Notes on Key Species for Energy Production

These notes have been put together to provide the basis of a series of instruction sheets that will support farmers developing an interest in the growing of energy crops.

They have been prepared in accordance to following structure: -

1. Introduction and Main Uses

2. Site Requirements

3. Seed Sources
    a. Provenances

4. Nursery and Establishment

5. Site Preparation

6. Management Practice

    a. For biomass
    b. Other products

7. Productivity

8. Income generation from biomass

9. References and in-country support

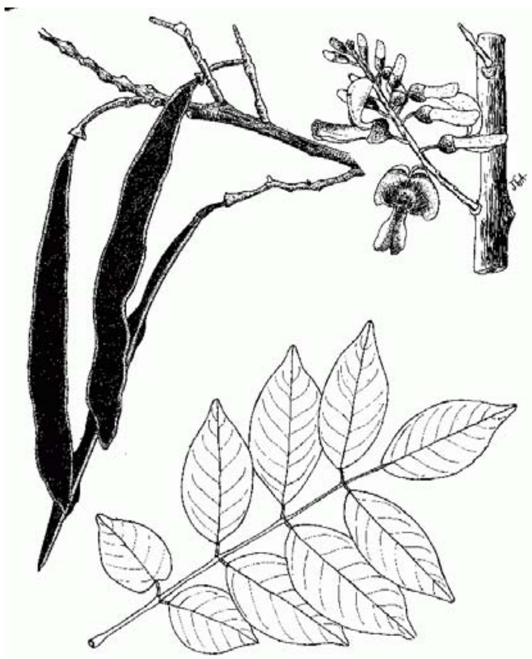
Gliricidia sepium

1. Introduction and Main Uses

Gliricidia sepium is a native of Central America and Mexico. Here it is one of the most common trees below 1500 m; however its true natural distribution is less clear due to the effects of man. It has now been widely introduced as an exotic in many parts of the tropics due to its high productivity and adaptability to a wide range of sites. It is easy to germinate, to establish and to grow either as an agroforestry species or as a pure crop. Is a fast growing species with the ability to fix nitrogen and can therefore improve the site and support other crops rather than act in direct competition.

The tree is a small thornless, semi-deciduous tree normally growing to 15 m if allowed, and will develop a trunk of about 30 cm diameter; however it is often grown under management systems which keep its overall size and development much smaller than this and its overall shape within agricultural environments tends to be modified by lopping and pruning. The leaves are alternate and pinnate meaning that each complete leaf is made of a group of smaller leaflets. Commonly the total leaf is 15-30 cm composed of 7-17 leaflet pairs plus a terminal leaflet.

The tree produces flowers called racemes or panicles measuring 5-12 cm, these are bourne at the base of the leaves. The tree produces flattened pods typical of many leguminous trees; these can vary from 10-15 cm and contain 3-8 circular and flattened seeds

