Report on a visit to CELBI's *Eucalyptus globulus* plantations in Portugal.

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Introduction

Wood pulp production is a large industry in Portugal and adjoining parts of Spain, and the predominant source of the wood is from plantation grown *E. globulus*. In Portugal, CELBI have one small pulp mill (250,000 m^3 yr^{-1}), Portucel have three large pulp mills and one small pulp mill, KIMA and Supocell each have one pulp mill. In adjoining parts of Spain, there are two pulp mills in the north and one in the south.

Celulose Beira Industrial (CELBI) have about 50,000 ha of *E. globulus* plantations. About 50% of this is in the regions around Lisbon, 15% is in the northern coastal regions and the remaining 35% is in the less productive southern and northern interior regions. The company harvest the wood from these plantations to supply their small pulp mill. Most of the pulp is sold to their parent company in Sweden, with the remainder sold on the open market.

I spent two days talking to a number of CELBI staff discussing recent changes at CELBI, their research (Project D95), nursery and plant propagation practices, and practices for site preparation and later operations. Some notes from these discussions follow:

Recent Changes at CELBI

The company have reduced its forestry staff from 300 to 100 over the last couple of years. This was achieved by natural attrition and by the retrenchment of 100 staff the week before I visited. The need for this drastic reduction in staff was two-fold:

(i) Staff numbers had previosly increased as the company prepared to increase the size of its pulp mill to 700,000 m^3/yr. However, after previously indicating support for larger pulp mill, the Portugese Government rejected CELBI's application.

(ii) The cost of producing CELBI's wood pulp has increased dramatically over the last five years or so, and the company was no longer competetive and consequently was making a loss. CELBI's costs have increased by 47% over this period compared to 5% in Brazil and the southern United States and 17% in Sweden. However, Sweden have subsequently reduced their costs and this leaves CELBI's pulp the most expensive to produce. The increase in costs for CELBI were largely attributed to high inflation, including wages, in Portugal over this period. Inflation has been 10-15%/yr whilst their dollar has remained tied to the German DM. Consequently, Portguese industry is under pressure to transform from a low wage economy to a high wage economy. It was interesting to hear that one of the other large pulp enterprises in Portugal, Portucel (owned by the Portugese Government), made a loss of $A 170 M in the last financial year.

Project D95

The objective of Project D95 was to double *E. globulus* pulp production per hectare per year for plantations established from 1995 onwards. Project D95 uses intensive genetic improvement and large-scale clonal forestry. Before 1991 nearly all plantations had been based on genetically unimproved trees, with no selection for pulp production or profitability. With this very poor base a doubling in production within 10 years was a realistic objective. The research project started in 1986 and has now moved to an operational phase.

From 1993, plantations will be based 100% on genetically improved trees from the project (Table 1). The improved trees will come from new second generation seed orchards and clonal cuttings. The new plantations will change from being based entirely on seedlings to being based largely on clonal cuttings.

Table 1: The effect of Project D95 on the percentage of CELBI plantations from genetically unimproved and improved plants.

Year of plantation establishment	Unimproved plants (%)	Genetically improved plants (%)		
		1st generation seed orchards	2nd generatio n seed orchards	Clonal cuttings
1965-1990	100	0	0	0
1991-1992	60	40	0	0
1993-1994		25	40	35
1995 onwards			40	60
expanded nursery				100

The anticipated doubling in pulp production comes from two areas:

(i) increased tree growth rates, and

(ii) an increase in pulp yield.

The increase in tree growth rate is achieved by selecting fast growing clones. The increase in pulp yield is achieved by selecting clones with greater weights of cellulose and hemicellulose per cubic metre of wood. Since over half the cost of wood production is due to logging, forwarding and road or rail transport, an increase in pulp yield can substancially reduce these costs per tonne of pulp.

Table 2 shows that average growth now is about 12 m^3/ha/yr, wood consumption is about 3 m^3 wood/tonne of pulp. Therefore, the plantations are producing 4 tonne pulp/ha/yr. Results from field trials show improvements in growth (to 20 m^3/ha/yr) and pulp yield (to 2.5 m^3/t) will double pulp production (to 8 tonne pulp/ha/yr). This will reduce wood costs by 40% per tonne of pulp.

Even though the seed orchards can deliver only half of the increase in pulp production they are considered important as:

(i) an insurance against failure of the clonal cuttings,

(ii) to make up the short-fall in cuttings production, and

(iii) sale of surplus seed from the orchards for profit.

