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Carob Agroforestry in the Low Rainfall Murray Valley

A market & economic assessment

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by

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in association with Bill Booth

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"Carob Agroforestry in the Low Rainfall Murray Valley: A market and economic assessment"

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Foreword

Previous work has shown that carob trees may be productive on marginal agricultural land, are salt tolerant and can survive in low rainfall areas (250 mm/year). These characteristics indicate that carob may be suitable as an agroforestry species in low to medium rainfall areas.

This report presents the results of a feasibility study into the development of a viable carob industry in the low rainfall Murray Valley region.

The feasibility study assessed 4 economic scenarios for carob agroforestry using a range of different plantation scales and management options. The results of the study indicate that a small scale (5,405 ha or less) carob agroforestry industry is viable, and represents an opportunity for the development of a niche industry.

This study was commissioned by the Joint Venture Agroforestry Program (RIRDC/LWRRDC/FWPRDC). Development of agroforestry systems in low rainfall areas is a key research issue in the Joint Venture Agroforestry Program.

Peter Core
Managing Director
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EXECUTIVE SUMMARY

This 6-month project assessed economic viability of a carob agroforestry industry in the low rainfall Murray Valley region. Economic analyses were completed for 4 scenarios, with two options for each scenario, including:

Economic scenario 1
- 100 ha orchard with mini-sprinkler irrigation
- 100 ha orchard with medium rainfall (500-700 mm/year)

Economic scenario 2
- 20 ha orchard with mini-sprinkler irrigation
- 20 ha orchard with medium rainfall (500-700 mm/year)

Economic scenario 3
- Linear plantings around 100 ha with mini-sprinkler irrigation
- Linear plantings around 100 ha in medium rainfall (500-700 mm/year)

Economic scenario 4
- Linear plantings around 20 ha with mini-sprinkler irrigation
- Linear plantings around 20 ha in medium rainfall (500-700 mm/year)

The carob fruit, typically produced on female and hermaphrodite trees older than 6 years, is valued for a range of products derived from the seed (also termed bean or kernel) and the pod (also termed pulp or flesh). The seed represents about 10% of the total fruit weight. From the seeds the endosperm is extracted for a galactomannan, which forms a gum (termed carob bean gum or LBG), which is a valuable natural food additive. The pulp is used for high energy stock feed (although high tannin content can limit its consumption) or the human food industry (with cocoa products and syrups).

Field investigations and literature indicates that there are areas in the Murray Valley where the environmental characteristics (eg. rainfall, soil type) are suitable for carob production. In areas of low or unpredictable rainfall, irrigation will be necessary to achieve required yields. While carob are reported to be tolerant of moderately saline water, it is uncertain as to what impact this may have upon yield. Also, 'best practice' horticulture suggest correct silviculture and fertiliser applications will also be required to achieve optimum yields.

Carob bean gum is used extensively in Australia as an emulsifier for canned pet food products. Other uses include chemical and paper manufacture, cosmetics and pharmaceutical drugs. World demand for the gum equates to approximately 35,000 tonne of carob seed, with current Australian imports valued at $10 million/year. The current Australian demand for carob bean gum is estimated at 1,200 t/year for 'pet food' and 'technical' grade, plus 200 t for 'food' grade. Assuming a modern plant was built in Australia, the current Australian demand could be met with approximately 2,250 t of carob seed (seed value at $1,600/t). This equates to 22,500 t of pods, or the yield from 562,000 trees (at 104 trees/ha) on 5,405 ha with medium rainfall, low technology management (40 kg/tree); or 225,000 trees (at 208 trees/ha) on 1,080 ha with supplementary irrigation and fertilising (100 kg/tree).

Carob may also have value for livestock producers with the kibble (pod pulp) being a useful fodder supplement, particularly during times of drought. However, under these circumstances, it is likely the pods will have to be collected (probably harvested before dropping) and stored. If this is done, kibbling may be a viable option, with the seeds sold to carob bean gum processors and the pod pulp retained as a fodder supplement. Kibble is valued at approximately $150/t, having a similar nutritive value to feed barley. Kibbling costs the grower 25% of the product value for processing and 15% for marketing, therefore returning approximately $90/t for carob pulp.

Carob powder is commonly used as a substitute for cocoa. The current Australian market for this product is between 60-100 t/year. Growth of this market for domestic carob growers is viewed with scepticism as surpluses of this product frequently exist within the Mediterranean. Carob pulp powder imported to Australia is valued at $1,500/t. Processing and marketing costs would amount to approximately 40% of the value. Therefore, the return to the grower is estimated at $900 per tonne of powder. Processing losses are estimated at 2% of pulp weight.

To supply companies with carob bean gum would require a kibbling and/or carob bean gum processing industry to be established. A kibbling industry could be established through a centralised kibbling plant as suggested by this project, or growers obtaining on farm kibbling facilities. The processing of seed to carob bean gum would require a plant be established. It has been estimated that such a plant, processing 1,500 t of seed/year would require an investment of $2 million. Processing costs are estimated at $500/t of seed processed.

The Project Team was involved in the first large-scale mechanical harvesting of carob in Australia. Mechanical harvesting has the potential to halve the current harvesting costs (currently 30% of total production costs) and considerably increase the viability of carob agroforestry. The mechanical harvesting trial proved it was possible to efficiently collect ripe pods. Further monitoring of trees is required to determine the impact of mechanical harvesting on long term flowering capabilities, and subsequent yields. This trial aroused considerable interest within the carob industry in Spain and Portugal, where harvesting still occurs by hand.

Carobs do offer the possibility of providing a return to the grower. This may be through the sale of pods, or as a supplement to livestock feeding. Carobs also provide another option for plantings which will increase the aesthetic value of the property and/or may decrease a region's hydrogeological pressure. Economically feasible returns from carob agroforestry were generated when trees had access to adequate water through medium-high rainfall or irrigation, and the grower had access to both the carob bean gum and carob powder markets. As the current Australian demand for carob bean gum is far in excess of that for powder, growers may require cross-subsidisation for the excess pod pulp produced or markets for carob powder (derived from pod pulp) will have to be considerably increased.

The economic analysis for a 100 ha orchard with mini-sprinkler irrigation illustrates the wide variation in the economic potential for carob agroforestry. Based upon market prices of $1,600/t for seed, $900/t for powder, $150/t for stockfeed (whole pod and kibble), and yields of 20.8 t/ha (100 kg/tree), unlimited access to seed and powder markets returned an IRR of 18.1% over a 30 year period. However, when calculated with access only to seed and stockfeed markets, the IRR was 2.0% over the 30 years. With just access to the stockfeed market the IRR was -3.3%, highlighting that the extent of access to the different carob markets is critical when determining the viability of carob production.

Comparative analysis of carob production and farm forestry in a high rainfall area (>700 mm/year) using the FARMTREE model indicated carob production could offer higher financial returns compared to a typical farm forestry option of bluegum pulpwood.

This research suggests a viable carob industry will involve a relatively small area of planting (5,405 ha or less). As such, a carob industry would not play a major role in managing rising regional watertables in the Murray Valley. Nevertheless, landholders should view carob production as an important tree crop option, with an opportunity for enterprising individuals/companies to develop a successful niche industry.

1. INTRODUCTION

Carob (*Ceratonia siliqua* L.) is a perennial leguminous tree native to the Mediterranean basin and southwest Asia. It has been cultivated throughout the Mediterranean region for over 4,000 years (Catarino 1996). The carob tree is an evergreen shrub growing to a height of 12-15 m, with a productive life span of more than 100 years. World carob pod production is approximately 315,000 t/year (Tous *et al*. 1996). The main carob bean producers and exporters are Spain (42%), Italy (16%), Portugal (10%), Morocco (8%), Greece (6.5%), Cyprus (5.5%) and Turkey (4.8%) (Tous *et al*. 1996, p.1).

1.1 The potential of an Australian carob industry

Carob has been intermittently explored over the last 20 years as a potential tree crop industry in low rainfall areas of Australia (<500 mm rainfall/year) (ACIL 1984; Esbenshade & Wilson 1986; Bulman *et al*. 1991; Esbenshade 1994). Preliminary investigations indicate that carob pod-seed mix has considerable commercial value as a livestock fodder supplement ($150/tonne), as a thickener (carob bean gum also referred to as locust bean gum (LBG)) in canned products such as pet food (approximately $3,200/t), and as an ingredient in confectionery ($1,500/t) (Hogan 1995). Carob processing in key regional locations could contribute to regional employment and enhance the viability of rural communities. A viable carob industry could contribute to C import replacement ($4-5 million/year for a major importer and $10 million/year Australia-wide) and have the potential to compete in a world CAROB BEAN GUM market worth $100 million/year (Hogan 1995).