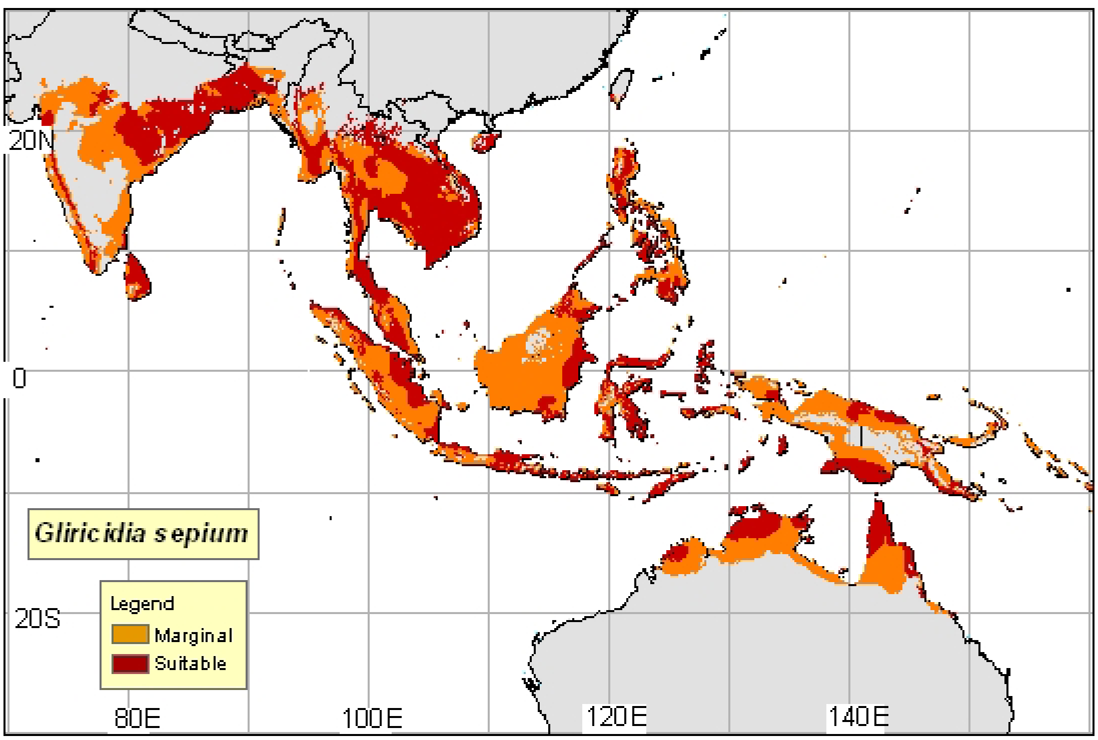


Gliricidia has found wide use as a fuelwood, green mulch, animal fodder and cover crop planted as a plantation, hedgerow and in range of agroforestry designs. In Sri Lanka it has been grown to good effect as an accompanying crop with coconut providing green manure or additional income as fuelwood. It has very positive properties, including the ease to which it can be propagated both from seed and also vegetatively; further, it coppices easily and demonstrates quick growth and can quickly establish itself and limit weed growth. It can successfully compete against the troublesome weed Imperata cylindrica once is has been successfully established. Because of it nitrogen-fixing properties it is used to improve sites and at the same time its wood and leaves provide a wide range of uses.

2. Site Requirements

Gliricidia sepium is a tolerate species suited to moderate altitudes (0-1,200 m). Its rainfall range is 600-1,500 mm and although it grows best where rainfall is well distributed throughout the year it can still tolerate a protracted dry season of 3-6 months. It is however intolerant of frost and should not be considered where the night temperature falls below 5^{o}C.

The species grows best in deep, well textured soils with good drainage and almost neutral in terms of acidity. However it will tolerate shallow soils and those with high lime content and can be considered for both clay and sandy textured soils. It can also be used in slightly saline soils. Because of its acceptance to a wide range of sites, its potential range within S. and S.E. Asia is extremely wide, as indicated in the following map.



Map Extracted from Tropical Forages Fact Sheet

Gliricidia can be used as a nurse crop for other species and in agroforestry combinations, however it does not grow well under shade, though it can tolerate such conditions and is reported to recover once the shade is removed.

3. Seed Sources

One of the problems that can arise with this species is, paradoxically, the result of its ease of propagation. There is a tendency for material to be derived from a narrow genetic base within any one region or even country. In Sri Lanka the seed used for the first introduction is believed to have come from Trinidad, which in turn had originated from Nicaragua. The species was first introduced in 1880 and has spread from the first single introduction. Although it performs well, the wide use of vegetative material has meant that the genetic base is extremely narrow and that the possibility of improving performance due to a better matching of provenance to site is being lost.

The Oxford Forestry Institute conducted a series of international provenance trials with this species in the 1980s and 1990s taking material from 28 collections and sourced from the natural range in Mexico and throughout Central America (Venezuela, Colombia, Panama, Costa Rica, Nicaragua, Honduras and Guatemala)[1]. The performance of each provenance in terms of both wood and fodder production was assessed. In terms of stem growth and wood production all the provinces from Guatemala tended to be consistently good with the Retalhuleu provenance being particularly dominant. This provenance was the most successful in this respect within Sri Lanka where it was planted at Madampe[2]. At the same site, the Guatemalan provenances from Volcan Suchitan and Gualan also performed extremely well in terms of stem growth. In the same series of trials, planting was also carried out at three sites in India –Mettupalayam within Tamil Nadu; Urulikanchan in Pune; and Vellanikhara in Kerala, though only the first site provided a wide representation of provenances in the final assessments. At this site the same three Guatemalan provenances performed well along with Belen Rivas from Nicaragua and the seed collected from Pontezuela in Colombia. In terms of wood production the Belen Rivas provenance gave the best results with 6.8 kg/tree at 36 months compared to 5.1 kg/tree for the Retalhuleu material.