The major improvement is achieved by clonal forestry, which involves establishing plantations from genetically identical cuttings (clones) taken from outstanding mother trees. The project had also investigated micropropagation techniques, but this work was abandoned because of poor progress.

Table 2: Genetic gains from using second generation seed orchards and clonal cuttings.

Production trait	Plantation today	2nd generation seed orchards	Clonal cuttings
Stem volume growth (m^3/ha/yr)	12	18	20
Wood consumption (m^3 wood/t bleach pulp)	3.0	3.0	2.5
Pulp production (t pulp/ha/yr)	4	6	8

A large part of their research was on the development of techniques to propagate cuttings. This research was carried out in their cuttings nursery, and when the techniques were well advanced a new US$ 5M glasshouse nursery was built. This nursery has the capacity to produce 5M cuttings per year, which would establish 2,000 ha of plantation. The nursery will soon be expanded to a capacity of 10M cuttings per year. A major problem that they experienced was the transfer of their propagation techniques from the old nursery, where the research was done, to the new nursery. They were achieving 80% rooting of cuttings in the old nursery, but this has dropped to 60% in the new nursery. A large part of their research on propagation techniques is having to be repeated in the new nursery as advances made in the old nursery are not applicable. Even the ranking of the rooting ability of clones is quite different. It seems that propagation techniques are glasshouse specific. They recommend that research on propagation techniques should be carried out in the facility that will be used for commercial scale propagation.

To reduce the potential risks from clonal forestry, their plantations will be based on at least 20 clones in any one year, and most of these will be replaced every six year breeding cycle. Therefore, across a plantation estate of 60,000 ha there should be at least 100 clones.

CELBI are using a nucleus breeding strategy to deliver both:
(i) rapid short-term gains in a relatively small nucleus population of outstanding trees, and
(ii) the development of the much larger main population to guarantee continuing genetic progress and stability in the future.

The project has shown that not only pulp quantity, but also pulp quality, can be genetically manipulated. For *E. globulus* there is a six-fold difference between extreme families in the beating time required to produce paper of a certain tensile strength. Large differences were also found in water retention value, bulk, tear and burst index, porosity and light scattering. These paper properties all appear to be moderately or highly heritable and should be able to be improved by genetic selection.

Nursery and plant propagation

CELBI's new $US 5M highly automated nursery is a standard Dutch design and built horticultural glasshouse. Of the $US 5M cost of the nursery, over half was for site preparation, and this will allow easy expansion of glasshouse facilities. The nursery employs 20 people to produce its 5M plants per year.

The glasshouse is divided into three sections:

(i) mother plant section,
(ii) cutting and planting section, and
(iii) propagation section.

Mother plants are grown in 2L pots, although smaller 120 cc pots would probably be more efficient. However, at present they do not have enough mother plants to use the smaller pots. This section grows about 90,000 mother plants in the 2L pots (Figure 1), whereas if small pots were used the capacity would be 768,000. About 4-6 cuttings are taken from each mother plant per month, with about a 10 day cycle between cuttings. In summer the plants are automatically irrigated about every 20 minutes, whereas in winter irrigation is less than once per day. The irrigation system allows for fertiliser to be added and fertigation is carried out at least once per week. The concentrations of N and P are varied depending on the appearance of the mother plants. High N is usually used to promote rapid leaf growth, but in summer more P and less N may be used to reduce wilting. This section of the glasshouse is 72 m by 32 m in area.

The cutting and planting section is also 72 m by 32 m in area. Cuttings of 3 to 5 leaf pairs are made from the mother plants (Figure 2), the cuttings are trimmed to reduce their leaf area, and then they are planted in 120 cc pots (Figure 3). The soil used is mixed and potted automatically with the mixture containing 2/3 peat, 1/3 perlite, and 3 kg of slow release fertiliser per m^3 of soil mixture. They have done considerable research on additives to promote rooting ability, but the results have been so variable that they decided not to use any rooting additive. A fungicide is also applied at this stage.

The propagation area contains two 72 m by 32 m sections and each of these has the capacity for 768,000 plants (Figure 4). Environmental conditions that they consider best for propagation are a day temperature of 22-28°C, a night temperature of 18°C and relative humidity greater than 90%. The irrigation system uses up to 480 kL/day in each of the two sections of the glasshouse. Because of this high water use they will soon be installing and testing a fogging/humidifier system. The cuttings are fertigated with a mixture containing low N and high P concentrations. These conditions result in good root growth, but very little shoot growth. The cuttings take 30-40 days for rooting to take. They beleive that a good rooting ability is dependent on three factors:

(i) temperature,
(ii) humidity, and
(iii) the clone.

