniformity of particle size, and have low and variable density. Meals have low density and prone to create dust problems.

Achievement of consistent pellet durability is likely to be a key factor if cassava pellets are to achieve acceptable levels of substitution for grain in beef cattle feedlot diets in Australia. Consistent pellet durability is achievable but requires constant monitoring in the pellet manufacturing process using a 'pellet durability test chamber'[6].

2.3.2 Feed Value Enhancement through Pelleting

Particle size of processed cassava can influence the ration’s physical nature, homogeneous mixing character and feed intake. The larger particles of cassava chip are easily ‘sorted’ from feed. Meals, on the other hand, with fine particles (i.e. flour consistency) can lower animal feed consumption. A desirable particle size for cassava can range from a minimum

[5] Compared to barley = 62.5, wheat = 75.0 and sorghum=75.0 kg/hectolitre
[6] This process involves taking a sample of pellets at ambient temperatures (i.e. cool and water evaporated for a constant % DM) and sieving with a screen slightly smaller than the pellet. Then 500 grams of sieved pellets is then placed into the tumbler for 10 minutes. The sample is removed, sieved and percent of whole pellets is calculated.

Pellet durability is defined: <u>Weight of pellets post tumbling</u>
Weight of pellets prior tumbling X 100

equal to the primary processed grain in the ration to a pellet no greater than 6.5mm diam. x 10.0 to 15.0 mm.

Where cassava chips are produced as the raw commodity, processing these chips through a pellet press is the most practical method for standardizing mechanical handling systems, transport procedures and nutritive value for feeding and provides a uniform product for manufacturing a homogeneous ration. Pellet size of 6.0-6.5 mm is optimum; smaller pellet size increases production run cost and possibly create handling difficulties.

Processing cassava into pellets improves nutrient digestibility and can play a role in decreasing potential toxicity.

Pelletisation (a hydro-thermal process) improves the nutrient digestibility by increasing the starch solubility and/or availability to ruminants of high starch feedstuffs. Cassava, a high starch feedstuff, is composed of amylose (20 %) and amylopectin (70 %) structures (i.e. linear or branched crystalline structure, resistance of solubility) and cassava digestibility can be improved, by disrupting the structural integrity of these compounds, by up to 7 percent, although the level of improvement is highly variable.

Hydro-thermal processing (heating to 60^0 C with water) disrupts the starch granules by breaking the hydrogen bonding of the starch molecule, a process similar to improving digestibility of starch obtained through steam flaking grain. For cassava, this process would allow further release of HCN remaining in the chip product.

2.4 Dietary Limitations

2.4.1 Beef Cattle

Zinn et al (1991)has shown that a blend of 86% cassava pellets and 14% peanut meal could substitute up to 30 % of the dry matter (otherwise fed as steam-flaked corn) in growing/finishing diets without adversely affecting average daily gain(ADG) or dry matter intake (DMI) of feedlot cattle. Importantly, at 15% substitution, ADG and DMI was higher than either 0% or 30% steam flake corn substitution. The achieved 9% increase in DMI is related to a lower energy content in cassava versus SFC diets (NEg Mcal/kg 1.40 versus 1.48).

Zinn et al (1991) also showed that when steam flake corn and cassava pellets were included in the diet at 67% on a dry matter basis, ruminal starch digestion and total tract digestion, as percentage of feed intake, were similar for SFC and cassava pellets (ruminal digestion: SFC - 91.8, T - 90.8) (total tract digestion: SFC - 99.1, T - 98.8). The digestible energy value (DE Mcal/kg - 3.71 versus 3.31) of the diet decreased 11.5% (P<.01) with the substitution of cassava for SFC.

From a dietary viewpoint, the main problem with cassava, compared to grains (eg. barley, sorghum or wheat), is it's extremely low level of protein and some minerals (see Table 2.1). While the work of Zinn et al suggests that from a dietary viewpoint cassava pellet may be used at reasonably high levels in a ration for cattle, it is the economics of augmenting cassava's low protein levels with protein rich feedstuffs which sets the ceiling to its inclusion.

The amount of cassava included in the diet is dependent upon (a) animal nutritional requirements, (b) nutrient content of the companion grains, and (c) availability of protein sources. Identification of the animal nutritional requirements, nutritive value of dietary grains (eg. barley, sorghum or wheat) and availability of various protein sources (ie. cottonseed, canola, soybean or peanut meal, lupins) enables economic feasibility of cassava feeding to be determined.

Based on the prevailing cost of supplemental protein, a *prima facie* 'rule of thumb' for requirement, hence fed diets with lower protein content. Cassava inclusion can be as high as 30% on a DMB for mature cattle on 150 to 400 day finishing programs (eg. Japanese export market).

As the level of cassava is increased within the diet several minerals must be supplemented in higher quantities. These minerals vary for each animal species and/or age of animal but generally includes phosphorus, magnesium and sulphur. Phosphorus is not supplemented in high quantities in feedlot diets unless feeding young animals (eg. < 250 kg) because both grain and protein sources provides a majority of the requirement. High levels of dietary phosphorus within feedstuffs and/or rations may not be utilized by mature cattle and excreted, becoming a waste management issue. The low level of sulphur (ie. sulphur amino acids - methionine, cystine and cysteine) in cassava requires supplementation to meet animal dietary requirement as well as acting as a donor group for detoxification of existing cyanide. Similar situation exist for poultry and pig diets, with added methionine (i.e. sulphur containing amino acid) being required to meet animals amino acid requirement.

2.4.2 Dairy Cows, Pigs and Poultry

Limitations of Cassava in Dairy, Pig and Poultry Diets

Feeding cassava to livestock is dependent upon identifying an economical protein and/or amino acid source to fulfil animal nutrient requirements for a desired level of production. Methionine is the primary limiting amino acid to cassava based diets for monogastrics and can be, for high lactating dairy cows. The supplementation of methionine aids in detoxification of cyanide by providing labile sulphur as well as other sulphur based amino acids (i.e. cystine and cysteine). Animals possessing high metabolic rates (chickens and pigs) and/or growth rates respond quickly (e.g. slowing growth or contracting disease) to diets deficient in vitamins (i.e. niacin and B_{12}) and trace minerals (ie. zinc and copper).

Dairy - Lactation

Dairy cows can be fed cassava up to 12% (DMB) as a source of energy for specified production (eg. milk 30 kg/d, 4% FCM 27 kg/d) in balanced diets. The major limitation when feeding cassava in dairy rations is meeting protein, essential amino acids (ie. methionine) or sulphur and fat requirement for lactating cows. Cassava inclusion in lactating rations (ie. 12 DMB) has not caused adverse milk fatty acid production (DePeters & Zinn, 1992).

Poultry

Cassava can be fed to broilers at levels between 10 to 20% and no greater than 20% in layer diets. The floury nature of cassava meal does create some problems when fed to poultry. Broiler diets are best pelleted in the compounded feed to minimize dust whereas molasses and fat can be added to layer mash.

The low protein and/or amino acid (ie. methionine) content of cassava requires supplemental sources for poultry diets. When substituted for corn, egg yolks whiten because of low fat and pigmented xanthophyll content.

2.5 Economics of Using Cassava in Cattle Diets

The economics of including cassava in various diets is dependent on cost of natural protein meal and desired energy density of diet. In this section a cost comparison is made between (a) dry rolled barley alone and (b) cassava plus various protein sources for which the crude protein levels have been standardised at 12% CP on a dry matter basis being equivalent to the protein level in barley. Barley is used because it is a standard grain used throughout the Australian beef cattle feedlot industry and because it has the same energy profile as cassava. Six protein sources are considered: cotton seed meal, peanut, whole cotton seed, canola, soybean meal and lupin.

The inputs into the cost comparison are shown in *Tables 2.2 to 2.6* below.

Table 2.2: Feedstuff Nutrient Analysis

Feedstuff	Dry Matter (%)	NE m (maintenance) (Mcal/kg DM)	NE g (growth) (Mcal/kg DM)	ME (MJ/kg DM)	CP (%DM basis)
Barley	88	2.06	1.40	12.72	12.00
Cassava pellets	***88***	***2.06***	***1.40***	***12.72***	***3.10***
Cotton Seed Meal	89	1.73	1.11	11.72	44.30
Canola	92	1.60	1.00	10.42	40.60
Peanut	91	1.85	1.22	11.63	45.20
Soybean Meal	90	2.06	1.40	12.72	49.00
Lupin	87	1.91	1.27	12.00	37.00
Whole Cotton Seed	90	2.34	1.63	13.60	24.00

Table 2.3 represents AS FED quantity of cassava and specified protein source required to achieve a 12% CP DMB barley equivalent. This allows one to calculate a relative nutrient price for cassava and protein source when compared to barley.

Table 2.3: Admixture of Cassava and Various Protein Sources on AS FED Basis Required to Standardise the Feedstuff to 12% CP DMB

Protein Source	Protein Source (%)	Cassava (%)
Cottonseed Meal	21.50	78.50
Canola Meal	23.00	77.00

Protein Source	Protein Source (%)	Cassava (%)
Peanut Meal	20.50	79.50
Soybean Meal	19.00	81.00
Lupin	26.50	73.50
Whole Cottonseed	42.00	58.00

Compared to the dry rolled barley, net energy value for cassava + protein source is enhanced where whole cotton seed is the protein source. For an admixture with soybean meal the net energy value is the same, and depressed for cassava in combination with cottonseed meal, lupin, peanut and canola (Table 2.4).

Table 2.4: Energy Value of a Mix of Cassava plus Various Protein Meals Standardised to 12% Crude Protein on a Dry Matter Basis

Feedstuff	Dry Matter (%)	NE m (Mcal/kg DM)	NE g (Mcal/kg DM)	ME (MJ/kg DM)	CP (% DM basis)
Cassava + Whole Cotton Seed	89	2.18	1.50	13.09	12
Cassava + Soybean Meal	88	2.06	1.40	12.72	12
Dry Rolled Barley Benchmark	**88**	**2.06**	**1.40**	**12.72**	**12**
Cassava + Cotton Seed Meal	88	2.02	1.36	12.70	12
Cassava + Lupin	88	2.02	1.36	12.53	12
Cassava + Peanut	89	2.01	1.36	12.49	12
Cassava + Canola	89	1.95	1.30	12.17	12

Assumed feedlot gate market price for the various feedstuff ingredients is shown in Table 2.5.

Table 2.5: Feedstuff Ingredient Price

Feedstuff	Assumed $/MT	$/MT DM	$/% CP (DM basis)	NE g $/Mcal	ME $/MJ
Barley	120.00	136.36	1.136	0.0974	0.01072
Cassava pellets	***75.00***	***85.23***	***2.449***	***0.0608***	***0.00670***
Cotton Seed Meal	235.00	264.04	0.596	0.2129	0.02089
Canola	250.00	271.74	0.669	0.2717	0.02608

Feedstuff	Assumed $/MT	$/MT DM	$/% CP (DM basis)	NE g $/Mcal	ME $/MJ
Peanut	185.00	203.30	0.450	0.1666	0.01748
Soybean Meal	380.00	422.22	0.862	0.3016	0.03319
Lupin	180.00	206.90	0.559	0.1629	0.01724
Whole Cotton Seed	180.00	200.00	0.952	0.1227	0.01470

Table 2.6: Comparative Price of Cassava Based Feedstuffs Standardised to 12% Crude Protein (ie. = dry rolled Barley) using Various Protein Sources to Raise Cassava Protein Level

Feedstuff	$/MT	$/MT DM	$/% CP (DM basis)	NE g $/Mcal-kg	ME $/MJ-kg	Rank by Least Cost Energy
Cassava pellet + Peanut	97.55	107.93	0.8994	0.0792	0.00864	1
Cassava pellets + Lupin	102.83	117.83	0.9819	0.0863	0.00940	2
Cassava pellets + Cotton Seed Meal	109.40	123.22	1.026	0.0903	0.00970	3
Cassava pellets + Canola	115.25	126.54	1.0545	0.0970	0.01040	4
Cassava pellets + Whole Cotton Seed	119.10	133.58	1.11.32	0.0871	0.01020	5
Barley	**120.00**	**136.36**	**1.1360**	**0.0974**	**0.01072**	**6**
Cassava pellets 7+ Soybean Meal	132.95	148.35	1.2360	0.1060	0.01166	7

Table 2.6 shows, based on the assumptions made, that five of the cassava admixtures standardised to 12% CP (ie. with peanut, lupin, cotton seed, whole cotton seed and canola) deliver energy at a lower unit cost than barley. Also these same admixtures deliver crude protein at a lower unit cost than dry rolled barley.

Protein equivalent nitrogen (PEN) is recognized as an excellent source of nitrogen for rumen bacteria and feedlot diets are traditionally supplemented with 1.0 to 1.80% PEN. This low quantity of PEN would contribute a small quantity to supplemental protein in diets with cassava inclusion. Primary nitrogen sources are derived from ammonium sulphate, urea and to a lesser extent soluble nitrogen from feedstuffs (e.g. silage). The determinant of protein equivalent nitrogen that can be utilized within a diet is dependent upon the concentration of non-structural carbohydrates and fat. Ultimately, PEN should not be viewed as a major contribution for rumen bacteria protein in diets containing cassava - supplementation of excessive PEN predisposes cattle to ammonium toxicity.

2.6 Animal Health Implications

Feeding a highly available starch source to ruminants can potentiate digestive disease when inadequate fibre is present in the ration. Cassava pellets should be treated as other grains for feedlot rations, requiring approximately 12% roughage or 23% NDF on DMB for finishing diets.

2.7 Carcase Quality Implications

Cassava cattle feeding trials and industry use has observed predicted live weight gain response with little reference to carcase quality characteristics.

Carcase quality characteristics are dependent upon the country's grading system. Meat Standard Australia (ie. grading system) was recently developed and is now under review. The most recognized carcase grading system is in the USA (ie. USDA, 1965), however it fails to recognize fat and meat colour which are major components of the Japanese grading system.

Cassava's high carbohydrate and low fat content would have little direct impact on carcase quality with inclusion of 30% DMB. For the Australian feedlot industry, a major concern when feeding new feedstuffs is the likely influence on meat and fat colour. The low fat and carotenoid or xanthophyll (ie. pigment) content of cassava would not compromise animal tissue colour. However, supplemental protein sources required to satisfy animals nutrient requirement may influence final carcase composition.

Zinn et al (1991) observed, cassava pellet inclusion at 0, 15 and 30% on a dry matter basis (DMB) in finishing diets. Live weight gain and empty body gain tended to be maximized at cassava inclusion at 15%. It appears that lower levels (ie. 15%, DMB) of inclusion were highly palatable and perhaps stimulatory to feed intake. Influence of cassava on carcase characteristics was small, although a slightly higher marbling score (i.e. USDA) for 15 % cassava treatment ($P > .10$).

2.8 Toxicity

The cassava plant is poisonous and livestock or humans should not eat the raw tubers and leaves. The toxins contained in all parts of the cassava plant are two glycosides, linamarin and lotaustralin. Concentration of these toxins varies with the variety and with environmental and cultural conditions. Cyanoglucoside content ranges from 15 to 400 ppm. "Bitter" varieties are so called because they have a high level of HCN (>100ppm) and "sweet" varieties have low levels of HCN (< 100 ppm).

The plant contains specific enzymes, linamarinase and lotautralinase. These enzymes are released when the plant is damaged (e.g. crushed) converting glycosides to HCN. The remaining HCN can be driven off by heat or reduced through fermentation.

Glycosides that are ingested are hydrolysed by intestine microflora to yield HCN. Low concentrations can be detoxified by the bodies enzyme rhodanase to a less toxic thiocynate

(SCN) and excreted via urine. Efficient detoxification utilizes methionine as a sulphur donor and methyl group. This makes methionine the first limiting amino acid in cassava-based rations. Thiocynate is a potent goitrogenic substance.

Detoxification processes (ie. reduction of HCN) vary in different countries. Methods vary from drying, soaking, boiling fermentation and/or a combination of two or more methods. Bound and free HCN can be detoxified through drying at temperatures above 60^0 C. Drying chips with heat, followed by pellet process would eliminate the majority of HCN.

Ruminants have been fed high levels of cassava in several forms (i.e. fresh, silage, dry chip & pellet) without ill effect. This may be related to the quantity consumed over time and in combination with other feedstuffs. High levels of HCN intake by ruminants in other feedstuffs (ie. sorghum grass) can induce toxicity. Wheeler et al, (1975) proposed *in vivo* detoxification through increasing activity of the enzyme rhodanase by supplementation of 1.2 g of sulphur per g of HCN ingested. Hence, higher levels of dietary S supplementation may be required to minimize any potential toxic effect of remaining HCN.

The levels of cassava inclusion considered in this investigation is no greater than 30% DM, considerably lowering the potential incidence of toxicity.

2.9 Purchase Specification, Receival Standards, Testing Procedures

Based on the use of a pelleted cassava product the following <u>purchase specifications</u> are proposed:

A. <u>Physical</u>

- % dry matter : > 87%
- density : > 65.0 kg/hectolitre
- Durability : assessed with sieve (slightly smaller than pellet) > 95 % durability prior plant departure.

B. <u>Nutrient</u>

- % dry matter : not less than 87%
- % starch : not less than 65%
- % CP : not less than 3.0%
- % ADF : not greater than 10.0%
- % Fat : not less than 0.5%
- % TDN : not less than 84.0%

<u>Feedlot receival procedure</u> would require random pellet samples (eg. 5 samples per truck-load) obtained with grain spear and pellets physical assessed as follows:

- % dry matter :> 87% DM
- density :> 65.0 kg/hectolitre
- fines :assessed with sieve, weight difference - fine weight/pellet weight - 90%.

3. CASSAVA PRODUCTION

3.1 Plant Description

Cassava (*Manihot esculanta* Crantz) is also commonly known as yuca, manioc, mandioca or tapioca. It is a perennial shrub growing to 5 metres tall with swollen starchy roots. The roots are used for human and stock feed and for making industrial starches and for the production of ethanol.

Cassava has a palmate leaf which may vary in colour from either light or dark green through reddish and purple colour to one variety which is variegated yellow and green and commonly planted in tropical and subtropical Australia as an ornamental plant.

Cassava originates from South America and has been used through the north of South America and Central America for human food for 4,000 years. During the past 400 years cassava was introduced into Central Africa followed by its introduction to Asia, probably through Indonesia. Today cassava is a large and valuable component of the total food intake for peoples living in the tropical and sub tropical belts of Central and South America, Africa, Asia and the Pacific regions.

Cassava is characterised by being high in carbohydrate and low in protein. Human or stock diets high in cassava must be supplemented to avoid severe protein, vitamin and mineral deficiencies. Numerous methods of preparation of roots exist and range from simple boiling, inclusion in wet dishes such as stews, to the manufacture of starch flour and bread. The inhabitants of some regions include cassava leaves in the cooking as they are high in protein although this does not provide a completely balanced protein intake, this practice avoids gross protein deficiency.

Some cultivars of cassava are high in cyanide compounds and can be toxic to humans and stock. Most of the commercial cultivars are relatively low in toxic compounds so do not normally pose a risk when eaten. The risk of poisoning is normally reduced greatly once cassava is cooked or processed.

Cassava is frequently used for subsistence agriculture as a crop of last resort under adverse conditions of low soil fertility and low rainfall. The ability of cassava to produce some crop under quite extreme conditions is frequently misinterpreted to indicate that continued cassava growing ruins the nutrient status of the soil.

3.2 Cultivar Availability for Industry Start-Up

ACP, during its cassava evaluation program in the 1980's, had grown, in its evaluation nursery, over 80 cultivars (See *Attachment G*) some of which had also been dispersed to the University of Queensland and to the Queensland Department of Primary Industries. These collections have not been maintained. Individual plants of superior identifiable cultivars have survived in private gardens, at Redland Bay Research Station and at Ayr Research Station.

Start-up of a cassava-based stockfeed industry would necessarily depend upon bulking-up of these remaining, albeit limited number of, superior cultivars. Vegetative propagation, using stem cuttings is necessary to preserve the yield potential. Cassava cannot be propagated from the tuber.

There are three identifiable cultivars with a high root yielding potential which have been brought to the notice of this study. These are:

<u>M Aus 7</u>, the benchmark standard Australian cultivar of the 1980's and the one on which all yield forecasts in this report are based. This cultivar was collected from a sugar mill garden in Cairns and probably came originally from Fiji. With a growth habit of medium height and non branching, this cultivar is well suited to mechanical farming. We understand identifiable individual plants of this are currently held by University of Queensland, QDPI and perhaps individual growers in North Queensland.

<u>ACP 444</u> is a cultivar which was selected by ACP at Torbanlea for superior root yield to M Aus 7 (25-50% higher) and exhibits some cold tolerance. ACP 444 is a taller growing plant with some branching and a more open leaf canopy. Identifiable individual plants of this cultivar are held by Lincoln Doggrell, a co-author of this report.

<u>M Col 1468</u> is a cultivar collected from CIAT in Colombia and has superior root yielding ability to M Aus 7. The growth habit of this cultivar is reasonably upright and more branched than M Aus 7. Identifiable individual plants of this cultivar are held by Lincoln Doggrell, a co-author of this report.

An additional 5 un-named superior cultivars which were selected during the ACP research from the first generation of open pollinated seedlings are also maintained by Lincoln Doggrell.

Cassava shows considerable genotype-by-environment interaction and work from CIAT indicates that any one genotype may not perform well in the full range of global ecological regions in which cassava grows. While MAus 7 has performed well over a wide range of environmental conditions in Australia, the performance of the other residual superior cultivars selected at Torbanlea would have to be tested at lower latitudes before commercial development occurred.

Strict quarantine conditions apply to the importation of cassava as Australia is free of major overseas diseases (e.g. African Cassava Mosaic and bacterial leaf blights). Generally previous importations from overseas have not performed as well as those which have been adapted to the Australian environment over the past 50 years. Re-establishment of the cassava industry is considered feasible based on the current available suite of cultivars but reassembling of the Australian collection to preserve the genetic diversity for future plant breeding would be warranted.

It would take 4 years to bulk-up 1 plant to 6 million plants (enough to plant 400 ha) given intensive propagation and good cultural practice. The following schedule applies:

Year 0 1 mature plant, intensive propagation -> 150 cuttings 50mm long
Year 1 150 mature plants, intensive propagation @ 150/plant -> 20,000 cuttings
Year 2 20,000 mature plants, semi intensive propagation @ 60/plant -> 1.2 mil.cuttings
Year 3 1.2 mil.mature plants, commercial propagation @ 5/plant -> 6.0 million.
Year 4 6.0 mil.cuttings would plant 400 ha @ 15,000/ha

3.3 Yield Potential

World average yield of cassava is a low 10 t FW /ha because of its principal role as a subsistence crop with minimal agricultural inputs and because often it is grown as a companion crop in food gardens. Fresh root yields of 70 t/ha/yr have been obtained in overseas experiments at CIAT.

In Australia, using the standard variety (MAus7) the root dry-matter yield potential of cassava grown under optimum soil conditions and crop husbandry were predicted (using a field validated simulation model[7]) to range between a low of 12.5 t DM/ha (Redland Bay) and 23.3 t DM/ha (Townsville) (*Table 3.1)*. With root dry matter levels of say 37.50% (range 35-40%) the fresh weight yield equivalents would be approximately 33 t/ha and 62 t/ha for Redland Bay and Townsville respectively. It is noteworthy that much lower yields may be expected under dryland conditions and raises a key question as to whether the irrigation of cassava, where it would be competing with high value crops for scarce water resources, is a commercial imperative or whether optimum financial returns occur under a dryland system. The question of irrigation vs. dryland is discussed elsewhere but it is noteworthy that the ACP venture in the 1980s was based on an irrigated production system.

Table 3.1 Simulated Yield Potential of Cassava Root

Location	Irrigated Root Yield (tonnes DM/ha/yr)	Dryland Root yield (tonnes DM/ha/yr)	Growing Season (weeks)	Rainfall (mm/season)
Cairns	22.6	13.0 (+/- 1.9)	48.3 (+/- 3.9)	1947 (+/- 518)
Townsville	23.3	7.0 (+/- 4.4)	35.8 (+/- 9.7)	836 (+/- 420)
Mackay	15.8	11.4 (+/- 2.9)	41.8 (+/- 4.9)	1929 (+/- 909)
Bundaberg	15.0	8.8 (+/- 4.5)	35.4 (+/- 6.3)	827 (+/- 391)
Redland Bay	12.8	9.8 (+/- 1.4)	37.9 (+/- 1.6)	1119 (+/- 208)

Source: Fukai. S, & Hammer, G.L.

Table 3.1 reflects the effect of climate factors (solar radiation, air temperature, day length, rainfall and pan evaporation) on yield and points to the low latitude requirement for highest yields. It is also noteworthy that the predictive yields in *Table 3.1* are based on the then standard MAus7 cultivar. However, cultivar ACP 444 achieved a 25 to 50% yield increase over M Aus7 at Torbanlea in southern Queensland in the 1980's.

Root yield is affected by the length of time in the ground and can approximately double if left in the ground for a second growing season. *Figure 3.1* shows that in southern Queensland the storage root yield was 17 t/ha dry matter and 34 t/ha dry matter respectively after one and two growing seasons.[8] Slight yield increases have been recorded in the third year. Harris (1978) has shown that over harvest dates, ranging from 7 months to 24 months, the fresh root yield was correlated with age at harvest according to the following relationship:

> *fresh root yield = 3.42 (age in months) - 6.42*
> (correlation coefficient = 0.876)

[7] Fukai,S and Hammer, G.L (1987)
[8] Hammer,GL, Hobman,FR & Shepherd,RK (1987)

Figure 3.1

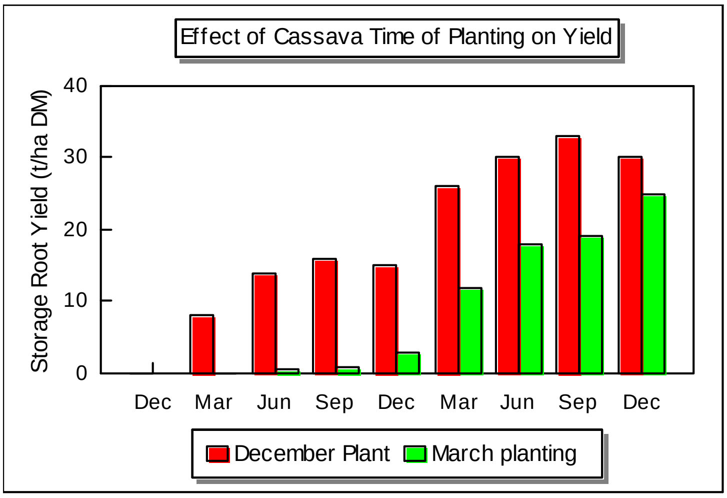


Figure 3.1 also shows that time of planting has a significant effect on the elapse time to harvest and the best time to plant for a quick return is in the spring. A late summer planting has minimal growth until the following wet season but ultimately, after the first growing season, yields as high as the spring planting.

Expected yields under large scale mechanised production could be expected to be lower than those indicated by these simulated models and under experimental conditions. Discounting of yield is necessary to account for a range in time of planting, age of plant at harvest and the need for optimising the annual period of operation of the processing facility which may extend harvest time into times of sub-optimum yield.

For budgeting purposes in this study we have assumed average commercial yields for irrigated MAus 7 grown as a biennial crop (harvesting over crop ages of 16 to 25 months) to be:

Bundaberg:	63 t FW/ha/crop (range 45 t to 73 t)
Darwin:	92 t FW/ha/crop (range 71 t to 114 t)

These yields are based on *Table 3.1* data, assuming (a) Darwin yields equate to Townsville, (b) a commercial-practice discount to 85% and, (c) pro-rata doubling of yield between 12 and 24 months.

3.4 Cassava Agronomy

3.4.1 Nutrition and Soil Requirements

The amount of each nutrient element to produce a cassava crop yielding 30t FW/ha has been calculated[9] as shown in *Table 3.2*.

A cassava crop extracts large amounts of potassium from the soil and may cause depletion of this element if grown continuously without adequate potassium fertilization. On the other hand cassava has a relatively low nitrogen requirement compared to other crops and high nitrogen application may lead to excessive top growth and a reduction in tuber development.

[9] Asher, Edwards & Howeler (1980) “Nutritional Disorders of Cassava. Dept. Agric., UQ, St Lucia, Australia 48 pp

Cassava is also susceptible to phosphorus and zinc deficiencies. Avoiding excessively high or low pH values is advocated to avoid induced mineral deficiencies and periodic liming on some acid soils (pH < 5.5) may be required. For industrial cassava crops which take the root portion only and returns most of the tops to the field, the nutrient drain is less than if the whole plant is utilised.

Table 3.2: Approximate amounts of each element needed to produce a 30tFW/ha crop of cassava

Element	Roots (kg)	Tops (kg)	Total (kg)
Potassium	76	124	200
Nitrogen	38	126	164
Calcium	9	71	80
Phosphorus	10	21	31
Magnesium	9	22	31
Sulphur	6	7	13
Iron			3.6
Manganese			1.53
Zinc			1.35
Boron			0.45
Copper			0.14

Cassava is a difficult crop on which to carry out fertilizer trials although ‘critical concentration’ research by Asher et al (1980) has developed mineral deficiency indicator levels for cassava leaf blades. Most fertilizer recommendations are, however, based on an estimate of what level of mineral nutrients are removed with each crop.