Overall, the results of the trials indicated that the top provenances in terms of three key traits of stem length, leaf production and wood production were as follows: -

Trait	**Provenance**
Stem length	1. Retalhuleu, Guatemala (17%) 2. La Garita, Honduras (13%) 3. Pontezuela, Colombia (11%)
Leaf Production	1. Retalhuleu (33%) 2. Belen Rivas , Nicaragua (14%) 3. Monterrico, Guatemala (14%)
Wood Production	1. Retalhuleu (53%) 2. Pontezuela (24%) 3. Belen Rivas (21%)

The figures in brackets indicate the level that the provenance mean exceeds that for all provenances across all sites. The Retalhuleu-derived material therefore demonstrates the greatest stability and reliability over all sites.

[1] Refer Tropical Forestry Paper No 33. Editor J.L.Stewart et al.
[2] Planted at the Coconut Research Institute, Lunuwila. Altitude 2m, rainfall 1,600mm

Both buyers and suppliers of *G. sepium* seed seem to lack any discerning requirement for seed quality. There tends to be little attention paid to the genetic source of the seed or its physical quality and since the species is such a prolific seeder, (it can start to seed within the first 12 months), seed prices can be low i.e. less than $5/kg. A well established seed orchard would be able to provide 50-100 kg of seed per year. The level of seed production has been noted to be increased through pollarding. There are 4,700-11,000 seeds per kg depending on the seed sources. Where farmers are collecting for their own use or for sale, an important message to convey is the need to collect seed from a large number of trees to minimize the risk of inbreeding. It should be noted that since the pods explosively dehisce, pods should be collected at a time close to the time of ripening, but before the pods commence to curl and release their seeds. The most satisfactory technique is to lay out the partly ripened pods in the sun under a wire mesh in order to control the spread of the seed. Material can then be placed in a sack and manually threshed in order to separate out any remaining seed and pods.

Where seed has to be purchased from external sources, some guidance as to seed suppliers and the quality of seed being supplied can be gained from the World Agroforestry Centre (www.worldagroforestry.org).

4. Nursery Practice.

Standard method for propagating this species tends to be through the use of cuttings since the species propagates so easily in this manner. However it can also be propagated without problems from seed. Unlike many legumes, seed treatment is not required prior to sowing. However it is worth paying attention to the need for inoculation. *Gliricidia* fixes atmospheric nitrogen through a symbiotic relationship with *Rhizobium* bacteria in nodules on the roots and where the species to be planted where it does not occur then growth and survival can be improved with inoculation. This could be done by purposely adding soil taken from an area where the species has been well established. *Rhizobium* taken from soils associated with such genera as *Calliandra* and *Leucaena* has also been shown to be effective. If there are no such areas then recourse might need to be taken to the importation of inoculum.

Direct sowing into the field is possible but is generally wasteful of seed and normally seed should be directly sown into polythene tubes or into germination beds for later transplanting (pricking out) into tubes. Since nursery stock grows quickly, frequent root wrenching is needed to control excessive root development and encourage a fine-rooting system.. Normally stock would be ready to plant out within 10 weeks when seedlings are 20 cm tall. If the seedlings are considered to be too tall for their rootstock, they should be cut back to 10cm two weeks before planting out.

