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CHAPTER 3
HYBRID POPLAR PRODUCTION FOR ENERGY IN ITALY

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INTRODUCTION

Conventional poplar cultivation

Conventional poplar cultivation in Italy occurs mainly in the Po Valley (about 70%) and occupies an area of about 80,000 ha (Lapietra *et al.*, 1991). In the last ten years the cultivated land area has been decreasing. This trend has now stopped, and is likely to recover in the next few years.

About 40% of the plantations are in bottom lands and the remaining 60% in agricultural lands. 67% of the land on which poplar is grown has a sandy soil, 17.5% a medium textured and 15.5% a clay-loam soil.

Poplar plantations are cultivated very intensively: using irrigation; fertilization; pruning; and discing of the soil. Maize, soya and grassland are interplanted with poplars in the first two years after establishment. Poplar stands are fertilized, and irrigation is used for one quarter of the total area cultivated. One-half of poplar plantations are regularly pruned at a height of 5-6 m from the ground and the other half are pruned at 3m.

The average establishment density is a little higher than $32m^2$ per tree and the most common lay-out of planting is rectangular.

The clone most commonly used in Italy, is I-214 (41% of the total planted) followed by a group of Canadian clones (BOCCALARI, ADIGE, and STELLA OSTIGLIESE) (about 29%) and by other clones of *P. x euramericana* (BL-COSTANZO, PAN, AND LUISA AVANZO). Clones of *P. deltoides* (LUX and ONDA) and the Carolinian clones (SAN-MARTINO and TRIPLO) are also often grown.

Two-year-old plants are commonly used for the establishment of poplar plantations, but one-year-old plants are used from clones with good dominant leaders (BL-COSTANZO, PAN, LUISA-AVANZO, SAN MARTINO, and LUX).

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The mean age of poplar stands is seven years. Seven-year-old and older plantations represent 54% of the total area cultivated with poplars.

The average rotation is about 10 years, with the relative yield being 208 m^3/ha and the mean annual increment is 20.4 m^3/ha/year. The average tree at full rotation has a diameter of 28 cm at 1.30 m above the ground, a total height of 24.1m and a volume of 0.66m. In 1990, 9,400 ha were felled and about 2 million m^3 of wood were obtained.

The quantity of wood produced has increased in recent years, but will rapidly decrease because of the small number of young plantations in existence.

The quality of wood produced is fairly high: in fact, 40% of the wood is very good, 38% good, 7% fairly good and 15% below standard.

The worst damage to cultivated poplar is due to bark necrosis (about 40% of the trees are attacked, 17% seriously) and to bark and wood boring insects (14% of the trees), in particular the large poplar borer (*Saperda carcharias*) and the European goat moth (*Cossus cossus*).

A study carried out in the period 1981-1987 showed that poplar wood is used as follows:

- 19% by the plywood industry;
- 11% for pulpwood production;
- 25% for chipboard;
- 36% for packaging;
- 9% for timber.

As the best price is paid for wood destined for the plywood industry, Italian poplar growers try to maximize the production of this kind of wood - adopting intensive cultural tending, including antiparisitic treatments.

Coppice of poplar plantations

The increase in the demand for raw material for the production of pulpwood and chipboard panels, along with the energy crisis have pushed researchers to examine in detail density and rotation lengths of poplar plantations. Research is focused on finding cultivation techniques suitable for dense plantations (approximately 1,000 to 2,500 plants per hectare) with very short rotations (5-6 years) in order to use coppice regeneration for the production of pulpwood size material for chipboard and for fuel wood - a renewable source of energy.

The woody biomass which can be obtained from these plantations increases as the actual number of plants per unit area (density) increases. However, it is necessary to stress the fact that, by increasing the density, the diameters of the tree trunks decrease, as does the range of possible uses of the material produced. On good sites, with dense spacings and short rotations, the trees obtained vary widely in size ranges: diameter at breast height 10 to 20cm; total height 15 to

20m; and fresh weight (above-ground biomass) 100 to 200 kg each.

Logs with diameters over 8-10cm are suitable for pulpwood and smaller ones for chipboard or as fuel wood. Commercial values decrease sharply from large to small diameters. As the density increases, with the intent of increasing yields, smaller diameter trunks are produced, suitable only for chipping or as fuel wood.

In view of the economic situation in Italy, it is more profitable to choose cultural models that ensure the production of pulpwood size material for which an established market is available and active. These plantations have very high production capacities but demand intensive cultural practices.

PLANT MATERIAL FOR SHORT ROTATION FORESTRY

Poplar culture in Italy is intensive, and rotations are short, when compared with other countries. Many of the characteristics that make a clone suitable for widely spaced commercial plantations are the same as those for very short rotation forestry. SRF is aimed at the production of high quantities of biomass, which does not have strict requirements as far as quality is concerned.

Thus, breeding and selection for conventional culture can, to a large extent share the same goals as for biomass production. However, there are some remarkable differences.