Farm experience indicates carob trees are suited to the marginally productive agricultural land in the Murray Valley. Carob can also withstand high levels of salt of up to 30,000 ppm (ACIL 1984). Carob has an extensive tap root system which can grow to depths of 20 m, enabling production with just 250 mm rainfall/year. However, conditions for commercial production require at least 500 mm (Esbenshade & Wilson 1986) or supplementation from irrigation. Carob begins to produce a commercial harvest after approximately 10 years (Gebhardt 1996).

The importance of investigating the potential of a carob agroforestry industry is heightened by the relative lack of options for low rainfall agroforestry and the need to improve natural resource management of the 250,000 ha with less than 700 mm annual rainfall within the Murray-Darling Basin. A viable carob industry (considered to be approximately 1,500 ha) would improve low rainfall agricultural productivity (shelter and fodder) and diversify farm incomes, assist in the management of land and water degradation (extensive and increasing dryland salinity emerging in this region of the MDB), and contribute to regional industry development and import replacement (Esbenshade 1994). Carobs regenerate after burning and in Spain and are frequently grown close to villages because they slow down the path of a grass fire. Carobs can also be a useful tree for wind breaks on paddock boundaries (Esbenshade & Wilson 1986).

Efforts to develop a carob industry in Australia have been impeded by lack of detailed biotechnology and economic data, and poor linkages between research and industry. In particular, there has been no investigation of the requirements to establish the critical mass for a viable regional carob industry. The Joint Venture Agroforestry Program (RIRDC/LWRRDC/FWPRDC) commissioned Charles Sturt University in association with Booth Associates to complete a feasibility study for the development of a viable carob industry in the low to medium rainfall Murray Valley region [Refer to Appendix 1: Approach of feasibility study].

2. MARKETS

The carob tree is cultivated primarily for the two commercial products that are derived from the mature fruit. These are from the:

- Seeds; and
- Pod or pulp.

Carob also yields carouge (moderately dense timber) which is used for specialty furniture purposes. However, this is a minor product with little market information available in Australia and so was not considered in detail by this study.

The carob fruit is valued for a range of products derived from the seed (also termed bean or kernel) and the pod (also termed pulp or flesh). The seed represents about 10% of the total fruit weight (Esbenshade & Wilson 1986). From the seeds the endosperm is extracted for a galactomannan, which forms a gum (termed carob bean gum or locust bean gum (LBG)). Carob bean gum is a valuable natural food additive (Tous *et al*. 1996). The pulp is used for high energy stock feed (although high tannin content can limit its consumption) or for the human food industry (with cocoa products and syrups). Tous *et al*. (1996) noted that a high proportion of seed within a pod usually corresponds to a low proportion of pulp. This additional processing involves cleaning, roasting and grinding the pulp (kibbling) (Figure 1).

After kibbling the seed is available for sale to be processed into carob bean gum. The production of bean gum, as explained in Esbenshade and Wilson (1986) involves:

- Removal of the outer seed coat (this may be achieved by mechanical or chemical processes);
- Mechanical separation of the seed embryo from the endosperm; and
- Grinding of the endosperm.

The yield of carob bean gum from seed varies with the processing technology used. However, the three basic grades and their indicative yield ranges are:

- Food Grade 45-50%
- Technical Grade 55-65%
- Pet Food Grade 70-90%

Current world production of carob seed averages approximately 30,000 tonne/year (Hogan 1995), or 315,000 t of pod before processing. More than 95% of this production originates in the Mediterranean. Current world production is summarised in Table 1.

Production of carobs in the traditional growing areas of the Mediterranean is expected to decrease in the future in response to increased labour costs. In these areas harvesting is accomplished by hand. It is unlikely carob growers in the Mediterranean will be able to adopt mechanical harvesting techniques due to the unsuitable nature of the land, cultivars and orchard design. Spainish researchers have reported that new orchards are being designed to allow mechanical harvesting.

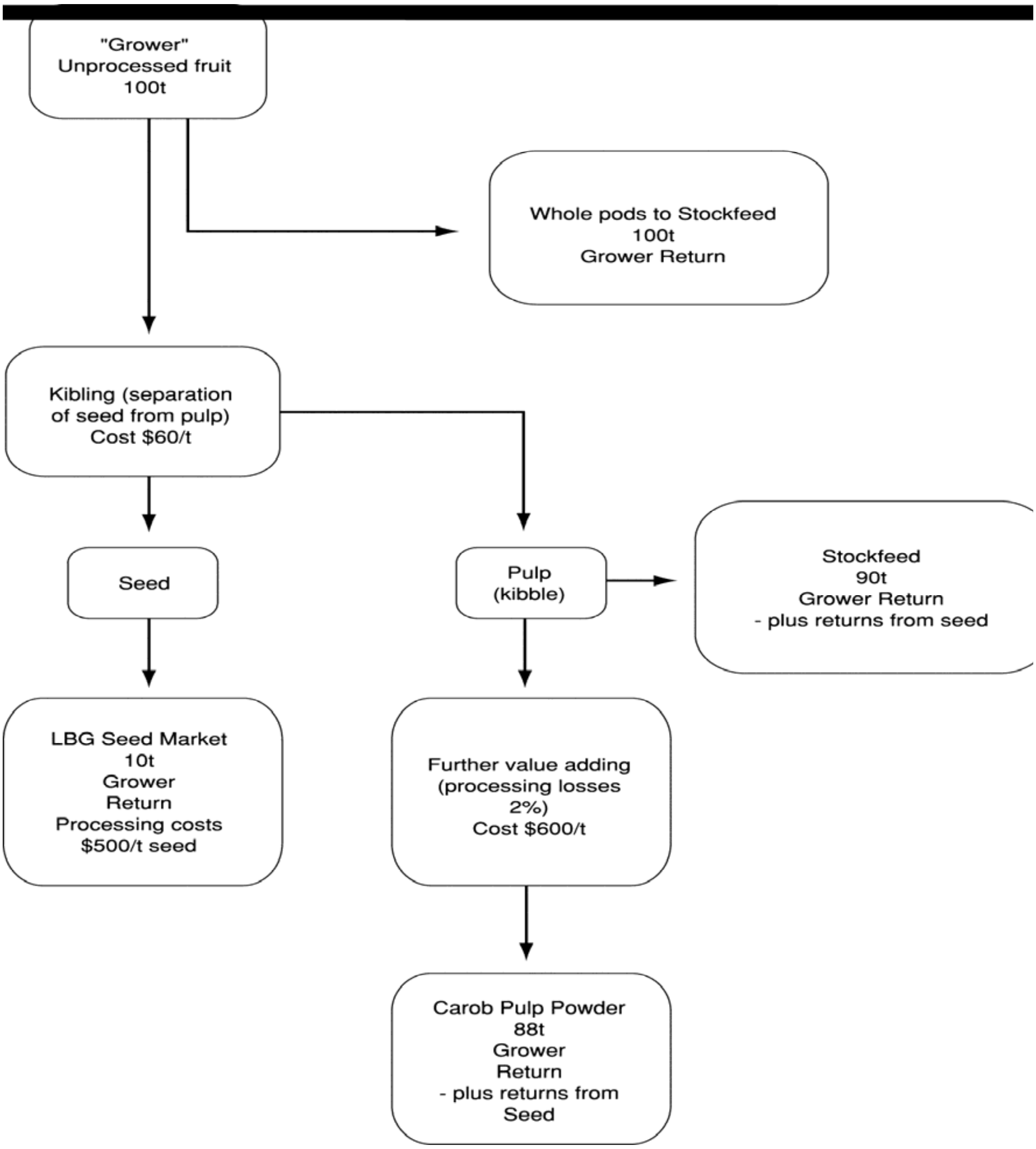

Figure 1: Sequence of carob processing
(Source: INEC 1986)

Table 1: World carob pod production.