<u>Vegetative propagation</u>

This species is most commonly propagated by cuttings since it is particularly easy to establish in this way. Cuttings of around 10 cm can be planted into large nursery tubes, or as is more usual, larger cuttings are planted directly into the prepared site. Cuttings of about 50 cm long and 1-2 cm in diameter should be prepared at the onset of the wet season. Larger material can be used especially if it is to be planted as a hedge or a live fence rather than as a fuelwood plantation. The upper cut should be made at an angle to preclude rain accumulation. Cuttings can be stored in shady conditions in wet sacking if necessary, but it is advisable to plan planting close to the time of collection of the cuttings. At the time of planting, the lower part of the cutting can be given small incisions in order to promote side branching. Coverage of the upper cut surface using a proprietary sealant or simply using clay and polythene is advisable to limit excessive drying out.

5. Site Preparation

The site should be cleared and prepared well in advance of the likely planting date. It should be prepared to agricultural standards with all competing weeds removed. If possible, the site should be ploughed and harrowed where there is the opportunity of having recourse to the use of agricultural machinery. Following the onset of the rains and the wetting of the upper 30 cm of soil, planting can commence. If tubed stock is being used, the plastic sleeves should be carefully split using a sharp knife to avoid distortion of the roots. When establishment is being made using cuttings a quarter of the stem should be inserted into the ground and firmed into position.

In terms of planting design, it is recommended that for energy plantations, where *Gliricida* is being planted as a pure crop that spacing should be within the range of 2 x 2 metre to 1 x 1 metres (2,500 -10,000 sph). As part of the recent studies carried out in Sri Lanka trials were carried out using a range of espacements giving stockings from 5,000-20,000 sph. Although the differences were not great the consensus was that an espacement of 1 x 2 metre (5,000 sph) and 1 x 1 m (10,000 sph) worked well. At these espacements, the crop could be expected to produce small diameter material within 18 months. For larger fuelwood blocks attention needs to be given to the problems of access and some unplanted strips need to be left. The recommendations from the work carried out in Sri Lanka being that if an espacement of 1 x1 m was adopted, then it would be judicious to leave a gap of 4 m between blocks of 12 rows. This leads to an effective density of 8,000 sph.

Where *Gliricidia* is being established along with another crop in an agroforestry or mixed cropping management system, then the planting design will vary with the overall management objectives. In Sri Lanka the combined planting of coconut and *Gliricidia* has been used to good effect where the overall objective is to provide green manure for the coconut crop and markedly reduce the need for inorganic fertilisers and at the same time provide small diameter biomass for heating and power applications. Coconut is normally managed at a final espacement of 7.9 x 7.9 m (26 x 26 feet) and the Gliricidia crop can be inserted between the overstorey as two rows 2 m apart and 1 metre between trees on each row. However there are a range of variations linked to the particular role of the *Gliricidia.*

For most soils the use of fertiliser for the *Gliricidia* would not be warranted and if it is required then questions should be raised about the overall suitability of the site for this type of land use.

6. Management Practice

Biomass Production

One of the main attributes of *Gliricidia* is the ease with which it responds to coppicing or pollarding.[3]. Therefore when managing this crop for biomass, the crop is harvested in such a way that regrowth is encouraged and the need for replanting becomes an infrequent activity and only indirectly linked to the harvesting process. Growing *Gliricidia* under a short-rotation coppice (SRC) regime is the normal and preferred manner for maximising biomass production. Coppicing can be carried out at fixed intervals, usually of 1-3 years, or on a semi-continuous manner in which shoots of an adequate size are removed as they are produced. In parts of Indonesia, *Gliricidia* is managed in woodlots cut every two to four years on a ten-year cycle which means that a maximum of five harvests can be made before the trees need to be replaced. In Sri Lanka, trials were carried out on the difference between pollarding at 1 metre and removing all usable regrowth on an annual basis and secondly removing replacement shoots as they reached a diameter of 25 mm. Generally it was considered that the annual cropping was more effective and often this could be reduced down to an 8-month cycle. However the material being produced is very small and consequently such a short cycle is adequate to enable the regrowth to be obtained. If the biomass is needed in a more traditional size regarded for fuelwood, then coppicing at ground level followed by a 3 year coppicing regime would be required. In order to allow for greater diameter development an initial espacement of 2 x 2 metres would be appropriate. The advantages of pollarding over coppicing is that material can be cut more easily by workers at waist height and the regrowth is above the level of grazing animals. Pollarding is however less suitable where it is intended to allow the regrowth to develop to a diameter in excess of 10cm.