After the cuttings pass out of the glasshouse they progress to a shadehouse were they are grown for about one month before being moved to another area. Planting occurs in both autumn and spring.

They had only been in this new glasshouse for six months and were ironing out many problems, but were already producing cuttings for about $A 0.3 each. This compares with seedlings which cost a little less than $A 0.2 each to produce.

Figure 1: Mother plants in CELBI's mother plant glasshouse.

Figure 2: Cuttings being taken from the mother plants.

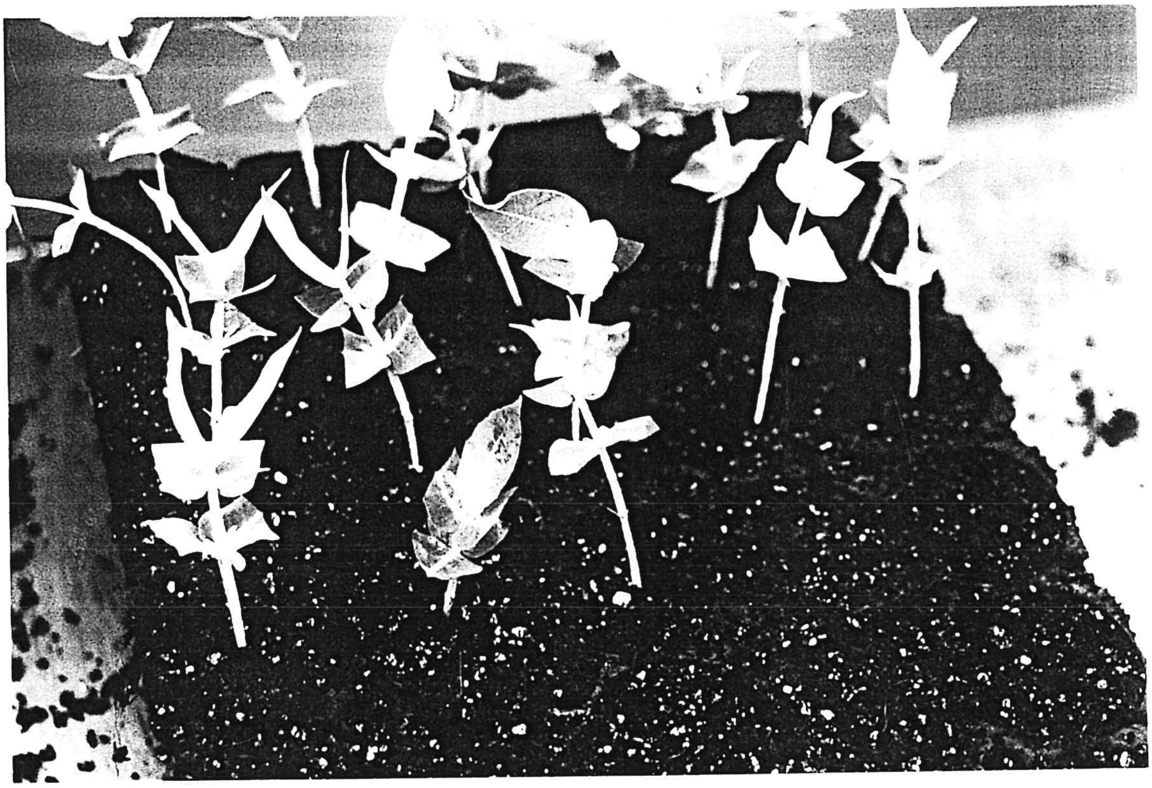

Figure 3: Potted cuttings with their leaves trimmed.

Figure 4: Cuttings in CELBI's propagation glasshouse.

Site preparation and later operations

They believe the profitability of their plantations depends on:
(i) the current land-use,
(ii) stand structure,
(iii) slope,
(iv) soil type and texture,
(v) season of soil preparation,
(vi) size of property (they plant as little as 2 ha),
(vii) depth of ripping (depends on soil structure),
(viii) equipment used for soil preparation, and
(ix) experience etc of driver of equipment.