The standard fertilizer dressing adopted by ACP at Torbanlea was pre-plant mix of N:P:K =12:11:19 + trace elements at 500kg/ha and a subsequent side dressing of N:P:K = 23:2:23 + sulphur at 300kg/ha. A split fertilizer application (pre-plant + side dressing) is usually desirable because of the proneness to leaching of the light textured soils on which cassava is grown. ACP also periodically applied gypsum to add calcium and maintain good soil texture for ease of mechanical harvesting.

Cassava cannot tolerate waterlogging and light textured soils are generally required to provide good drainage to optimise growth and to facilitate mechanical harvesting. Therefore the preferred soils are sands to sandy loams with the A_1 horizon at lease 40 cm deep and a permeable sub soil. In northern Australia suitable soil types include the duplexes, podsolics and red and yellow earths.

Once cassava is established it has good drought tolerance. However high yields are a function of good soil moisture during the warmer growing season. Comparatively shallow soils given good summer rainfall or irrigation will yield well.

3.4.2 Plant Population Effect on Yield

Planting density trials done in Australia by ACP with three cultivars of different growth habit (viz. MAus1 - tall height/non branching; MAus7 - medium height/non branching; Maus10 - medium height/branching) showed that there was no yield benefit at two harvest dates (18 mths and 25 mths) by increasing the plant population above 10,000 plants/ha, up to 35,700 plants/ha. Generally as the population increased, the proportion of underground plant parts (i.e. *harvest index)* decreased.

A higher plant population may, however, help to shade the interrow space more quickly and reduce cost of weed control.

3.4.3 Weeds

Weed control in the first 2 to 4 months after planting (i.e. until canopy close) is essential to achieve high root yields in cassava. One CIAT trial showed that root yield at 9 months, with no weed control, was only 1.4 t FW/ha (ie. depressed 93%) compared to 21.1 t FW/ha with full chemical weed control[10].

Weed trash, and dirt collected therewith, present serious difficulties for mechanical harvesting and chemical weed control is particularly important for mechanised production systems. In Australia Harris (1978) showed that *alachlor* as a pre-emergence, if it could be applied with rain or irrigation, was effective for 60 days but this still allowed weed growth before canopy close and post-emergence application, using *paraquat*, was still necessary. Chemical weed control recommendations have been developed at CIAT (Doll & Piedrahita (1996)) as shown in *Table 3.3.*

Table 3.3 Chemical weed control recommendations for cassava

Herbicide	**Rate (commercial product per hectare)**	**Time of Application**	**Note**
Fluometuron (*Cotoran)*	4 - 5 kg	pre-emergence	most annual weeds
Diuron (*Karmex)*	2 - 3 kg	pre-emergence	most annual weeds
Alachlor (*Lasso)*	4 - 6 litre	pre-emergence	excellent on grasses
Linuron *(Afalon/Linuron50)*	2 - 3 kg	pre-emergence	most annual weeds
Fluometuron + Alachlor	2 kg + 2.5 litre	pre-emergence	tank mix
Diuron + Alachlor	1 kg + 2.5 litres	pre-emergence	tank mix
Trifluralin (*Treflan)*	2.5 - 3.5 litres	pre-planting incorporated	excellent on grasses
Butylate (*Sutan)*	5 - 6 litres	pre-planting	grasses and sedges

[10] Pre-emergence application of Alachlor + Fluometuron and post-emergence application of paraquat with a shielded sprayer as needed.

Herbicide	Rate (commercial product per hectare)	Time of Application	Note
		incorporated	
Dalapon (*Dowpon or Agripon)*	8 kg	post-emergence	direct application
Paraquat (*Grammoxone)* + Diuron	2 litres + 2 kg	post emergence	tank mix; direct application with shield

The Australian experience of pre-emergence weed control has shown a number of chemicals to be effective, including *alachlor, diuron, oxyfluofen and trifluralin.* Although expensive, *oxyfluofen* (4 L/ha) is easiest to manage as it does not require soil incorporation or rainfall or irrigation to be effective and gave good weed control until canopy close. It is applied during the planting operation as a 50 cm band over the top of the planted strip.

Alachlor has to be harrowed in or needed rain or irrigation within 10 days to be effective. Some phytotoxicity occurred with *diuron* on sandy soils and *trifluralin* needed to be incorporated immediately after soil application and the turning of the soil in this process turned up a fresh crop of untreated weed seeds.

3.4.4 Pests and Diseases

In Australia, cassava is relatively free of serious diseases. The cuttings need to be sprayed with fungicide and insecticide to protect them during sprouting from soil-borne diseases and insects. *Copper oxychloride* at 8,000 ppm and *Maldison* at 300 ppm are applied at planting. One percent zinc sulphate is also applied to the sets at planting to prevent zinc deficiency to which cassava is highly susceptible.

Rats have been reported as a problem in some situations and it is suggested that the new, environmentally friendly approach to rat control used in the northern cane industry, namely improved adjacent owl habitat may be appropriate. Termites were reported as a significant problem with early trial plantings of cassava in the Daly/Katherine area and continue to be a problem with tree crops in that area. *Dursban* is used, today, in other crops for termite control but its efficacy for termite control in cassava and residual impact, or indeed the magnitude of the problem in a continuously cropped situation, is not known.

3.5 The Agricultural System

3.5.1 Land Development

It is probable that development of a significant cassava industry would require farms to undertake further timber clearing and primary land preparation. This is likely to be the case in both SE Queensland and the Northern Territory, but particularly in the Northern Territory. Because cassava is a root crop, this task has to be thorough and may be expensive. If on-farm irrigation infrastructure is to be developed at the same time, today's costs, as a rule-of-thumb, may vary between $2,000 to $4,500 per hectare.

Typical operations involved in land clearing include: timber felling by chaining, stacking, burning, 'cutter barring' (i.e. deep ripping to bring up tree roots), mechanical stick picking, hand stick picking and macro land levelling and land planning.

Cassava cultural practices predispose water erosion. Factors contributing to this are: the generally light textured soils, the tropical environment prone to severe storms, the slowness for cassava to close canopy and the severe effect annual or biennial root harvest has on soil structure. An imperative of initial farm layout is consideration of soil conservation practices.

3.5.2 Cropping Operations

Optimum Cropping Cycle

An optimum cycle (from the point of view of maximising yield and minimising cost and predisposition to erosion) is one in which the crop is planted in early spring (September) and harvested during the dry season (April to September). The crop may be harvested during the first dry season at 7 - 13 months or in the following dry season at 19 - 25 months. This cycle presupposes the availability of irrigation to allow planting in September which is the driest part of the year. Warmer winter temperatures in the top end of the NT may enable more flexibility in the crop cycle and provide operational economies. A typical calendar of farming operations for cassava would be as shown in *Figure 3.2.*

Figure 3.2

Operation	J	F	M	A	M	J	J	A	S	O	N	D
Tillage (rip, plough, land plane, hill)	/--------------26 weeks------------------/											
Planting	/--13 weeks----/											
Spraying herbicide	/---13 weeks-----/											
Harvesting	/------------------ 28 weeks -------------/											

Figure 3.2 indicates that continuous cropping would not be possible, at least for some parts of the farm and, in any case a rotational crop would be desirable to aid in weed control and improve soil structure. Although it did not reach full commercial production, it is gleened from ACP documentation that objective was to have under crop, in any one year, 440 ha (ie. plant 220 ha/hear on a biennial harvest system) out of a total farmed area of 750 ha (ie. about 60%under crop) after allowing for fallow, variable periods to harvest and time of planting. We judge this to be conservative as an annual fallow between crops would achieve a utilisation level of 66% and an annual fallow is unlikely to apply each year. Utilisation levels of 70-80% are probably achievable.

Land Preparation

The ACP system generally involved:

- after harvesting, fields re-levelled using a tractor-drawn land plane;
- contour banks and waterways and field ends re-trimmed to original slope;
- fallow weed growth treated with weedicide;

- where soil pH is below 5.5 agricultural lime applied;
- where hard clay sub soils exist, deep rip to 30-35 cm using vibrating tyne chisel plough;
- on better structured soils, chisel ploughing foregone and disc ploughed to 20 cm;
- fields left in rough condition with minimum tillage until spring planting;
- tandem disc harrow; and
- brought to a fine tilth with a rotating spindle cultivator.

Hilling and Fertilizer Application

For shallow soils with poor drainage hilling is necessary to minimise root rot, to which cassava is prone. Hilling also makes for easier harvesting. (See machine in *Attachment F, photo F13 and F.14*). The ACP-developed hilling implement formed three broad-based hills approximately 20cm wide, 1.5 m apart and fertilizer is placed in a band 15-20 cm deep in the middle of each row.

Planting

Cassava is planted from stem cuttings (billets) which should be 20-30 cm long with at least 5 nodes. The planting material is fresh stem taken from cassava plants 12-18 months old. Suitable cuttings have a cross section which is 50% pith and 50% lignified stem and should be 2.5 - 4.0 cm in diameter. The cuttings should be cut cleanly with sharp knives.

For large scale operations, a modified cane harvester (*Attachment F, photo F.4 and F.5*) is used to cut the stems direct from the field and dissect into billets ready for planting. These are dumped into a transport bin which transfers the billets to the planter.

The 3-row planter (*Attachment F, Photos F.7, F.8 and F.9)* opens 3 furrows , 1.5 m apart and drops the billets horizontally into furrow about 5-10 cm deep to give a plant density of less than 20,000 per hectare. The planter sprays the billets with fungicide and insecticide and zinc trace element solution.

Interrow Fertilizer Application and Weed Control

One interrow fertilizer application is usually carried out using a side-delivery fertilizer applicator. Interrow weed control before canopy close (up to 4 months) can be achieved mechanically using rolling spindle cultivators. Special high clearance tractors with shielded sprayers (*Attachment F. Photo F15)* may also be used to apply interrow herbicides of either glyphosate or fluazifop.

Harvesting

The ACP harvesting process on the Torbanlea farm involved:

- removal of top growth using a heavy duty slasher and retain in the field as organic ameliorant;

- the underground portion of the plant (comprising the tuberous root, the swollen underground part of the stem and the original planting piece) dug and elevated into a trailing haul-out bin using a purpose-designed harvester (*Attachment F, Photos F.1, F.2 and F.3)* including about 25% extraneous matter;

- transfer of the harvested material to an infield root cleaner (*Attachment F, Photos F.1*6) which, through a series of shaker conveyors further reduced the extraneous matter to around 5% and returned to the haul-out trailer ready for transport to the processor.

3.6 Specialised Machinery

ACP during the 1980's developed specialised machinery for cassava production and harvesting. This was a unique outcome of the pilot farming activity and here we collate the results of this commercial development. The key items of cassava-specific specialised machinery were:

- Cutting harvester (modified cane harvester);
- Root harvester;
- Infield root cleaner;
- Planter;
- Hilling and fertilizer box.

These items of machinery are briefly described below and photographs are shown in *Attachment F*. The scale of machinery described here is generally geared to a 400 ha or larger plantation.

<u>Cutting harvester (modified cane harvester)</u>

History: ACP modified a Massey Ferguson cane harvester (MF201); any harvester using a fixed knife cutting device (needed to avoid damage to sets) could be adapted for the purpose; essentially removed the lifting gear of the cane harvester (less volume)

Estimated cost: $25,000 to buy second hand machine and adapt

Primary Dive: Self driven

Function: Harvests tops from cassava field, cuts into billets 20-25cm and throws them into a trailed bin which transports the billets to the planter

Rate of work: Effective 11 km/hr; 1.2 ha/hr

<u>Harvester</u>

History: Developed by ACP and Toft in 1980's; needed some refinement when ACP operation ceased; unique, purpose built machine

Estimated cost: $60,000 to build from scratch

Primary Dive: 70-75 dbKW

Function: Lifts cassava roots from depth of 350mm, elevates into a trailing haul-out bin and undertakes preliminary cleaning. This machine does the biggest task of all due to the lifting of large quantities of soil and extraneous matter; key feature is the concave cutter bar edge without which it does not work

World Experience: It is understood that some other countries use lifters (eg. Brazil and Cuba) but have not developed a machine which completely removes the crop from the field.

Rate of work: 3 km/hr; 0.2 ha/hr

Labour: 1 driver + 1 haul-out bin driver

Infield root cleaner

History: System adapted from the European sugar beet industry; manufactured from scratch by ACP in Australia

Estimated cost: $20,000

Function: Received partly cleaned root from haul-out bin and further sifts out soil and extraneous matter and delivered the cleaned roots (5% extraneous matter) to a truck or haul-out bin to transport to processor

Mobility: towed by tractor to the point of harvest in the field

Power: PTO tractor or own on-board diesel motor

Rate of work: 20t/hr

Labour: operated by the haul-out trailer driver

Planter

History: Developed by ACP in conjunction with Moller Pty Ltd (Maryborough)

Estimated cost: $84,000 to have constructed by Moller Pty Ltd

Primary drive: 70-75 dbKW

Special function: 3-row planter designed to handle knobbly, sometimes branched, cassava billets which are planted at 1.5 metres row spacing with in-row spacing to achieve a plant population of 13,000 to 18,000 plants/ha; splits pre-constructed hill and places cutting horizontally at about 50mm, reforms planting hill, sprays fungicide and critical trace elements onto billets and places a band of pre-emergent herbicide over the re-established hill.

Labour: 2 men - one driving tractor; one attending the planter

Rate of work: Effective - 4.5 km/hr; 1.4ha/hr

<u>Hilling and fertilizer box</u>

History: ACP purpose-developed machine; adoption of other crop hilling machinery

Estimated cost: $13,000

Primary drive: 70-75 dbKW tractor

Function: Beds up 3 hills at a time in a precision pattern to enable planting of rows in the middle of the hill at 1.5 m apart; incorporates a band of fertilizer; hilling is essential to facilitate field drainage and minimise work involved in mechanical harvesting of roots

Rate of work: 4.5km/hr; 1.7ha/hr

Labour: 1 person operation

In the decade since ACP developed the above machinery technology has generally advanced the rate of work in most farming operations. Today it could be expected that significantly better rates of work could be achieved over those specified above.

In addition to the above, there is other specialised machinery required for growing cassava but is commonly available from most farm machinery retailers. *Attachment E.1 and E.2* show the rate of work and capital cost of these machines. This includes:

- Very high clearance tractor (40-50ddKW
- Interrow cultivator - 4.5m 3 x 1.5 m row (eg. Lilliston)
- Shielded boom spray
- Side dress fertilizer distributor.

3.7 Machinery Rate of Work and Constraints to Enterprise Scale

Matching the number of machinery units (particularly the high priced units such as harvesters and tractors) to the number of hectares farmed is fundamental to achieving scale economies.

Rates of work established by ACP on its Torbanlea farm (*Attachment E, Table E.1)* provide a basis for calculating optimum enterprise scale. The primary constraints to a mechanised cassava farming operation are: (a) the slow rate of work of the harvester, and (b) the overlapping demand on tractors during the dry season when harvesting, land preparation and planting are occurring concurrently. A factor affecting the optimum machinery profile is the effective number of machine working hours per week as determined by down-time from wet weather and farm labour employment policy (e.g. use of overtime).

For SE Queensland, one harvester can handle only 220 ha in a 6 month season, assuming a 6- day week, 8 hours/day and 12% down time from wet weather (*Attachment E, Table E.2(a))*. For the Top End of the NT less down time from wet weather might be envisaged and a longer harvest season might be possible. For the Top End, given the same labour configuration, but with only 1% down time for wet weather, and an extended harvesting season to 8 months, one harvester could handle over 350 ha per season. The area one harvester can handle is very sensitive to field efficiency and hours or work per day (*Table 3.4).*

Table 3.4: Effect of harvester field efficiency and hours work per day on potential area of crop harvested annually

Field efficiency of harvester (%)->	**50%**	**60%**	**70%**
Hours worked per day:	(ha)	(ha)	(ha)
8	220	297	351
10	275	371	439

It is likely that with proposed new innovations to the harvester (e.g. vibrating cutter bar) field efficiency of 70%, rather than 50%, is achievable and thus one harvester is capable of handling 400 ha or more in SE Qld over a 6 months harvesting season with 10 hour working day.

Calculation of the season demand on tractors (*Attachment E, Table E.2(b))* indicates that peak demand occurs on the bigger tractors in winter and the smaller tractor in summer. *Figure 3.3* shows the number of different types of tractors required for different farm sizes, given the most conservative labour use and weather interruption assumptions.

Figure 3.3: Number of Tractors Required for Different Size Cassava Farms

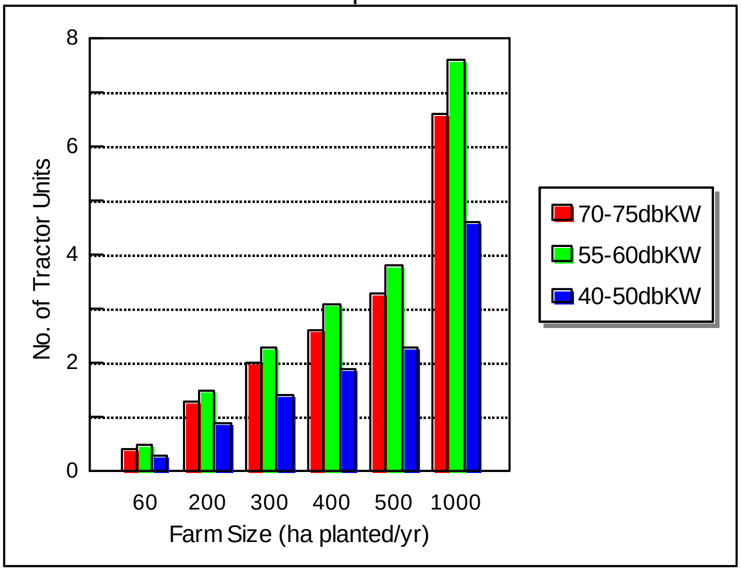


Figure 3.3 shows that for a 400 ha unit the tractor requirement would be three 70-75dbKW tractors, three 55-60dbKW tractors and two 40-50dbKW tractors. Improved efficiency in

labour use and less interruption from weather would not reduce the number of tractors required.

Attachment E, Table E.2 lists the machinery required for a 400 ha cassava cropping enterprise.

4. PROCESSING AND STORAGE

4.1 Introduction

A cost-effective, non labour-intensive method for processing cassava into stockfeed, appropriate to Australian conditions has not yet been commercially developed. The labour-intensive overseas systems are not applicable and previous Australian R&D into processing cassava for starch or ethanol production provide only partial insights into the most appropriate process for stockfeed manufacture. Here we review the literature and past experience on this subject but, in the end, further R&D will inevitably be required, and, indeed, entrepreneurial risk-taking to launch a cassava processing business for the production of stockfeed. We propose a 'best bet' processing pathway for stockfeed manufacture from cassava in Australia and provide some preliminary estimates of capital and operating costs.

Key issues are:

- the nature of the end product for stockfeed use in Australia (eg. does the market need a pellet which has structural integrity and could substitute for grain in a feedlot ration or, say, a flour which could be incorporated into the manufacture of hay cubes used for feeding live cattle exported from northern Australia);

- the acceptable level of impurities for stockfeed use (eg. mechanical harvesting of cassava incorporates all the underground plant parts, not just the tuber, and may also include varying amounts of wood fibre from left-over native timber roots and some sand); a trade-off between level of impurities and cost of processing is implied;

- whether the most cost-effective processing pathway is: (a) to create a dried chip as the intermediate product as a feedstock for the sequential production of pellets or flour, and which, in some circumstances, could be fed direct, or (b) to first pulp the harvested cassava material, as was ACP's proposed process for starch and ethanol manufacture, and then on-process by first drying the pulp and using the dried pulp to manufacture the desired stockfeed end product.

The underlying problem is that cassava root when first dug has a high moisture content, commonly around 60-65% (and sometimes higher) and will suffer rapid physical deterioration unless the moisture is reduced. Fourteen % moisture is suggested in the literature as that required for long term storage to be possible.

4.2 The Overseas System

The production of cassava pellets for stockfeed in Thailand, the world's largest producer of cassava-based stockfeeds, involves, firstly the production of chips which are subsequently pelletised. The important preliminary drying process involves the hand harvested roots being sliced (in chipping machines, either hand operated or motorised) into irregular size and shaped chips which are sun-dried on concrete aprons. The thinly spread chips are turned every 2 hours using a wooden rake to achieve even drying and usually takes 2 to 3 days under good conditions. Drying is more efficient where there is appreciable wind, requiring less turning and enabling drying to continue throughout the night.

Pellets are made by grinding the chips and compressing them into uniform cylindrical shapes using standard stock feed pelleting equipment. This results in an attendant increase in bulk density and reduced transport cost. Pelleting is done in Thailand mainly for export to Europe, but also in Indonesia for export as stockfeed.

Artificial cassava dehydration has been attempted in Malaysia and Indonesia using rotary drum driers. Although these were successful, they were abandoned due to the high cost of heating oil which not competitive with sun drying.

4.3 Australian Research

4.3.1 Whole Root Storage

The practical experience is that mechanically harvested cassava has to be processed very quickly, say within 24 hours. Whole root storage cannot be contemplated without significant loss of dry matter. This is contrary to research findings which suggested that cassava roots simply dumped in aerated heaps could be kept for at least 6 days without any significant loss in dry matter (e.g. 35% DM down to 32%). The point at issue is that mechanical harvesting, unlike hand harvesting, presents a significant amount of partly broken tubers, swollen underground stems and the original planting piece which collectively are very prone to rapid physical deterioration. The treatment of hand harvested material, overseas or experimentally, cannot be extrapolated to mechanised farming of cassava.

4.3.2 Drying

Cassava drying usually occurs after chipping. Jolly (1983) concluded from a review of artificial drying that the size and uniformity of the chip was an important factor is achieving efficient drying and that cassava can be dried in less than 2 hours through circulation packed bed driers using temperatures less than 80^0C.

An Australian experiment into air drying of cassava chip on fly-screen mesh trays, loaded at various levels (10 kg/m^2, 15 kg/m^2 and 20 kg/m^2) and exposed to prevailing winds (2.7m/sec) showed that fresh cassava chip dried very rapidly (in 3 hours, from 12 midday to 5 pm, down from 70% to 35% moisture at 10 kg/m^2 tray density) but the final drying phase down from 35% to 14% moisture took another 48 hours. The important conclusion was that air circulation was more important than temperature or relative humidity, pointing, perhaps, to wind tunnel drying as a commercial option. An interesting aside to this research showed that maximum cassava chip moisture of 14% occurred at 65% air relative humidity (*Table 4.1).*

Table 4.1: Air relative humidity and cassava chip equilibrium content

Air relative humidity (%)	50	57	65	72	77	82	86	87	88
Cassava chip moisture content (%)	12	13	14	15	16	17	18	19	20

When ACP was wound-up research into least-cost artificial drying options for cassava chip were incomplete but simulation models were pointing to the following conclusions:

- due to the short 120 day harvest season, solar energy was not economically viable for drying cassava chip when taking into account interest on capital as well as operating costs and coal only was the least cost option for supplying heat;

- of two driers investigated, drying costs were less for the best configuration of a continuous 'circulation belt drier' ($10.02/tonne) than for a 'rotary drum drier' ($10.59/tonne[11]); drying costs using the circulation belt drier were least with, (a) larger belt loadings (eg. belt loading increased from 11 to 44 kg FW/m^2 reduced drying costs by 15%), (b) higher temperatures (eg. temperature increase from 60^{0}C to 80^{0}C reduced drying cost by 14%), and (c) lower specific air flow rates;

- drying costs of the 'circulation belt drier' could be further reduced by 24 hour operation rather than 8 hour operation; and

- accelerating the rate of drying by reducing the chip size and increasing the temperature reduced the fixed capital expense of cassava chip drying.

New technologies, such as attrition drying involving refrigeration or osmotic dehydrators, microwaves and low grade heat (e.g. maximum temperature 50^{0}C) all of which are now being investigated/applied in other agricultural sectors are seen as having a potential to significantly further reduce the artificial drying costs of cassava.

4.4 The Problem of Extraneous Matter and Non Tuber Plant Parts

Mechanical harvesting of cassava collects, along with the tubers, about 25% 'extraneous matter' (e.g. underground tree roots, soil clods, weeds etc) plus a proportion of swollen underground parts of the cassava plant which are not the tuber. Infield cleaning and 'front end' processing (trommel + washing) might be expected to reduce extraneous matter to less than 1% (*Figure 4.1)* but is less successful at separating out the non-tuber plant parts. Because the non tuber plant parts contain some starch, a processing system which can handle this material, rather than discard it, is preferred (see discussion below).

[11] Capital cost of a Buell rotary drying and coal firing system which would process 40tFW/day, operating 120 days per year was estimated to be around $0.5 million - ACP report

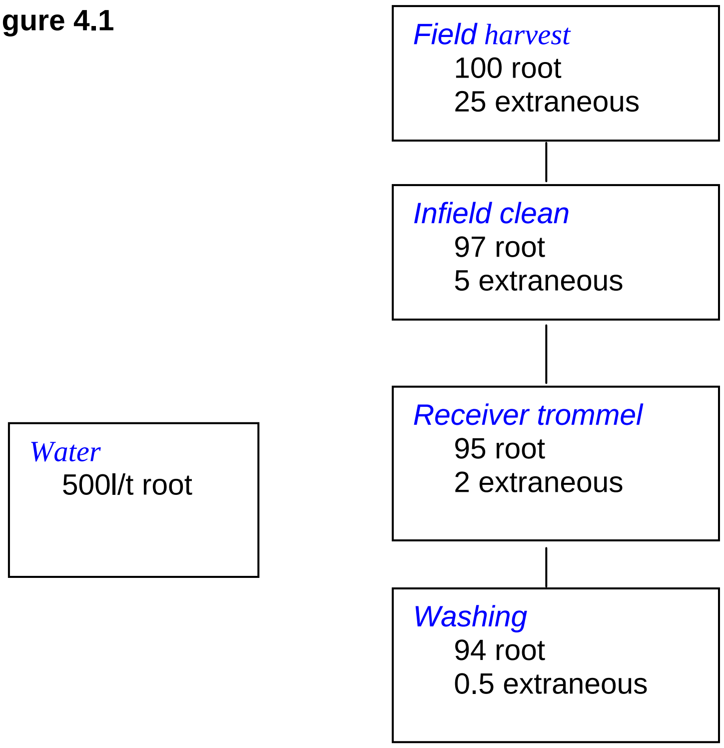
It is noteworthy that the pre-treatment requires a significant amount of water. At approximately 500 litres per tonne FW, adequate water supply and disposal plan for the water tailings needs to be taken into account in processor design. *Table 4.2* shows the amount of water required for processing the output from various sized operations.

Table 4.2 Water requirements for pre-washing of cassava (megalitres)

Area Harvested:	**200 ha**	**400 ha**	**600 ha**	**800 ha**
@ 30t FW/ha	3.0	6.0	9.0	12.0
@ 50tFW/ha	5.0	10.0	15.0	20.0

Tailing water from the washing process could be filtered and reused for the primary washing and/or returned to the field for irrigation.

Figure 4.1

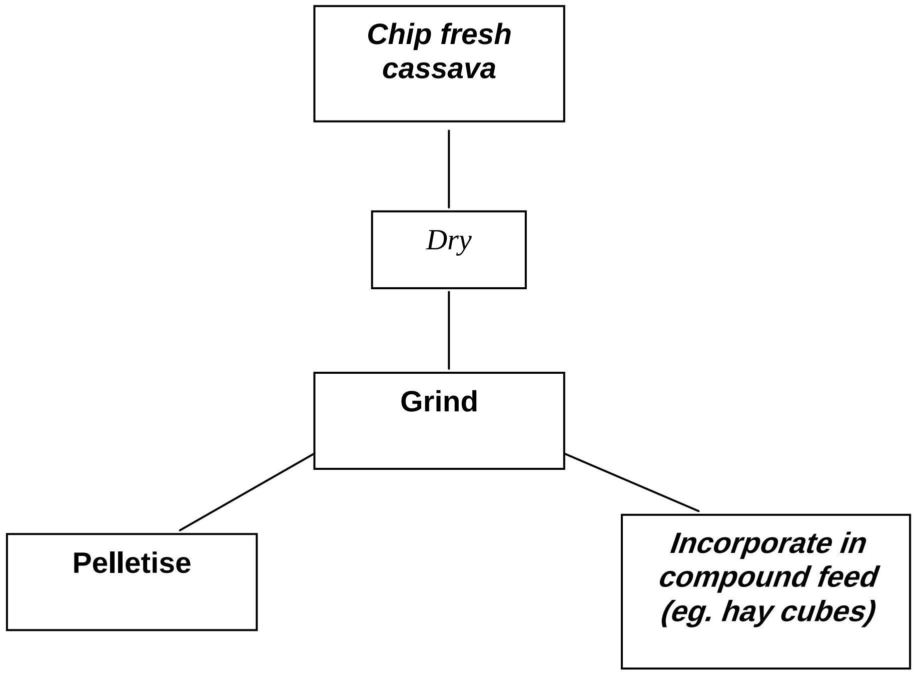


Notwithstanding the significant reduction in extraneous matter in the 'front end' process, the 'best bet' option for the final process will be governed by how efficiently it can handle the hard non tuber parts of the plant plus the embodied extraneous matter after it leaves the washer. Capital cost of the plant and equipment for the 'front end' of the processor, capable of reducing the 'extraneous matter to 1% @ 15 t FW/hour, is estimated to be $105,000 (see *Attachment E, Table E.12)*.