[3] Coppicing refers to the development of regrowth from the cut stump at, or close to, ground level; pollarding is the term used when the stem is cut well above ground level usually in the range of 1.0 -1.5 m

Other Products

Gliricidia whilst being grown for biomass as the main product will also provide substantial leaf material that can be used as a green manure or as animal fodder. Leaf prunings or the tops from harvested shoots can be directly laid onto the soil surface as mulch or incorporated into the soil as green manure. The leaves have several characteristics that make them particularly suitable for use as green manure and are particularly high in nitrogen with figures of 3-4.5%. In Sri Lanka and India the leaf material is laid directly onto the top of flooded paddy a few weeks before the rice is transplanted. In coconut plantations the best results are obtained when the leaf material is incorporated in to the upper soil. Considering the issue of soil fertility, the nutrition of coconut palms was increased by its association with *Gliricidia* especially with respect to nitrogen. With the exception of Potassium, other plant nutrients such as P, Ca and Mg levels were also improved as a result of the inter-cropping. The deep root system of *Gliricidia* appears to have the effect of mining nutrients from the deeper soil layers to and returning them to the upper layers through the process of pruning and decomposition of the foliage. As a green manure, it has been estimated that 15t/ha/yr of leaf biomass can provide the equivalent of 40 kg/ha/year of nitrogen[4]. The nutrient contribution of the species is provided in the following table:

	Nutrient (kg/ha) derived from different amounts of prunings (kg/ha)			
Nutrient	**500**	**1000**	**2000**	**3000**
Nitrogen	15-23	30-45	60-90	90-135
Phosphorous	1-1.5	2-3	4-6	6-9
Potassium	8-18	16-36	32-72	48-108
Calcium	7	14	28	42
Magnesium	2-3	4-6	8-12	12-18

Source: Glover 1989, quoted in Stewart *et al* 1996

In Sri Lanka, Gliricidia leaves used as a green manure for coconut mean that the addition of inorganic fertiliser for nitrogen can be avoided, with 50 kg of leaves and tender shoots being the equivalent of 800 gm of urea. In a management system geared to the production of fuelwood and green manure, the production of the latter is of the order of 20-25 tonnes (fresh weight) of leaf material per ha.

The leaves of this species are widely used as a fodder for cattle and goats and there seems to be few toxicity problems with ruminant animals, though stock not used to the leaves may demonstrate initial reluctance to consume the leaves and there can be some minor problems with monogastric animals (i.e. non ruminants) such as poultry and rabbits if the fodder represents a high proportion of the total diet; however diets containing upto10% of Gliricidia can be fed to chicks with good effect, but this level should not be exceeded for non-ruminants. The leaves however provide a high nutritive value with a crude protein content of 18-30% and an in-vitro digestibility of 60-65%. Where the species is grown

[4] Tropical Forages Fact Sheet.

specifically for fodder then the production of green leaves can exceed 40 tonnes/ha or around 15 tonnes of dry matter.

Gliricidia is normally used as a supplement for low quality feeds, but can be used as the sole feed in the dry season. Feeding levels have been 1-3% of body weight for cattle and goats indicating a supplementation level of 30-100%, although a 20-40% is more normal. There is an indication that the palatability improves on drying the leaves and therefore makes the crop more suitable for cut- and- carry rather than for direct browsing.

7. Productivity

Fuelwood derived from *Gliricidia* can be used for domestic use as well as for the drying of tobacco and other such uses. The wood is of moderately high density (47-75 g/cm^3) and has a calorific value of 4,900 kcal/kg.