The size and type of equipment they have used for site preparation has evolved over time. In 1965 they used a 125 hp tractor. The hp of the equipment increased to 150 hp in 1970, 180 hp in 1975, 320 hp in 1981, 335 hp in 1983 and 685 hp in 1990 (Figure 5). In 1966 they used a fixed plough, a NARD plough in 1969, a line plough in 1972, a D8 with 3 rippers to 1.2 m in 1982. In 1986 they changed to a big (13 t) plough with 13 x 127 cm discs which were used to kill tree roots. They also used a stem crusher. In 1988 the heavy plough used had 11 x 127 cm discs or 9 x 127 cm discs (Figure 6), although the later was not very stable on steep slopes. In 1989 they used a Scandinavian DONNAREN to create furrows for good drainage, but later decided this was not particularly important on their sites. They also used a 3 blade ripper and subsoiler combination. In 1990 they introduced a Rotovator and reversible plough. The plough is used in some soil types and rippers in other soil types.

The cost of their site preparation and later operations is detailed below. All costs are in $A per ha.

Ploughing

(i) 16 x 81 cm disc plough weighing 4 t takes 1.5 h/ha and costs $130.
(ii) 12 x 91 cm disc plough weighing 6 t takes 2 h/ha and costs $180.
(iii) 9 x 127 cm or 13 x 127 cm disc plough weighing 10-13 t takes 2.6 h/ha and costs $515 ($900 for 2 passes).

Windrowing

Using 140-155 hp takes 10-16 h/ha and costs $750-1200

Ripping

(i) on easy rocky sites
(a) <15% slope using 155-335 hp takes 2-3.2 h/ha and costs $290.
(b) >15% slope using 155-335 hp takes 3-5.5 h/ha and costs $430.

(ii) on difficult rocky sites
(a) <15% slope using 285-335 hp takes 7.5 h/ha and costs $1150.
(b) >15% slope using 285-335 hp takes 8.5 h/ha and costs $1250.

Normal ploughing (not used any more)

Using 140-155 hp takes 10-12 h/ha and costs $800-1000.

Row ploughing

Using 140-155 hp

(i) on slopes <20%

Figure 5: 685 hp bulldozer with rotovator at the front to grind stumps and ripper at the rear (photo from video on pause, thus poor quality).

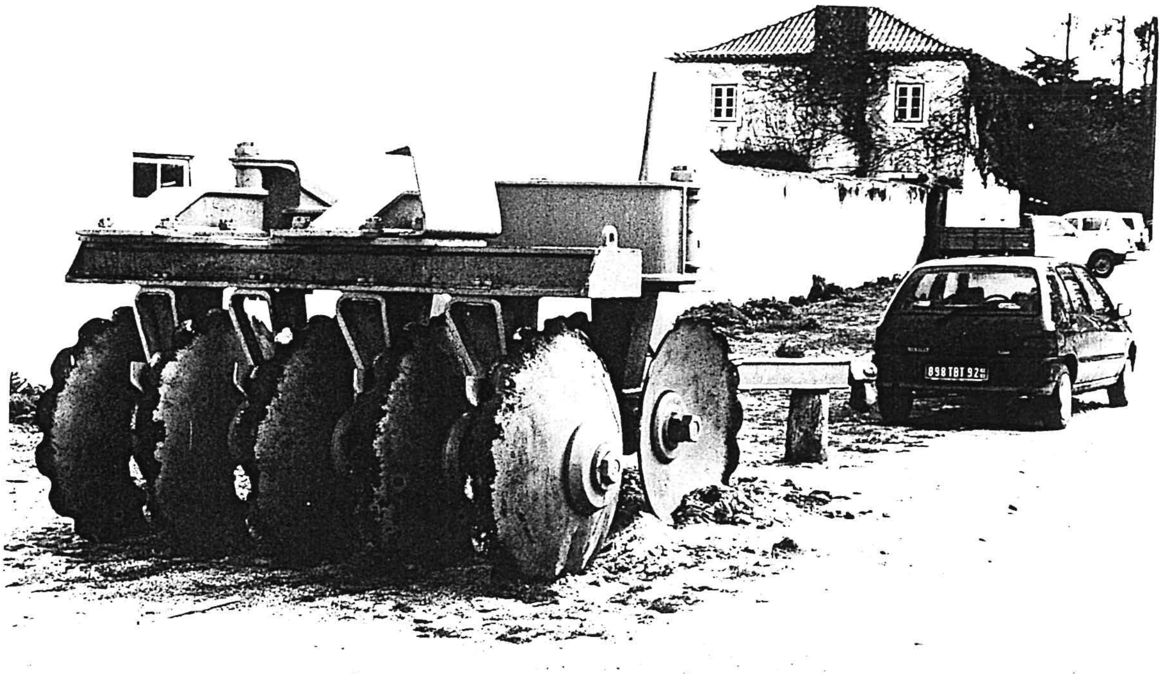

Figure 6: 10 tonne disc plough with 9 x 127 cm discs.