Country	tonnes	% of total
Spain	150,000	46.8
Italy	50,000	15.6
Portugal	30,000	9.4
Morocco	25,000	7.8
Greece	20,000	6.2
Cyprus	20,000	6.2
Turkey	10,000	3.1
Algeria	5,000	1.5
other	10,000	3.1
Total	320,000	100.0

Source: Martini 1994, p.46.

Major markets

The prices listed below reflect a 10-year average of world prices. The major markets for carob products are as follows:

Whole pods

Whole pods are sold to the stockfeed market. These are used extensively throughout the Mediterranean as a fodder supplement. The seed passes through livestock undigested. Therefore, whole pods and the fruit pulp are considered to have the same nutrition value as feed barley. On this basis, a price similar to that obtained for feed barley could be expected. Currently the long term trend price for feed barley sold to the New South Wales Grains Board is assessed at $150/t.

Carob seed for carob bean gum (LBG) production

Carob bean gum is used extensively in Australia as an emulsifier for canned pet food products. Other uses include chemical and paper manufacture, cosmetics and pharmaceutical drugs. World demand for the gum equates to approximately 35,000 t of carob seed (Hogan 1995). Current Australian imports are valued at $10 million/year (Hogan 1995). The current Australian pet food and technical market demand is estimated at 1,200 t/year, plus 200 t of food grade. Assuming a plant was built in Australia, with modern processing techniques, the current Australian carob bean gum demand could be met with approximately 2,250 t of carob seed. This equates to 22,500 t of pods, or the yield from 562,000 trees (at 104 trees/ha) on 5,405 ha with medium rainfall, low technology management (40 kg/tree); or 225,000 trees (at 208 trees/ha) on 1,080 ha with supplementary irrigation and fertilising (100 kg/tree). In the Mediterranean, seed prices average around US$1,250/t delivered to the milling plant. This equates to approximately $1,600/t (Hogan 1995). After processing carob seed, carob bean gum prices during recent years have ranged between $2,940-3,450 (pet-grade) (Hogan 1995).

Carob pulp for stockfeed

Carob kibble (chipped fruit pulp) can be fed direct to livestock as a supplement. However, due to the high ratio of carbohydrates to proteins it is necessary for livestock to have access to additional sources of protein and roughage. Overfeeding of kibble may result in constipation and growth rate reductions. As indicated, kibble is valued at approximately $150/t. Esbenshade and Wilson (1986) estimated that kibbling would cost the grower 25% of product value for processing and 15% for marketing, returning approximately $90/t of pulp.

Further processing of carob pulp into carob pulp powder (flour) and syrup

Carob powder is commonly used as a substitute for cocoa. The current Australian market for this product is between 60-100 t/year (Hogan 1995). Growth of this market for domestic carob growers is viewed with scepticism as surpluses frequently exist in the Mediterranean. Carob pulp powder imported to Australia is valued at $1,500/t. Processing and marketing costs would amount to approximately 40% of the value (Gebhardt 1995). Therefore grower return is estimated at $900/t of powder. Processing losses are estimated at 2% of pulp weight. Carob syrup has a range of uses, including as a sweetener or flavouring agent in foods and beverages. Carob syrup remains in suspension in liquids and may have greater application in the food industry than carob powder (Gebhardt 1995).

Other products

Market technical research is continuing into other carob products (requiring pulp and carob bean gum), both in Australia and internationally.

Australian interest in carobs centres on the supply of seed for carob bean gum production. Companies expressing an interest in carobs include Uncle Ben’s of Australia, Germantown Australia and Scalzo Food Industries.

A kibbling and/or carob beangum processing industry would need to be established to supply companies. A kibbling industry could be established with a centralised kibbling (as suggested by this study), or by growers obtaining on-farm kibbling facilities. This study estimated that a carob bean gum plant processing 1,500 t of seed/year would require an investment of $2 million. Processing costs are estimated at $500/t of seed processed.

The demand for carob products will only continue whilst they remain competitive against other products. For example, carob bean gum is currently a competitive product for use as a flavouring and emulsifier agent in pet foods. Developments of substitutes or changes in the carob industry may see the current market conditions change over time.

3. PLANT CULTURAL DETAILS

3.1 Overview

Carob has been reported growing in all Australian mainland states and territories. In most cases, carob is planted as a shade tree or as shelterbelts. Carob is growing in many sites in the Murray Valley, including: Yackandandah (rainfall 700 mm/year), Dookie, Deniliquin, Swan Hill and Burra (350 mm/year). This indicates that the general environmental conditions (eg. rainfall, soils, frosts) of the Murray Valley do not impose significant limitations on carob growth. However, continuous commercial yields will require detailed attention by growers to water requirements, temperature and soils.

There are few large-scale plantings of carob in Australia (Table 2).

Table 2: Major carob growers in Australia

Carob growers	Carob varieties *	Age (years)	No. of trees
A. & J. Gebhardt Burra, SA.	Amele, Laguna, Tantillo, Casuda, Sfax, Santa Fe, Cypriot, Tylliria, Clifford, Badan, Molino, Maitland, Waite, Bath, Irlam, Paxton	8-12	4,000
C. & D. Solomon Port Elliot, SA.	Seeds established only - for rootstock. Expect to graft Waite and Santa Fe with other varieties.	1-2	1,050
A. Murphy Nth Perth, WA.	Sfax, Santa Fe	1-6	3,500
G. Matchett Geraldton, WA.	Santa Fe, local variety	11	170

* No estimate of tree numbers per variety or average yields per variety is given.

3.2 Water needs

Mature carobs are drought tolerant and are able to survive in areas with a rainfall of 250 mm/year (Esbenshade & Wilson 1986). However, carobs have rarely been intensively cropped and there is little information available on optimum water requirements. Esbenshade and Wilson (1986) reported that for commercial carob yields without irrigation, a minimum rainfall of 500 mm/year is required. The available data is not related to evaporative demand, so a cautious approach to interpreting reported water usages needs to be applied.

In the Catalina region of Spain (rainfall 500 mm/year), mature trees with drip-irrigation receive approximately 300 L of additional water per tree per year over 9 irrigations. Average yields for this approach are between 6-7 t/ha after 11 years.

The Project Team believed the carob's ability to 'survive' under marginal rainfall conditions should not be the basis for commercial production. In areas of very low rainfall (<500 mm/year) carobs will be no better than an alternative shade or shelter tree, or bio-pumper of ground water. For low rainfall areas, irrigation (or access to groundwater) will be a critical factor in obtaining consistent yields and establishing desirable growth characteristics during the early years of development (Esbenshade 1994). There remains much uncertainty regarding the optimum volume and frequency of irrigation for commercial carob yields. Long term monitoring will be required to determine optimum irrigation practices. Carobs can withstand saline conditions of up to 30,000 ppm (ACIL 1984) and they may have considerable merit as a cash crop for saline catchments.

Field observations by the project team indicated that:

- Where irrigation is limited yet supplementary to rainfall, trees:

i) can become 'lazy' and only develop roots sufficient to sustain limited foliage growth;
ii) may senesce the main tap-root rather than use this to seek deeper ground water supplies.

- Soil profile wetting patterns can significantly influence tree rooting patterns, and therefore the ability of the trees to take up nutrients.
- Full soil volume wetting should promote tree growth and enhance production levels.
- Drip-irrigation (surface) under limited water application has predisposed trees to uprooting by wind.
- Limited irrigation:
  i) will reduce flowering, pod set, abort flowers and pods, and reduce pod size;
  ii) may reduce the tree's ability to 'accept' budding and grafting;
  iii) may reduce nutrient uptake.
- Subject to further investigations, the preferred water application system is with mini-sprinklers.

3.3 Temperature

Young carob trees are sensitive to frost. Temperatures below -4.4^{o}C have been reported as killing young trees. Esbenshade and Wilson (1986) also reported that temperatures of -5.6 to -3.9^{o}C in the autumn, when the flower and pod ripening periods overlap, have the potential to destroy 2 years crop. ACIL (1984) recommended carob should not be grown in regions where the temperature falls below -3.0^{o}C. ACIL (1984) noted that carobs were less frost sensitive than citrus. Citrus may be a potential environmental indicator of regions suitable for the production of carobs in southern Australia.