4.5 'Best Bet' Final Processing Pathway

Two possible pathways to producing a cassava-based stockfeed would seem to exist. Pathway A is to develop an automated Thai system whereby the harvested material is washed, chipped and artificially dried. The output from this part of the process is a dried chip which could then be either on-processed on site by grinding and pelletising, or alternatively sold to a feed manufacturer for grinding and incorporation into a wide range of proprietary compound feedstuffs, including hay cubes. *Figure 4.2* schematically represents the process.

Figure 4.2



Pathway B is to modify the ACP planned process for manufacture of industrial starch whereby the harvested material is washed, broken down and hammer milled into a pulp which is then dried and then manufactured into a flour or pellet.

Relative Advantages & Disadvantages

The major advantage of Pathway A is the expected lower cost of drying, although this has yet to be developed and demonstrated for a non-labour intensive process. The major disadvantage of Pathway A from a practical viewpoint is that the extraneous matter in the mechanically harvested product, albeit less than 1% after leaving the washer, causes problems for chipping and difficulty in pre-sort before it presents to the chipper. Solutions to this problem would have to be solved as well as the best artificial heat drying process.

While ACP had carried out some research on pre-drying, a solution to this problem was not really necessary for starch extraction or ethanol production which was carried out on a wet product. A pilot plant would have to be established to research the problem and the answer may lie in a study of how other industries handle a similar problem. One solution may be a pathway which partly chips and partly dries the mechanically harvested product before final sorting of extraneous matter, finer chipping and drying. We are reasonably optimistic that economical drying could be achieved, particularly in the NT using low grade heat. The lower bulk density of the finished chip product, compared to pellets, and its higher cost of transport to enduser may be a concern if it was remote from the enduser.

The major advantage of Pathway B is that it avoids the chipping phase and attendant problems as the extraneous matter is macerated in breakers and hammermills along with the cassava tuber component. Using conventional drying technology the cost of drying hammermilled pulp via Pathway B could be quiet high. Promising new drying technologies may be appropriate to treatment of this pulp, but as with Pathway A, detailed investigation of this process needs to be carried out.

Grain Tech Engineering (New Zealand)[12] have provided a preliminary proposal and quotation to supply and install a 'final' cassava processing unit which takes the cassava feedstock through to a pelleted product. The following specifications apply:

- To prepare, dehydrate and pellet up to 40,000 mt per annum of finished pelleted cassava;
- Annual production finished product: 40,000 mt;
- final pellet product m/c: 12.5% - 13.5% ;
- cassava tuber m/c following harvest: 62%;
- % of moisture to be removed from seedstock: 49-50%;
- Total tonnage of feedstock (harvested) - cassava tuber to be handled at 50% m/c: 55,000mt;
- Processing period (assuming staggered planting throughout year): 45 weeks;
- Processing plant operating hours (22 hours/day; 6 days/week = 132 hours/week), therefore: (a) hourly drying capacity required is 9.26 mt per hour at 62% m/c, (b) hourly pelleting capacity required is 6.75 mtph.

At today's exchange rate, the capital cost of this processing plant was quoted at A$1.473 million, excluding the cost of land, buildings, utility connection and miscellaneous plant. We hold detailed design and component costings for the *Grain Tech Engineering* proposal which can be supplied as an addendum to this report if required.

This system is designed to handle clean tuber feedstock and is what we would call the typical "Thai processing system" except with the drying and pelleting incorporated into one

[12] Grain Tech, Engineering, New Zealand P O Box 97-420 S.A.M.C, Wiri, Auckland Tel. +64 9 263 6926 Fax. +64 9 262 1335

operation. In our view some further modification to this process would be required to handle the hard non-tuber parts of the cassava plant which are collected with mechanical harvesting. The ‘best-bet’ solution, in our view, is to attach the front-end pre-cleaning (*Fig. 4.1*) onto the *Grain Tech Engineering* design, but, notwithstanding, further modification is expected to be required.

This design assumes a 45 week/year operation. We estimate that the annual operating period at best (viz in NT) would be 36 weeks. Also our model farm of 400 ha producing 36,800 mt and 25,200mt of tuber for the NT and SEQld operations respectively, is less that the assumed annual cassava feedstock intake of 55,000 mt. However, 36,800 mt/36 weeks in the NT equates to 1,220 mt/week which is approximately the same rate of processing assumed by the *Grain Tech Engineering* design (55,000mt/45 weeks = 1,222 mt/week).

For the purpose of the financial analysis in this study we have applied the *Grain Tech Engineering* estimate of capital and operating cost of processing but with the qualification that more modification and detailed design is required.

5. POTENTIAL GROWING AREAS

5.1 Regions of Australia with Suitable Climate and Soil Types

Optimum temperatures for the growth of cassava is considered to between 25^{0}C and 29^{0}C (Kay, 1993). Temperatures above 35^{0}C and below 18^{0}C adversely affect cassava yields (Jones, 1959) although varietal differences could extend these ranges. De Boer and Forno (1975) have suggested that the selection of cassava growing areas should be confined to areas where the mean minimum temperature of the coldest month (July) is greater than 13^{0}C which includes most of coastal Queensland and large parts of the Northern Territory.

Globally, cassava is grown in areas where annual rainfall ranges from 500 mm to 5,000 mm, but optimum conditions for commercial production are considered to be rainfall between 1,000 mm and 1,500 mm, well distributed over the growing season (Kay, 1973).

Trials with irrigation of cassava under Australian growing conditions suggest that irrigation is useful where the rainfall is erratic during the growing season. Fukai and Hammer (1987) developed a model to predict cassava root yield under irrigation and dryland conditions for different locations in Queensland and showed a substantial yield benefit from irrigation in most localities (see *Table 3.1*)

Fukai (1985) produced a generalised map of where cassava might be grown in Australia (Fig. 6.1) based on mean minimum July temperature and summer rainfall moisture index of > 0.8.

Cassava needs a light textured soil for optimum growth and mechanical harvesting. Considering soil as well as climatic factors, Harbison et al (1980) estimated that, in Queensland there was 406,000 ha net potential for raingrown cassava, exclusive of sugarcane growing areas. Seventy-eight percent of this potential was located in the Far North Statistical Division mainly in the Weipa hinterland with the only other significant area south of the Atherton Tableland (Fig.6.2). Given its edapho-climatic requirements, cassava could also compete with sugarcane for land use. Therefore if cassava was economically competitive with sugarcane (see Ch.9) the unrealised potential for cassava and/or sugarcane was, at the time of the Harbison report, 750,000 ha (*Table 5.1*).

Table 5.1: Potential Cassava & Sugarcane Growing Area in Queensland

Statistical Division	Sugarcane Net Potential Area not Presently Growing Cane ('000 ha)	Cassava Net Potential Area exclusive of Sugarcane ('000 ha)	Net Potential for Sugarcane and/or Cassava ('000 ha)
Moreton	13	0	13
Wide Bay/Burnett	93	11	104
Fitzroy	40	3	43
Mackay	86	3	89
Northern	31	72	103
Far North & Peninsula	81	317	398
Queensland	**344**	**406**	**750**

Source: Harbison et al. 1980

Since 1980 the sugar industry has expanded and additional land set aside for National Parks so the net area available for cassava production would have contracted significantly, particularly in the Peninsula. Stewart et al. (1979) suggested that there was possibly 180,000 ha of adequate land available for annual cropping in northern Australia with a potential annual yield of 29 t FW/ha. On the Ord River irrigation scheme in NW Western Australia, the dominant soil type is a heavy clay which is unsuitable for cassava production.

5.2 Availability of Land Close to Livestock Industry Endusers

A prime determinant of cassava's potential to competitively supply an alternative energy dense feedstuff to the intensive livestock industry, is the proximity of the livestock industry enduser and suitable cassava growing areas.

Given the geographic disposition and needs of the intensively fed livestock industries in Australia (viz. feedlot, poultry, pig and dairy), it is proposed that there are two potential production localities for cassava-based stockfeed production which are more likely to prevail. These are:

(A) the coastal area of the Wide Bay Burnett region of Queensland which has a net potential area of around 100,000 ha suitable for growing cassava (*Table 5.1)* and which is, in terms of transport, sufficiently close to the feedlot heartland of SE Queensland and which is periodically unable to supply its own feedgrain requirements.

(B) the 'top end' of the Northern Territory which has a substantial area suitable for cassava production which, because of the high import price parity for feedgrain, could, at first consideration, competitively supply the intensive livestock industries (poultry, pig and dairy) and contribute as a feedstuff component for beef cattle being prepared and shipped live to SE Asian markets.

A detailed assessment of the availability of land suitable for cassava growing has not been carried out in these respective regions but is judged not to be a constraint. In the Wide-Bay Burnett region the site of ACP's 4,000 ha leasehold experimental farm in the 1980's has since been acquired by the Hervey Bay City Council and would be unavailable for cassava production. However, parcels of suitable freehold land, undeveloped, or partially developed for grazing would be available in the price range of $1,000 to $1,500 per hectare. Cassava grown as an adjunct to sugarcane production may be possible in the Wide-Bay Burnett region.

In the 'top end' of the Northern Territory, the availability of suitable land for a cassava production is generally not seen as a constraint (I.Quinn, DPIF). In the Katherine/Daly basin light textured soils overlying aquifers capable of supplying water for irrigation can be acquired for $80 to $300 per hectare (H.Mills, Elders Real Estate, Katherine) but, as a rule of thumb the cost of development of irrigation potential amounts to $3,500 to $4,500 per hectare (B.Cann, DPIF).

6. POTENTIAL MARKET: LIVESTOCK FEEDSTUFF

6.1 Top End Northern Territory

6.1.1 Feedstuff for Live Export Cattle

The live cattle export market requires cattle fodder to maintain animals during the sea voyage and usually for an additional 4 days for backgrounding prior to loading. Because live cattle exporters are paid on weight on arrival, there is an incentive to prevent cattle from losing weight during the sea voyage. Guidelines have been developed[13] for ship rations as follows:

Dry Matter	87.5%	
Ash	13%	maximum
Protein	7.5%-10%	
Urea	1.0%	maximum
Acid detergent fibre	11.5-30%	
Digestibility	55%	minimum
Metabolisable energy	8.5 MJ/kgDM	steers
	9.5 MJ/kgDM	cows

[13] By Steering Committee on Live Export (1988) Workshop Proceedings No. 3

Hay cubes are the favoured feedstuff used by the live cattle export trade. The manufacture of cubes is based on either lucerne (imported as cubes from southern Australia) or based on local forage legume (e.g. Cavalcade Centro). A high energy, peak performance ration is not an imperative, rather ease of handling the feedstuff on board ship and weight maintenance are more important.

A cube manufacturer at Katherine (S. Bakelion) indicated that cubes based on Cavalcade Centro alone do not have a feeding value as high as the lucerne-based cubes, and although very palatable, rarely have metabolisable energy values above 7MJ/kgDM without energy supplement and protein level is usually around 10%. This energy value is low, even for the boat trade, and could be boosted by the relatively simple inclusion of cassava flour in the cubing process. Cassava flour was also seen as a possible substitute for 'bentonite' as a binding agent for the cube and Katherine cube maker suggested he could use 2,000t cassava per year for this purpose if the price was right. Cubing is estimated to cost around $100/tonne (B.Cann, DPIF) and the incremental cost of including cassava flour would be negligible.

It has been proposed that incorporating cassava in boat cattle diets could help ease cattle onto the cassava-based diets in some destination countries (eg. Indonesia), avoiding checks in growth due to diet change.

A benchmark price for locally grown cassava product is imported cassava waste or chips back loaded on empty cattle ships from Indonesia. Investigations of this possibility (by DPIF, 1997) demonstrated that it was marginally uncompetitive, after on-land transport in Australia was considered.[14]

A boat cattle diet based on cassava/local hay avoids the excessive protein of lucerne based cubes and attendant respiratory problems on board ship and, in the long run, may command a premium for cattle going onto feedlots in SE Asia which use cassava in the ration.

In the present depressed state of the live cattle trade (*Table 6.1)*, it is unlikely that a premium will be paid in the destination markets for cattle backgrounded on a cassava-based diet.

The current benchmark price for lucerne hay cubes is $400-$420/tonne and for cubes from local hay around $300/tonne.

[14] Brian Cann, DPIF (pers.com.) Cassava chip US$90/t FOB Lampung, Indonesian, at March, 1997 exchange rate translated into A$112. Ship freight rates ranged between A$80/t to A$130/t to give a cif Darwin minimum price of A$192/t

Table 6.1: Live Cattle Export via Darwin Port

Destination	**1996**	**1997**	**1998 yr to date 31/10/98**
Brunei	4,041	5,650	4,900
Indonesia	232,207	244,701	10,135
Philippines	124,284	167,186	102,726
Sabah	4,465	3,278	541
Sarawak	0	479	0
West Malaysia	17,718	17,384	9,622
Thailand	820	0	0
Egypt	0	0	34,286
Libya	0	9,518	15,163
Total	**383,535**	**448,196**	**177,373**

How big is the market?

If the local centro hay has the low metabolisable energy value of 7 MJ/kg DM, inclusion of 30% cassava could lift this to a more acceptable 8.7 MJ, consistent with the guidelines. Given, 100% market share and an average of 8 days feeding (in depot and on boat) the total demand for cassava flour (or pellets) would be around 3,000 tonne for 150,000 cattle shipped and around 9,000 tonne if the trade returned to 450,000 cattle shipped (*Table 6.2).* Obviously market share would be determined by price competitiveness against lucerne based cubes transported in from the south.

Table 6.2: Cassava Requirement to Increase Energy Value of Centro Cubes used for Boat Cattle Diets

Assumed Total Cattle Export via Darwin	**head/year**	**150,000**	**250,000**	**450,000**
Number of feed days	days	8	8	8
Avg. Weight of cattle	kg	350	350	350
Cube consumption @ 2.5kg/100kg LW	kg/hd/day	8.75	8.75	8.75
ME of cubes without cassava	MJ/kg DM	7	7	7
ME of cubes with cassava	MJ/kg DM	8.7	8.7	8.7

Assumed Total Cattle Export via Darwin	head/year	150,000	250,000	450,000
CP of cubes without cassava	%	10	10	10
CP of cubes with cassava	%	7.9	7.9	7.9
Cassava in cubes	%	30	30	30
Total cube requirement per year: - @ 25% of market	tonnes	2,625	4,375	7,875
- @ 50% of market	tonnes	5,250	8,750	15,750
- @ 75% of market	tonnes	7,875	13,125	23,625
- @ 100% of market	tonnes	10,500	17,500	31,500
Total CASSAVA requirement per year: - @ 25% of market	tonnes	788	1,313	2,363
- @ 50% of market	tonnes	1,575	2,625	4,725
- @ 75% of market	tonnes	2,363	3,938	7,088
- @ 100% of market	tonnes	3,150	5,250	9,450

6.1.2 Poultry, Pig and Dairy Industry

Until cessation of operations in late 1997, the NT Grain Marketing Board purchased all the grain coming into the NT and resold it onto endusers, mainly the poultry industry, but also the dairy and pig industries. Peak annual throughput was around 11,000 t and at cessation of operation throughput was around 9,000 tonne with the poultry industry (Lowan Farms) being the dominant user. Grain is mainly road freighted in, usually from Emerald, costing $140/tonne freight. A small amount of grain (maize) is also sourced from the Ord R irrigation area and some grown locally. Currently the cost of grain in the top end of the NT is around $260/tonne.

Given that cassava pellets could substitute part of the grain in the poultry pig and dairy industry, market potential here might be 3,000 t minimum (30% x 9,000t) and perhaps 5,000 t if other industries were included.

6.2 Coastal Queensland

6.2.1 Regional Feedgrain Deficits - Darling downs

A key finding of the Meyers Strategy Group (1995) was that feedgrain deficits are likely to continue for the intensive livestock industries (beef feedlot, poultry, pig and dairy) in southern Queensland and northern New South Wales. The Meyer Group has forecast this deficit would continue in the region due to the prospect of increased demand from further expansion of the intensive beef feedlot and pig industries and reduced supply from the main feedgrain crops (feed barley and sorghum) which have been progressively substituted over recent years by higher value crops such as malting barley, cotton, sunflower and chick peas.

Since 1995 the forecast expansion of the beef feedlot and pig industries in these regions has not been realised but in the long term the fundamentals remain sound for an expanding demand for feedgrains. In the beef feedlot sector, this is likely to be driven by the high cattle population and the relative climate volatility in northern Australia coupled with the unsuitability of low quality of tropical pastures to reliably finish a beef animal for premier markets, increasing demand for lot finished beef on the domestic market and the meat processing capability in the region.

Furthermore, from a study on regional feed markets in Australia (Hafi and Andrews 1997) it is noted that in the absence of a strategic plan for the feedgrain industry, interregional movement of feedgrain from surplus to deficit regions is unlikely to completely satisfy periodic demand shortfalls in deficit areas. The barriers to interregional trade in feedgrains include high transport costs in Australia, inadequate infrastructure and lack of coordination between statutory bodies and the action of exporters to continue to supply export markets in order to honour long term contracts, even though in the short term it might be more profitable to supply feed deficit regions.

This suggests that a *prima facie* opportunity exists for an Australian cassava industry which is purpose-developed to supply an energy dense feedstuff for the intensive animal industries. Prospects for a cassava industry are enhanced if it is located in, or close to, the deficit region, and particularly if it utilises a land resource unsuitable for broad acre farming and is grown in a more reliable, higher rainfall zone.

The Price of Feedgrain in SE Queensland

Over the nine year period from May ‘89 to March ‘98 the cash price of feed barley and sorghum delivered Brisbane has shown considerable volatility (*Fig.6.1a and Fig.6.1b)* with a $120 variation between lowest and highest price for both feedgrains as shown in *Table 6.3.* The price of feed barley and grain sorghum has more or less moved in unison. Over the nine year period the price of feed barley has topped $180 delivered Brisbane for 48 months (about 45% of the time) and grain sorghum has been above this figure for a slightly shorter period.

Table 6.3: Cash Price Amplitude for Feedgrains Delivered To Brisbane

	Lowest Price ($/mt)	**Highest Price ($/mt)**
Feed Barley	$130 (Nov.’93)	$250 (Nov.’94)
Sorghum	$120 (Mar.’91)	$240 (Jan.’95)

Source: after FarMaCo

These prices present an indicative price framework for a potential cassava pellet industry targeting the SE Queensland feedlot industry. Given the feedlot gate price differential with Brisbane is $10/mt and transport costs for cassava pellets from a nominal Bundaberg factory site to the feedlot varies between $10/mt and $30/mt, the low and high substitution price for cassava pellets ex a cassava factory in Bundaberg is shown in *Table 6.4* to range from $80/mt to $230/mt.

Table 6.4: Indicative Cassava Pellet Price at a Bundaberg Factory at which it could Substitute for Feedgrain in High and Low Price Years

	Low Feedgrain Price ($/mt)	**Low** Cassava Substitution Price ($/mt)	**High** Feedgrain ($/mt)	**High** Cassava Substitution Price ($/mt)
Delivered Brisbane	$120		$250	
Feedlot Gate	$110	$110	$240	$240
Cassava Factory Gate (Bundaberg); - $10/t freight to feedlot		**$100**		**$230**
- $20/t freight to feedlot		**$90**		**$220**
- $30/t freight to feedlot		**$80**		**$210**

While a cassava industry, based in a different climatic zone or grown under irrigation, could be expected to reliably deliver an energy dense feedstuff to the feedlot industry in years when feedgrain is at a high price (i.e. deficit years), for long term business survival the cassava industry would also have to compete in low price years. These data are used in the financial analysis (Ch. 9) to evaluate the viability of a cassava pellet industry in SE Queensland.

How Big is the Potential Market?

The beef feedlot industry in Queensland, with an average of around 200,000 head on feed over the past 3 years (range 167,885 to 238,605 head) with under utilised resources (39% to 57% utilisation) consumed approximately 630,000 mt[15] of feedgrain per year. Assuming cassava pellets could replace say 5% of the current feedgrain market, the potential static

[15] Assume 2.7kg DM/100kg LW/hd/day; avg. onfeed weight of 425kg; grain comprising 75% of ration with 88% dry matter

market for cassava pellets amounts to about 30,000 mt per year. At a cassava pellet recovery of 10 mt DM/ha/yr this equates to the production from 3,000 ha.

6.2.2 Poultry, Pig and Dairy Industry

As with the beef feedlot industry the geographic disposition of the cassava factory in relation to these industries will decide the competitive substitution of energy dense feedstuffs.

7. OTHER POTENTIAL MARKETS

Apart from the supply of an energy dense feedstuff for the intensive livestock industries (beef, pig, poultry dairy), the cassava root could be used to manufacture starch or ethanol. Also the tops have a potential to supply a protein meal for livestock uses.

7.1 Starch and Ethanol

Manufacture of starch and ethanol was the reason for interest in the crop in the 1980's. Ethanol production from cassava was not pursued because of the non competitiveness cost of ethanol blend petrol (see Section 1.1.2) and, with the demise of the ethanol potential the continued interest in cassava as a starch source waned. Obviously with a different end product, the manufacture of starch or ethanol requires a different final processing to stockfeed manufacture and is beyond the scope of this study.

7.2 Protein Meal from Cassava Tops

McCann and Saddler (1975), in their consideration of a cassava-based agro-industrial complex, proposed the use of cassava tops for leaf protein production, as an adjunct to starch processing from the roots.

In the context of a stockfeed industry this requires serious consideration.

This could have particular merit for irrigated cassava crop in say the top end of the Northern Territory where the winter leaf fall, experienced around Bundaberg, is unlikely to occur, enabling the tops cut prior to harvesting the roots (and otherwise wasted), to be collected for the manufacture of a protein source. Although cassava tops can be harvested at a different time to the roots without destroying the plant, independent harvest depresses tuber yield until the plant tops re-grow and the best commercial opportunity for harvesting tops would be in concurrent harvesting of the tops and roots.

The amino acid profile of cassava tops compares favourably with soya bean meal (*Table 7.1)* although McCann and Saddler report feeding trials have shown a marked increase in biological value (49 to 80) when synthetic methionine is added to cassava leaf protein concentrate (LPC) suggesting that the availability of amino acids in cassava LCP is less than in other protein concentrates.

Cassava tops, under irrigated well fertilized conditions in northern Australia, might yield up to 40tFW/ha and could be expected to contain 4.5% protein (15% DM basis), 70% water, 18% fibre and 7.5% other. A penalty cost of harvesting the tops would be a more complete extraction of nutrients with each harvest and the inevitable need for higher fertilizer rates.

Cassava tops are likely to deteriorate rapidly once cut and would need to be processed within a couple of hours and a parallel purpose-built processing facility for the tops would have to be created. McCann & Sadler (1975) outlined the process involved in converting cassava tops to a protein concentrate containing 50% to 60% crude protein plus a cassava bagasse by-product which would contain reasonable protein and maybe fed also to livestock.

Table 7.1: Comparison of Amino Acid Profiles (gms/16gm total N)

Amino Acid	**Cassava leaves**	**Soya bean meal**
Isoleucine	5.0	3.5
Leucine	8.9	6.1
Lysine	7.2	6.4
Methionine	1.7	0.6
Phenylalanine	5.8	4.8
Threonine	4.9	3.7
Tryptophan	1.5	1.2
Valine	5.7	5.0

Source: McCann & Saddler

Based on 1975 prices and a very large scale operation, the cost of production of the protein concentrate appeared favourable, estimated to be $186/t (including fixed and variable costs and profit) and after allowing a farm gate raw material price of $4.20/t FW tops (@ 40tFW/ha = $168/ha).

These data suggest that, at least in the top end of the NT, harvesting of the cassava tops could be an important adjunct to the energy dense feedstuff production from the roots and could substantially enhance the overall enterprise viability. With some additives, the protein concentrate thus produced could augment the protein level of centro hay cubes for the live export trade, or alternatively provide a direct protein source for the other intensive livestock industries in the area. The McCann & Saddler proposal would need to be re-visited based on the more moderate scaled operation for stockfeed manufacture, along with yield validating and fertilizer trials and an evaluation of the benefit/cost of a small scale leaf processing facility as an adjunct to the root processor.

8. ENVIRONMENTAL CONSIDERATION

A cassava industry for stockfeed manufacture is unlikely to command the large area envisaged when it was being appraised for ethanol and starch production and global environmental impact is therefore likely to be low. Notwithstanding, clearing of eucalypt woodland to establish this sunrise industry will most probably be required and depending upon the local authority may require special approval.

There are some on-farm environmental issues which would require the 'duty of care' of a responsible operator. The biennial digging of the crop will lay bare the soil in an erosion prone condition and has a potential for soil loss from water and wind erosion, particularly from storms in a late planted crop (eg. November and December). An optimum cropping cycle would try to avoid such late planting but as it is inevitable that some fields in some years would be exposed and good soil conservation practices would be an imperative.

The tail water from crop washing, and from final processing (depending upon the specific system), would require special consideration for environmentally friendly disposal. The preferred disposal of this water, under the irrigated-crop model, would be to filter and re-use in the washing process as much as possible and finally return to the field via the irrigation system.

9. FINANCIAL ANALYSIS

9.1 Approach

This financial analysis considers the growing of cassava in two geographic localities: SE Qld and the top end of the Northern Territory. The analysis comprises: (a) steady state variable costs of cassava crop production (growing, harvesting and transport of roots to processing facility, (b) alternative crop gross margins and cassava break-even values for various cassava yields and prices, (c) indicative capital cost for the establishment of a 1,000 ha cassava plantation, (d) the estimated capital and operating cost of a processing facility; and (e) the overall fixed and variable cost of growing and processing cassava as an energy dense feedstuff.

9.2 Assumed Cassava Enterprise Structure

The simplifying assumption is made that the venture will be a corporate owned integrated growing/harvest & transport/processing venture. The assumed steady-state enterprise parameters are shown in *Table 9.1.*

Table 9.1: Enterprise Parameters

Parameter	SE Qld	Top End NT
Total plantation irrigated crop area (ha)	1,000	1,000
Area under crop at the beginning of each harvest season (ha)	800	800
Area planted/harvested each year (ha)	400	400
Length of harvest season (weeks)	24	36
Annual plantation production of fresh weight cassava (net of extraneous matter) as feedstock input to processor (t)	25,200	36,800
Processor operating time (hours/year)	3170	4752
Loss of fresh weight cassava feedstock on processing (%)	10	10
Processor output of pelleted cassava (12.5-13.5% moisture) (t)	11,227	16,394

This scale of operation approximates the upper limit of annual harvesting capacity of one harvester (see *Section 3.7*).

9.3 Variable Costs of Growing and Harvesting

Variable costs are based on crop husbandry practices developed by ACP at Torbanlea in the 1980's which are assumed to apply to both SE Qld and the NT. Variable costs include cost of material and cost of fuel, oil and R&M for various machinery operations, based on machinery rates of work assumptions shown in *Attachment E, Tables E.1 and E.2*. Variable costs for a biennial irrigated crop are compared with a dryland annual crop regime. A summary of the results are shown in *Table 9.2* and details in *Attachment E, Tables E.3 to E.6.*

Table 9.2: Variable Costs of Cassava Production for Various Cultural Practices and Localities

Location	Irrigated (yes/no)	Year of harvest	Variable cost per crop ($/ha/crop)	Variable cost per tonne dry ($/t DM)	Variable cost per tonne fresh ($/tFW)
Bundaberg	yes	second	$1,024	$44	$16
Top End NT	yes	second	$1,142	$34	$12
Bundaberg	no	first	$614	$68	$25
Top End NT	no	first	$708	$64	$24

Table 9.2 show that variable costs/tonne of cassava are sensitive to location, length of time in ground and availability of irrigation. Variable cost/tonne are lower in the NT because of higher expected yields which more than offsets higher input costs.

9.4 Alternative Crop Gross Margin Comparisons

9.4.1 Cassava vs Sugarcane - SE Queensland

Various cassava price and yield determinations have been made at which cassava breaks-even with a typical cane farm in the Bundaberg district. In 1997, assuming a price of sugar of $350/tonne, BSES data showed that a typical 60 ha irrigated cane farm, with 50 ha under crop would have a farm gross margin of $65,802 or $1093 per arable hectare excluding R&M on plant and equipment and assuming contract planting and harvesting (Refer *Attachment E, Table E.7*).

Using a comparable data set for cassava (i.e. excluding R&M on plant and assuming contract planting and harvesting[16]) and assuming optimum cultural practice (ie. irrigated biennial crop) the various cassava root prices needed to equate the sugarcane gross margin for a range of yield assumptions are shown in *Table 9.3*.

Table 9.3: Root Price (dry wgt equivalent) of Cassava at Various Assumed Yields to equate a Sugarcane Gross Margin of $1,093/ha/year

Assumed fresh weight yield of biennial cropped cassava root \1 (t FW/ha/crop)	**40**	**50**	**63 most likely**	**70**	**80**	**90**	**100**
Equivalent dry weight yield @ 37.5% dry matter (t DM/ha/crop)	15	18.8	23	26.3	30	33.8	37.5
Price on dry matter basis needed for cassava root to achieve a gross margin of $1093/ha/year ($/t DM)	$256	$205	$163	$147	$128	$114	$103

\1 root = all underground material, including the swollen planting piece

The most likely yield of irrigated cassava, using the currently available varieties and good agronomic practice would be around 63 t FW/ha/crop, thus *Table 9.3* indicates that a farm gate price for cassava root of $163/ t DM would be required to equate the returns from a sugarcane activity.