(a) Using a 1 plough blade takes 1.5 h/ha and costs $140.
(b) Using a 2 plough blade takes 3 h/ha and costs $280.
(c) Using a 3 plough blade takes 4.5 h/ha and costs $420.

(ii) on slopes of 20-35%
(a) Using a 1 plough blade takes 2 h/ha and costs $185.
(b) Using a 2 plough blade takes 4 h/ha and costs $370.
(c) Using a 3 plough blade takes 6 h/ha and costs $550.

Using 70-90 hp with a 1 blade plough takes 1-1.5 h/ha and costs $40-60 (but this also requires ripping beforehand).

Terracing (on slopes >35%)

(i) on easy rocky sites
(a) Using 140-155 hp takes 18 h/ha and costs $1330.
(b) Using 285-335 hp takes 8 h/ha and costs $1330.

(ii) on difficult rocky sites
(a) Using 140-155 hp takes 35 h/ha and costs $2630.
(a) Using 285-335 hp takes 18 h/ha and costs $2630.

Stump crushing

(i) >40 cm diameter and easy to destroy (at 400 spha)
(a) Using 148 hp takes 3.5 h/ha and costs $257.
(b) Using 125 hp takes 4 h/ha and costs $257.

(ii) >40 cm diameter and difficult to destroy (at 400 spha)
(a) Using 148 hp takes 5.5 h/ha and costs $410.
(b) Using 125 hp takes 6.5 h/ha and costs $410.

Subsoil ripping

(i) on slopes <15% using 285-335 hp takes 3.3 h/ha and costs $500.
(ii) on slopes >15% using 155 hp takes 1.5 h/ha and costs $140.

Comparison of site preparation systems

(i) For slopes <15%
(a) Total plough + small disc plough + 1 blade plough costs $970.
(b) Ripping + small disc plough + 1 blade plough costs $460-1670.
(c) Row ploughing in contours costs $280-420.

(ii) For slopes 15-30%
(a) Row ploughing in contours costs $280.
(b) Ripping and ploughing costs $430-1530.

(iii) For slopes >30% terracing costs $1330-2630.

(iv) New system which has 3 separate operations of stump gringing + heavy plough + subsoiling costs $1265-1830.

(v) Old system which had 4 separate operations of windrowing + ripping + disc ploughing + contouring costs $1460-2050.

Planting

Including plants, fertiliser, transport, planting and replanting costs $750-850. On clay soils they use a fertiliser with an NP ratio of 3:21 and apply 200 g per plant in a granular form. On non-clay soils an NPK ratio of 7:21:21 is applied at 200 g per plant, again in granular form.

Fertilising during the rotation

They report good results in poor soils and their intention is to fertilise at 300-500 kg/ha of total fertiliser at 3 or 4 year intervals. This equates 30 kg/ha N at each application assuming an NPK ratio of 7:21:21.

Coppicing and thinning

They have a full rotation experiment looking at the effects of retaining all sprouts, or thinning to 1, 2 or 3 sprouts per stump. However, no results were available.

Their normal system is to thin to:
1 sprout where the stump <20 cm diameter,
2 sprouts where the stump is 20-30 cm diameter,
3 sprouts where the stump is 30-40 cm diameter,
sprouts 20 cm apart where the stump >40 cm diameter,

In the 1st rotation they planted at 1100 spha, whereas in the second rotation there is more like 2,000 spha. Only about 80% of stumps resprout and these are thinned to 2-2.5 resprouts per stump. If thinning was not done there would be about 5 resprouts per stump.

Thinning of the coppice is done 1.5-2 years after harvesting of the previous crop. Thinning takes 2.5-3 mandays/ha using a chainsaw. The thinnings have no market and so are placed in the inter-rows and 0.5-1 year later they are ploughed into the soil. This operation is apparently done for fire prevention and costs $120.

They believed they were losing some pulp production in the second rotation because of the greater number of stems and consequently their smaller size (the top diameter size accepted by the pulp mill is 5 cm under bark). However, they believed that total biomass production in the second rotation was greater than the first rotation because of the more rapid early growth of coppice compared to seedlings. They had no data to support this contention.

Harvesting

A mix of methods are used including manual felling with chainsaws, manual debarking (although this has reduced greatly in recent years) and mechanical cutter, debarker and length chopper.

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