Esbenshade and Wilson (1986, p.58) reported that fruit ripening requires '... 5000 to 6000 degree hours (above 10^{o}C). Hot dry weather during the late summer and autumn ripening period is critical to achieve maximum sugar content.' Carob is found growing in warm, coastal environments although these environments pose additional problems. In these environments trees do not have a regular winter dormancy, making propagation by budding and grafting difficult.

3.4 Soils

Carobs prefer a calcareous, well-drained, low-clay soil, yet will tolerate a wide range of soil characteristics. Esbenshade and Wilson (1986, p.58) reported that carob can be found growing on '... almost any soil type that is well drained and aerated, including sands, clay loams, limestone, and alkaline or moderately acid soils.'

The extent carob will tolerate highly acid soils (pH <4.5) in the Murray Valley remains uncertain. However, based on field observations and available literature, carob production should not be limited by the dominant soil types of the Murray Valley. Again, carob may tolerate harsh soil conditions, but these sites would not produce reliable commercial yields.

3.5 Fertiliser

Martini (1994) explained traditional Spanish carob orchards receive 50 kg of nitrogen, 20 kg of phosphorous and 50 kg of potassium per hectare per year. Nitrogen is supplied in a split application with 12.5 kg/ha applied in the autumn and 37.5 kg/ha applied in spring. Traditional Spanish orchards yield approximately 2.5 - 3.0 t/ha. Esbenshade and Wilson (1986) suggested Spanish carob orchards require the following fertilisers to achieve a target 100 kg/tree yield:

- 5 kg/tree of ammonium sulphate;
- 2 kg/tree of calcium phosphate; and
- 2 kg/tree of potassium sulphate.

It should also be noted that in Spain up to 3 - 4 t/ha of manure can be applied every 3rd or 4th year, and leguminous annual crops are frequently grown between trees.

Esbenshade and Wilson (1986) stated that appropriate slow release fertilisers or manures applied at planting will provide adequate nutrition for seedlings. Phosphorous is required for seedling root development, with nitrogen and phosphorous applications valuable for mature trees. However, fertiliser rates should be tailored to individual sites. Nutrient requirements for mature carob trees can be monitored through the use of leaf tissue analysis. Results from these analyses should indicate levels of 1.6% nitrogen, 0.2% phosphorus and 0.6% potassium (Martin 1994). Foliage samples of carob growing at Burra in 1996 revealed zinc deficiencies (Gebhardt 1996).

3.6 Pests

There are no major existing pests for carob in Australia, although potential pests include the carob moth (*Ectomyelois ceratoniae*) and citrus red scale. Chemicals are available for the control of carob moth in Australia (Esbenshade and Wilson 1986), and red citrus scale is controlled by the *Aphytis* wasp. The Rutherglen bug has been reported as defoliating seedlings in Western Australia, forcing a complete replanting. The Rutherglen bug is common in the Murray Valley and will require close attention by those establishing carob orchards in this region.

Fungi will attack the carob seed and germinating carob seedling. The fungi of importance in Australia are:

- *Rhizupus nigricons* and *Mucor hiemalis* which will cause carob seed rot preventing the germination of seed; and
- *Rhizoctinia solani* and *Fusarium* species will kill germinating seedlings.

Grazing animals may damage immature plants by browsing the growing tip. When this occurs the plant must be replaced as it will never renew a vigorous main leader. When mature, stock browsing of the lower branches does not seriously harm the carob (Esbenshade & Wilson 1986).

3.7 Propagation techniques

Direct seeding

Carobs are traditionally direct seeded in the autumn or early spring (Esbenshade and Wilson (1986). The seeds may be:

- Pre-soaked in water and planted to a depth of 5 cm; or
- Pre-germinated and planted to a depth of 2.5 cm where supplementary irrigation is available.

In Spain, the entire pod is usually fed to livestock and stock manure is then buried in the fields. The carob seed, which is undigested by the livestock, sprouts directly from the manure.

With the above techniques, care must be taken to protect the seedling from frost and grazing animals. Particular care must be taken during establishment as the carob seed is susceptible to fungal attack.

Nursery Production

Due to the susceptibility of carob seedlings to disease, grazing animals and environmental factors, nursery production and subsequent transplanting is the method preferred by the Project Team.

The preferred greenhouse production time is during early spring and autumn, when temperatures are not extreme. To aid germination and to break seed dormancy, the seeds are scarified by soaking for 1 hour in concentrated sulphuric acid and then thoroughly washed and soaked in water at room temperature for 24 hours. According to Esbenshade and Wilson (1986), this process obtains the greatest germination rates, although germination is still below 40%. Soil sterilisation to prevent fungal infection may double the seedling survival rate. Alternatively, Gebhardt (1996) prefers soaking seed in hot water (about 80^{o}C) for 4 hours and collecting the seeds that have swollen for planting. This treatment is repeated for the seeds that have not begun to swell.

Seeds are sown into germination trays or directly into individual containers (and transplanted into larger containers before the tap root is restricted by the container). Transplanting from small individual containers will usually occur at the second true leaf stage.

Roots grow between 2 and 5 times the length of the above ground shoots. Care must be taken to prevent root damage, particularly ‘J’ rooting, which will slow growth rates in the field. Esbenshade and Wilson (1986) state that no procedure has been developed which will prevent damage of the taproot prior to field planting.

Budding and grafting

Budding may occur once the root stock has reached 6 mm in diameter (Esbenshade and Wilson 1986). Budding occurs most successfully in autumn. Excessive spring sap flows may push buds out of stocks and prolonged dry summer conditions or late winter frosts can burn buds.

Commercial carob trees are grafted to improve the productivity of the carob crop. In Spain it is common practice in traditional orchards to graft a male branch onto a female tree, thus minimising the area of non-bearing trees.

3.8 Reproduction

Little research has been conducted on the carob varieties established in Australia, so comparisons to Mediterranean varieties remain inconclusive. There is some concern that there are few robust genetic pools of carob in the wild from which to draw for plant breeding. Initial work has begun to survey native carob populations, such as in Spain, Italy and Portugal, and to develop a comprehensive arboretum of the many native and cultivated carob varieties. Techniques are being developed to enable genetic analysis to identify carob varieties (Barracosa *et al*. 1996).

Over the centuries growers have selected trees suited for their requirements and environmental conditions. Selection pressure has primarily applied to females, with the aim of increasing fruit bearing quantity and quality. Although carob is a trioecious tree, with male, female and hermaphrodite inflorescences (usually on different trees), the ‘... most important trees in commercial orchards are usually the female cultivars’ due to their higher yield (Tous *et al*. 1996, p.2). Hermaphrodite varieties tend to have lower yields, with the male varieties established for use as pollinators. Currently it is not possible for genetic analysis to determine tree gender from seeds. In the orchard, pollination can occur by:

- planting 1 hermaphrodite tree for every 8 female trees. This has been reported to maximise pollination.
- grafting of a male or hermaphrodite scionwood on to female trees. This occurs in traditional Spanish orchards to maximise the number of female trees. Hermaphrodites are preferred as pollinators as they have a longer flowering period than males. Hermaphrodites appear more susceptible to disease, particularly the fungal disease oidium (Gebhardt 1995). (Note: oidium is not evident in Australia at this time).

Opinions vary as to the optimum ratio of male to female trees for pollination in an orchard (5-20% of orchard with male trees), although about 1:8 (12%) is the most popular ratio. However, research on pollination of carob suggest the lack of available pollen for female trees may be a primary cause of low fruit production (Martins-Loucao *et al*. 1996). It was also noted that despite carob having a long pollen period (ie. several months), the quantity of airborne pollen was low. A greater number of male trees within an orchard may therefore be beneficial. Wind and insects were noted as important pollinating agents (Martins-Loucao *et al*. 1996).

The most common and recommended practice for establishing carob orchards is to graft selected varieties onto seedling rootstocks (grafting represents about 10% of total production costs). Grafting has been the cultivation technique of carob in the Mediterranean region for centuries, originally with shepherds completing the grafting while minding their flocks. Darley and Sarafis (1996) noted that seedlings took about 20 days before the cotyledons began to function photosynthetically, so application of nutrients will not be beneficial prior to this stage.

Although there appears little comprehensive breeding of varieties in the world, preliminary varietal breeding is occurring in Spain to improve:

- agronomic (bearing age, yield, regularity of yield, growth habit, harvesting ease, disease resistance); and
- processing (kernel/endosperm yield, gum quality, pod size, sugar content) qualities.