Two mitigating factors could alter this comparative analysis. Firstly, sugar is not without its intrinsic volatility, with the price of No.2 Pool sugar ranging over the past 10 years from a high of $408/t in 1989 to a low of $271/t in 1991. Secondly, some selected cultivars from the ACP agronomic research were yielding 25% higher than the standard MAus 7 and could have a potential to consistently yield more than 60t FW/ha. In a sensitivity test which applies

[16] Cost of contract planting and harvesting of cassava is based on the machinery rate of work and financial costs (Table E.1) plus 20% for profit and depreciation

the best possible yield for cassava and the lowest price of sugar over the past decade, the break-even farm gate price of cassava root would be $114/tDM.

9.4.2 Cassava vs Alternative Crops in Northern Territory

Two alternative crops in the Katherine/Daly basin of the Northern Territory are dryland sorghum or irrigated peanuts. Typical 1997 gross margins for these crops (*Attachment E, Tables E.8 and E.9*.) are:

Irrigated peanuts: $2,640 Wet season sorghum: $460

The various cassava root prices needed to equate the irrigated peanut gross margin for a range of yield assumptions are shown in *Table 9.4*.

Table 9.4: Root Price (dry wgt equivalent) of Cassava at Various Assumed Yields to equate a Irrigated Peanuts Gross Margin of $2,640/ha/year

Assumed fresh weight yield of biennial cropped cassava root \1 (t FW/ha/crop)	**70**	**80**	**92 most likely**	**100**	**110**	**120**	**130**
Equivalent dry weight yield @ 37.5% dry matter (t DM/ha/crop)	26	30	35	38	41	45	49
Price on dry matter basis needed for cassava root to achieve a gross margin of $2640/ha/year ($/t DM)	$255	$223	$193	$177	$161	$148	$137

\1 root = all underground material, including the swollen planting piece

Table 9.4 shows that cassava, at its 'most likely' yield has to return $193/t DM to equate the peanut gross margin of $2,640/ha

9.5 Capital Cost Cassava Plantation Establishment

This figure is likely to be quite variable. The lower cost of land in the NT is likely to be offset by the higher cost of development. Plantation plant and machinery requirements have been determined on the basis of rate of work and enterprise scale and are based on the ACP Torbanlea model. Irrigation capital costs will vary according to the source of water, irrigation design and water charges. Farm buildings and plantation infrastructure include a workshop, farm roads and utilities. Residential accommodation is constructed for the full complement of 5 plantation staff. *Table 9.5* estimates apply.

Table 9.5: Estimated Plantation Capital Cost

Item	Purchase Price ($,000)	
Land (1,000 ha @ $2,500/ha timber treated ready for cultivation)		
	2,500	2,500
Plant & Equipment:		
- farming plant	786	
- irrigation plant	900	
- vehicles & sundry	110	1,796
Buildings and farm infrastructure:		
- machinery shed and workshop	100	
- farm roads and electricity	20	
- accommodation	500	620
Total		**4,916**

9.6 Summary of Plantation Operating Costs

This summary includes overhead and fixed costs as well as variable costs. Fixed costs are based on the enterprise structure shown in *Table 9.1*. Other assumptions relating to fixed and overhead costs are shown in *Attachment E, Table E.10.*

Table 9.1 shows the cost of delivering cassava feedstock to the processor-gate would be $51/tFW for the top end of the Northern Territory and $73/tFW for SE Qld. This delivered material contains around 10% of underground cassava plant parts which are not tubers and which would have some feed value if processing was feasible. In addition to the cassava material there would be an additional 4-5% extraneous material (foreign roots, soil clods, weeds etc) which would have to be removed during processing

Table 9.6: Summary of Plantation Operating Costs

	TopEnd NT	**SE Qld**
Assumed yield (tFW/ha/crop)	*92*	*63*
Production per plantation per year (t FW)	*36,800*	*25,200*
	($/tFW)	($/tFW)

	TopEnd NT	SE Qld
Overhead and Fixed Costs		
Labour	4.7	6.8
Road vehicle operating	0.9	1.3
Maintenance, plantation buildings & infrastructure	0.3	0.5
Administration	0.5	0.8
Depreciation	5.4	7.9
Rates and Taxes	0.1	0.1
Total Overhead and Fixed Costs	**11.9**	**17.4**
Variable Costs		
Cultivation	0.8	1.0
Plant	0.2	0.3
Fertilizer	5.9	7.3
Crop protection	0.4	0.5
Irrigate	3.5	5.2
Harvest	1.6	2.0
Total Variable Costs	**12.4**	**16.2**
Return on Capital in Plantation (@20%)	**26.7**	**39.0**
Total Plantation Costs	**51.0**	**72.6**

The cost of harvesting cassava tops, which would be available in the Northern Territory, for processing into protein meal, has not been taken into account. The incremental cost of collecting the tops with a forage harvester, rather than slashing and retuning to the field would be low.

9.7 Capital Costs of Processor

he processing unit would comprise, (a) a building with intake bunker storage, product storage and staff amenities, (b) 'front end' pre-cleaning unit and handling machinery, and (c) drying, pelleting and bagging machinery fully installed. Cost estimates are summaries in *Table 9.7* and details shown in *Attachment E, Table E.13* .

Table 9.7: Capital Cost of Cassava Processing Unit (Drying capacity = 9.26mt/hr; pelleting capacity = 6.75mt/hr)

Item	Estimated Cost ($)	Estimate Source
Building (48 x 30 m) & utilities	$275,000	ASI Building Systems, Brisbane
Front end precleaner and loading machinery	$105,000	Consultants' estimate based on ACP installation
Drying, pelleting and bagging plant	$1,473,000	Grain Tech Engineering, New Zealand
Total Cost	**$1,853,000**	

9.8 Summary of Processor Operating Cost

Fixed and variable costs are shown in *Table 9.8*. Processing plant operating hours are based on 22 hours/day, 132 hours per week during the harvest season. It requires 3 labour units to supervise the plant while it is running, thus assuming 2 shifts per day, total labour requirements are assumed to be 1 permanent and 5 part-time during the season. As an integrated unit with the plantation, administration costs are assumed to be carried by the plantation activity. One road vehicle for use by the processing unit is provided. Detailed cost assumptions are shown in *Attachment E. Table E.14- E.17.*

Power is a major cost item for processing and new drying technologies (e.g. refrigeration dehydration) have the potential to reduce power costs by 50%[17], and overall processing costs by $10/tonne FW, to around $35/tonne.

Table 9.8: Summary of Processor Operating Costs

	Top End NT	SE Qld
Feedstock received from plantation per year (t FW)	*36,800*	*25,200*
	($/tFW)	($/tFW)
Overhead and Fixed Costs		
Labour	4.7	5.8
Road vehicle operating	0.2	0.3
Maintenance, plantation buildings & infrastructure	0.1	0.1

[17] Possibility suggested by Mr T. McGeechan, ERGON, Maryborough

	Top End NT	SE Qld
Administration	0.0	0.0
Depreciation	5.7	5.8
Rates and Taxes	0.0	0.0
Total Overhead and Fixed Costs	**10.7**	**12.0**
Variable Costs		
Power	21.1	16.9
R&M - processing plant & equipment	2.7	2.7
Consumables (bags etc)	1.5	1.0
Total Variable Costs	**25.3**	**20.6**
Return on Capital in Processing Unit (@20%)	**9.7**	**14.3**
Total Processor Costs	**45.7**	**46.9**

9.9 Summary of Whole Enterprise Operating Costs

For the whole enterprise, based on an integrated plantation/processor structure the overall cost of production of cassava pellets for 'best bet' assumptions amounts to $218/tonne of cassava pellets for the top end of the northern Territory and $267/tonne for SE Queensland (*Table 9.9).*

Table 9.9: Whole Enterprise Summary Costs

Item	**Top End NT**	**SE Qld**
Per tonne fresh weight harvested	($/tFW)	($/tFW)
Growing and harvesting	51	72
Processing	46	47
Total	**97**	**119**

Item	Top End NT	SE Qld
Per tonne pellets produced	($/t pellets)	($/tpellets)
Growing and harvesting	115	162
Processing	103	106
Total	**218**	**267**

9.10 Regional Market Prospects at Indicative Cost of Production

9.10.1 Top End Northern Territory

At $218/tonne, cassava pellets would appear to be competitive against feedgrain which, in the main, commands a premium of $140/tonne over SE Queensland prices. In the current year of low feedgrain prices, grain delivered to the top end of the NT is $260/tonne indicating a margin of $42/tonne in favour of cassava. In most years a premium above this would apply.

The market is, however, small (see *Section 6.1*) and a cassava factory producing 11,000 tonnes of pellets per year would rely on all intensive livestock industries incorporating some cassava pellets into their ration. Our preliminary analysis suggests there may be a market for 5,000 t in the poultry and dairy industry if it was used to substitute 30% of the grain ration. The other potential market is as an energy spike for low grade locally manufactured hay cubes used for the live export market. This market is supplied by the local product and imported lucerne based pasture cubes. The size of this market will depend upon how competitive the energy-enhanced locally produced hay cubes are against the cubes imported from southern Australia and the size of the future live export market. *Table 6.2* (page 47) indicates that, at the present export levels, the market for a cassava pellet energy spike to local hay cubes would be only 2,300 t at 75% of the boat market being serviced from local product. With a return to live export numbers of 450,000 per year ex Darwin, the cassava pellet market, based on 75% supply from local cubes, could rise to around 7,000 t..

It is concluded that, given the recovery of the live cattle export market, there is good prospect that production of an energy dense feedstuff from cassava would be a viable business in the top end of the northern Territory, subject to the qualification production qualifications raised in this assessment. The prospect that the cassava tops could be harvested to produce a protein meal may enhance the commercial feasibility of cassava growing in this region.

9.10.2 South East Queensland

At $267/tonne, cassava pellets produced in south east Queensland would not be competitive with feedgrain in any year. The feedgrain price over the past decade in SE Queensland has ranged from around $110/tonne to $240/tonne at feedlot gate. At $270/tonne, ex cassava factory, cassava pellets could not compete with feedgrain, even in the worst case scenario for feedgrain price. Give freight rates to feedlot gate are likely to be $10 to $30/tonne the competitive position of cassava pellets is further diminished with the present geographic disposition of feedlots in SE Queensland.

The conclusion is reached that cassava as an energy dense feedstuff for the intensive livestock industry is unlikely to be viable in this region.

Attachment A

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Attachment B

A summary of the global and Australian cassava industry in the mid 1980s prepared by Australian Cassava Products Pty Ltd.

ACP

AUSTRALIAN CASSAVA PRODUCTS PTY. LTD.

AUSTRALIAN
CASSAVA
PRODUCTS PTY. LTD.

Shareholders:

Fielder Gillespie Ltd.—40%
CSR Ltd.—40%
Bundaberg Sugar Company—20%

Senior Staff:

Mr.N.V.Harris
(Manager/Senior Agronomist)
Mr.L.M.Doggrell
(Operations Manager)

Company address:
P.O. Box 1034, Bundaberg Qld.
4670, Australia.

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FIRST cultivated more than 4,000 years ago, Cassava (*Manihot esculenta Crantz*) also commonly known as manioc, mandioca and tapioca, is a shrubby, perennial plant whose swollen carbohydrate-rich roots have been used for centuries in tropical lowlands as a subsistence crop. ACP is looking at other uses for it.

Plate by courtesy of OPTIMA.

Cassava, a root crop first cultivated more than 4,000 years ago, has been used for centuries as a subsistence crop in lowland areas of many tropical countries. It is now seen to have potential as a major source of carbohydrate for industry and alcohol fuels. This, allied with suitable climate and soils in northern areas of Australia, has generated increasing local interest in this crop. ACP is among the leaders in Australian research into cassava's potential. *

Cassava

Cassava (commonly known as manioc, mandioca and tapioca), is a shrubby, perennial plant that produces swollen edible roots. In their fresh-peeled state, cassava roots usually contain 20–30% starch, small percentages of soluble sugars, fibre, protein and 60–70% water.

Cassava is, therefore, a source of carbohydrate-derived energy. The crude protein content is only one third to one quarter that of cereals.

World production of roots in 1977 was estimated at 110 million tonnes, two thirds of which came from five countries, Brazil, Zaire, Indonesia, Nigeria and Thailand.

In all, 40% of global output comes from Africa with the rest produced almost equally between Asia and Latin America.

The spread of cassava through the tropical world in recent years has been almost exclusively in connection with its use as a food.

It is now the staple of more than 200 million people in 80 countries. Indeed cassava is now the eighth most important food crop in the world after wheat, rice, potatoes, maize, barley, millet and sugar.

The rest of the world's cassava production is used as animal feed and in starch manufacture for textile, adhesive and other industries.

Cassava has traditionally been grown by small farmers who have come to value the crop for its drought tolerance, its ability to grow in poor soils and its relative resistance to weeds and insect pests.

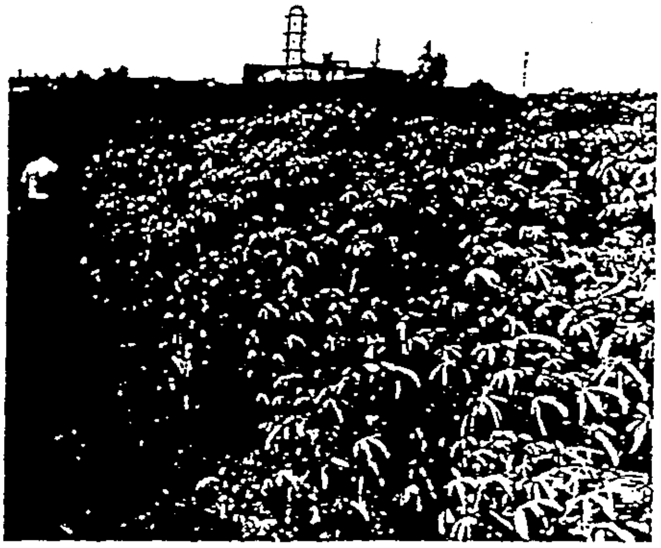
It is not season-bound and can therefore be planted and harvested any time of the year. These characteristics and the fact that the roots can be left for a long time in the ground gave cassava farmers security against famine.

Yields have, however, been low under subsistence farming conditions with low levels of husbandry and losses from diseases and pests.

Apart from its value as a subsistence crop, it has also been recognised that cassava has considerable potential in the tropics from the standpoint of resource development. Under favourable conditions, it can produce more carbohydrate per hectare per annum than any other non-irrigated tropical crop.

As comparatively little plant breeding research has been undertaken on the crop, exciting opportunities are also seen for bringing about considerable yield increases through genetic selection.

*(Parts of this article are based on a recent article in Optima by Dr Barry Nestel, an international consultant on agricultural affairs)

Stages in the development of cassava—young plants and shrubs.

In early 1970 two new international agricultural research establishments, the International Centre for Tropical Agriculture (CIAT) in Colombia and the International Institute for Tropical Agriculture (IITA) in Nigeria, began large-scale, well-financed investigations into cassava.

Both centres have since made enormous strides not only in their own research but also in training scientists from other national research programs.

The upsurge of interest in cassava is based on a recognition of the need for better understanding of what is now a major world energy crop; its increasing importance as an element in the international feed trade; and, finally, the plant's potential as a source of alcohol for fuel and the chemical industry.

Cassava was first introduced to Australia in the 19th century. Interest in the crop as a potential source of starch and ethanol was reported in 1916.

In 1925, improved cultivars were imported from Indonesia for evaluation as a feedstock for the power alcohol distillery at Sarina, Queensland.

Experimental yields were promising. When the distillery began operations, however, inexpensive molasses from sugarcane was found to be adequate for its needs.

Interest in large scale cassava production subsequently declined and the crop has since been grown on a limited scale in coastal Queensland mainly as a pig feed.

In the mid-1970s, high experimental yields, particularly those obtained at CIAT, Colombia, encouraged the re-evaluation of cassava as a potential low cost source of carbohydrate in Australia.

Agronomic research was initiated by several organisations, notably the Queensland Department of Primary Industries, the University of Queensland, Fielder Gillespie Limited and CSR.

Fielder Gillespie undertook a program of cassava research and propagation on a 250 hectare property near Bundaberg which was acquired for this purpose in 1975.

Work on cassava agronomy, varietal selection and commercial production techniques was undertaken.

An experimental plant was also installed on the property to investigate cassava processing.

In 1978, Fielder Gillespie acquired from the Queensland Government a lease on 4,000 hectares of land at Torbanlea, near Maryborough. This was intended for commercial development of cassava as warranted by feasibility studies.

Meanwhile, CSR had embarked concurrently on a program of research into cassava agronomy and varietal selection. The activities were conducted on a number of company properties and other locations in Queensland and New South Wales.

In 1979, Fielder Gillespie and CSR investigated the merits of researching cassava on a joint basis. Joint commercial development of the Torbanlea property was also envisaged.

This culminated in the formation of Australian Cassava Products Pty Ltd in mid-1980.

Later in the year, Bundaberg Sugar Company Limited also took on ownership interest in ACP. Current shareholdings in ACP are 40% each for the original partners and 20% for Bundaberg Sugar.

ACP now owns all physical resources previously employed directly in cassava by the shareholders and undertakes all cassava agronomy research on their behalf.

The Torbanlea property has been developed for continued research and the establishment of cassava as a commercial crop within Australia.

Close-ups of cassava roots—the plant's source of carbohydrate-derived energy.

At this point, Australian interest in cassava is based on its potential as a competitive source of starch for use in food preparations and industrial processes and also as a source of biomass for alcohol fuels.

Cassava starch is seen to be particularly suitable in certain areas because of its special characteristics. Its low-amylose, high-amylopectin content gives it unusual viscosity characteristics and great dimensional strength.

Such properties are of great value to the food, textile and paper industries. Cassava starch can also be processed into modified starches for specialised uses particularly in the food industry.

Cassava is currently attracting greatest interest as a raw material for producing ethanol.

Ethanol production involves preparing a mash from cassava roots and cooking it to release the starch, which is then broken down into fermentable sugars by an enzymatic process; following this the sugars are fermented to ethanol, which is extracted by distillation. A tonne of cassava roots will yield 165-180 litres of ethanol.

The most advanced work on this usage has been undertaken in Brazil which is also the country which has the most extensive program for replacement of petrol as an automotive fuel with ethanol from sugarcane.

In fact, Brazil, the world's largest producer of cassava, first produced ethanol commercially from both cassava and molasses between 1932 and 1945.

Production on a much larger scale is envisaged. Brazil's first cassava distillery, located in Minas Gerais, began operations late in 1978 with a capacity of 60,000 litres a day.

Considerably bigger plants are in the design or construction phase although the Minas Gerais distillery still has its problems, particularly in ensuring a regular supply of roots.

Elsewhere, Papua New Guinea is reported to be proceeding with plans to build a plant on the Baiyer River capable of producing two megalitres a year of ethanol from cassava.

In Australia, CSR has recently been awarded a grant by the Commonwealth Government's National Energy Research Development and Demonstration Committee (NERDDC) for research into processing cassava into ethanol.

The grant covers a pilot plant study to be undertaken over the next two years.

Earlier, both Fielder Gillespie and CSR had been awarded grants by NERDDC for research into the potential of cassava as an energy crop.

NERDDC-funded research into cassava agronomy is continuing under ACP.

The Queensland Department of Primary Industries and the University of Queensland are also carrying out significant research programs with NERDDC support.

The common pre-occupation is with yield improvement of this long neglected crop. ACP has been researching this aspect of cassava under Australian soil and climatic conditions and is also in close liaison with international bodies to monitor overall progress.

Global research efforts begun less than a decade ago have already produced a useful body of knowledge. The Colombian centre has screened a collection of about 2,500 New World cassava varieties and has identified high-yielding, widely adaptable and disease-resistant lines as well as determining some of the morphological and physiological characteristics associated with these features.

At CIAT and IITA, tens of thousands of hybrid seedlings are produced each year and are evaluated for economic characteristics, first at the centres themselves, then at regional trials in Colombia or Nigeria, and finally in tests throughout the world.

Plant resistance to disease has also been extensively investigated. The most important research relates to cassava mosaic disease and to contagious bacterial blight.

In the long run, the most effective method of control of diseases may prove to be the development of genetic resistance.

Australia's unique challenge is to develop cassava farming and processing systems consistent with the economic realities of a developed country.

Breakthroughs are required in mechanical planting, harvesting, root handling and processing to reduce the labour content.

Encouraging results have been produced in Australian research into cassava. Promising cultivars have been identified for propagation as initial commercial varieties.

Mechanical planting and harvesting systems are being developed simultaneously as are new processes for the handling of cassava roots. The ACP program at Torbanlea, Queensland, will establish important bases for commercial development of cassava in Australia.

Left: At their full height cassava stems tower over a tall man. Insert: A cross-section of cassava root.

World production of cassava

Country	Million tons	Percent of world total
Brazil	26.5	
Zaïre	12.3	
Indonesia	12.2	
Nigeria	10.6	
Thailand	10.6	66 in 5 countries
India	6.5	
Tanzania	4.0	75 in 7 countries
Ghana	2.5	
Moçambique	2.4	
Colombia	2.1	
Paraguay	1.7	
Angola	1.7	
Vietnam	1.5	
Madagascar	1.3	
Uganda	1.1	80 in 15 countries
75 other countries	13.2	
Total	110.2	

Source: United Nations Food and Agricultural Organisation

Cassava consumption in selected countries

Country	Population in millions	Kilojoules per day from cassava	Kilojoule intake from cassava (Percent)
Brazil	104	867	8*
Zaïre	23	4 200	54
Indonesia	129	611	7*
Nigeria	72	1 440	17*
Thailand	39	142	1
India (whole country)	584	96	1
India (cassava area)	20	2 814	34
Tanzania	15	1 955	24
Mocambique	9	2 797	31
Congo	13	5 187	55
Central Africa	1.7	2 956	33
Gabon	0.5	4 338	45

*Countries in which cassava consumption ranges from negligible levels to more than 50 percent of kilojoule intake in selected areas.

Source: United Nations Food and Agricultural Organisation

View of Torbanlea plantation and dam. Insert: A modified cane planter is used for small areas.

Attachment C

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Attachment D

Literature Search Summaries

Searching database ABOA (Australian Bibliography of Agriculture) for information on Cassava (Manihot esculenta Crantz) and Australia

Record 1 of 15 - AG&NR:ABOA (Agriculture)
TI: Mineral nutrition of cassava (Manihot esculenta Crantz) grown in replaced soil after bauxite mining at Weipa, Queensland
AU: Fulton-MC; Bell-LC (University of Queensland, Department of Agriculture, Brisbane); Asher-CJ (University of Queensland, Department of Agriculture, Brisbane)
SP: Comalco Limited
SO: Australian Journal of Experimental Agriculture, 1996, 36 (7), p905- 912, 5 tables, 2 figs, refs, ISSN 0816-1089.
PY: 1996
AB: A study was undertaken to evaluate the yield potential of cassava (Manihot esculenta) with optimal mineral nutrition in a lateritic red earth that was replaced after bauxite mining at Weipa Qld. In eight separate experiments, five rates each of nitrogen (N), phosphorus (P, as triple superphosphate and rock phosphate) potassium (K), magnesium (Mg), sulfur, copper, zinc, boron or molybdenum fertilizers were banded into the soil. After two wet seasons, maximum tuber yields were produced by the banded application of 200 kg P/ha as triple superphosphate, 20 kg Mg/ha and 8 kg Zn/ha. An average yield of 26.0 t/ ha of tubers (fresh weight) was obtained with a 51-week growing season, and the recommended rates of fertilizers (A).
DE: Cassava-; Manihot-esculenta; Red-soils; Fertilizers-; Crop-yield; Fertilizer-requirement-determination; Nutrient-requirements; Mineral-nutrition; Mined-land; Tropics-;
DT: Journal-article
LO: Weipa Qld; Embley River (IX24); AER (4)
DN: AG9701189

Record 2 of 15 - AG&NR:ABOA (Agriculture)
TI: Bitterness of cassava: identification of a new apiosyl glucoside and other compounds that affect its bitter taste
AU: King-NL; Bradbury-JH; (Australian National University, Division of Botany and Zoology, Canberra)
SP: Australian Centre for International Agricultural Research
SO: Journal of the Science of Food and Agriculture, 1995-06, 68 (2), p223-230, 4 tables, 1 fig, refs, ISSN 0022-5142.
PY: 1995
AB: Cassava (Manihot esculenta) has been traditionally classed as bitter or non-bitter, based on the taste of the tubers. The bitter taste is used as a warning of a high cyanide potential, but there is evidence that some bland varieties may have significant cyanide potential, while some slightly bitter varieties may have low cyanide potential. An experiment was conducted to test the possible presence of bitter compounds other than cyanogenic glucosides, and to determine the content of sugars and organic acid salts. Compounds extracted from cassava parenchyma and cortex were examined, leading to the identification of a new apiosyl glucoside (IAG). Linamarin was the sole contributor to bitterness in the parenchyma, but IAG contributes more to the bitterness of the cortex. Citrate and malate were found to modify the bitterness of linamarin. Since many compounds contribute to the taste of cassava tubers, the bitterness is not always correlated positively with the cyanide potential.
DE: Cassava-; Manihot-esculenta; Cyanogenic-glycosides; Cyanides-; Linamarin-; Bitterness-; Tastes-; Flavour-compounds; Glucosides-; Chemical-analysis; Chemical-composition; Sugars-; Organic-acids;
INP: Infoscan-Pty-Ltd;
DT: Journal-article
DN: AG9600841

Record 3 of 15 - AG&NR:ABOA (Agriculture)
TI: **Report on the International Vetiver Grass Field Workshop, Kuala Lumpur**
AL: Queensland Department of Primary Industries, Indooroopilly
AU: Truong-P
SO: Australian Journal of Soil and Water Conservation; ISSN 1032-2426; (Feb 1993), v. 6(1) p. 23-26; 3 tables, 3 fig., Summary (En)
PY: 1993
AB: The various applications and effectiveness of Vetiver grass (Vetiveria zizanioides) hedges were reviewed and discussed at the International Vetiver Grass Field Workshop in Kuala Lumpur, Malaysia from 13 to 16 April 1992. In India, land protected by vetiver hedges produced the highest grain yield, and the lowest runoff and soil loss compared with land protected by other soil conservation measures. Similarly, cassava yield was greatly improved and soil loss was much reduced under the vetiver hedge system in Colombia. In Australia, vetiver grass was found to be salt-tolerant and could be established on a highly alkaline and sodic soil. Vetiver hedges are shown to be superior to other vegetative barriers in stablising steep slopes in rubber and oil palm plantations in Malaysia. Other uses in Malaysia include the stabilisation of road embankments, fish pond and irrigation channel embankments, tin mine rehabilitation and mulch for tree crops. Other applications elsewhere include filter strip and weed barriers. Potential applications of vetiver hedges in Queensland and other tropical and subtropical regions of Australia are discussed.
DE: Australia-; Soil-conservation; Vetiveria-zizanioides;
ID: Land-stabilisation;
INP: CSIRO-;
DT: Journal-article
LI: Summary

Record 4 of 15 - AG&NR:ABOA (Agriculture)
TI: **Responses of cassava (Manihot esculenta Crantz) to phosphorus fertilisation when grown on a range of soil types**
AL: Queensland Univ., St Lucia. Department of Agriculture
AU: Hicks-LN Fukai-S Asher-CJ
SO: Australian Journal of Experimental Agriculture; ISSN 0816-1089; (1991), v. 31(4) p. 557-566; 2 tables, 5 fig., 22 ref., Summary (En)
PY: 1991
AB: In field tria's on 5 contrasting soils (yellow podsolic, lateritic podsolic, podsol, alluvial, krasnozem) in south-eastern Cueensland, the yellow podsolic soil of low initial P status was the most responsive to P application, with yield being increased by 170 percent with 120 kg P per ha, but no further significant yield increase above that rate. A strong response (96 percent yield increase with 10 kg per ha) was also obtained on the podsol. Yields of 9.0-13.6 t per ha were achieved at the optimum rate of P for each site, with the exception of the podsol where yield was only 3.0 t per ha.
DE: Cassava-; Phosphorus-fertilizers; Fertilizer-requirement-determination; Crop-yield; Soil-types; Queensland-;

Record 5 of 15 - AG&NR:ABOA (Agriculture)
TI: **The response of cassava to water deficits at various stages of growth in the subtropics**
AL: Queensland Univ., St Lucia. Department of Agriculture
AU: Baker-GR Fukai-S Wilson-GL
SO: Australian Journal of Agricultural Research; ISSN 0004-9409; (1989), v. 40(3) p. 517-528; 8 fig., 1 table, 16 ref., Summary (En)
PY: 1989
AB: Field experiments, covering 10-month growth durations from planting in spring to harvesting in winter, showed that water stress occurring in summer or winter had small effects, but in autumn severely reduced the final yield. Similarly, in a glasshouse experiment, plants recovered rapidly during early stages of growth, but when stress occurred later leaf area was reduced greatly, and recovery after its termination was poor. In all experiments, water deficits affected yield of storage organs but not the pattern of assimilate distribution, resulting in similar harvest indices among the plants of different watering treatments. It is concluded that the reduction in cassava yield is caused by the reduction in total biomass production, and that stress occurring later in the season is most detrimental to yield because of the additional effect of reduced ability of old plants to recover leaf area after the stress is relieved.
DE: Cassava-; Water-stress; Yield-losses; Growth-; Seasonal-variation;

Record 6 of 15 - AG&NR:ABOA (Agriculture)
TI: **The effect of phosphorus fertilizer application and the time of harvest on production risk of cassava in southeast Queensland**
AL: Queensland Univ., St Lucia. Department of Agriculture
AU: Anaman-KA Murphy-JE
SO: St Lucia Qld, 1988. 18 p. Agricultural Economics Discussion Paper - University of Queensland Department of Agriculture; no. 4-88; 3 tables, 17 ref., Summary (En)
PY: 1988
AB: Cassava gave small positive response to increased P on each of 3 soils, with no effect on the variability of yield. Banding as against broadcasting fertilizer reduced yield on one soil, variability on another, and had no effect on the third. Delaying the harvest gave yield increases on 2 soils, but had no effect on variability.
DE: Cassava-; Phosphorus-fertilizers; Production-functions; Risk-; Placement-; Harvesting-date;

Record 7 of 15 - AG&NR:ABOA (Agriculture)
TI: **Thesis (Ph.D.); Photosynthetic productivity of cassava (Manihot esculenta Crantz) in the field**
AU: Zamora-OB
CA: Queensland-University-St; Lucia
SO: Journal of the Australian Institute of Agricultural Science; ISSN 0045-0545; (1986), v. 52(2) p. 108-109; Summary only
PY: 1986
DE: Cassava-; Photosynthesis-; Productivity-;
CLC: F62 1540 ; F174 S007
INP: CSIRO-;
DT: Journal-article
LI: Summary
DN: AG8703611

Record 8 of 15 - AG&NR:ABOA (Agriculture)
TI: **Soil conservation for cassava in coastal southern Queensland: a report on soil conservation in cassava based on experience at plantations at Yandaran and Torbanlea**
AL: Queensland Department of Primary Industries, Indooroopilly. Soil Conservation Services Branch
AU: Lavercombe-DP Stone-BJ
SO: Brisbane Qld, 1986. 15 p. Project Report - Queensland Department of Primary Industries; ISSN 0727-6281; no. QO86010
PY: 1986
AB: The land was divided into erosion hazard zones according to its limitations, and those zones suitable for growing cassava were identified. Land management recommendations for the different zones were developed. Special problems associated with cassava growing in the area were noted. Guidelines have been drawn up and produced in a report along with special conditions imposed in the lease for the project. The soil conservation plant for the Yandaran project is reproduced.
DE: Cassava-; Soil-conservation; Queensland-;

Record 9 of 15 - AG&NR:ABOA (Agriculture)
TI: **Effect of photoperiod on growth and development of cassava (Manihot esculenta Crantz)**
AL: Queensland Univ., St Lucia. Department of Agriculture
AU: Keating-BA Wilson-GL Evenson-JP
SO: Australian Journal of Plant Physiology; ISSN 0310-7841; (1985), v. 12(6) p. 621-630; 7 graphs, 1 table, 26 ref., Summary (En)
PY: 1985
AB: In controlled environments, long photoperiods resulted in large increases in leaf area and favoured shoot growth. Photoperiod altered dry matter partitioning between shoots and storage roots. A short day (10h) plus a 1-h period of illumination in the middle of the dark period produced growth similar to that with long days (16h). Cultivars differed in response.
DE: Cassava-; Photoperiod-;

Record 10 of 15 - AG&NR:ABOA (Agriculture)
TI: Salt balance and regulation of enzymes of starch synthesis in cassava (Manihot esculenta Crantz)
AL: Commonwealth Scientific and Industrial Research Organization, Adelaide. Division of Horticultural Research
AU: Hawker-JS Smith-GM
SO: Australian Journal of Plant Physiology; ISSN 0310-7841; (1982), v. 9(5) p. 509-518; 5 graphs, 3 tables, 22 ref, Summary (En)
PY: 1982
AB: Glasshouse tests showed this cultivar, MAUS7, to have medium sensitivity to salinity; distributions of ions throughout the plant are recorded. Starch concentrations in the tubers on a fresh weight basis were not affected, although tubers were much reduced in size by NaCl treatment. The activities of the enzymes of starch synthesis resembled those found in leaves and storage organs of other starch-synthesizing plants.