When looking at productivity and making comparisons between different species, care has to be taken on the units that are being used. Yields of timber tend to be quoted in terms of m^3/ha, i.e the amount of solid wood that is produced from one complete hectare of the site. When dealing with biomass and energy, it is more common to consider biomass in terms of (metric) tonnes/ha, assuming that the green timber has been oven or air dried before weighing. In Sri Lanka, Gliricidia established under coconut at around 1,300 stems/ha will provide some 13 m.t/ha. of wood each year along with 11.25 m.t of green foliage. *Gliricidia* close planted as a fuelwood/fodder block can provide annually over some 15-30 m.t./ha of wood depending on site and espacement. This level of production is however geared to the production of small diameter material from close planted crops intensively harvested on a continuous cropping cycle. Stewart *et al*, 1996 reports that growth models for *Gliricidia* based on sample plots in Central America indicated growth of 16.5 tonnes/ha for a three year rotation i.e. 5-6 tonnes/ha/an. However this relates to plantations established at 2 x 2 metres where the ultimate product would be stems of around 15 cm diameter. It does seem that on the right sites that the productivity of this species in terms of biomass is comparable to that of the faster growing species of Eucalypts and has the advantage that it does not give the same negative site effects that can be associated with Eucalypts and some other fast growing plantation species, especially with respect to competition with neighbouring crops.

8. Income Generation

Gliricidia is clearly suitable as a component of a mixed farming enterprise, providing fodder for livestock and green manure for food crops. It is also suited to the small-scale farmer as an energy crop if a suitable market or collection point is within an economically acceptable transportable distance. Models have been derived for a range of potential farm conditions to provide guidance on the sort of returns that might be expected. These are appended to this information sheet. The variables that need to be considered by an individual farmer or association of growers are the following:-

1. Area of land that can be dedicated to energy crops. It is suggested that to make it a worthwhile exercise around 1 ha should be set aside for this activity. Useful supplements to household income can be derived from small areas i.e. the collection of small diameter material from hedges, but this would only equate to a relative minor part of the total farm income.
2. Site productivity – a combination of factors related to rainfall, soil fertility and depth, altitude etc
3. Distance to collection point or market.
4. Reliability of the market - is the demand still going to be there in 5 years?
5. Is there sufficient spare labour either within the family or available for hire to meet the demands of establishment and harvesting. The table below provides an indication of the levels of labour that might be expected for the main tasks. One of the advantages of growing energy crops is that there is some slight room for modifying the calendar of activities to fit into demands for other crops.

Model 1 Annual harvesting of small diameter material (Gliricidia)											Labour Cost =	2.35
											Wood Value =	20
Estimated Labour inputs (man-days per ha) by years												
Activity	**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**	**Yr 6**	**Yr 7**	**Yr 8**	**Yr 9**	**Yr 10**		
Site Preparation	50											
Planting	25											
Filling blanks (beating up)	10											
Weeding (1)	30											
Weeding (2)	20											
Year 2 operations												
Pollarding		40										
Weeding		25										
Harvesting		65										
Year 3+ operations												
Harvesting			65	65	65	65	65	65	65	65		
Subtotals for labour input	135	130	65	65	65	65	65	65	65	65		
Subtotal for labour cost	317.25	305.5	152.75	152.75	152.75	152.75	152.75	152.75	152.75	152.75		
Materials												
Purchase of improved cuttings	300											
Total Costs	617.25	305.5	152.75	152.75	152.75	152.75	152.75	152.75	152.75	152.75		
Yields (dry tonnes/ha)		4	6	10	12	15	15	15	15	15		
Value		80	120	200	240	300	300	300	300	300		
Total Income	-617.25	-225.5	-32.75	47.25	87.25	147.25	147.25	147.25	147.25	147.25	-4.75	

The above simple table illustrates that on the basis of good-average production of 15 tonnes/ha/annum and at a current value of $20/tonne a farmer over the first 10 years would just about break even if he costs his labour at around $2.35/man day. The table below considers the discounted value using a more realistic current value of labour at $3.50/day over a production rotation of 20 years. This would provide a positive return at a discount rate of 15%.