Carob appear to have highly variable flower and fruit production within orchards and between years, although there have been few comprehensive studies of this behaviour. Recent research by von Haselberg (1996) on the fluctuations of flowering and fruiting of carob, found the presence of fruit had an inhibiting effect on the formation of the current season's flowers and fruit production the following year. Although harsh climatic conditions appeared to reduce flowering and fruiting, von Haselberg (1996) believed unspecified endogenous (internal) factors played a more important role.

Mature carob trees with desirable characteristics can be found in a variety of locations. Micropropagation of these trees would allow clones to be established at a scale sufficient for large orchard development. Some progress has been made towards cloning carob trees (Alorda & Medrano 1996).

3.9 Cultivars

Tables 3 and 4 describe the main world carob cultivars and their characteristics (Martin 1994).

Table 3: Agronomic characteristics of the main world carob cultivars

Cultivar	Growth habit	Bearing age	Resistance to fruit abscission*	Effect of Oidium**
Rojal	erect	very early	low	low
Matalafera	open-weeping	early	low	low
Duraio	weeping	early	low	medium
B. de Cabra	open	medium	medium	medium
Ramillete	weeping	very early	medium	medium
Negra	open	late	high	high

* Abscission refers to pods dropping from tree.
** Oidium is a fungal disease (not evident in Australia at this time).

Table 4: Commercial characteristics of the main world carob cultivars

Cultivar	Pod Size	Pulp content	Kernel yield %	Kernel thickness (cm)
B. de Cabra	long	low	13-14	0.40
Duraio	medium	low-medium	12-13	0.43
Matalafera	long	medium	10-12	0.41
Rojal	long	medium	10-11	0.38
Ramillete	medium-long	high	8-10	0.35
Negra	short	high	7-9	0.36

Source: Martini (1994, p.48)

Little research has been conducted on the Australian cultivars, the main varieties being: Irlam, Paxton, Bath, Waite and Maitland. All of these varieties are reported to have low resistance to abscission, making them suitable for mechanical harvesting. Tous *et al*. (1996) concluded that the current trend is to establish mechanically-harvestable orchards with dual purpose carob varieties (eg. medium-high seed yield, medium pulp yield, high gum quality) to help stabilise returns to farmers from an erratic world carob bean gum market.

3.10 Yield

The pod usually contains between 5-15 seeds, of which one kilogram of seed contains between 4,970 and 5,500 seeds (Esbenshade and Wilson 1986). The seeds constitute approximately 10% to 20% of the pod’s dry weight.

In Australia flowering commences in the January to April period, finishing by mid winter. There is considerable variability of flower production between years and within an orchard, which produces significant uncertainty regarding orchard production. This variability is described as an alternate bearing habit of one heavy, two medium and one light year in four years. Esbenshade and Wilson (1986) go on to state that in Spain the alternate bearing habit has been evened out by attention to irrigation, fertiliser and weed control. Flower reduction has been linked to the presences of fruit remaining on the tree, climatic conditions and other internal factors (Race 1996). This uncertainty undermines markets for buyers and sellers alike.

Esbenshade and Wilson (1986) reported that pod drop occurs during February to April in Western Australia. Field observations by the Project Team reported that pod drop occurs during March to May at Yackandandah (Vic.), and during April to May at Burra (SA). It is uncertain to what extent environmental, varietal and tree management factors affect pod maturity. The timing of the pod drop is significant if the pods are not mechanically harvested and left for livestock to feed upon. Maximum benefit will be obtained if the pods drop during the period when stock feed is low. In the Murray Valley this generally occurs in the autumn, when pods are dropping. However, in other areas (eg. Burra) evidence suggests that the majority of carob pods drop after the worst of the autumn feed shortage has passed.

Carob trees have been reported to begin bearing between 4 and 10 years after grafting, depending upon cultivar, environmental, agronomic, and cultural practices. The majority of trees begin bearing at between 5 and 8 years after budding (ie. 7-10 year trees). (Esbenshade and Wilson 1996). Increases in yield can be expected up to 25 years following grafting (ACIL 1984). Californian carob orchards have been reported as averaging 9 t/ha, with yields of up to 50 t/ha in exceptional years. If a carob orchard has access to adequate water, either medium-high rainfall or irrigation, then planting densities could be increased to 6 m x 8 m (208 trees/ha). Accepted treecrop management under such conditions suggest yields of 100 kg/tree or greater could be achieved, equating to a yield of 20.8 t/ha. In Australia, trees grown under dryland conditions are expected to yield between 8 - 12 t/ha (ACIL 1984). This is consistent with figures used by Booth Associates for the economic analyses in this report.

3.11 Harvesting

With high Australian labour costs, harvesting would have to be completed mechanically if likely to develop a viable enterprise. The Project Team conducted a mechanical harvesting trial at Burra (SA), which enabled efficient collecting of ripe pods. At this stage, it appears mechanical harvesting does not damage new flowers and the subsequent crop.

Most of the carob crop in the Mediterranean region is harvested by hand, which represents about 30-35% of total production costs. Most of the land used in Portugal and Spain for carob is rocky and steep with irregular orchard designs, making conditions unsuitable for mechanical harvesting. Some industry analysts expect hand harvesting to become uneconomic causing a decline in total carob yield from these regions. However, if new commercial orchards are established, they are likely to be developed to facilitate mechanical harvesting. Varieties best suited to mechanical harvesting appear those with a relatively small canopy, erect growth habit, rigid fruit bearing branches, with regular tree spacing at an orchard density of about 150-200 trees/ha (ie. 6 m x 11 m - 6 m x 8 m tree spacing) (Tous *et al*. 1996).

3.12 Factors affecting product quality

Carob pods vary in composition with variety, season and source. An analysis of pod composition was conducted by the United Nations (1953; cited by Esbenshade & Wilson 1986, p.41) and is presented in Table 5. To date there has been little varietal breeding. Some preliminary work aimed at agronomic and processing qualities is occurring in Spain (Race 1996).

Table 5: Average carob pod composition by weight

Pods without seeds	7.90	% moisture	Carob germ meal	28.18	% galactans
	0.46	% oil		59.42	% mannans
	5.69	% crude protein		5.28	% proteins
	2.90	% ash		3.54	% cellulose
	7.08	% crude fibre		2.75	% pentosans
	75.97	% nitrogen free extract		0.82	% minerals
	40.00	% min sugar			
	50.00	% max sugar			

Source: United Nations 1953; cited by Esbenshade & Wilson 1986, p.41.

Esbenshade and Wilson (1986) reported extended periods of high humidity during flowering and pod ripening may result in delayed maturity and promote moulds, fermentation and insect infestation of the ripening pods. This may limit production of carobs in the tropical regions of Australia. Pods may be stored after harvest for 2-3 years without appreciable deterioration in quality. Pods should only be stored after reaching a moisture content of 10% or less. Failure to reach this moisture content may result in fermentation of the pod in storage. Control measures for insects may be necessary (Esbenshade & Wilson 1986), although no registered chemicals are known for this purpose although permits may be obtained on application to the relevant state authorities.

4. ECONOMIC ANALYSES

The focus of this project was on the farm production economics of carob agroforestry in the lower rainfall areas of the Murray Valley. During the preliminary stages of investigation it became clear to the Project Team that a viable carob agroforestry industry would need reliable carob yields from year to year. While the literature often reports carobs are drought tolerant, carob trees have little yield under low rainfall conditions (<500 mm/year). Carob yields increase with increasing rainfall, with 500+ mm/year considered necessary for reliable yields. Given the field observations and review of Australian and international literature, the project team decided to include analysis of medium rainfall and irrigation options in an effort to better define the characteristics of a viable carob agroforestry industry for the Murray Valley region.

4.1 Analysis scenarios

Economic analyses have been completed for low rainfall area plantings which are irrigated (drip- or mini-sprinkler), and dryland plantings in a medium rainfall (500-700 mm/year) area. The scenarios include:

1. 100 ha orchard with row spacings of:
- 6 m x 8 m (208 trees/ha) for the irrigated scenario; and
- 12 m x 16 m (104 trees/ha) for the medium rainfall scenario.