Record 11 of 15 - AG&NR:ABOA (Agriculture)
TI: Response of cassava to irrigation ; <Conference paper>
AL: Queensland Univ., St. Lucia. Department of Agriculture
AU: Baker-GR Fukai-S Wilson-GL
CO: 2. Australian Agronomy Conference; Wagga Wagga NSW (Australia); 15 Jul 1982
SO: Norman=MJT (ed.) Agronomy Australia 1982: Proceedings of the second Australian agronomy conference; Parkville Vic., Australian Society of Agronomy, 1982. p. 314 Proceedings - Australian Agronomy Conference; ISSN 0729-4093; no. 2; 1 table
PY: 1982
AB: In southern Queensland, there was a strong yield response to irrigation even in a high-rainfall coastal area. Carbohydrate partitioning was not influenced by water stress. Stomatal control was so effective that leaf water potential did not vary between treatments.

Record 12 of 15 - AG&NR:ABOA (Agriculture)
TI: The response of cassava to phosphorus fertilizer on five soils in south-east Queensland; <Conference paper>
AL: Queensland Univ., St. Lucia. Department of Agriculture
AU: Hicks-LN Fukai-S Asher-CJ
CO: 2. Australian Agronomy Conference; Wagga Wagga NSW (Australia); 15 Jul 1982
SO: Norman=MJT (ed.) Agronomy Australia 1982: Proceedings of the second Australian agronomy conference; Parkville Vic., Australian Society of Agronomy, 1982. p. 273 Proceedings - Australian Agronomy Conference; ISSN 0729-4093; no. 2; 1 table, 1 ref.
PY: 1982
AB: P uptake was increased by P applications on all soils. The relationship between index leaf P status and yield was clearly seen only on the yellow podzolic and the podzol soils. On the yellow podzolic, response of underground storage yield to applied P was large.

Record 13 of 15 - AG&NR:ABOA (Agriculture)
TI: Estimation of cassava leaf area by a simple, non-destructive field technique; <Technical Note>
AL: Queensland Department of Primary Industries, Brisbane. Agriculture Branch
AU: Hammer-GL
SO: Journal of the Australian Institute of Agricultural Science; ISSN 0045-0545; (Xxx 1980), v. 46(1) p. 61-62; Illus., 1 graph, 1 table, 3 ref., Summary (En)
PY: 1980

Record 14 of 15 - AG&NR:ABOA (Agriculture)
TI: Cassava observation trial on the wet tropical coast 1973-1974; Final report and summary
AL: Queensland Department of Primary Industries, South Johnstone. South Johnstone Research Station
AU: Hobman-FR
SO: Brisbane Qld, Queensland Dept. of Primary Industries, 1976. 10 p.; 2 tables, Summary (En), +Queensland Dept. of Primary Industries, Brisbane (Australia)
PY: 1976

Searching Database CAB 1987-1998(April) for information on Cassave and Australia

Record 1 of 18 - CAB Abstracts 1996-7/98
TI: **Zinc treatments applied to cassava (Manihot esculenta Crantz) setts changes early growth and zinc status of plants.**
AU: Fulton-MC; Asher-CJ
AD: PO Box 182, Rainbow, Vic. 3424, Australia.
SO: Australian-Journal-of-Experimental-Agriculture. 1997, 37: 7, 825-830; 19 ref.
PY: 1997
LA: English
AB: Zinc (Zn) deficiency limited the early growth of cassava in nutritional trials on a Zn-deficient lateritic red earth that was replaced after bauxite mining at Weipa, Queensland (12ø28'S, 141ø53'E). The symptoms developed at 2 weeks after emergence, despite the band application of 0-32 kg Zn/ha and were not related to rates of Zn or other fertilizers applied to the soil. The Zn deficiency in the cassava plants was attributed to low Zn in setts before root access to soil and fertilizer Zn. Two techniques were studied to establish if they could be used to correct Zn deficiency early in the growth of cassava: one was fertilizer application to cassava plants before cutting the stems for planting setts, and the other was soaking cassava setts in Zn solutions for various times at 101 kPa (atmospheric pressure) or 51 kPa (partial pressure). Setts, after treatments, were planted into pots of lateritic soil from Weipa. Plants grown from setts soaked in ZnSO4 solutions varying from 17.4 to 348 mmol Zn/litre did not develop Zn-deficiency symptoms, whereas, 62% of plants grown from either unsoaked setts or setts soaked in water developed symptoms. However, the prior fertilizer application to cassava plants failed to decrease the incidence of Zn deficiency in plants and did not increase the Zn concentration in setts. Several treatments in Zn solutions significantly increased the Zn concentration in setts, were not detrimental to shoot emergence nor the subsequent growth of plants, and provided an adequate Zn concentration in leaf blades. These treatments were: soaking in 17.4 or 69.5 mmol Zn/litre for 5 h and in 69.5 mmol Zn/litre for 0.5 h at 51 kPa; and soaking in 69.5 mmol Zn/litre for 5 h and in 139 mmol Zn/litre for 0.5 and 5 h at 101 kPa. These treatments could be used to overcome early Zn deficiency in cassava plants where the deficiency is a problem despite the soil application of Zn fertilizers.
DE: sets-; cassava-; growth-; zinc-; plant-nutrition; mineral-nutrition; planting-stock; vegetative-propagation; zinc-fertilizers; treatment-; mined-land; lateritic-soils; mineral-deficiencies; fertilizers-
OD: Manihot-esculenta
GE: Australia-; Queensland-

Record 2 of 18 - CAB Abstracts 1996-7/98
TI: **Notes on the naturalised flora of Queensland, 3.**
AU: Forster-PI
AD: Queensland Herbarium, Meiers Road, Indooroopilly, Queensland 4068, Australia.
SO: Austrobaileya. 1997, 5: 1, 113-119; 33 ref.
PY: 1997
LA: English
AB: The naturalized genera of Crassulaceae, Euphorbiaceae, Oleaceae and Polygonaceae in Queensland, Australia are presented. Naturalized species are Manihot esculenta, M. grahamii and M. glaziovii, Graptopetalum paraguayense, Kalanchoe lateritia, Jasminum mesneyi, Jatropha podagrica, Persicaria capitata, Sedum praealtum and Vernicia fordii. The orthography of Aloaceae and name changes in Aloe are also discussed.
DE: volunteer-plants; nomenclature-; geographical-distribution; weeds-; cassava-
OD: Crassulaceae-; Euphorbiaceae-; Oleaceae-; Polygonaceae-; Manihot-esculenta; Manihot-glaziovii; Graptopetalum-paraguayense; Jatropha-podagrica; Sedum-praealtum; Aloe-
GE: Queensland-; Australia-

Record 15 of 15 - AG&NR:ABOA (Agriculture)
TI: **Cassava: a potential agro-industrial crop for tropical Australia**
AL: Queensland Univ., St. Lucia. Department of Agriculture; International Bank for Reconstruction and Development, Washington, DC (USA)
AU: De Boer-AJ; Forno-DA
SO: Journal of the Australian Institute of Agricultural Science; ISSN 0045-0545; (Dec 1975), v. 41(4) p. 241-252; 6 illus., 1 graph, 8 tables, bibliography, 37 ref.
PY: 1975

Record 3 of 18 - CAB Abstracts 1996-7/98

TI: Mineral nutrition of cassava (Manihot esculenta Crantz) grown in replaced soil after bauxite mining at Weipa, Queensland.

AU: Fulton-MC; Bell-LC; Asher-CJ

AD: PO Box 182, Rainbow, Vic. 3424, Australia.

SO: Australian-Journal-of-Experimental-Agriculture. 1996, 36: 7, 905-912; 38 ref.

PY: 1996

LA: English

AB: The yield potential of cassava with optimal mineral nutrition was evaluated in a lateritic red earth that was replaced after bauxite mining at Weipa, Queensland. There were 9 field experiments. In 8 separate experiments, 5 rates each of N, K, Mg, S, Cu, Zn, B or Mo fertilisers were banded into the soil. In the P experiment, triple superphosphate (TSP) and rock phosphate (RP) were compared, each with 5 rates of P banded, broadcast or spot-placed into the soil. After 2 wet seasons (66 weeks after planting), tuber yields were highest with the banded application of 200 kg P/ha as TSP, 20 kg Mg/ha and 8 kg Zn/ha. With RP, broadcast application was the optimum for yield. Highest yield was obtained with 400 kg P/ha as TSP. In addition, there was evidence that 100 kg N/ha and 300 kg K/ha were needed for maximum yields. Therefore, based on the results of these individual experiments over 2 seasons, 100 kg N, 200 kg P as TSP or 400 kg P as RP, 300 kg K, 20 kg Mg and 8 kg Zn were recommended for cassava grown in replaced soil at Weipa. In addition, early Zn deficiency symptoms (not related to any applied fertilizers) may necessitate a foliar spray of 4 kg Zn/ha as well as the soil-applied Zn. However, the use of dolomite at 80 kg Mg/ha may have decreased the tuber yields and/or increased the requirements for certain soil-applied fertilizers. An average yield of 26.0 t/ha of tubers (fresh weight) was obtained with a 51-week growing season, and the recommended rates of fertilizers. This yield was reasonable when compared with 32 t/ha of fresh tubers predicted by a growth model for cassava, grown in North Queensland for 52 weeks without irrigation.

DE: reclaimed-soils; triple-superphosphate; rock-phosphate; broadcasting-; placement-; nitrogen-fertilizers; phosphorus-fertilizers; potassium-fertilizers; magnesium-fertilizers; dolomite-; sulfur-fertilizers; copper-fertilizers; zinc-fertilizers; boron-fertilizers; molybdenum-fertilizers; cassava-; fertilizers-; phosphorus-; sources-; application-methods; nitrogen-; potassium-; magnesium-; sulfur-; copper-; zinc-; boron-; molybdenum-

OD: manihot-esculenta

GE: Australia-; Queensland-

Record 4 of 18 - CAB Abstracts 1996-7/98

CA: International Institute of Entomology.

SO: Distribution-Maps-of-Pests. 1996, No. 562, 6 pp.; many ref.

PY: 1996

LA: English

AB: The geographical distribution of Tetranychus urticae, which attacks cotton, cassava, soyabeans, tea and many other fruits and vegetables in Europe, Asia, Africa, Australasia, Pacific Islands, Caribbean, North, Central and South America, is mapped.

DE: insect-pests; plant-pests; fruits-; vegetables-; geographical-distribution; cotton-; cassava-; soyabeans-; tea-; crops-; maps-; distribution-; techniques-; agricultural-entomology

OD: Gossypium-; Manihot-esculenta; Glycine-max; Camellia-sinensis; Tetranychus-urticae; Glycine-Fabaceae

GE: Europe-; Asia-; Africa-; Australasia-; Pacific-Islands; Caribbean-; North-America; Central-America; South-America; Australia-; America-

Record 5 of 18 - CAB Abstracts 1996-7/98

TI: ACIAR in Africa - an assessment.

AU: Beckmann-R

SO: Partners-in-Research-for-Development. 1996, No. 9, 24-31.

PY: 1996

LA: English

AB: An assessment is presented of 11 Australian Centre for Agricultural Research (ACIAR) sponsored projects in Africa, suggesting that there is a good level of return on the initial investments. The paper presents a brief analysis of these 11 projects by categorizing them into four groups according to their cost. The projects cover a range of agricultural research: improving dryland crop and forage production in the semi-arid tropics, particularly Kenya; using Australian trees and shrubs to provide benefits for people as well as the land in sub-Saharan Africa; the control of ticks and tick-borne diseases; and developing a low-cyanide

cassava plant. The conclusion discusses the benefit to cost ratio, and other information is presented on the benefits to Australia.
DE: forest-resources; dry-farming; production-; tickborne-diseases; vaccines-; cassava-; plant-breeding; agricultural-research; projects-; development-aid; cost-benefit-analysis; case-studies; introduced-species; forest-trees; shrubs-; multipurpose-trees; development-projects; exotics-; rural-development
OD: Manihot-esculenta
GE: Australia-; Africa-; Africa-South-of-Sahara

Record 6 of 18 - CAB Abstracts 1987-1989
TI: **The effect of phosphorus fertilizer application and the time of harvest on production risk of cassava in southeast Queensland.**
AU: Anaman-KA; Murphy-JE
AD: Dep. Agric., Univ. Queensland, St. Lucia, Qld 4067, Australia.
SO: Agricultural-Economics-Discussion-Paper,-Department-of-Agriculture,-University-of-Queensland. 1988, No. 4-88, 18 pp.; 14 ref.
PY: 1988
LA: English
AB: Results of field trials on 3 soil types (alluvial, lateritic podzolic and yellow podzolic soils) in 1980-81 in which cassava was given 0, 20, 60, 120, 200 or 300 kg superphosphate/ha broadcast or as a banded application, were used to determine cassava response to P using least squares procedures. P application resulted in small but significant increases in expected cassava production with no effect on yield variability on all 3 soils. Band application decreased expected yields with no effect on yield variability as compared with broadcasting on the lateritic podzolic soil. On the yellow podzolic soil band application led to decreased yield variability without significant differences in expected yields when compared with broadcasting. However, there were no differences in either expected yields or yield variability between band application and broadcasting on the alluvial soil. Expected yields were increased by delaying harvesting from 7 to 10 months after planting on all soils except the yellow podzolic soil. However, the delay in harvesting had no effect on yield variability on any of the 3 soils.
DE: Cassava-; fertilizers-; phosphorus-; application-methods; yields-; production-possibilities; harvesting-date; phosphorus-fertilizers; Application-
OD: Manihot-esculenta
GE: Australia-; Queensland-

Record 7 of 18 - CAB Abstracts 1987-1989
TI: **Choices and challenges: farming alternatives for Queensland. Field crops.**
AU: Jenkins-DL
AD: Dep. Primary Industries, Brisbane, Qld 4001, Australia.
SO: Queensland-Department-of-Primary-Industries-Information-Series. 1989, No. QI88026, 53-85.
PY: 1989
LA: English
AB: The uses, environmental requirements, production and harvesting, marketing and economics and advantages and disadvantages of Ricinus communis, jojoba, niger seed, rape, sesame, Amaranthus spp. (grain), chickpeas, Vicia faba, Trigonella foenum-graecum, Cyamopsis tetragonoloba, lentils, lupins, Vigna radiata, Vigna mungo, pigeonpeas, kenaf, ramie, cassava, guayule and tea are discussed.
DE: Rape-; Sesame-; Cassava-; Economics-; Production-; fibre-plants; oilseed-plants; chickpeas-; faba-beans; fenugreek-; guar-; lentils-; pigeon-peas; kenaf-; jojoba-
OD: Ricinus-communis; Amaranthus-; Cicer-arietinum; Vicia-faba; Trigonella-foenum-graecum; Cyamopsis-tetragonoloba; Lens-culinaris; Vigna-radiata; Vigna-mungo; Lupinus-; Cajanus-cajan; Guizotia-abyssinica; Hibiscus-cannabinus; Boehmeria-nivea; Simmondsia-chinensis; Sesamum-indicum; Manihot-esculenta; Brassica-napus-var.-oleifera
GE: Australia-; Queensland-

Record 8 of 18 - CAB Abstracts 1987-1989
TI: **Growth and yield of cassava as influenced by intercropped soybean and by nitrogen application.**
AU: Tsay-JS; Fukai-S; Wilson-GL
AD: Dep. Agric., Univ. Queensland, St. Lucia, Qld 4067, Australia.
SO: Field-Crops-Research. 1989, 21: 2, 83-94; 14 ref.
PY: 1989
LA: English

AB: Effects of soyabeans cv. Fiskeby V on cassava cv. MAus 7 when intercropped and effects of 0 or 80 kg N/ha applied at planting or after soyabean harvest were studied at Redland Bay, Queensland in 1983-84. In monocropped cassava application of N at planting enhanced leaf area and DM production during early stages of growth, but the effects did not persist until the final harvest. DM partitioning to tubers was reduced, and in consequence tuber yield tended to be less in this treatment than in control plots without N. Application of N at day 85 had negligible effects on DM production and partitioning. The adverse effect of soyabeans on the growth and morphology of intercropped cassava was similar to, but more severe than, that of no N application in the monocrop. Total DM of intercropped cassava was always less than that of monocropped cassava in any N treatment. Lateral branch production and leaf turnover were reduced by the presence of soyabeans, and the consequent reduction in shoot demand for assimilates resulted in an increased proportion of assimilates partitioned to tubers. When N was applied at planting, harvest index was higher in intercropped than in monocropped cassava but tuber yield was similar in the 2 crops. Intercropping without N made only a slight further improvement in harvest index over the corresponding monocropped cassava, while severely reducing total DM production.
DE: Cassava-; intercropping-; soyabeans-; fertilizers-; nitrogen-; nitrogen-fertilizers; responses-; Cropping-systems; yields-

Record 9 of 18 - CAB Abstracts 1987-1989
TI: **The response of cassava to water deficits at various stages of growth in the subtropics.**
AU: Baker-GR; Fukai-S; Wilson-GL
AD: Dep. Agric., Univ. Queensland, St. Lucia, Qld 4067, Australia.
SO: Australian-Journal-of-Agricultural-Research. 1989, 40: 3, 517-528; 16 ref.
PY: 1989
LA: English
AB: In field experiments in 1979-81 at Redland Bay, Queensland covering 10-month growth durations from planting in spring to harvesting in winter, water stress occurring in summer or winter had only a small effect on LAI and DM production in cassava cv. M Aus 7 grown from stem cuttings but in autumn severely reduced the final yield. Autumn was the time of max. bulking of underground storage organs in well-watered plants, and water stress which reduced assimilate production also reduced bulking. Temp. at this time was suboptimal for canopy development and leaf area which was reduced during the stress did not increase after its relief, affecting further the growth of storage organs. Similarly, in a greenhouse experiment, plants recovered rapidly when water stress was relieved during early stages of growth, but when stress occurred later leaf area was reduced greatly, and recovery after its termination was poor. In all experiments, water deficits affected yield or storage organs but not the pattern of assimilate distribution, resulting in similar harvest indices among the plants of different watering treatments. It was concluded that reduction in cassava yield due to water stress was caused by a reduction in total biomass production, and that stress occurring late in the season was most detrimental to yield because of the additional effect of reduced ability of old plants to recover leaf area after the stress was relieved.
DE: Cassava-; water-stress; growth-stages; leaf-area-index; Plant-water-relations
OD: Manihot-esculenta
GE: Australia-; Queensland-

Record 10 of 18 - CAB Abstracts 1987-1989
TI: **Soybean response to intercropping with cassava.**
AU: Tsay-JS; Fukai-S; Wilson-GL; Shanmugasundaram-S (ed.); Sulzberger-EW (ed.); McLean-BT
AD: Dep. Agric., Queensland Univ., St. Lucia, Qld. 4067, Australia.
SO: Soybean-in-tropical-and-subtropical-cropping-systems. 1985, 13-24; 9 ref.
PB: Asian Vegetable Research and Development Center; Shanhua; Taiwan
PY: 1985
LA: English
AB: In field experiments in Queensland (a) cassava was grown alone, (b) soyabean cv. Fiskeby V seeds were sown 1, 5, 9 or 14 weeks after planting the cassava alone or intercropped with the cassava, or (c) soyabean cv. Collee and Bragg were sown alone or intercropped 5 weeks after planting cassava. Time to maturity of Fiskeby V decreased from 88 days to 75 and 79 days in the Oct., Dec and Jan., sowings, resp. Cassava plant height was higher in the intercropped than the sole-cropped plant throughout the soyabean growth period but the difference decreased when the soyabean plants reached max. height. Final soyabean total DM yields were 5.8, 5.1, 4.2 and 2.5 t/ha for sole-cropped Fiskeby V sown 1, 5, 9 and 14 weeks after cassava planting, resp.; the ratio of total DM in the sole-cropped plants to the intercropped was 0.63, 0.63, 0.48 and 0.27 t/ha, resp. Max. Fiskeby V LAI was 2.04, 3.45, 3.02 and 1.64 for sole-crop sowings after 1, 5, 9 and 14 weeks, resp., but LAI was decreased by intercropping. Max. LAI and leaf area duration was in the

order cv. Bragg>Collee>Fiskeby V. In (a) <10% light was transmitted after 120 days but with intercropping 15% was transmitted after 56 days, but transmission increased on soyabean leaf senescence. The yield ratio intercrop:sole-crop of soyabean seed was 0.70, 0.69, 0.34 and 0.16 for sowings after 1, 5, 9 and 14 weeks. Yields of cv. Collee and Bragg were lower than Fiskeby V.
DE: Cassava-; intercropping-; soyabeans-
OD: Manihot-esculenta; Glycine-Leguminosae
GE: Australia-; Queensland-

Record 11 of 18 - CAB Abstracts 1987-1989
TI: **The response of cassava (Manihot esculenta) to spatial arrangement and to soybean intercrop.**
AU: Tsay-JS; Fukai-S; Wilson-GL
AD: Dep. Agric., Univ. Queensland, St. Lucia, Qld. 4067, Australia.
SO: Field-Crops-Research. 1987, 16: 1, 19-31; 20 ref.
PY: 1987
LA: English
AB: Response of cassava to row spacing and plant population density (0.62 plants/m2 in rows 180 cm apart, 1.23 plants/m2 in 90, 180, 270 and 270 + 90 cm (i.e. paired rows) and 2.46 plants/m2 in rows 90 and 180 cm apart), and to soyabean intercropping at 2 row spacings of cassava (90 and 270 cm apart) was studied at a high latitude (27øS) in SE Queensland, Australia, where low temp. limits the growing season to 9 months. Detailed observations were made in sole crops on leaf canopy structure and light penetration in the 3 row spacings at the medium density to allow an estimation of light availability for an intercrop between cassava rows. The low plant density or the 270 cm row plants produced the lowest total DM and tuber yield at harvest, while the 2 higher densities or the 2 narrower rows produced similar total and tuber DW. Intercropped cassava produced a similar tuber yield to the sole crop at the corresponding spatial arrangement, but total DM was lower in the former. LAI was similar among the 90, 180 and 270 cm row spacings in the sole crops throughout the growth period. Leaf area was unevenly distributed horizontally for a longer time as row spacing increased, resulting in light penetrating the inter-row space for a longer period in wider rows in sole crops, more than 50% full sunlight reaching soil level for 90, 120 and 130 days after sowing in the 90, 180 and 270 cm rows, resp. This light environment would be available for an intercrop if cassava growth is not affected by the intercrop. The results for cassava intercropped with soyabean show that in fact cassava was reduced by the associated soyabeans, and hence light available for the soyabean growth would have been more than that estimated above.
DE: Cassava-; intercropping-; soyabeans-; plant-density; Spacing-
OD: Manihot-esculenta; Glycine-Leguminosae
GE: Australia-

Record 12 of 18 - CAB Abstracts 1990-1991
TI: **Analysis of cyanide in cassava using acid hydrolysis of cyanogenic glucosides.**
AU: Bradbury-JH; Egan-SV; Lynch-MJ
AD: Department of Botany, Australian National University, Canberra, ACT 2601, Australia.
SO: Journal-of-the-Science-of-Food-and-Agriculture. 1991, 55: 2, 277-290; 35 ref.
PY: 1991
LA: English
AB: An acid hydrolysis method was developed for cyanide analysis in cassava. 6 locally grown cultivars (Australia) contained hydrogen cyanide <30 mg/kg in fresh tuber, and one cultivar (SM1-150) contained only HCN 4 mg/kg fresh weight. Analyses of the same cultivar grown more recently gave values of HCN 13-27 mg/kg, showing the need for a study of the environmental factors influencing the cyanide content of casava tubers.
DE: Cyanides-; cassava-; estimation-
OD: Manihot-esculenta
GE: Australia-

Record 13 of 18 - CAB Abstracts 1990-1991
TI: **Effects of nitrogen supply on cassava/pigeonpea intercropping with three contrasting cassava cultivars.**
AU: Cenpukdee-U; Fukai-S
AD: Department of Agriculture, University of Queensland, Qld. 4072, Australia.
SO: Fertilizer-Research. 1991, 29: 3, 275-280; 14 ref.
PY: 1991
LA: English

AB: In field experiments in Queensland in 1987-88 tuber DM yields of cassava cv. MAus 19, MAus 10 and MCol 1468 grown alone were 657, 1061 and 1002 g/m2, resp., without N and 479, 848 and 834 g, resp., with 90 kg N/ha. Intercropping with Cajanus cajan cv. Quantum gave tuber DM yields of 95, 359 and 599 g without N, and 131, 519 and 573 g with 90 kg N and C. cajan seed yields of 163, 112 and 83 g without N, and 133, 74 and 35 g with N with cv. MAus 19, MAus 10 and MCol 1468, resp.
DE: Intercropping-; cassava-; fertilizers-; nitrogen-; nitrogen-fertilizers; pigeon-peas
OD: Cajanus-cajan; Manihot-esculenta
GE: Australia-; Queensland-