Fuelwood Establishment Costs based on planting density of 10,000/ha

Model 1 Annual harvesting of small diameter material (Gliricidia)

Labour Cost = 3.50 US dollars perday
Wood Value = 20.00 US dollars per tonne

Estimated Labour inputs (man-days per ha) by years

Activity	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Site Preparation	50									
Planting	25									
Filling blanks (beating up)	10									
Weeding (1)	30									
Weeding (2)	20									
Year 2 operations										
Pollarding		40								
Weeding		25								
Harvesting		65								
Year 3+ operations										
Harvesting			65	65	65	65	65	65	65	65
Subtotals for labour input	135	130	65	65	65	65	65	65	65	65
Subtotal for labour cost	472.5	455	227.5	227.5	227.5	227.5	227.5	227.5	227.5	227.5
Materials										
Purchase of improved cuttings	300									
Total Costs	772.5	455	227.5	227.5	227.5	227.5	227.5	227.5	227.5	227.5
Yields (dry tonnes/ha)		4	6	10	12	15	15	15	15	15
Value		80	120	200	240	300	300	300	300	300
Total Income	-772.5	-375	-107.5	-27.5	12.5	72.5	72.5	72.5	72.5	72.5
Discount rate (8%)	1	0.9259259	0.8573388	0.7938322	0.7350299	0.6805832	0.6301696	0.5834904	0.5402689	0.500249
Discounted value (8%)	-772.5	-347.22222	-92.163923	-21.830387	9.1878732	49.342282	45.687298	42.303054	39.169494	36.26805
Discount factor (10%)	1	0.9090909	0.8264463	0.7513148	0.6830135	0.6209213	0.5644739	0.5131581	0.4665074	0.4240976
Discounted value (10%)	-772.5	-340.90909	-88.842975	-20.661157	8.5376682	45.016796	40.92436	37.203964	33.821785	30.747077
Discount factor (15%)	1	0.8695652	0.7561437	0.6575162	0.5717532	0.4971767	0.4323276	0.375937	0.3269018	0.2842624
Discounted value (15%)	-772.5	-326.08696	-81.285444	-18.081696	7.1469156	36.045313	31.343751	27.255435	23.700379	20.609025
Discounted factor (20%)	1	0.8333333	0.6944444	0.5787037	0.4822531	0.4018776	0.334898	0.2790816	0.232568	0.1938067
Discounted value (20%)	-772.5	-312.5	-74.652778	-15.914352	6.0281636	29.136124	24.280103	20.233419	16.861183	14.050986

Activity	Yr11	Yr12	Yr13	Yr14	Yr15	Yr16	Yr17	Yr18	Yr19	Yr20	
Harvesting	65	65	65	65	65	65	65	65	65	65	
Subtotals for labour input	65	65	65	65	65	65	65	65	65	65	
Subtotal for labour cost	227.5	227.5	227.5	227.5	227.5	227.5	227.5	227.5	227.5	227.5	
Total Costs	227.5	227.5	227.5	227.5	227.5	227.5	227.5	227.5	227.5	227.5	
Yields (dry tonnes/ha)	15	15	15	15	15	15	15	15	15	15	
Value	300	300	300	300	300	300	300	300	300	300	
Total Income	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	
Discount rate (8%)	0.463193488	0.4288829	0.3971138	0.3676979	0.340461	0.3152417	0.2918905	0.270269	0.250249	0.2317121	
Discounted value (8%)	33.58152789	31.094007	28.790748	26.6581	24.683425	22.855024	21.162059	19.594499	18.143055	16.799125	-768.39691
Discount factor (10%)	0.385543289	0.3504939	0.3186308	0.2896644	0.2633313	0.239392	0.2176291	0.1978447	0.1798588	0.163508	
Discounted value (10%)	27.95188848	25.410808	23.100734	21.000668	19.091516	17.355924	15.778112	14.343738	13.039762	11.854329	-837.73409
Discount factor (15%)	0.247184706	0.2149432	0.1869072	0.162528	0.1413287	0.1228945	0.1068648	0.0929259	0.0808051	0.0702653	
Discounted value (15%)	17.92089119	15.583384	13.550768	11.783277	10.246328	8.9098502	7.7476958	6.7371268	5.8583711	5.0942358	150.16561
Discounted factor (20%)	0.161505583	0.134588	0.1121567	0.0934639	0.0778866	0.0649055	0.0540879	0.0450732	0.037561	0.0313009	
Discounted value (20%)	11.70915476	9.757629	8.1313575	6.7761312	5.646776	4.7056467	3.9213722	3.2678102	2.7231752	2.2693126	-1006.0688

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