2. 20 ha orchard with row spacings of:
- 6 m x 8 m (208 trees/ha) for the irrigated scenario; and
- 12 m x 16 m (104 trees/ha) for the medium rainfall scenario.

3. Linear plantings around 100 ha with spacings of:
- 6 m for the irrigated scenario; and
- 12 m for the medium rainfall scenario.

4. Linear plantings around 20 ha with spacings of:
- 6 m for the irrigated scenario; and
- 12 m for the medium rainfall scenario.

The above scenarios are assessed under 3 marketing alternatives. These are:

1. No processing plant is established and all the product is sold into the stock feed market for $150/t;
2. A kibbling plant is established selling the seeds for export or to Australian processors at $1,600/t (Hogan 1995). The fruit pulp is sold into the stock feed market at $150/t; and
3. A kibbling plant is established selling the seeds for export or to Australian processors at $1,600/t. The fruit pulp is processed into carob powder and sold into the domestic market valued at $1,500/t (Gebhardt 1995).

4.2 Method of analysis

Each economic scenario included in this report is examined using:

- **Net Present Value** (NPV) - discounts the value of future cashflows to a current value using a rate of interest of 7%. The interest rate of 7% has been used in these analyses as it is the lowest desirable yield required by a discerning rural business manager.
- **Internal Rate of Return** (IRR) - calculates the percentage return the investment is capable of generating after allowing for expenses and capital recovery at the end of the stated period. The IRR represents the maximum interest rate the investor is capable of meeting as a result of borrowed capital.
- **Benefit/Cost Ratio** - calculates the total benefit per dollar invested. If the ratio is greater than 1 then the investment is profitable.
- **Payback Period** - is the time taken for the business venture to repay the cost of capital.

The analyses are based upon 10% of the pod's weight being seed, and processing losses approximately 2% of the pulp weight. While the productive life span of a healthy carob tree is in excess of 100 years, a 30-year period is used for the investment appraisal.

An annualised allowance is used in the budgets for the continuous renewal and updating of capital items. Therefore the resultant 'scrap' value of the orchard at the end of the 30-year period is the same as in the initial outlay plus an allowance for the increased value of harvestable timber. The value of the timber is derived from records held by Booth Associates (Hay, NSW) and assumes a yield of 15 m^3/ha of timber at 20 years, 22 m^3/ha at 25 years, and 30 m^3/ha at 30 years. The estimated return on carob timber is \$25/m^3. Actual returns to the grower would vary with market conditions at the time of harvest and proximity to points of processing (eg. sawmill). The development costs used in the economic analyses are shown in Table 6.

For linear plantings it is assumed the scrap value of an orchard is the value of land, plant and equipment, structures, and irrigation and that the timber is realised at the end of the period. In a farm situation, this may allow the re-allocation of these resources to other enterprises.

In all the scenarios, the pods were harvested and not allowed to drop for consumption by livestock. To maximise the fodder potential for livestock the pods must be gathered, stored and fed to livestock at an advantageous time (eg. during drought). If this does not occur, the target livestock can be expected to only consume a small percentage of pods, with undesirable or feral animals being attracted to consume the remaining pods. Grower returns are maximised by harvesting the pod and valuing them as the equivalent of feed barley (\$150/t). For example, a 200 ha property in the Albury-Wodonga district with 2 x 100 ha linear plantings - producing 4.2 t/ha of pods, the property could be expected to carry an extra 5 cows because the April-May period when pods drop coincides with the autumn 'feed gap' for cattle. With a gross margin of \$300/head for cattle, an addition to gross farm income could be \$1,500. Alternatively, to harvest the linear plantings will cost an estimated \$830 in contracting fees, \$270 in transport, \$100 in labour, \$50 in fuel and \$44 in repairs and maintenance. With returns from the sale of pods valued at \$4,030, the margin from harvesting is \$1,904, or \$404 more than the above example with cattle.

Table 6 Development costs used in economic analyses. The analyses were completed using a 20 ha orchard with harvest beginning in year 6 and increasing till year 14, then steady production at 20.8 t/ha (100 kg/tree).

Item	Cost
land value	$300/ha (with 25% used for roads, fences, etc)
sub-total	$7,500
survey & design	$50/ha
land preparation	$120/ha
installation of drip/micro-sprinkler irrigation	$8,000/ha (NB: for irrigation sites only)
sundry earthworks	$30/ha
fencing	$205/ha
sundry expenses	$845/ha
sub-total	$185,000 (at $9,250/ha)
plant & equipment	$50,000 (eg. tractor, slasher, sprayer, ripper)
provision for capital renewal	$22,000 pa.
trees	$33,280 (with 208/ha - spacing 6m x 8m - at $8/tree)
sundry expenses	$1,720
sub-total	$35,000 (at $1,750/ha)
variable operating costs:	
cartage	$10/t of pods harvested
pruning	$200/ha in years 1-6, then $20/ha from year 7 onwards
fuel	$85/ha
repairs & maintenance to equipment	$72/ha
repairs & maintenance to irrigation equipment	$50/ha (for irrigation sites only)
irrigation charges & energy	$108/ha (for irrigation sites only)
fertiliser	$698/ha
weed control chemicals	$79/ha
labour	$143/ha
contract fertilising & harvesting	$754/ha
sub-total	$39,780 (at $1,989/ha)
overhead & management expenses (eg. rates, administration, travel, insurance, consultant fees, bank charges, phone, vehicle registration, management)	$10,100 (at $505/ha)

While farmers may appreciate the additional gross income, considerable work would be involved. However, the example is useful in illustrating comparative options.

4.3 Discussion of economic analyses

Tables 7 and 8 present summaries of the key outcomes of the economic analyses.

Table 7: Summary of indicator 30-year IRRs for each of the production scenarios in the economic analyses

	Irrigated orchard 100 kg/tree		Linear planting irrigated 100 kg/tree		Medium rainfall orchard 100 kg/tree		Medium rainfall linear 100 kg/tree	
	100 ha	20 ha	100 ha	20 ha	100 ha	20 ha	100 ha	20 ha
Seed + powder	18.1%	16.8%	15.5%	15.2%	17.9%	16.5%	13.9%	11.5%
Seed + stockfeed	2%	0.3%	0.1%	-1%	1.1%	-1%	-1.7%	-4.4%
Stockfeed only	-3.3%	-5.6%	-5.2%	-7.1%	-5.3%	-7.8%	-7%	-11%

Table 7 highlights the rapid decline in economic returns when the access to higher value markets is removed. Similarly, the economic returns will fall in direct relationship with the decline in tree yields. Finally, there is minimal difference between the high rainfall and irrigation options, although there is a major fall in profitability with the low rainfall dryland scenario.

Table 8: Summary of indicator payback period, BCR and scenario acceptability for selected scenarios in the economics analyses

	Irrigated orchard			Linear dryland			Medium rainfall orchard		
	100 ha x 100 kg/tree			100 ha field			100 ha x 100 kg/tree		
	Payback years	BCR	Accept	Payback years	BCR	Accept	Payback years	BCR	Accept
Seed + powder	2	2.51	Y	12	1.82	Y	11	2.35	Y
Seed + stockfeed	30	0.55	N	30	0.48	N	25	0.66	N
Stockfeed only	>30	0.43	N	>30	0.32	N	>30	0.44	N

Table 8 highlights the importance of a reliable and high value market for carob in sustaining the viability of farming enterprises and an associated carob processing industry. All the economic analyses and sensitivity appraisals indicate that market access will be critical for a viable carob industry. Also, access is required to the carob bean gum and powder market.

The current Australian demand for carob seed is approximately 2,250 t/year. This equates to 22,500 t of pods, or the yield from 562,000 trees (at 104 trees/ha) on 5,405 ha with medium rainfall (40 kg/tree); or 225,000 trees (at 208 trees/ha) on 1,080 ha with supplementary irrigation and fertilising (100 kg/tree).

The current Australian demand for carob powder is between 60-100 t/year. Such a demand could be met from 2,840 trees yielding 40 kg of pods/tree, or 1,135 trees yielding 100 kg of pods/tree. This equates to approximately 11 ha of trees in medium rainfall areas, or 5.5 ha of trees with irrigation.