Record 14 of 18 - CAB Abstracts 1992
TI: **Responses of cassava (Manihot esculenta Crantz) to phosphorus fertilisation when grown on a range of soil types.**
AU: Hicks-LN; Fukai-S; Asher-CJ
AD: Department of Agriculture, University of Queensland, St Lucia, Qld 4072, Australia.
SO: Australian-Journal-of-Experimental-Agriculture. 1991, 31: 4, 557-566; 22 ref.
PY: 1991
LA: English
AB: Trials were performed concurrently on 5 contrasting soils (yellow podzolic, lateritic podzolic, podzol, alluvial, krasnozem) in SE Queensland, to provide information on the P requirements of cassava. The study also examined the productivity of cassava when grown under conditions appropriate to commercial population. These conditions included the use of mainly infertile soils, with no irrigation after establishment. The yellow podzolic site of low initial P status (Colwell P of 4.1 æg/g) was the most responsive to P application, with tuber DM yield being increased by 170% with 120 kg broadcast P/ha. Above that rate there were no further significant increases in yield. A strong response (96% yield increase with 10 kg P/ha) was also obtained on the podzol site (Colwell P of 3.0 æg/g). For the lateritic podzolic and krasnozem sites, which were higher in Colwell P, the responses to P were not significant, but deficiencies of other nutrients contributed to the lack of response at the lateritic podzolic site. Although the alluvial site was highest in P (Colwell P of 49 æg/g), a 15% increase in yield was obtained with 20 kg P/ha. Banded P and broadcast P were also compared over most sites, but the differences between the methods of application were generally small. Yields of 9.0-13.6 t/ha were obtained at the optimum rate of P for each site, with the exception of the podzol where yield was only 3.0 t/ha because of low availability of water and nutrients from the sandy profile.
DE: Cassava-; soil-; phosphorus-; fertilizers-; soil-types; phosphorus-fertilizers
OD: Manihot-esculenta
GE: Australia-; Queensland-

Record 15 of 18 - CAB Abstracts 1992
TI: **Cassava/legume intercropping with contrasting cassava cultivars. 1. Competition between component crops under three intercropping conditions.**
AU: Cenpukdee-U; Fukai-S
AD: S. Fukai, Department of Agriculture, University of Queensland, Qld. 4072, Australia.
SO: Field-Crops-Research. 1992, 29: 2, 113-133; 14 ref.
PY: 1992
LA: English
AB: Seven contrasting cassava cultivars were grown in SE Queensland as sole crops or intercropped with soyabeans or pigeonpeas [Cajanus cajan]. In 1985-86, 4 rows of pigeonpeas cv. QPL95 were sown between rows of cassava at cassava planting, and in 1986-87 2 rows of pigeonpeas cv. QPL3 or soyabeans cv. Fiskeby V were sown between the cassava rows 35 d after planting cassava. In 1985-86 cassava emerged later than pigeonpeas. Canopy width of cassava did not increase once the cassava interrow was occupied by pigeonpeas. Total production of all cassava cultivars was severely affected in intercropping by the time of pigeonpea harvest. Subsequent recovery was slow and final tuber yield in all cultivars was less than 25% of the corresponding yield in sole-crop. The pigeonpea cultivar used in 1986-87 was less competitive and only the short cassava cv. MAus 19 was severely affected by pigeonpeas. Tall cultivars gradually became much taller than pigeonpeas, and in most cultivars tuber yields were reduced by only up to 30%. However, the pigeonpeas were almost completely suppressed by these cassava cultivars, and seed yield was very poor. Total solar radiation intercepted by the 2 species combined in intercropping was similar to that of sole cassava, but combined biomass production of the 2 species was lower. Harvest index of cassava cultivars was also reduced slightly by intercropped pigeonpea. It was concluded that the species competed with each other for too long, and there was a yield loss of cassava/pigeonpea intercropping over sole-cropping with any cassava cultivars, except one (MCol 1468) which was strongly competitive and produced a full cassava yield in intercropping. Soyabeans cv. Fiskeby V was short-statured and quick-

maturing, and had little adverse effect on growth and tuber yield of any cassava cultivar. Radiation available to the soyabeans, and hence soyabeans growth and seed yield, was greatly reduced by tall cassava cultivars. Short or compact cassava cultivars, on the other hand, affected growth of soyabeans less severely, and in some cases their tuber yield was increased by the associated soyabeans.
DE: Cassava-; intercropping-; soyabeans-; light-; crop-mixtures; yields-; pigeon-peas
OD: Cajanus-cajan; Manihot-esculenta; Glycine-Leguminosae
GE: Australia-; Queensland-

Record 16 of 18 - CAB Abstracts 1992
TI: **Cassava/legume intercropping with contrasting cassava cultivars. 2. Selection criteria for cassava genotypes in intercropping with two contrasting legume crops.**
AU: Cenpukdee-U; Fukai-S
AD: S. Fukai, Department of Agriculture, University of Queensland, Qld. 4072, Australia.
SO: Field-Crops-Research. 1992, 29: 2, 135-149; 14 ref.
PY: 1992
LA: English
AB: Eighteen cassava cultivars of contrasting canopy size were intercropped with the short, early maturing soyabeans cv. Fiskeby V or tall, late maturing pigeonpeas [Cajanus cajan] cv. Quantum. The legumes were sown in double rows between rows of cassava 37 d after planting cassava. Intercropped soyabeans had little adverse effect on growth and tuber yield of cassava, and in some cases enhanced tuber yield of cassava cultivars with small compact canopies. The effect of cassava on soyabeans yield was least with short-statured cassava cultivars as solar radiation available to the soyabeans was highest. As the canopy development of cassava was hardly affected by soyabeans in any cultivars, the selection of cassava genotypes can be made in sole-cropping with selection criteria of high tuber yield and narrow canopy width measured at about 90 d after planting cassava. Intercropped pigeonpeas had an adverse effect on canopy development and tuber yield of cassava, particularly of short-statured cultivars. Whilst tall cultivars with spreading canopies were least affected by pigeonpeas they reduced seed yield of pigeonpeas to a very low level. It was therefore difficult to determine cassava types suitable for this intercropping. When strongly competitive species, such as pigeonpeas, are to be intercropped with cassava, selection can be made initially in sole-cropping with selection criteria of high tuber yield and height which is at least similar to that of the associated crop. It is concluded that ideal cassava cultivars for intercropping depend on the competitive ability of the associated species. It is suggested that competitiveness of component crops should be identified using a few cassava cultivars under typical growing conditions before selection is carried out.
DE: Cassava-; intercropping-; soyabeans-; light-; crop-mixtures; plant-height; yields-; pigeon-peas
GE: Australia-; Queensland-

Record 17 of 18 - CAB Abstracts 1992
TI: **Agronomic modification of competition between cassava and pigeonpea intercropping.**
AU: Cenpukdee-U; Fukai-S
AD: Department of Agriculture, University of Queensland, Qld. 4072, Australia.
SO: Field-Crops-Research. 1992, 30: 1-2, 131-146; 14 ref.
PY: 1992
LA: English
AB: In a field experiment at Redland Bay Farm, Queensland, in 1987/88 cassava cv. MAus 19 (short) or MCol 1468 (tall and spreading) was intercropped with pigeonpeas. Pigeonpeas were sown 0 or 35 d after cassava planting, and at plant densities of 6.7 or 26.7 /m2. In all intercropping treatments, radiation interception by the combined canopy increased rapidly, and full ground cover was maintained up to pigeonpea harvest. When pigeonpeas were sown simultaneously with cassava, their canopy occupied most of the cassava interrow space. When sown 35 d after cassava, MCol 1468, dominated pigeonpeas almost completely, whereas MAus 19 occupied up to only about half the total interrow area. Pigeonpeas at high plant density (based on 4 rows between cassava rows) had similar height to that at low density (based on 2 rows), but their canopy occupied more interrow space and enhanced their competiveness. The canopy width during the time of the complete ground cover was directly related to total DM production and partial land equivalent ratio (LER) for economic yield of each component crop. However, cassava LER was more sensitive to reduced cassava canopy width than was pigeonpea LER, and higher total LER was obtained when a large cassava canopy width was maintained. It was therefore concluded that a vigorous cassava cultivar and late sowing of pigeonpeas at a low density can sustain the desirable canopy width and competiveness for high productivity of cassava/pigeonpea intercropping.
DE: Cassava-; intercropping-; sowing-date; plant-density; pigeon-peas
GE: Australia-; Queensland-

Record 18 of 18 - CAB Abstracts 1993-1994

TI: Distribution maps of pests nos. 61 (1st revision), 278 (2nd revision), 279, 290, 466, 476 (all 1st revision), 535, 536 and 537.

CA: International Institute of Entomology.
AD: 56 Queen's Gate, London SW7 5JR, UK.
SO: 1993, 2-4 pp. each; many ref.
PB: CAB International; Wallingford; UK
PY: 1993
LA: English

AB: These maps (numbers 61 (1st revision), 278 (2nd revision), 279, 290, 466, 476 (all 1st revision), 535, 536 and 537) cover, resp.: the polyphagous noctuid Spodoptera litura attacking a range of crops, mostly in India, South East Asia, Australasia and Oceania; the curculionid Cylas formicarius attacking root vegetables, mainly in the tropics; C. puncticollis attacking sweet potatoes, other species of Ipomoea and maize in Africa; the mirid Cyrtopeltis tenuis attacking tobacco, fruit vegetables, potatoes and sesame, mainly in the Old World; the pseudococcid Phenacoccus manihoti attacking cassava and other species of Manihot in Africa and South America; the aleyrodid Aleurodicus dispersus attacking fruits, coconuts and Terminalia catappa in the tropics; the curculionid Sitona discoideus attacking lucerne in Europe, North Africa, South Africa, Australia and New Zealand; S. humeralis attacking lucerne and Onobrychis viciifolia in Europe and the Middle East; and Cylas brunneus attacking sweet potatoes in Africa.

DE: Cereals-; Stimulant-plants; Oilseed-plants; Nuts-; Nut-crops; Sainfoin-; Fodder-crops; Geographical-distribution; sweet-potatoes; lucerne-; insect-pests; Tropical-fruits; tropics-; Coconuts-; crops-; Maps-; distribution-; Root-vegetables; Maize-; Cassava-; Potatoes-; Fruit-vegetables; Tobacco-; Sesame-; agricultural-entomology

OD: Noctuidae-; Lepidoptera-; Curculionidae-; Coleoptera-; Miridae-; Hemiptera-; Pseudococcidae-; Aleyrodidae-; Onobrychis-viciifolia; Sitona-humeralis; Sitona-discoideus; Aleurodicus-dispersus; Terminalia-catappa; Cyrtopeltis-tenuis; Spodoptera-litura; Cylas-puncticollis; Cylas-formicarius; Phenacoccus-manihoti; Cylas-; Ipomoea-; Manihot-; arthropods-; Ipomoea-batatas; Medicago-; Cocos-nucifera; Zea-mays; Manihot-esculenta; Nicotiana-; Sesamum-indicum

GE: Africa-; Australia-; New-Zealand; South-Africa; Australasia-; Oceania-; South-East-Asia; India-; Europe-; South-America

Searching database AGRICOLA (United States Dept of Agriculture) for information on Cassava and Australia

Record 1 of 19 - AGRICOLA 1/98-6/98
AU: Dry,-I.B.; Krake,-L.R.; Rigden,-J.E.; Rezaian,-M.A.
TI: A novel subviral agent associated with a geminivirus: the first report of a DNA satellite.
SO: Proc-Natl-Acad-Sci-U-S-A. Washington, D.C. : National Academy of Sciences,. June 24, 1997. v. 94 (13) p. 7088-7093.
CN: DNAL 500-N21P
PA: Other-US
PY: 1997
LA: English
CP: District-of-Columbia; USA
CO: PNASA6
IS: ISSN: 0027-8424
NT: Includes references.
PT: Article
SF: IND
DE: tomato-leaf-curl-virus. geminivirus-group. satellite-dna. nucleotide-sequences. dna-replication. viral-replication. coat-proteins. lycopersicon-esculentum. infectivity-. viral-proteins. mutants-.
ID: dna-replicative-forms. replication-associated-protein. tomato-leaf-curl-geminivirus. circular-dna. molecular-sequence-data. genbank/u74627-.
CC: F833
AB: Numerous plant RNA viruses have associated with them satellite (sat) RNAs that have little or no nucleotide sequence similarity to either the viral or host genomes but are completely dependent on the helper virus for replication. We report here on the discovery of a 682-nt circular DNA satellite associated with tomato leaf curl geminivirus (TLCV) infection in northern Australia. This is the first demonstration that satellite molecules are not limited to RNA viral systems. The DNA satellite (TLCV sat-DNA) is strictly dependent for replication on the helper virus replication-associated protein and is encapsidated by TLCV coat protein. It has no significant open reading frames, and it shows no significant sequence similarity to the 2766-nt helper-virus genome except for two short motifs present in separate putative stem-loop structures: TAATATTAC, which is universally conserved in all geminiviruses, and AATCGGTGTC, which is identical to a putative replication-associated protein binding motif in TLCV. Replication of TLCV sat-DNA is also supported by other taxonomically distinct geminiviruses, including tomato yellow leaf curl virus, African cassava mosaic virus, and beet curly top virus. Therefore, this unique DNA satellite does not appear to strictly conform with the requirements that dictate the specificity of interaction of geminiviral replication-associated proteins with their cognate origins as predicted by the current model of geminivirus replication.
XAU: Commonwealth Scientific and Industrial Research Organization, Urrbrae, South Australia.

Record 2 of 19 - AGRICOLA (1979 - 1984)
AU: Khajarern,-S.; Kajarern,-J.M.; Phalaraksh,-K.; Kitpanit,-N.; Terapuntuwat,-S.
TI: Cassava: a potential concentrate for animal nutrition in the tropics.
SO: Animal health and nutrition in the tropics : research for development : seminar one / Australian Development Assistance Bureau. Townsville, Qld. : James Cook University of North Queensland, 1980. p. 135-156.
CN: DNAL SF724.A54
PA: Foreign
PY: 1980
LA: English
IS: ISBN: 0909714576
NT: Literature review.
Includes references.
PT: Article
DE: Tropics-.

Record 3 of 19 - AGRICOLA (1979 - 1984)
AU: McPhee,-J.E.
TI: **Development of a rotary dryer for cassava Stock feeds.**
SO: Agricultural Engineering Conference 1982 : resources--efficient use and conservation, Armidale, NSW, 22-24 August 1982, preprints of papers / National Commit. Agric. Engineering of Institution of Engineers, Australia. Barton, A.C.T. : The Institution, 1982. p. 92-94. ill.
CN: DNAL S671.3.A36-1982
PA: Foreign
PY: 1982
LA: English
NT: Includes references.
PT: Article
CC: R100

Record 4 of 19 - AGRICOLA (1979 - 1984)
AN: IND 81084362
UD: 8100
AU: Evenson,-J.P.; Keating,-B.A.
TI: **Cassava cultivar evaluation in southeast Queensland.**
SO: Pathways to productivity : proceedings of the Australian Agronomy Conference, Queensland Agricultural College, Lawes, April, 1980. s.l., Australian Institute of Agricultural Science, 1980. p. 232.
CN: DNAL S590.2.A9-1980
PA: Foreign
PY: 1980
LA: English
DE: Australia-.

Record 5 of 19 - AGRICOLA 1992-1997
AU: Ravindran,-V.
TI: **Evaluation of a layer diet formulated from non-conventional feedingstuffs.**
SO: Br-poult-sci. Oxfordshire : Carfax Publishing Company. Mar 1995. v. 36 (1) p. 165-170.
CN: DNAL 47.8-B77
PA: Foreign
PY: 1995
LA: English
CP: England; UK
CO: BPOSA4
IS: ISSN: 0007-1668
NT: Includes references.
PT: Article
SF: IND
DE: hens-. hen-feeding. small-farms. finger-millet. coconut-oilmeal. cassava-leaf-meal. leaf-meal. poultry-manure. feed-evaluation. laying-performance. feed-intake. feed-conversion. liveweight-gain. production-costs. egg-shell-thickness. egg-yolk-color. egg-quality. sri-lanka.
ID: ipil-ipil-leaf-meal.
CC: L500; L100
AB: 1. A layer diet, the formulation of which was based on several non-conventional feedingstuffs, was evaluated at the research station and under small farm conditions in Sri Lanka. The new feeding stuffs included finger millet, rice polishings, rubber seed meal, cassava leaf meal, ipil ipil leaf meal and dried poultry manure. A commercial mash, that is normally used on the farm, served as the control. 2. The performance and egg quality characteristics were similar between the test and control diets, the only exception being the egg yolk colour which was improved ($P < 0.05$) by feeding the test diet. Food cost per dozen eggs was lowered by feeding the test diet. 3. It is possible to formulate layer diets using non-conventional feedingstuffs, achieve acceptable production and lower the food costs under small farm conditions in tropical developing countries.
XAU: University of Sydney, Camden, NSW, Australia.

Record 6 of 19 - AGRICOLA 1992-1997
AU: King,-N.L.R.; Bradbury,-J.H.
TI: **Bitterness of cassava: identification of a new apiosyl glucoside and other compounds that affect its bitter taste.**
SO: J-sci-food-agric. Sussex : John Wiley & Sons Limited. June 1995. v. 68 (2) p. 223-230.
CN: DNAL 382-So12
PA: Foreign
PY: 1995
LA: English
CP: England; UK
CO: JSFAAE
IS: ISSN: 0022-5142
NT: Includes references.
PT: Article
SF: IND
DE: cassava-. taste-. bitterness-. linamarin-. hplc-. glucosides-.
CC: Q505
AB: Compounds extracted by methanol from cassava parenchyma and cortex have been separated on a preparative HPLC column and identified by (1)H and (13)C NMR spectroscopy. A new compound isopropyl-beta-D-apiofuranosyl-(1 leads to 6)-beta-D-glucopyranoside (IAG, structure I) has been found as well as small amounts of phenylalanine and tryptophan. The composition of another HPLC fraction has not been elucidated. The amounts of the identified compounds and of linamarin, lotaustralin, citrate, malate and the various sugars present in cassava have been determined by HPLC methods. The threshold levels of bitterness of aqueous solutions of linamarin, lotaustralin and IAG, have been determined and together with published data on L-phenylalanine and L-tryptophan have allowed our evaluation of their contributions to the bitterness of cassava. Linamarin is the sole contributor in the parenchyma but (with two cultivars out of six studied) IAG contributes more to the bitterness of the cortex than does linamarin. The perception of bitterness of linamarin solutions is confounded in the presence of neutral citrate and malate which have a sour taste. These modify the taste of cassava tubers. There are many compounds that contribute to the taste of cassava tubers, hence it is not surprising that the bitterness of cassava is not always correlated positively with the cyanide potential.
XAU: Australian National University, Canberra, ACT, Australia.

Record 7 of 19 - AGRICOLA 1992-1997
AU: Bradbury,-J.H.; Egan,-S.V.
TI: Improved methods of analysis for cyanide in cassava and screening for low cyanide varieties in the Pacific.
SO: Acta-hortic. Wageningen : International Society for Horticultural Science. Nov 1994. (380) p. 237-242.
CN: DNAL 80-Ac82
PA: Foreign
PY: 1994
LA: English
CP: Netherlands
CO: AHORA2
IS: ISSN: 0567-7572
NT: Paper presented at the symposium on Tropical Root Crops in a Developing Economy, October 20-26, 1991, Accra, Ghana.
Includes references.
PT: Article
DE: cassava-. cyanides-. screening-. food-safety.
XAU: Australian National University, Canberra, ACT, Australia.

Record 8 of 19 - AGRICOLA 1992-1997
AU: Bradbury,-J.H.; Bradbury,-M.G.; Egan,-S.V.
TI: Comparison of methods of analysis of cyanogens in cassava.
SO: Acta-hortic. Wageningen : International Society for Horticultural Science. Nov 1994. (375) p. 87-96.
CN: DNAL 80-Ac82
PA: Foreign
PY: 1994
LA: English

CP: Netherlands
CO: AHORA2
IS: ISSN: 0567-7572
NT: Paper presented at the International Workshop on Cassava Safety, March 1-4, 1994, Ibadan, Nigeria. Includes references.
PT: Article
DE: manihot-esculenta. linamarin-. colorimetry-. chemical-analysis. comparisons-. ph-.
XAU: Australian National University, Canberra, ACT, Australia.

Record 9 of 19 - AGRICOLA 1992-1997
AU: Beretka,-J.
TI: By-products gypsum from the tapioca starch process.
SO: J-Chem-Technol-Biotechnol. Essex : Elsevier Applied Science Publishers. 1992. v. 55 (3) p. 269-271.
CN: DNAL TP1.J686
PA: Foreign
PY: 1992
LA: English
IS: ISSN: 0268-2575
PT: Article
DE: starch-industry. cassava-starch. agroindustrial-byproducts. gypsum-. plaster-of-paris. strength-. physical-properties.
XAU: Commonwealth Scientific and Industrial Research Organisation, Highett, Victoria, Australia.

Record 10 of 19 - AGRICOLA (1984 - 12/91)
AU: Bradbury,-J.H.; Egan,-S.V.; Lynch,-M.J.
TI: Analysis of cyanide in cassava using acid hydrolysis of cyanogenic glucosides.
SO: J-Sci-Food-Agric. Essex : Elsevier Applied Science. 1991. v. 55 (2) p. 277-290.
CN: DNAL 382-SO12
PA: Foreign
PY: 1991
LA: English
IS: ISSN: 0022-5142
NT: Includes references.
PT: Article
DE: cassava-. food-composition. cyanides-. laboratory-methods. hydrolysis-. cyanogenic-glycosides.
XAU: Australian National University, Canberra, ACT, Australia.

Record 11 of 19 - AGRICOLA (1984 - 12/91)
AU: Mitchell,-D.A.; Greenfield,-P.F.; Doelle,-H.W.
TI: Development of a model solid-state fermentation system.
SO: Biotechnol-Tech. Kew, Surrey, England : Science & Technology Letters. Mar 1988. v. 2 (1) p. 1-6.
CN: DNAL TP248.24.B55
PA: Foreign
PY: 1988
LA: English
CO: BTECE6
IS: ISSN: 0951-208X
NT: Includes references.
PT: Article
DE: rhizopus-oligosporus. fermentation-. cassava-starch. carrageenan-. gels-. cell-culture. models-. protein-synthesis. protein-content. dry-matter-accumulation. laboratory-equipment.
ID: kappa-carrageenan-. fermenters-.
XAU: University of Queensland, Australia.

Record 12 of 19 - AGRICOLA (1984 - 12/91)
AU: Hobman,-F.R.; Hammer,-G.L.; Shepherd,-R.K.
TI: Effects of planting time and harvest age on cassava (Manihot esculenta) in northern Australia. II. Crop growth and yield in a seasonally-dry environment.
SO: Exp-Agric. Cambridge : Cambridge University Press. Oct 1987. v. 23 (4) p. 415-424.
CN: DNAL 10-EX72

PA: Foreign
PY: 1987
LA: English; Summary in: Spanish
IS: ISSN: 0014-4797
NT: Includes references.
PT: Article
DE: manihot-esculenta. planting-date. harvest-date. age-. tropics-. dry-season. crop-yield. growth-rate. queensland-.

Record 13 of 19 - AGRICOLA (1984 - 12/91)
AU: Hammer,-G.L.; Hobman,-F.R.; Shepherd,-R.K.
TI: **Effects of planting time and harvest age on cassava (Manihot esculenta) in northern Australia. I. Crop growth and yield in moist environments.**
SO: Exp-Agric. Cambridge : Cambridge University Press. Oct 1987. v. 23 (4) p. 401-414. maps.
CN: DNAL 10-EX72
PA: Foreign
PY: 1987
LA: English; Summary in: Spanish
IS: ISSN: 0014-4797
NT: Includes references.
PT: Article
DE: manihot-esculenta. planting-date. harvest-date. age-. crop-yield. humid-tropics. humid-climate. subtropics-. growth-rate. queensland-.

Record 14 of 19 - AGRICOLA (1984 - 12/91)
AU: Jeffrey,-A.J.
TI: **A rapid screening method for estimation of total fermentable value of selected plant materials.**
SO: Queensl-J-Agric-Anim-Sci. Brisbane : Queensland Dept. of Primary Industries. June 1987. v. 44 (1) p. 43-49. ill.
CN: DNAL 23-Q37
PA: Foreign
PY: 1987
LA: English
IS: ISSN: 0033-6173
NT: Includes references.
PT: Article
DE: cassava-. cornflour-. carbohydrates-. ethanol-. fermentation-tests. rapid-methods. screening-.

Record 15 of 19 - AGRICOLA (1984 - 12/91)
AU: Fukai,-S.; Hammer,-G.L.
TI: **A simulation model of the growth of the cassava crop and its use to estimate cassava productivity in northern Australia.**
SO: Agric-Syst. Essex : Elsevier Applied Science Publishers. 1987. v. 23 (4) p. 237-257. maps.
CN: DNAL HD1.A3
PA: Foreign
PY: 1987
LA: English
IS: ISSN: 0308-521X
NT: Includes references.
PT: Article
DE: manihot-esculenta. productivity-. growth-. biomass-accumulation. solar-radiation. air-temperature. photoperiod-. rain-. evaporation-. simulation-models. prediction-. tropics-. queensland-.

Record 16 of 19 - AGRICOLA (1984 - 12/91)
AN: CAT 85825215
UD: 8507
AU: Fukai,-Shu.
TI: **Tabular descriptions of crops grown in the tropics : 5. Cassava (Manihot esculenta Crantz).**
OT: Cassava.

ST: Technical memorandum / Institute of Biological Resources Australia, Division of Water and Land Resources ; 85/3.
SO: Canberra : CSIRO, Institute of Biological Resources, Div of Water and Land Resources, 1985. 51 p.
CN: DNAL S918.A8T44-no.85/3
PA: Foreign
PY: 1985
LA: English
CP: Australia
IS: ISBN: 0643038205
NT: "February 1985."
Bibliography: p. 49-51.
PT: Monograph; Bibliography

Record 17 of 19 - AGRICOLA (1984 - 12/91)
AN: GUA 85007252
UD: 8502
AU: Aresta,-R.B.; Fukaf,-S.
TI: Effects of solar radiation on growth of cassava (Manihot esculenta Crantz.). II. Fibrous root length.
SO: Field-Crops-Res. Amsterdam : Elsevier Scientific Publishing Company. Dec 1984. v. 9 (5) p. 361-371.
CN: DNAL SB183.F5
PA: Foreign
PY: 1984
LA: English
IS: ISSN: 0378-4290
NT: Includes references.
PT: Article
SF: ENE
DE: cassava-. solar-radiation. shading-. root-systems. queensland-. subtropics-.

Record 18 of 19 - AGRICOLA (1984 - 12/91)
AU: Fukai,-S.; Alcoy,-A.B.; Llamelo,-A.B.; Patterson,-R.D.
TI: Effects of solar radiation on growth of cassava (Manihot esculenta Crantz.). I. Canopy development and dry matter growth.
SO: Field-Crops-Res. Amsterdam : Elsevier Scientific Publishing Company. Dec 1984. v. 9 (5) p. 347-360.
CN: DNAL SB183.F5
PA: Foreign
PY: 1984
LA: English
IS: ISSN: 0378-4290
NT: Includes references.
PT: Article
DE: cassava-. solar-radiation. canopy-. shading-. leaf-area-index. growth-. tubers-. yields-. queensland-. subtropics-.

Record 19 of 19 - AGRICOLA (1984 - 12/91)
AU: Khajarern,-S.; Kajarern,-J.M.; Phalaraksh,-K.; Kitpanit,-N.; Terapuntuwat,-S.
TI: Cassava: a potential concentrate for animal nutrition in the tropics.
SO: Animal health and nutrition in the tropics : research for development : seminar one / Australian Development Assistance Bureau. Townsville, Qld. : James Cook University of North Queensland, 1980. p. 135-156.
CN: DNAL SF724.A54
PA: Foreign
PY: 1980
LA: English
IS: ISBN: 0909714576
NT: Literature review.
Includes references.
PT: Article
DE: Tropics-.

Attachment E

Financial Data

Table E.1

Cassava Agronomic Practices: Machinery Rates of Work and Financial Costs (SE Qld)

Operation	Working Width (m)	Ground Speed (km/hr)	Field Effic. (%)	Effective Rate (ha/hr)	Labour (mh/ha)	Tractor Power (dbKW)	Diesel Use (litre/hr)	Diesel Use (litre/ha)	F.O.R.M ($/ha planted) Diesel \3	Oil \4	R& M \5	Total	Labour ($/ha planted) \6	FORM + Labour \7
Growing the Crop														
Ripping	4.5	5	80	1.8	0.6	70-75	10	5.56	$1.67	$0.25	$3.66	$5.58	$8.59	$14.17
Ploughing	1.5	5	85	0.6	1.6	70-75	15	23.53	$7.06	$1.06	$10.08	$18.20	$24.27	$42.47
Discing	4	6.4	80	2.0	0.5	70-75	15	7.32	$2.20	$0.33	$3.42	$5.95	$7.55	$13.50
Land planing \1	3	6.4	80	1.5	0.7	50-60	10	6.51	$1.95	$0.29	$3.63	$5.87	$10.07	$15.94
Power harrowing	3	4.2	80	1.0	1.0	50-60	10	9.92	$2.98	$0.45	$5.77	$9.20	$15.35	$24.54
Hilling/fertilizing	4.5	6.4	60	1.7	0.6	70-75	13	7.52	$2.26	$0.34	$3.96	$6.56	$8.95	$15.51
Cultivation, interrow (x 2)	4.5	9	80	3.2	0.3	50-60	8	2.47	$0.74	$0.11	$1.59	$2.44	$4.77	$7.22
Herbicide spraying	4.5	6.4	65	1.9	0.5	40-50	3	1.60	$0.48	$0.07	$2.51	$3.06	$8.26	$11.32
Side dressing fertilizer	4.5	6.4	70	2.0	0.5	40-50	10	4.96	$1.49	$0.22	$2.56	$4.27	$7.67	$11.94
Cultivation, interrow (x 2)	4.5	9	80	3.2	0.3	40-50	8	2.47	$0.74	$0.11	$1.59	$2.44	$4.77	$7.22
Herbicide spraying	4.5	6.4	65	1.9	0.5	40-50	3	1.60	$0.48	$0.07	$2.51	$3.06	$8.26	$11.32
Sub total growing					*7.0*				*$22.04*	*$3.31*		*$66.63*	*$108.54*	*$175.16*
Planting														
Cutting collection \2	1.5	11	70	1.2	0.9	sp \8	14	12.12	$0.36	$0.05	$0.27	$0.69	$1.34	$2.03
Cutting haulage	-	-	-	0.3	0.4	50-60	6	24.00	$0.72	$0.11	$1.82	$2.65	$0.62	$3.27
Planting cuttings \9	4.5	4.2	75	1.4	1.4	70-75	7.5	5.29	$1.59	$0.24	$11.47	$13.30	$21.66	$34.95
Sub total planting					*2.7*							*$16.64*	*$23.62*	*$40.25*
Harvesting the Crop														
Slashing tops	3	5	80	1.2	0.8	50-60	8	6.67	$2.00	$0.30	$4.23	$6.53	$12.89	$19.42
Harvesting roots	1.5	3	50	0.23	4.4	70-75	20	88.89	$26.67	$4.00	$33.60	$64.27	$68.76	$133.02
Infield root haul & clean	-	-	-	0.2	5.0	50-60	6	30.00	$9.00	$1.35	$23.30	$33.65	$77.35	$111.00
Sub total harvesting					*10.3*							*$104.44*	*$159.00*	*$263.44*

\1 50% of the planted area planed each year
\2 Costs are for a 10:1 multiplication rate (i.e. collect from 0.1 ha to plant 1.0 ha)
\3 Delivered price on farm of 64.8c/ litre less diesel fuel rebate of 34.766c/litre
\4 assume 15% of fuel cost
\5 R&M for tractor and equipment is a standard accounting estimate based on % of purchase price and expected life of machinery (refer Table E.2)
\6 Based on award rates for cane industry at Bundaberg & 38 hr week - avg. of Grade 1 & Grade 2 of $454.00 and $487.00 per week plus on-costs of 25%
\7 FORM = fuel, oil, repairs and maintenance
\8 self propelled adapted cane harvester
\9 two people
Net farm gate price of diesel = $0.30

Table E.1(a)

Cassava Agronomic Practices: Machinery Rates of Work and Financial Costs (Darwin)

Operation	Working Width (m)	Ground Speed (km/hr)	Field Effic. (%)	Effective Rate (ha/hr)	Labour (mh/ha)	Tractor Power (dbKW)	Diesel Use (litre/hr)	Diesel Use (litre/ha)	F.O.R.M Costs ($/ha planted) Diesel \3	Oil \4	R& M \5	Total	Labour ($/ha planted) \6	FORM + Labour \7
Growing the Crop														
Ripping	4.5	5	80	1.8	0.6	70-75	10	5.56	$2.22	$0.33	$3.66	$6.22	$8.59	$14.81
Ploughing	1.5	5	85	0.6	1.6	70-75	15	23.53	$9.41	$1.41	$10.08	$20.90	$24.27	$45.17
Discing	4	6.4	80	2.0	0.5	70-75	15	7.32	$2.93	$0.44	$3.42	$6.79	$7.55	$14.35
Land planing \1	3	6.4	80	1.5	0.7	50-60	10	6.51	$2.60	$0.39	$3.63	$6.62	$10.07	$16.69
Power harrowing	3	4.2	80	1.0	1.0	50-60	10	9.92	$3.97	$0.60	$5.77	$10.34	$15.35	$25.68
Hilling/fertilizing	4.5	6.4	60	1.7	0.6	70-75	13	7.52	$3.01	$0.45	$3.96	$7.42	$8.95	$16.37
Cultivation, interrow (x 2)	4.5	9	80	3.2	0.3	50-60	8	2.47	$0.99	$0.15	$1.59	$2.73	$4.77	$7.50
Herbicide spraying	4.5	6.4	65	1.9	0.5	40-50	3	1.60	$0.64	$0.10	$2.51	$3.25	$8.26	$11.51
Side dressing fertilizer	4.5	6.4	70	2.0	0.5	40-50	10	4.96	$1.98	$0.30	$2.56	$4.84	$7.67	$12.51
Cultivation, interrow (x 2)	4.5	9	80	3.2	0.3	40-50	8	2.47	$0.99	$0.15	$1.59	$2.73	$4.77	$7.50
Herbicide spraying	4.5	6.4	65	1.9	0.5	40-50	3	1.60	$0.64	$0.10	$2.51	$3.25	$8.26	$11.51
Sub Total Growing					*7.0*							*$75.08*	*$108.54*	*$183.61*
Planting														
Cutting collection \2	1.5	11	70	1.2	0.9	sp \8	14	12.12	$0.48	$0.07	$0.27	$0.83	$1.34	$2.17
Cutting haulage	-	-	-	0.3	0.4	50-60	6	24.00	$0.96	$0.14	$1.82	$2.93	$0.62	$3.55
Planting cuttings \9	4.5	4.2	75	1.4	1.4	70-75	7.5	5.29	$2.12	$0.32	$11.47	$13.90	$21.66	$35.56
Sub Total Planting					*2.7*							*$17.66*	*$23.62*	*$41.28*
Harvesting the Crop														
Slashing tops	3	5	80	1.2	0.8	50-60	8	6.67	$2.67	$0.40	$4.23	$7.29	$12.89	$20.18
Harvesting roots	1.5	3	50	0.2	4.4	70-75	20	88.89	$35.56	$5.33	$33.60	$74.49	$68.76	$143.24
Infield root haul & clean	-	-	-	0.2	5.0	50-60	6	30.00	$12.00	$1.80	$23.30	$37.10	$77.35	$114.45
Sub total harvesting					*10.3*							*$118.88*	*$159.00*	*$277.88*

\1 50% of the planted area planed each year
\2 Costs are for a 10:1 multiplication rate (i.e. collect from 0.1 ha to plant 1.0 ha)
\3 Delivered price on farm of 74.8c/ litre less diesel fuel rebate of 34.766c/litre
\4 assume 15% of fuel cost
\5 R&M for tractor and equipment is a standard accounting estimate based on % of purchase price and expected life of machinery (refer Table E.2)
\6 Based on award rates for cane industry at Bundaberg & 38 hr week - avg. of Grade 1 & Grade 2 of $454.00 and $487.00 per week plus on-costs of 25%
\7 FORM = fuel, oil, repairs and maintenance
\8 self propelled adapted cane harvester
\9 two people
Net farm gate price of diesel = $0.40

Table E.2

Inventory of Farm Machinery Required for Plantation planting 400ha/year

Item	Specialised Machinery Required (yes/no)	Assumed Purchase Price	R&M Proportion of Purchase Price (%)	Expected Life (hours)	Repairs & Maintenance ($/hr)
Tractor 70-75 dbKW	no	$80,000	72	10000	$5.76
Tractor 70-75 dbKW	no	$80,000	72	10000	$5.76
Tractor 70-75 dbKW	no	$80,000	72	10000	$5.76
Tractor 55-60 dbKW	no	$60,000	72	10000	$4.32
Tractor 55-60 dbKW	no	$60,000	72	10000	$4.32
Tractor 55-60 dbKW	no	$60,000	72	10000	$4.32
Tractor 40-50 dbKW (v.high clear)	no	$50,000	72	10000	$3.60
Ripper, 4.5 m multi- tyne	no	$10,000	20	2400	$0.83
Plough, 1.5m reversible, square	no	$8,000	20	2400	$0.67
Offset disc, 4.0 m	no	$15,000	20	2400	$1.25
Land plane, 3.0 m	no	$15,000	20	2400	$1.25
Power harrow, 3.0 m	no	$12,000	30	2400	$1.50
Hilling & fert. box 4.5 m	yes	$13,000	20	2400	$1.08
Modified cane harvester (cutting collection)	yes	$25,000	30	2400	$3.13
Haulage trailer, high lift tip	no	$12,000	20	10000	$0.24
Haulage trailer, high lift tip	no	$12,000	20	10000	$0.24
Planter, 3 row, specially constructed	yes	$84,000	30	2400	$10.50
Cultivator, interrow, 4.5m	no	$10,000	20	2400	$0.83
Shield boom spray & tank	no	$4,500	20	2400	$0.38
Side dressing fertilizer distributor, 3 row	no	$10,000	20	2400	$0.83
Slasher, 3m	no	$9,000	20	2400	$0.75
Harvester, single row, custom designed	yes	$60,000	30	10000	$1.80
Infield root cleaner	yes	$17,000	20	10000	$0.34
Total		$786,500			
Total specialised purpose built machinery		$279,000			

Table E.2(b)

Cassava Agronomic Practices: Tractors Hours by Season

Tractor Type by Use	Spring (hrs)	Summer (hrs)	Autumn (hrs)	Winter (hrs)	Total (hrs)
Hectares planted each yr = 400					
Growing					
70-75 dbKW	592	592			1,184
55-60 dbKW	540	540			1,080
40-50 dbKW \1		848			848
Harvesting					
70-75 dbKW	400		400	1,200	2,000
55-60 dbKW	468		468	1,400	2,336
Total					
70-75 dbKW	992	592	400	1,200	3,184
55-60 dbKW	1,008	540	468	1,400	3,416
40-50 dbKW \1	0	848	0	0	848
Available Time					
Assumption A \1	*458*	*458*	*458*	*458*	*1830*
Assumption B \2	*618*	*618*	*618*	*618*	*2471*
Assumption C \3	*721*	*721*	*721*	*721*	*2883*
Operation (Surplus/Deficit)					
70-75 dbKW					
Assumption A	(534)	(134)	58	(742)	(1,354)
Assumption B	(374)	26	218	(582)	(713)
Assumption C	(271)	129	321	(479)	(301)
55-60 dbKW					
Assumption A	(550)	(82)	(10)	(942)	(1,586)
Assumption B	(390)	78	150	(782)	(945)
Assumption C	(287)	181	253	(679)	(533)
40-50 dbKW					
Assumption A	458	(390)	458	458	982
Assumption B	618	(230)	618	618	1,623
Assumption C	721	(127)	721	721	2,035
Number of Tractor Units Required:					
70-75 dbKW					
Assumption A	2.2	1.3	0.9	2.6	1.7
Assumption B	1.6	1.0	0.6	1.9	1.3
Assumption C	1.4	0.8	0.6	1.7	1.1
55-60 dbKW					
Assumption A	2.2	1.2	1.0	3.1	1.9
Assumption B	1.6	0.9	0.8	2.3	1.4
Assumption C	1.4	0.7	0.6	1.9	1.2
40-50 dbKW					
Assumption A	0.0	1.9	0.0	0.0	0.5
Assumption B	0.0	1.4	0.0	0.0	0.3
Assumption C	0.0	1.2	0.0	0.0	0.3

\1 5 day week, 8 hour day, 12% wet weather down-time

\2 6 day week, 8 hour day, 1% wet weather down-time

\3 7 day week, 8 hour day, 1% wet weather down-time

Attachment E
Table E.3

CASSAVA CROP GROSS MARGIN - two year crop, irrigated, Bundaberg

(Source : consultants calculations @1998 prices based on cultural practices at ACP Torbanlea experimental farm)

Assumptions:

Farm gate price for fresh weight underground material (S/t FW)	$40	
Equivalent price on dry matter basis @ 37.25%DM ($/t DM)	*$107*	$748
Yield underground material fresh weight (t/ha/crop)	63	
Equivalent yield on dry matter basis (t DM/ha/crop)	*23*	
Area planted (ha)	1	

	Unit	No. Units per ha per crop	Unit Price	Total per ha
Income:				
Cassava sales	t FW	63	$40.00	$2,520.00
Variable Costs: \1				
Cultivation				
Ripping	ha	1	$5.58	$5.58
Ploughing	ha	1	$18.20	$18.20
Discing	ha	1	$5.95	$5.95
Land planing	ha	1	$2.93	$2.93
Power harrowing	ha	1	$9.20	$9.20
Hilling/fertilizing	ha	1	$6.56	$6.56
Interrow cultivation	ha	4	$2.44	$9.76
Side dressing fertilizer	ha	2	$3.06	$6.12
Sub total cultivation costs				*$64.30*
Planting				
Cutting collection	ha	1	$0.69	$0.69
Cutting haulage	ha	1	$2.65	$2.65
Cutting planting	ha	1	$13.30	$13.30
Sub total planting				*$16.64*
Fertilizer				
Pre-planting (N:P:K = 12:11:19 + tr.)	tonne	1 x 0.5	$573.50	$286.75
Side dressing (N:P:K = 23:2:23 + S)	tonne	1 x 0.3	$410.00	$123.00
Lime	tonne	1	$49.50	$49.50
Sub total fertilizer				*$459.25*
Crop Protection				
Herbicide application	ha	1 x 3	$3.06	$9.18
Termite treatment	ha	x		$0.00
Rat treatment	ha	x		$0.00
Cutting pretreat \2	ha	1 x	$5.00	$5.00
Herbicide 1 (oxyfluofen "Goal") \3	10 kg pack	1 x 0.05	$200.00	$10.00
Herbicide 2 (glyphosate)	20 L	0.66 x 0.07	$135.00	$6.24
Herbicide 3 (glyphosate)	20 L	0.33 x 0.07	$135.00	$3.12
Sub total crop protection				*$33.54*
Irrigation				
Winch	ML	1 x 5	$65.00	$325.00
Flood	ML	1 x	$0.00	$0.00
Sub total irrigation				*$325.00*
Harvesting				
Slashing tops	ha	1	$6.53	$6.53
Harvesting roots	ha	1	$64.27	$64.27
Infield root haulage/cleaning	ha	1	$33.65	$33.65
Contract harvester profit & depreciation				$20.89
Sub total harvesting				*$125.34*
Total Variable Costs				$1,024.07
Gross Margin per hectare per crop				$1,495.93
Gross Margin per hectare per year				$747.97

\1 include fuel, oil, parts for repairs and maintenance for machinery and other material costs

\2 mix of Maldison, copperoxychloride and zinc sulphate

\3 based on 'diruron' prices

File: cassava/cane_gm-sheetA

Attachmen
Table E.4

CASSAVA CROP GROSS MARGIN - two year crop, irrigated, DARWIN

(Source : consultants calculations @1998 prices based on cultural practices at ACP Torbanlea experimental farm)

Assumptions:

Farm gate price for fresh weight underground material (S/t FW)	S40
Equivalent price on dry matter basis @ 37.25%DM (S/t DM)	*S107*
Yield underground material fresh weight (t/ha/crop)	92
Equivalent yield on dry matter basis (t DM/ha/crop)	*34*
Area planted (ha)	1

	Unit	No. Unit per ha	Unit Price	Total per ha
Income:				
Cassava sales	t FW	92	S40.00	S3,680.00
Variable Costs: \1				
Cultivation				
Ripping	ha	1	S6.22	S6.22
Ploughing	ha	1	S20.90	S20.90
Discing	ha	1	S6.79	S6.79
Land planing	ha	1	S3.31	S3.31
Power harrowing	ha	1	S10.34	S10.34
Hilling/fertilizing	ha	1	S7.42	S7.42
Interrow cultivation	ha	4	S2.73	S10.92
Side dressing fertilizer	ha	2	S4.84	S9.68
Sub total cultivation costs				*S75.58*
Planting				
Cutting collection	ha	1	S0.83	S0.83
Cutting haulage	ha	1	S2.93	S2.93
Cutting planting	ha	1	S13.90	S13.90
Sub total planting				*S17.66*
Fertilizer \4				
Pre-planting (N:P:K = 12:11:19 + tr.)	tonne	1 x 0.5	S683.10	S341.55
Side dressing (N:P:K = 23:2:23 + S)	tonne	1 x 0.3	S520.00	S156.00
Lime	tonne	1	S49.50	S49.50
Sub total fertilizer				*S547.05*
Crop Protection				
Herbicide application	ha	1 x 3	S3.25	S9.75
Termite treatment	ha	x		S0.00
Rat treatment	ha	x		S0.00
Cutting pretreat \2	ha	1 x	S5.00	S5.00
Herbicide 1 (oxyfluofen "Goal") \3	10 kg pack	1 x 0.05	S200.00	S10.00
Herbicide 2 (glyphosate)	20 L	0.66 x 0.07	S135.00	S6.24
Herbicide 3 (glyphosate)	20 L	0.33 x 0.07	S135.00	S3.12
Sub total crop protection				*S34.11*
Irrigation				
Winch	ML	1 x 5	S65.00	S325.00
Flood	ML	1 x	S0.00	S0.00
Sub total irrigation				*S325.00*
Harvesting				
Slashing tops	ha	1	S7.29	S7.29
Harvesting roots	ha	1	S74.49	S74.49
Infield root haulage/cleaning	ha	1	S37.10	S37.10
Contract harvester profit & depreciation				S23.78
Sub total harvesting				*S142.66*
Total Variable Costs				**S1,142.05**
Gross Margin per hectare per crop				**S2,537.95**
Gross Margin per hectare per year				**S1,268.97**

\1 include fuel, oil, parts for repairs and maintenance for machinery and other material costs

\2 mix of Maldison, copperoxychloride and zinc sulphate

\3 based on 'diruron' prices \4 Darwin fertilizer price = Qld price + S120/t freight less S55/t subsidy

File: cassava/cane_gm-sheetA

Attachment E
Table E.5

CASSAVA CROP GROSS MARGIN - one year crop, dryland, Bundaberg

(Source : consultants calculations @1998 prices based on cultural practices at ACP Torbanlea experimental farm)

Assumptions:

Farm gate price for fresh weight underground material ($/t FW)	$40
Equivalent price on dry matter basis @ 37.25%DM ($/t DM)	*$107*
Yield underground material fresh weight (t/ha)	25
Equivalent yield on dry matter basis (t DM/ha)	*9*
Area planted (ha)	1

Income:	Unit	No. Units per ha	Unit Price	Total per ha
Cassava sales	t FW	25	$40.00	$1,000.00
Variable Costs: \1				
Cultivation				
Ripping	ha	1	$5.58	$5.58
Ploughing	ha	1	$18.20	$18.20
Discing	ha	1	$5.95	$5.95
Land planing	ha	1	$2.93	$2.93
Power harrowing	ha	1	$9.20	$9.20
Hilling/fertilizing	ha	1	$6.56	$6.56
Interrow cultivation	ha	4	$2.44	$9.76
Side dressing fertilizer	ha	1	$3.06	$3.06
Sub total cultivation costs				*$61.24*
Planting				
Cutting collection	ha	1	$0.69	$0.69
Cutting haulage	ha	1	$2.65	$2.65
Cutting planting	ha	1	$13.30	$13.30
Sub total planting				*$16.64*
Fertilizer				
Pre-planting (N:P:K = 12:11:19 + tr.)	tonne	1 x 0.5	$573.50	$286.75
Side dressing (N:P:K = 23:2:23 + S)	tonne	1 x 0.1	$410.00	$41.00
Lime	tonne	1	$49.50	$49.50
Sub total fertilizer				*$377.25*
Crop Protection				
Herbicide application	ha	1 x 3	$3.06	$9.18
Termite treatment	ha	x		$0.00
Rat treatment	ha	x		$0.00
Cutting pretreat \2	ha	1 x	$5.00	$5.00
Herbicide 1 (oxyfluofen "Goal") \3	10 kg pack	1 x 0.1	$200.00	$10.00
Herbicide 2 (glyphosate)	20 L	0.66 x 0.07	$135.00	$6.24
Herbicide 3 (glyphosate)	20 L	0.33 x 0.07	$135.00	$3.12
Sub total crop protection				*$33.54*
Irrigation				
Winch	ML	1 x	$0.00	$0.00
Flood	ML	1 x	$0.00	$0.00
Sub total irrigation				*$0.00*
Harvesting				
Slashing tops	ha	1	$6.53	$6.53
Harvesting roots	ha	1	$64.27	$64.27
Infield root haulage/cleaning	ha	1	$33.65	$33.65
Contract harvester profit & depreciation				$20.89
Sub total harvesting				*$125.34*
Total Variable Costs				$614.01
Gross Margin per hectare per crop				$385.99
Gross Margin per hectare per year				$385.99

\1 include fuel, oil, parts for repairs and maintenance for machinery and other material costs

\2 mix of Maldison, copperoxychloride and zinc sulphate

\3 based on 'diuron' prices

File: cassava/cane_gm-sheetA

Attachment E
Table E.6

CASSAVA CROP GROSS MARGIN - one year crop, dryland, DARWIN

(Source : consultants calculations @1998 prices based on cultural practices at ACP Torbanlea experimental farm)

Assumptions:

Farm gate price for fresh weight underground material ($/t FW)	$40
Equivalent price on dry matter basis @ 37.25%DM ($/t DM)	*$107*
Yield underground material fresh weight (t/ha)	30
Equivalent yield on dry matter basis (t DM/ha)	*11*
Area planted (ha)	1

	Unit	No. Units per ha		Unit Price	Total per ha
Income:					
Cassava sales	t FW	30		$40.00	$1,200.00
Variable Costs: \1					
Cultivation					
Ripping	ha	1		$6.22	$6.22
Ploughing	ha	1		$20.90	$20.90
Discing	ha	1		$6.79	$6.79
Land planing	ha	1		$3.31	$3.31
Power harrowing	ha	1		$10.34	$10.34
Hilling/fertilizing	ha	1		$7.42	$7.42
Interrow cultivation	ha	4		$2.73	$10.92
Side dressing fertilizer	ha	1		$4.84	$4.84
Sub total cultivation costs					*$70.74*
Planting					
Cutting collection	ha	1		$0.83	$0.83
Cutting haulage	ha	1		$2.94	$2.94
Cutting planting	ha	1		$13.90	$13.90
Sub total planting					*$17.67*
Fertilizer					
Pre-planting (N:P:K = 12:11:19 + t	tonne	1 x	0.5	$683.10	$341.55
Side dressing (N:P:K = 23:2:23 + S	tonne	1 x	0.1	$520.00	$52.00
Lime	tonne	1		$49.50	$49.50
Sub total fertilizer					*$443.05*
Crop Protection					
Herbicide application	ha	1 x	3	$3.25	$9.75
Termite treatment	ha	x			
Rat treatment	ha	x			
Cutting pretreat \2	ha	1 x		$5.00	$5.00
Herbicide 1 (oxyfluofen "Goal") \3	10 kg pack	1 x	0.05	$200.00	$10.00
Herbicide 2 (glyphosate)	20 L	0.66 x	0.07	$135.00	$6.24
Herbicide 3 (glyphosate)	20 L	0.33 x	0.07	$135.00	$3.12
Sub total crop protection					*$34.11*
Irrigation					
Winch	ML	1 x			
Flood	ML	1 x			
Sub total irrigation					
Harvesting					
Slashing tops	ha	1		$7.29	$7.29
Harvesting roots	ha	1		$74.49	$74.49
Infield root haulage/cleaning	ha	1		$37.10	$37.10
Contract harvester profit & depreciation					$23.78
Sub total harvesting					*$142.66*
Total Variable Costs					$708.22
Gross Margin per hectare per crop					$491.78
Gross Margin per hectare per year					$491.78

\1 include fuel, oil, parts for repairs and maintenance for machinery and other material costs

\2 mix of Maldison, copperoxychloride and zinc sulphate

\3 based on 'diruron' prices

\4 Darwin fertilizer price = Qld price + $120/t freight less $55/t subsidy

File: cassava/cane_gm-sheetA

Attachment E
Table E.7

GROSS MARGIN COMPARISON CANE AND CASSAVA BUNDABERG

('Best Bet' cassava yield; cassava price altered to equate GMs of cassava and sugarcane) \1

		Cassava	Sugarcane
Assumptions:			
Farm arable area		60	60
Harvested area per year	ha	25	50
Yield	t/ha FW	63	85
Area under crop harvest start	ha	50	50
Farmgate Price	S/t FW	S61	S32
Farmgate Price cassava DW	S/t DM	S163	
Income:	S/farm/yr	S96,343	S136,000
Costs:			
Variable:			
- fertilizer		S11,481	S17,400
- fuel		S700	S5,000
- Irrigation		S8,125	S17,000
- Crop protection		S609	S5,150
- contract plant \2		S1,450	S2,500
- contract harvest \2		S10,439	S21,250
- levies		S0	S2,100
Total variable costs		S32,804	S70,400
Gross margin per farm per year		S63,539	S65,600
Gross margin per arble hectare per year		$1,059	$1,093

\1 cassava GM excludes R&M to equate to cane GM format

\2 for cassava includes fuel,oil,repairs & maintenance plus 20% profit and depreciation

Attachment E
Table E.8

WET SEASON IRRIGATED PEANUTS KATHERINE/DALY NORTHERN TERRITORY

(Source DPIF,1997)

Assumptions:				
Yield peanuts	t/ha	5.0		
Price	$/t	$750.00		
Yield hay	t/ha	5.0		
Price hay	$/t	$150.00		
Fertilizer subsidy	$/t	$95.00		
Inclusions	fuel,oil,R&M on machinery			
Exclusion	labour			
Activity Unit	ha	1		
	Unit	No. Units per ha	Unit Price	Total $ per farm
Income:				
Peanut sales	tonne	5	750	$3,750
Hay sales	tonne	5	150	$750
Fertilizer subsidy	tonne	0.85	95	$81
Total Income				*$4,581*
Variable Costs				
Land preparation	ha	1	$21.00	$21
Seed	kg	100	$3.50	$350
Innoculant	kg	100	$0.05	$5
Sowing	hr	0.238	$16.00	$4
Fertilizer	ha	1	$323.00	$323
Fertilizer application	ha	1	$8.00	$8
Weedicide	ha	1	$106.00	$106
Weedicide application	ha	1	$5.00	$5
Interrow cultivation & hilling	ha	1	$21.00	$21
Insecticide\other disease control agent	ha	1	$231.00	$231
Application	ha	1	$13.00	$13
Irrigation	ML	3	$56.00	$168
Cutting, digging and threshing peanuts	ha	1	$85.00	$85
Haymaking	ha	1	$150.00	$150
Marketing (cartage to Kingaroy)	t	5	$90.00	$450
Total variable cost				*$1,940*
Gross Margin (total revenue - variable costs)				
- per hectare				$2,641

Attachment E
Table E.9

WET SEASON DRYLAND SORGHUM KATHERINE/DALY NORTHERN TERRITORY

(Source: DPIF, 1997)

Assumptions:				
Yield sorghum	t/ha	2.7		
Price	$/t	$275.00		
Stubble agistment	$/hd/wk	2.0		
Fertilizer subsidy	$/t	$95.00		
Inclusions	fuel,oil,R&M on machinery			
Exclusion	labour			
Activity Unit	ha	1		
	Unit	No. Units per ha	Unit Price	Total $ per farm
Income:				
Sorghum sales	tonne	2.7	275	$743
Agistment	weeks	17	2	$34
Fertilizer subsidy	tonne	0.275	95	$26
Total Income				*$803*
Variable Costs				
Land preparation	ha	1	$20.00	$20
Seed	kg	8	$3.70	$30
Sowing	hr	0.238	$16.00	$4
Fertilizer	ha	1	$157.00	$157
Fertilizer application	ha	1	$6.00	$6
Weedicide	ha	1	$18.00	$18
Weedicide application	ha	1	$2.00	$2
Harvesting	hr	0.317	$76.87	$24
Marketing (freight to enduser)	t	2.7	$30.00	$81
Total variable cost				*$342*
Gross Margin (total revenue - variable costs)				
- per hectare				$461

Table E.10

PLANTATION OVERHEAD AND FIXED COSTS

	Total Plantation ($)	Per Tonne FW @ 36,800t/yr ($)	Per Tonne FW @ 25,200t/yr ($)
Overhead			
Wages & on-costs \1	$172,386	$4.7	$6.8
Vehicle operating costs \2	$32,834	$0.9	$1.3
R&M farm buildings & infrastructure \ 3	$12,400	$0.3	$0.5
Fixed			
Administration \4	$20,000	$0.5	$0.8
Depreciation \5	$199,609	$5.4	$7.9
Rates & taxes \4	$2,200	$0.1	$0.1
Total Fixed and Overhead	$439,429	$12	$17

\1 From Table E.11

\2 From Table E.12

\3 On residential and farm buildings

\4 ACP data for 1984 increased by CPI (= x 1.74)

\5 Straight line depreciation (purchase price -salvage value/life of item) plant & equipment & fixed improvements

Table E.11

PLANTATION LABOUR REQUIREMENTS

(Source: same as ACP Torbanlea farm)