The current Australian demand for carob powder would require just 0.5% of the carob yields needed to satisfy Australian demand for seed for carob bean gum processing. As mentioned previously, access to both markets is critical if a viable carob agroforestry industry is to develop. Unless substantial overseas markets for carob powder can be accessed, or other markets of equivalent value can be established, domestic processor support from those wishing to use carob seed for carob bean gum will be essential for industry establishment.

Economic scenario 1

100 ha orchard with mini-sprinkler irrigation

Estimated costs for capital expenditure, operating expenditure and overheads of $4,737,000 were used ($4,737,000 is the present value of the total project costs over 30 years discounted by a factor of 7%). When the scenario was calculated with yields of 20.8 t/ha (100 kg/tree) with unlimited access to seed and powder markets, an IRR of 18.1% over the 30 year period resulted. However, when calculated with access only to seed and stockfeed markets the IRR was 2.0% over the 30 years. With just access to the stockfeed market the IRR was -3.3%.

100 ha orchard with medium rainfall (500-700 mm/year)

Carob production with this option could be expected to yield 10.4 t/ha of pods. The marketing option which involved the further processing of the pod into carob powder and the seed sold for carob bean gum manufacture resulted in a positive NPV after 30 years. This option had an IRR of 17.9%. With only access to the seed and stockfeed markets, the IRR dropped to 1.1%; and with only the stockfeed market, the IRR was -5.3% over 30 years.

Economic scenario 2

20 ha orchard with mini-sprinkler irrigation

It was estimated that an initial capital investment of $277,500 in year 1 is required for this scenario. This equates to an average cost of $13,875/ha which is consistent with other horticultural plantings. The yield of 20.8 t/ha was used in this analysis. This is the same target yield per tree as used in Spanish orchards. At this yield and access to the seed and pulp powder markets an IRR of 16.8% over 30 years was calculated. However, if only the seed and stockfeed markets are accessed, then the IRR over 30 years is 0.3%, and with access just to the stockfeed market only returns -5.6%.

20 ha orchard with medium rainfall (500-700 mm/year)

An initial capital investment of $123,800 in year 1 is required for this scenario. With an average yield of 10.4t/ha and access to seed and pulp powder markets, an IRR of 16.5% over 30 years was calculated. Seed and pulp powder. However, if only the seed and stockfeed markets are accessed, then the IRR over 30 years is -1%, and with access just to the stockfeed market only returns -7.8%.

Economic scenario 3

Linear plantings around 100 ha with mini-sprinkler irrigation

This option was assessed with trees spaced 6 m apart in a linear design around the inside of a 100 ha paddock. Only one row is planted because of the windbreak capacity of the species and large canopy cover per tree at maturity. A yield of 20.8 t/ha is applied to the area covered by trees only. For this option, selling seed to the carob bean gum market and the pulp powder market resulted in an IRR of 15.5% over 30 years. However, if only the seed and stockfeed markets are accessed, then the IRR over 30 years is 0.1%, and with access just to the stockfeed market only returns -5.2%.

Linear plantings around 100 ha with medium rainfall (500-700 mm/rainfall)
This option was assessed with trees spaced 12 m apart in a linear design. Again, only one row of carob trees are planted. A yield of 10.4 t/ha is applied to the area covered by trees only. For this option, selling seed to the carob bean gum market and the pulp powder market resulted in an IRR of 13.9% over 30 years. However, if only the seed and stockfeed markets are accessed, then the IRR over 30 years is -1.7%, and with access just to the stockfeed market only returns -7.0%.

Economic scenario 4
Linear plantings around 20 ha with mini-sprinkler irrigation
This option was assessed with trees spaced 6 m apart in a linear design around the inside of a 20 ha paddock. Only one row is planted because of the windbreak capacity of the species and large canopy cover per tree at maturity. A yield of 20.8 t/ha is applied to the area covered by trees only. For this option, selling seed to the carob bean gum market and the pulp powder market resulted in an IRR of 15.2% over 30 years. However, if only the seed and stockfeed markets are accessed, then the IRR over 30 years is -1.0%, and with access just to the stockfeed market only returns -7.1%.

Linear plantings around 20 ha with medium rainfall (500-700 mm/year)
This option was assessed with trees spaced 12 m apart in a linear design. Again, only one row of carob trees are planted. A yield of 10.4 t/ha is applied to the area covered by trees only. For this option, selling seed to the carob bean gum market and the pulp powder market resulted in an IRR of 11.5% over 30 years. However, if only the seed and stockfeed markets are accessed, then the IRR over 30 years is -4.4%, and with access just to the stockfeed market only returns -11%.

4.4 Sensitivity analysis

While the cost of land and machinery could be excluded, it was decided that the cost of land must be included as there are alternative investments available other than land. By including land in the investment analyses, the real opportunity cost of owning that land is considered and for alternative uses of that land. The cost of some machinery items (already owned by farmer) incorporated into the analysis may be debatable. They are included so that the orchard planting (100 ha and 20 ha) could operate separately to the original farming investment. This is not likely to be the case with linear plantings.

By applying the IRR calculations, a simple analysis of the medium rainfall (500-700 mm/year) scenarios indicated the following for a 30 year period for:

100 ha linear planing at 100 kg/tree selling to best market advantage:
- IRR increases from 13.9% to 17.4%; and
- NPV increases from $86,200 to $100,900.

100 ha orchard planting:
- IRR increase from 17.9% to 22.2%; and
- NPV increase from $3,275,700 to $3,622,800.

Superficially the above changes may appear significant. However, when reviewing all the scenarios, it is only Economic scenario 4: 100 ha orchard in medium rainfall (40 kg/tree) and

Economic scenario 5: Linear plantings with mini-sprinkler irrigation (60 kg/tree) that produce sound financial returns.

From the economic analyses conducted by this project, the enterprise prospects require field production to focus upon being well-managed (adequate soil moisture and fertility to allow reliable yields of 40 kg/tree or greater) and selling to the high value carob bean gum and powder markets.

4.5 Analysis using FARMTREE model

To further compare the viability of carob production, a comparative analysis was conducted against a common farm forestry option - bluegum pulpwood, with the baseline conditions being:

- Albury-Wodonga district (processing available/potentially available);
- Rainfall of 700 mm/year;
- Haulage of 70 km to processing site;
- 20 ha of cleared agricultural land;
- Soil depth (60 cm) and fertility adequate for good tree growth; and
- Discount rate of 7%.

Carob production was assessed with the following features:

- Establishment cost of $3,530/ha ($15.90/tree for 222 trees/ha);
- Pruning cost from Yr.1-10 of $128/ha;
- Annual site maintenance from Yr.1-29 of $695/ha;
- Gradual loss of trees from 222 in Yr.1 to 200 in Yr.30;
- Commercial pod yields begin in Yr.10;
- Pod yields are 55 kg/tree from Yr.11-30; and
- Net returns valued at $172/t ($226/t gross value - selling costs of $54/t).

IRR before tax = <u>4.9%</u>
IRR after tax = 1.3%
NPV of returns = $11,432/ha
Annuity equivalent = $921/ha/year

Bluegum pulpwood farm forestry was assessed with the following features:

- Spacing of 3 m X 3 m (1,111 trees/ha);
- Stumpage value of $21/m^3;
- Harvest at Yr.15; and
- MAI 17.3 (volume of commercial timber produced m^3/ha/year).

IRR before tax = <u>2.7%</u>
IRR after tax = 0.6%
NPV of returns = -$1,139/ha
Annuity equivalent = -$125/ha

Applying the above scenario, for a high rainfall area (>700 mm/year) carob production could offer a higher financial return than a typical farm forestry option - bluegum pulpwood.

5. CONCLUSION

This research indicates there are areas in the Murray Valley where the environmental characteristics (eg. rainfall, soil type) are suitable for carob production. However, a viable carob agroforestry industry will require reliable yields that can only be achieved with rainfall of 500 mm or greater. In areas of low or unpredictable rainfall, irrigation will be necessary to achieve required yields. While carob are reported to be tolerant of moderately saline water, it is uncertain what impact this has upon yield. Best practice horticulture suggest correct silviculture and fertiliser applications will also be required to achieve optimum yields, although the extent these practices will enhance carob agroforestry remains uncertain.

Economically feasible returns were generated when trees had access to adequate water through medium rainfall or low rainfall with irrigation, and the grower had access to both the carob bean gum and carob powder markets. An analysis for a high rainfall area (>700 mm/year) indicated carob production could offer a higher financial return than a typical farm forestry option - bluegum pulpwood. As the current Australian demand for carob bean gum is far in excess of demand for carob powder, growers may require cross-subsidisation for the excess pod pulp produced or the markets for carob powder (derived from pod pulp) to be considerably increased.

Carobs do offer the possibility of providing a positive return on the grower’s investment. This largely relies on securing access to the pulp powder market. Carobs also provide another option for plantings which will increase the aesthetic value of the property or may assist the management of rising ground water levels. Although this research suggests a viable carob industry will involve a relatively small area of plantings (5,405 ha or less). A carob industry would not play a major role in managing rising regional watertables in the Murray Valley. Nevertheless, landholders should view carob production as an important tree crop option, with an opportunity for enterprising individuals/companies to develop a successful niche industry. Carobs are well suited to dry, moderately saline conditons and with some management, can provide valuable shade and shelter, stockfeed, and groundwater use.

6. RECOMMENDATIONS

This research was based upon field observations, discussions with key stakeholders, and a review of Australian and international literature. While it has been possible to develop indicative parameters of a viable carob agroforestry industry, there remains some uncertainty about the precise potential due to information gaps. In particular, attention should be given to research and development in the areas of:

1. Refining the optimum biophysical conditions for reliable commercial yields, in terms of carobs response to:
- water requirements for reliable commercial yields,
- soil pH,
- soil fertility,
- fertiliser application,
- waterlogging,
- irrigation volume and frequency, and
- irrigation with treated waste water.

2. Tree breeding (increase the selection of carob varieties available for varying agroecological zones) and propagation techniques (eg. grafting, direct seeding).

3. Assessing the impact of mechanical harvesting on flowering and subsequent yields.

4. Developing monitoring guidelines to assist commercial growers record varietal agronomic characteristics (eg. bearing age, yield, regularity of yield, growth habit, harvesting ease, disease resistance).

5. Investigating product qualities (eg. kernel/endosperm yield, gum quality, pod size, sugar content).

6. Increasing effort to market carob syrup. This should link market research with product development.

7. Improving information exchange by expanding the availability of the Western Australian carob growers' occasional newsletter '*Algarrobo*' to growers and prospective growers in other states, and producing 'carob growing' information notes.

8. Conducting socio-economic research to identify communities likely to adopt carob production.

9. Promoting the value of growers aggregating supplies to support industry development (eg. growers association/cooperative).

10. Increase collaboration with international carob research and development efforts.

7. REFERENCES

ACIL Australia Pty Ltd. (1984). *Agroforestry in Victoria - Appraisal of Viable Systems*. Consultant's report: Collingwood, Vic.

Alorda, M. and Medrano, H. (1996). Micropropagation of *Ceratonia siliqua* L.: A method to clone mature carob trees selected from the field. In: *Proc. Third International Carob Symposium* (Tavira, Portugal), University of Lisbon: Portugal.

Barracosa, P., Almeida, M.T. and Cenis, J. (1996). Characterization of cultivars of carob tree, Algarve, Portugal (*Ceratonia siliqua* L.). In: *Proc. Third International Carob Symposium* (Tavira, Portugal), University of Lisbon: Portugal.

Bulman, P., Scarvelis, J., Mason, B. and Wallace, M. (1991). Trees for other products - South Australia. In: *Proc. The Role of Trees in Sustainable Agriculture*, Bureau of Rural Resources: Canberra, ACT.

Catarino, F. (1996). Carob - an old and sustainable Mediterranean crop: Its potential for the future. In: *Proc. Third International Carob Symposium* (Tavira, Portugal), University of Lisbon: Portugal.

Darley, E. and Sarafis, V. (1996). Physiological plant anatomy of the phloem in seedlings of the carob. In: *Proc. Third International Carob Symposium* (Tavira, Portugal), University of Lisbon: Portugal.

Esbenshade, H. (1994). Olives and carobs for landcare and profit in South Australia. In: *Proc. National Symposium on Olives and Carobs for Landcare and Profit*, The University of Adelaide: Roseworthy, SA.

Esbenshade, H.W. and Wilson, G. (1986). *Growing Carobs in Australia*, Goddard and Dobson Publishers: Box Hill, Vic.

Gebhardt, A. (1995). Carob Production. Tree and Shrub crops for Dryland Areas in the Riverina. In: *Proc. of Seminar on Business Advice on Rural Areas*, Riverina Regional Development Board: Wagga Wagga, NSW.

Hogan, M. (1995). *Carob*. Unpublished notes, Uncle Bens of Australia: Wodonga, Vic.

Martini, J.T. (1994). Carobs: A worldwide perspective of the industry and management. In: *Proc. National Symposium on Olives and Carobs for Landcare and Profit*, The University of Adelaide: Roseworthy, SA.

Martins-Loucao, M.A., Cabrita, R. and Silva, J.M. (1996). Pollination studies in Portuguese carob landraces. In: *Proc. Third International Carob Symposium* (Tavira, Portugal), University of Lisbon: Portugal.

Race, D. (1996). Carob agroforestry: Report on a visit to Portugal & Spain. Report No.66, The Johnstone Centre - Charles Sturt University: Albury, NSW.

Tous, J., Romero, A., Plana, J. and Batlle, I. (1996). Current situation of carob plant material. In: *Proc. Third International Carob Symposium* (Tavira, Portugal), University of Lisbon: Portugal.

von Haselberg, C. (1996). Factors influencing flower and fruit development in carob (*Ceratonia siliqua* L.). In: *Proc. Third International Carob Symposium* (Tavira, Portugal), University of Lisbon: Portugal.

PERSONAL COMMUNICATION

Gebhardt, A. (1996). Carob grower: Burra, SA.

Appendix 1: Approach of feasibility study

The feasibility study was conducted between August 1996 and May 1997 [$36,500 from RIRDC/LWRRDC/FWPRDC; $26,400 from Uncle Ben's of Australia]. The project principals (Dr Allan Curtis & Mr Digby Race) have involved key carob grower and industry participants in the project's design and implementation. The Project Team had representatives from growers and industry.

The Project Team was established at the commencement of the project (1st October) and continued to communicate regularly throughout the 6-month project period. The Project Team comprised Mr Mark Hogan and Ms Emma Welsh (Uncle Ben's of Australia), Mr Bill Booth (Booth Associates), Mr Andrew and Mrs Jen Gebhardt (carob growers & processors), Dr Allan Curtis and Mr Digby Race (Charles Sturt University). The project principals chaired the Project Team and managed the project. During the project, the Project Team has convened twice in Burra, South Australia (at Australia's largest carob plantation) and once at Albury, NSW (Charles Sturt University). A workshop to discuss the project's preliminary findings was held in January 1997, at Charles Sturt University, with input from the full Project Team. In between meetings, members of the Project Team maintained regular contact via telephone.

The continuous exchange of information between the Project Team and additional grower, industry and government stakeholders underpinned the research. The Project Team was assisted with field observations and analysis by Ms Catherine Spencer (Charles Sturt University), Ms Carmen Zerafa (Department of Natural Resources & Environment, Vic) and Mr Ashley Lipman (Department of Primary Industries, SA). The Project Team also sought advice from an experienced carob grower - Mr Tony Murphy (WA), carob researcher - Dr Henry Esbenshade (International Tree Crops Institute, WA) and gum processor - Mr Ian Parkin (Australian Gum Products Pty. Ltd., Qld.). The evaluation of carob biotechnology, particularly of international research, was largely achieved through participation by members (Mr Andrew Gebhardt & Mr Digby Race) at the Third International Carob Symposium (May 1996) held in Portugal.

The analyses of carob market competitiveness and farm production economics were conducted by Mr Bill Booth (Booth Associates). A draft report by Booth Associates was reviewed by the Project Team. A revised report by Booth Associates was reviewed by the principals, with a subsequent draft project report reviewed by 2 independent experts - Mr Bill Loane, Manager - Private Forestry Policy Development (Department of Natural Resources & Environment, Vic) and Mr Rev Cant, Principal Horticultural Consultant (Cant & Associates Pty. Ltd., SA). This final report submitted to the Joint Venture Agroforestry Program has addressed the key points raised by the two reviewers [confidential reports by the reviewers have been submitted to the Joint Venture Agroforestry Program].

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