Staff	Weekly Wage	Annual Wage	On Cost (@ 25%)	Total Labour
Foreman	$646	$33,571	$8,393	$41,964
Mechanic	$516	$26,857	$6,714	$33,571
Field hand, permanent	$470	$24,440	$6,110	$30,550
Field hand, permanent	$470	$24,440	$6,110	$30,550
Field hand, casual	$550	$28,600	$7,150	$35,750
Total				$172,386

Table E.12

VEHICLE OPERATING COSTS

Vehicles	Rego ($/yr)	Insur. ($/yr)	Fuel \1 ($/km)	Oil ($/km)	R&M ($/km)	Use (km/yr)	Annual Cost
4 wd, foreman	520	230	0.088	0.0132	0.35	30000	$14,286
4 wd, field hands	520	230	0.088	0.0132	0.35	20000	$9,774
Service van, mechanic	520	230	0.088	0.0132	0.3	20000	$8,774
			\1 7.2km/l @ $0.64/l			Total	$32,834

ATTACHMENT E

Table E.13

CASSAVA PROCESSING PLANT - ESTIMATED CAPITAL COST

Item	Purchase Price ($)	NT Deprec. ($/yr)	Qld Deprec. ($/yr)
Front End			
Tractor with front end bucket (1cum)	$45,000		
Elevator, variable speed (0.75m wide)	$6,000		
Trommel, dry 2.5 m long	$10,000		
Wash trough	$2,000		
Wash trough componends:			
- stone sorter	$2,000		
- agitator	$2,000		
- pump,filters sprays	$4,000		
- elevator 3.5 m	$4,500		
- motors	$3,500		
Breaker to produce coarse product	$16,000		
Contingencies @ 10%	$9,500		
Total Front End	*$104,500*	*$17,100*	*$11,714*
Drying, Pelleting and Bagging			
Raw material intake transfer conveyor	$4,973		
Vibratory transfer screener/conveyor	$8,900		
Metering feed conveyor to chipper	$5,584		
Cassava tuber chipper	$56,714		
Receival cyclone & transitional unit	$3,228		
Horizontal belt dryer	$160,981		
Dryer discharge conveyor	$14,135		
Attrition dryers & grinders (2)	$307,129		
Filter collectors (2)	$59,681		
Pre-pellet press	$6,282		
Pre-pellet press	$6,631		
Pellet press	$161,417		
Transfer belt conveyor	$5,453		
Transfer bucket elevator	$7,635		
Counter flo cooler	$28,793		
Pellet screener	$11,125		
Pellet cooler/pellet screener	$6,762		
Transfer bucket elevator	$7,635		
Finished product pack-out bin	$15,269		
Discharge conveyors	$11,648		
Automatic belt weigh	$27,777		
Bag transfer	$8,523		
Bulk bag packing station	$15,095		
Bag shrink wrapping station	$21,115		
Set transitions & spouting	$6,561		
Fines return conveyor	$3,682		
Steam supply asystem	$56,714		
Packing & freight of equipment	$30,538		
Installation, mechanical	$81,000		
Installation, electrical	$161,417		
Project management	$36,646		
Contingencies @ 10%	$133,904		
Total Drying, Pelleting and Bagging	*$1,472,947*	*$185,299*	*$125,930*
Building and Utilities			
	$250,000		
Contingencies @ 10%	$25,000		
Total Building and Utilities	$275,000	*$8,250*	*$8,250*
Total Cost	$1,852,447	$210,649	$146,894
$/t FW		$5.7	$5.8

ATTACHMENT E

Table E.14

PROCESSOR OVERHEAD AND FIXED COSTS

	Total Processor NT ($)	Total Processor Qld	NT per t feedstock @36,800t/yr ($)	Qld per t feedstock @25,200t/yr ($)
Overhead				
Wages & on-costs \1	$174,680	$145,800	$4.7	$5.8
Vehicle operating costs \2	$8,774	$8,774	$0.2	$0.3
R&M farm buildings & infrastructure \ 3	$2,750	$2,750	$0.1	$0.1
Fixed				
Administration \4	$0	$0	$0.0	$0.0
Depreciation \5	$210,649	$146,894	$5.7	$5.8
Rates & taxes \4	$0	$0	$0.0	$0.0
Total Fixed and Overhead	$396,853	$304,218	$10.8	$12.1

\1 From Table E.15

\2 From Table E.16

\3 On processor building

\4 Accounted for in plantation costs

\5 From Table E.13; straight line depreciation (purchase price -salvage value/life of item) plant & equipment & fixed improvements

Table E.15

PROCESSOR LABOUR REQUIREMENTS

(Source: same as ACP Torbanlea farm)

Staff	Weekly Wage	NT Annual Wage	Qld Annual Wage	NT On Cost (@ 25%)	Qld On Cost (@ 25%)	NT Total Labour	Qld Total Labour
Foreman, permanent	$688	$35,776	$35,776	$8,944	$8,944	$44,720	$44,720
Foreman, night shift,casual	$688	$24,768	$19,264	$6,192	$4,816	$30,960	$24,080
Hough loader driver,casual (x 2) \1	$1,100	$39,600	$30,800	$9,900	$7,700	$49,500	$38,500
Pack-out operative, casual (x 2)	$1,100	$39,600	$30,800	$9,900	$7,700	$49,500	$38,500
Total					Total	$174,680	$145,800

\1 x2 = 2 shifts

Table E.16

PROCESSOR VEHICLE OPERATING COSTS

Vehicles	Rego ($/yr)	Insur. ($/yr)	Fuel \1 ($/km)	Oil ($/km)	R&M ($/km)	Use (km/yr)	Annual Cost
Foreman van	520	230	0.088	0.0132	0.3	20000	$8,774
					Total		$8,774

\1 7.2km/l @ $0.64/l

Table E.17

PROCESSOR VARIABLE COSTS

	Litres/MT drie	$/litre (NT)	$/litre (Qld)	Mt dried (NT)	MT dried (Qld)	Total $ (NT)	Total $ (Qld)
Dehydration, light fuel oil	91	0.37	0.27	16394	11227	$551,986	$275,847
	Avg load KW/hr	c/KW (NT)	c/KW(Qld)	hrs (NT)	hrs(Qld)		
Electricity	787	6	6	4752	3170	$224,389	$149,687
					Fuel & power: total $	$776,375	$425,535
					Fuel & power: $/tFW	$21.1	$16.9
	$/t output			Mt dried (NT)	MT dried (Qld)		
R&M (incl.front end)	6			16394	11227	$98,364	$67,362
					R&M 4/tFW	$2.7	$2.7

Attachment F

Photographs

F.1 Early version of cassava root harvester; important feature is concave cutter bar and debris splitting posts

F.2 Cassava root harvester; Toft prototype May '80; the front elevator/cleaning shaking bar remained part of the final harvester as did the rear loading elevator

F.3 Improved feature of cassava root harvester was the hydraulic shaker which vibrated the cutter bar in the ground; oscillation of the bar was side-to-side NOT back and forward; vastly improved digging in dry or very wet conditions

F.4 Cutting Harvester; a modified MF201 cane harvester with front crop gatherers removed and replaced with counter-balance front weight; used to harvest tops and prepare billets for planting

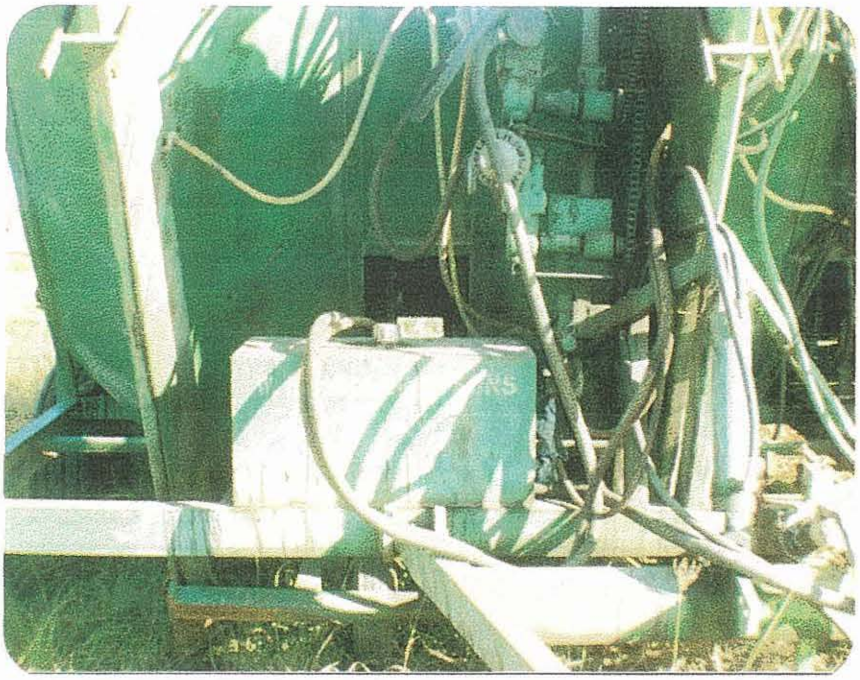
F.5 Cassava cutting harvester; front end modification which smoothed the flow of stems into the machine throat.

F.6 Haul-out bin fitted with slotted elevator to regulate out-feed.

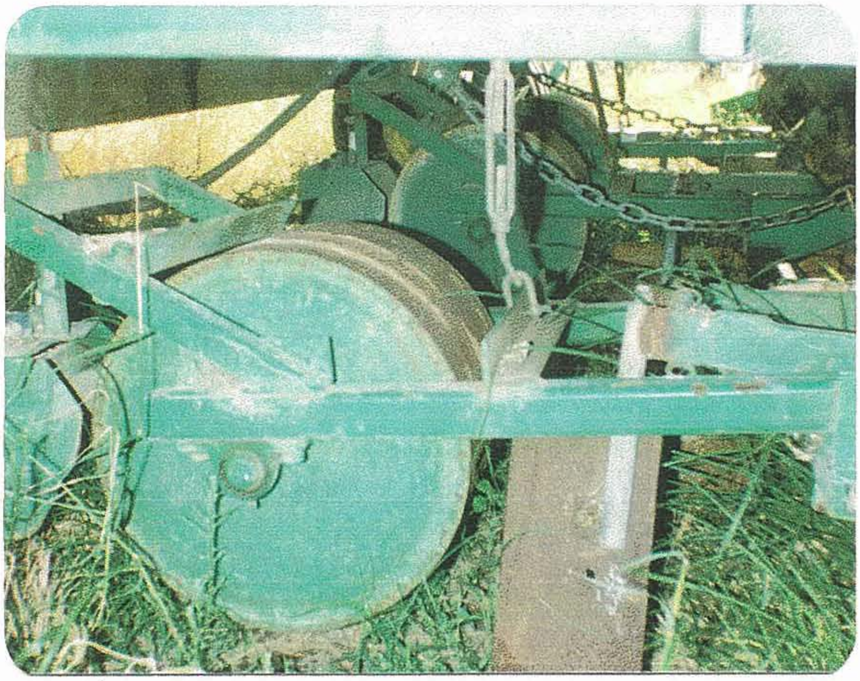
F.7 Three-row Moller planter; planted billets in 1.5 m rows at 13,000 to 18,000 per ha

F.8 Three-row Moller planter; trailed by a 70-75dbKW tractor; one operator attended the planter

F.9 Three-row Moller planter; each of three bins had a moving slat floor to pull the cuttings towards the front shutes; operator on the planter had control over rate of movement of each floor



F.10 Three-row Moller cassava planter; two hydraulic spray tanks - one for spraying billets with fungicide and trace elements and one spraying pre-emergent herbicide after planting



F.11 Three row Moller cassava planter; press wheel for smoothing the top of the hills after cuttings planted to provide a smooth surface for pre-emergent herbicide spraying immediately behind the press wheel

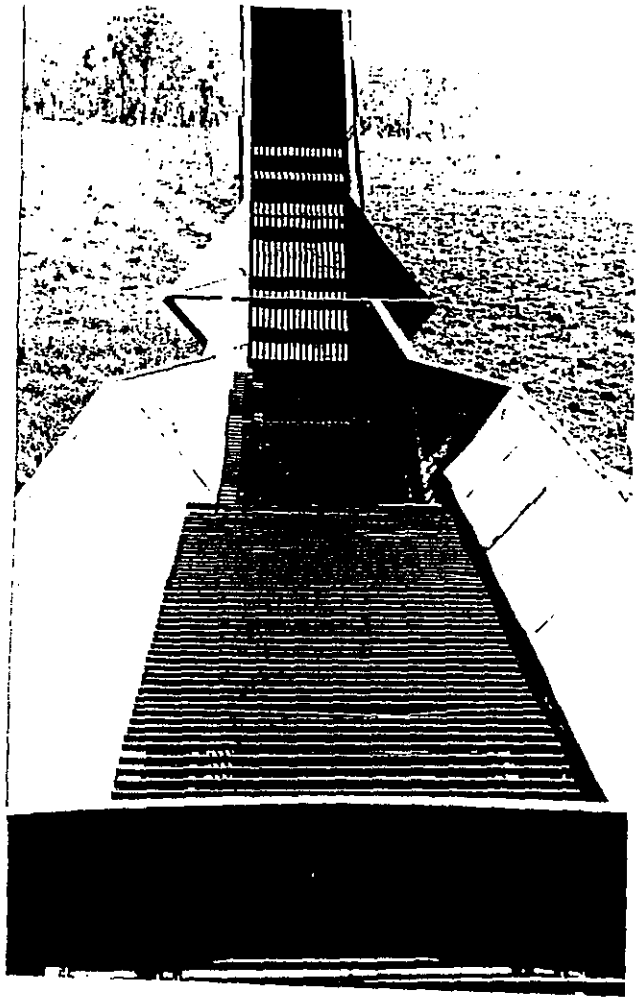
F.12 Single row cassava planter; modified cane planter

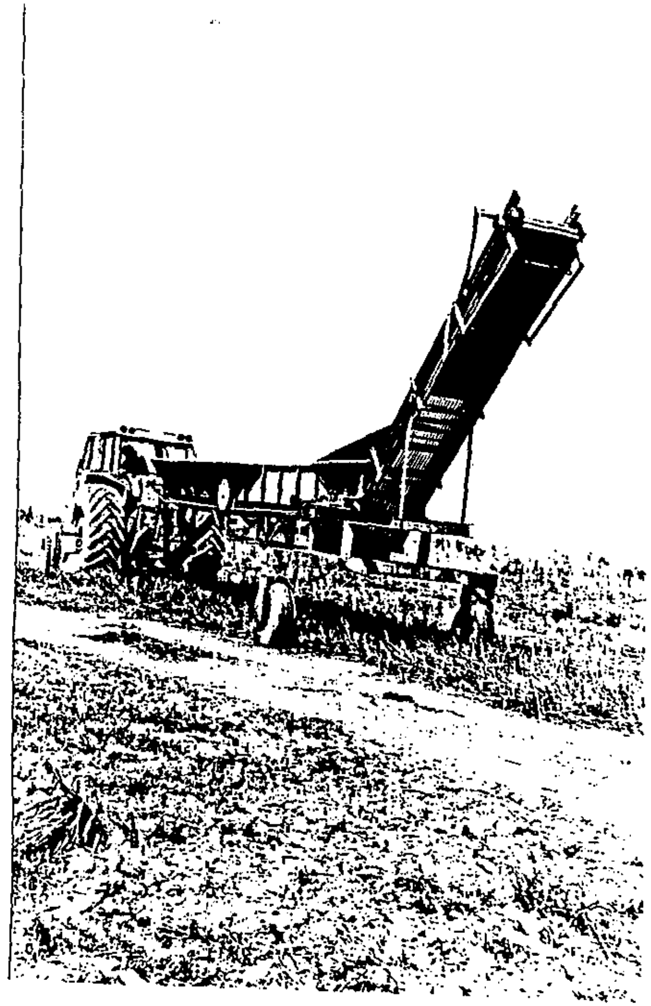
F.13 One version of the 3-row hiller/fertilizer box

F.14 Hiller/fertilizer box - tyned version

F.15 Shielded boom sprayer for delivery of herbicides and very high clearance tractor

F.16 Infield Root Cleaner. Comprises a slatted creep feeder belt, vibrating cleaning belt and exit elevator





Attachment G

Cassava Cultivar Collection held in ACP Nursery at Torbanlea in 1980s

Cultivar	Site of Collection
M Aus 1	Bundaberg, Qld
M Aus 2	Cardwell, Qld
M Aus 3	South Johnstone, Qld
M Aus 4	Malaysia (cv Black Twig)
M Aus 6	Miallo, Qld (ex PNG)
M Aus 9	Flying fish Point, Qld
M Aus 10	Mourilyan Harbour Qld
M Aus 11	Daintree, Qld
M Aus 12	Innisfail, Qld
M Aus 13	Kamerunga, Qld
M Aus 14	Unkown (cv. Giant Red)
M Aus 15	Babinda Qld
M Aus 16	Mitchie, Qld
M Aus 17	Kununurra, WA
M Aus 18	Cairns, Qld (CCC)
M Aus 20	Cairns, Qld
M Aus 21	Weipa, Qld
M Aus 22	St. Lucia, Qld (variagated)
M Aus 23	Ingham, Qld
M Aus 26	Puerto Rico (cv. Mameya)
M Aus 27	Puerto Rico (cv. Ceiba)
M Aus 30	Puerto Rico (cv. Seda)
M Aus 101	ACP selection from CIAT CM 208-10 x M Col 638
M Aus 102	ACP selection from CIAT CM 208-10 x M Col 638
M Aus 104	ACP selection from CIAT CM 208-10 x M Col 638
M Aus 106	ACP selection from CIAT M Mex 24 x M Col 690
M Aus 107	ACP selection from CIAT M Mex 24 x M Col 690
M Aus 110	ACP selection from CIAT M Mex 24 x M Col 690
M Aus 111	ACP selection from CIAT M Mex 24 x M Col 690
M Aus 112	ACP selection from CIAT CM 234 x CM 204-5
M Mex 23	Mexico, ex CIAT, Colombia
M Mex 52	Mexico, ex CIAT, Colombia

Cultivar	Site of Collection
M Mex 55	Mexico, ex CIAT, Colombia
M Mex 59	Mexico, ex CIAT, Colombia
M Ven 119	Venezuela, ex CIAT, Colombia
M Ven 185	Venezuela, ex CIAT, Colombia
M Ven 218	Venezuela, ex CIAT, Colombia
M Ven 259	Venezuela, ex CIAT, Colombia
M Ven 307	Venezuela, ex CIAT, Colombia
M Col 22	CIAT, Colombia
M Col 136	CIAT, Colombia
M Col 595	CIAT, Colombia
M Col 600	CIAT, Colombia
M Col 670	CIAT, Colombia
M Col 673	CIAT, Colombia
M Col 755	CIAT, Colombia
M Col 930	CIAT, Colombia
M Col 978	CIAT, Colombia
M Col 1467	CIAT, Colombia
M Col 1468	CIAT, Colombia (ICA CMC 40)
M Col 1501	CIAT, Colombia
M Col 1150	CIAT, Colombia
COMML	Thailand (commercial cv. Possibly Rayong 3)
Pandesi	Indonesia, ex Waite Institute S.Aust.
Faroka	Indonesia, ex Waite Institute S.Aust.
Ndora	Indonesia, ex Waite Institute S.Aust.
JD 1	Rockhpamton, Qld
JD 2	Rockhampton, Qld
ACP 13	ACP selection, yield and cold tolerance
ACP 37	ACP selection, yield and cold tolerance
ACP 45	ACP selection, yield and cold tolerance
ACP 53	ACP selection, yield and cold tolerance
ACP 68	ACP selection, yield and cold tolerance
ACP 86	ACP selection, yield and cold tolerance

Cultivar	Site of Collection
ACP 100	ACP selection, yield and cold tolerance
ACP 231	ACP selection, yield and cold tolerance
ACP 305	ACP selection, yield and cold tolerance
ACP 309	ACP selection, yield and cold tolerance
ACP 444	ACP selection, yield and cold tolerance
ACP 540	ACP selection, yield and cold tolerance
ACP 604	ACP selection, yield and cold tolerance
ACP 750	ACP selection, yield and cold tolerance
ACP 760	ACP selection, yield and cold tolerance
ACP 810	ACP selection, yield and cold tolerance
ACP 930	ACP selection, yield and cold tolerance
ACP 1107	ACP selection, yield and cold tolerance
ACP 1124	ACP selection, yield and cold tolerance
ACP 1187	ACP selection, yield and cold tolerance
ACP 1220	ACP selection, yield and cold tolerance
ATR	somoclonal variant M Aus 7 atrazine tolerance

Attachment H

Terms of Reference

MEAT RESEARCH CORPORATION
FEEDLOT CONSISTENCY & SUSTAINABILITY KEY PROGRAM

ALTERNATIVE ENERGY DENSE FEEDSTUFFS FOR THE CATTLE FEEDLOT INDUSTRY - PHASE 2.

CASSAVA STUDY

TERMS OF REFERENCE

THE CONSULTANCY SERVICES

BACKGROUND

The business plan for the Feedlot Consistency and Sustainability Key Program (FCSKP) identified a likely increase in the real price of energy dense feedstuffs, and the security of its supply, as a core problem affecting the long term prosperity of the cattle feedlot industry in Australia.

It was postulated that in Australia a more competitive unit cost, and security of supply, of energy dense cattle feedstuffs could be achieved from purpose-grown alternative crops or, by better use of existing energy dense by-products.

The Meat Research Corporation ("MRC" or "the Corporation") initiated a 3-phased R&D project to evaluate the above proposition and, if feasible, help to stimulate the establishment of commercial supply of alternative energy dense feedstuffs. The 3 phases of the project included:

- Phase 1 A review and preliminary feasibility study of alternative crop and by-product options.
- Phase 2 Specific technical research into issues and constraints identified in the first phase.
- Phase 3 Catalysing commercial development.

Phase 1 work concluded that there was potential for cassava to be grown locally as an energy dense animal feedstuff. However, the last substantial commercial assessment of cassava in Australia was to evaluate the crop as a potential alternative fuel energy source. There has been no full evaluation of the crop as a potential animal feedstuff.

Research was suggested in the form of a feasibility study to assess the financial practicality of growing cassava in Australia, as an energy dense feedstuff for the intensive cattle industries.

OBJECTIVE

The objective of Phase 2 of this work is to review past research and commercial experience in Australia and overseas and on the basis of this:

a) Compile and collate the information available on the use of cassava in cattle feedlot rations and present it in the form of a reference document for use by industry operators.
b) Evaluate the technical and financial feasibility of establishing a commercial cassava production and processing industry in Australia capable of supplying the intensive cattle industries with an energy dense feedstuff.
c) Make recommendations on the feasibility of establishing a commercial cassava production and processing industry in Australia, outlining the necessary steps for catalysing commercial development, should such development be recommended as feasible.

REQUIREMENTS UNDER THE CONSULTANCY

Scope

The scope of the work will be wide reaching in terms of the sources of information reviewed but, in particular will focus on the scientific literature from Australia and overseas and commercial experience within Australia. The scope of the work will include, but not necessarily be limited to the following:

- description of the nutritional properties of cassava, including its comparative energy value;
- a review of the nutritional limitations to the use of cassava in rations for cattle, expected production responses from including cassava in feedlot rations, and criteria for evaluating whether cassava is an economic alternative for inclusion in feedlot rations;
- impact of feeding cassava on meat quality and animal health;
- particular problems that may be encountered when feeding cassava;
- purchase specifications, appropriate receival standards and testing procedures for cassava, suitable for inclusion in QA manuals;
- recommendations on levels of cassava that can be utilised in feedlot rations and other ration adjustments that may be required;
- establishment of the edapho-climatic limits for cassava production;
- identification of the potential growing areas for cassava and suitable cultivars for use in these areas;
- description of the crop agronomy and sustainable production systems which are most appropriate for Australia, including specific requirements for planting, harvesting and storage;
- assessment of the present availability of planting material of suitable cultivars in Australia and/or the constraints to the importation of start-up planting material from overseas;
- an evaluation of the capital and operating costs associated with moving from the existing production system to a cassava production system;
- an analysis of the potential on-farm costs and returns for the grower of cassava compared with the presently grown crops, sensitivity tested for a range of yields and product prices and an estimation of the threshold price

and yield required for farmers to be attracted to change from existing crops to cassava production;

- identification of specific processing requirements to convert cassava to a feedstuff suitable for use in the cattle feedlot industry;
- an evaluation of the capital and operating cost of establishing and operating a processing facility for cassava, and an estimation of optimum throughput requirements, and area under crop needed to achieve viability of the processing operation;
- determination of the present feedlot capacity which could be beneficially supplied from the potential production area for cassava;
- identify alternative market outlets for cassava, including an assessment of their ability to be price competitive (eg. dairy, pigs, poultry, ethanol production);
- identify and comment on any other potential constraint (eg. environmental, crop residue, and legislative) which might constrain the growing of cassava in Australia; and,
- make recommendations on the technical and financial feasibility of establishing a commercial cassava production and processing industry in Australia, outlining necessary steps for catalysing commercial development, should such development be recommended as feasible.

Methodology

This Phase 2 work will be a desk study involving:

- a review of the scientific literature, particularly with respect to the nutritional properties of cassava, performance responses from inclusion of cassava in feedlot rations, limitations to inclusion rates, and cassava agronomy;
- consultation, as far as commercial-in-confidence constraints permit, with commercial operators with previous experience and expertise in this area (eg. cassava growing by Goodman Fielder in Queensland in early 1980's, CSR who investigated the role of cassava for ethanol production);
- consultation with researchers and advisors with past direct experience with the production and feeding of cassava;
- review of old Government departmental reports and, where permitted, unpublished files of previous initiatives.

The study will require an analysis of regional cropping statistics, climatic data and a capacity to interpret and extrapolate potential growing areas from existing soil maps. Farm models will need to be developed to analyse the potential net returns and break-even yields and prices, to demarcate the present feedlot capacity which could be economically supplied by a new cassava industry and, to establish optimum sizing of any processing facility.

Output

The output of the research will be a Report which will be presented, in the first instance, as a Draft Final Report for the consideration and comments of the Corporation and the FCSKP Consultative Group. The Final report will be revised to address comments made on the Draft Final Report and re-presented to the Corporation. The report will contain an Executive Summary which will, as far as possible, read as a stand alone document which effectively summarises the full document. A list of contacts interviewed during the course of the research will be appended. If the Consultant has access to commercial-in-confidence data, germane to the study outcome, the MRC would not require this to be presented in the Report nor sources identified. Subject to agreement between the parties involved, such commercial-in-confidence data may be presented in an unpublished, Part 2 document.

Ten (10) bound copies of the Draft Final and Final Reports will be provided to the MRC, as well as a disk copy of the Final Report using agreed software.

Consultative Group

This project is a component of the MRC Feedlot Consistency and Sustainability Key Program which has a Consultative Group of Industry representatives. The outcome of this project will be referred to this group for endorsement prior to acceptance of the Final Report.

Access to Information

Where information is available which may assist the Consultant in meeting the requirements of this research, such information will be provided to the Consultant on a confidential, or other basis as indicated, by the Corporation and members of the FCSKP Consultative Group. Confidential information would not be reproduced in the Report, consistent with the caveats mentioned under 'Output'.

Timing

The Corporation is anticipating that a contract with the Consultant, to proceed with the study, will be finalised by 22 May 1998. An elapse time of 4 months to complete the Report is envisaged with the Final Report being delivered to the Corporation by 18 September 1998. Within the first fortnight of the Study, the Consultant will deliver a brief Inception Report in which suggestions (if any) on fine tuning of the Study scope and potential outcomes will be presented for consideration by the Corporation and FCSKP Consultative Group.

Costing

The Corporation seeks a quotation for the Phase 2 work to be carried out under these Terms of Reference. The details of costing provided to the Corporation will include professional fees, calculated on a daily rate for each person, or party involved, and will cover professional services of the Consultant, provision of office facilities, electricity, local telephone and facsimile calls, postage, clerical/secretarial services and indirect costs (overheads). Out-of-pocket expenses will be reimbursed at cost for travel and accommodation, long distance telephone and facsimile calls and external costs of report preparation.

Progress payments will be made by the Corporation against completion of the components of the study identified, with milestones agreed to by the Corporation. Final payment by the Corporation will be subject to written acceptance of the Report by the Corporation. All payments will be subject to receipt of invoices from the Consultant.

Subcontracting

Certain activities and analysis may be subcontracted by the Consultant to other parties. In this case full details of the party or parties to be subcontracted, their capabilities and background and the activities or analysis which they would perform in the context of this study will also be provided to the Corporation. Notwithstanding this, the responsibility for the performance of the subcontractor will rest completely with the prime Consultant, with whom the MRC would be contracted.

Reporting and Liaison

The Consultant shall report to the Corporation through Mr. Des Rinehart. Apart from an Inception Report at the end of the first fortnight, the Consultant will provide a brief statement of progress (by letter or facsimile) at the end of each fortnight.

Industry Presentations

The Consultant will be available to give presentations on the conclusion of the Study at up to three Industry meetings, if so invited by the Corporation. The costing of such presentations will be separately identified within the Consultancy Agreement.

Confidentiality

The Consultant may divulge that the Study is being undertaken at the request of the Corporation. Otherwise, the specification of the Study, contents and conclusions of the Study and the Report produced are strictly confidential. The Consultant may not disclose any details or information in respect of the Study to any party without the prior consent of the Corporation.