Stem form, a major concern in the selection of clones suitable for veneer peeling, has very limited importance if the wood will be reduced to chips. A single stem habit is, however, important in both situations. Positive characteristics for biomass plantations, such as good resprouting ability and the natural tendency to have only one dominant shoot after coppicing, have no importance in conventional culture, where stumps are extracted from the ground before replanting.

Fast juvenile growth is certainly required in both cases, although in densely-spaced biomass plantations, its importance is taken to the extreme.

As far as resistance to disease is concerned, the goal of clonal selection largely coincides in the two situations. Leaf diseases such as *Marssonina brunnea* (Ell. et Ev.) P. Magn., *Venturia populina* (Vuill.) Fabr. and *Melampsorae* spp. can severely reduce production and can weaken the trees, leaving them susceptible to parasites such as the bark disease *Dothichiza populea* Sacc. et Br. The micro-climate of a densely-spaced plantation favours the propagation of leaf diseases. Practical resistance to disease, that is no need for chemical protection even if it is economically and technically feasible, is an absolute necessity.

Poplar Mosaic Virus (PMV) is more dangerous in biomass plantations than in conventional culture. Diffusion of the disease is carried out in part by infected cutting devices, and thus, coppicing spreads it.

As a consequence of the above, breeding and clonal selection for biomass have been and will probably continue to be minor branches of the main research dedicated to conventional culture.

Some very interesting results come from progeny trials recently performed with hybrid (*P. deltoides* Bartr. x *P. nigra* L.) families:

- the additive components of genetic variances are much larger than non additive ones; thus breeding strategies exploiting general combining ability are needed;
- resistance to *M. brunnea* depends more on the *P. nigra* than the *P.deltoides* parent, whereas growth-related traits are mainly under the influence of the *P. deltoides* parent;
- the interaction between genetic components and the environment is negligible: thus there is no need to have separate breeding programmes for different ecological zones;
- much is to be gained from breeding for resistance to *M. brunnea* (and possibly to other leaf diseases); better results will be obtained by clonal selection for growth traits.

The choice of a clone from within those already available is still a matter of research. Only sixty clones have been tested in densely-spaced stands. Twenty of them displayed a yielding ability significantly higher than I-214, used as a control in all the trials. They are: LUISA-AVANZO; CIMA; GUARDI; BELLOTTO; FLEVO; SAN-MARTINO; BL-COSTANZO; PAN; NE-222; PI70-001 (all *P.x euramericana* (Dode) Guinier); FIEROLO; LUX; DIVINA; NL-1454 (=PE68-004); PE70-003; 2-KEN-8; S7C2; 14-9; 6-67 (*P. deltoides*) and the Belgian interamerican clone 69.042/2.

Some of the above-mentioned clones, however, should be excluded from commercial short rotation intensive culture (SRIC) plantations due to sanitary problems. For example, CIMA is very susceptible to leaf rusts (LUISA-AVANZO is now susceptible to the new race E3 of *Melampsora allii-populina* Kleb.); BL-COSTANZO and PAN can be severely damaged by *M. brunnea*, *Melampsorae* spp. and *Phloeomyzus passerinii* Sign. LUISA-AVANZO and BELLOTTO are very susceptible to water stress which probably favours attacks by *D. populea* and is probably the cause of a physiopathological phenomenon commonly called 'brown bark spots'.

Clones of *P. deltoides* are generally resistant to leaf diseases, other than the poplar mosaic virus, and to bark diseases. However, since the euramerican poplars exhibit a generally poorer rooting ability, attempts to establish stands by means of cuttings (as would be expected in SRIC plantations) is discouraged.

The interamerican clone 69.042/2 is practically resistant to all relevant diseases and has a very high growth rate in the first rotation. However, after coppicing, it displays a singular plagiotropic habit which prevents any mechanical operation in a stand.

Even though early results are only moderately encouraging, there is certainly a very high potential for selection in the tens of thousands of new genotypes that annually enter the selection flow. Several clones have never been tested in SRIC plantations but display a very high growth rate in the nursery (two years from planting of a cutting with 1 m^2/plant) and good resistance to diseases. Among them are some euramerican clones (CERVO, ORBA, PANARO, 80-084), some *P.deltoides* (S7C8, 1-13-13-2), and some *P. nigra* (BRISIGHELLA, N369). They could be available for large scale trials in a the near future.

Some clones of *P. alba* L. have also shown very encouraging early results: they seem to be well suited to the drier environments of southern Italy.

Willow (*Salix* L.) also requires research in Italy. Various clones of *Salix* have been selected for their rapid growth and excellent rooting and sprouting ability. At present their potential is limited by a rather high susceptibility to active lime in the soil (a very common occurrence in Italy), and this susceptibility worsens after coppicing. However the effort put in willow breeding has been negligible when compared to poplar, and quick progress can be expected in the next few years.

PLANTING STOCK SELECTION AND PRODUCTION

Planting stock selection

Cuttings of variable lengths, and one and two-year-old plants are the type of planting stock commonly used in Italy for SRIC forestry.

A test carried out in Pomposa (Frison, 1984), on a sandy soil of low fertility with the clone I-214, at a spacing of 2.50 x 1.60 m, showed that, at the end of the fifth year, the cuttings (approximately 50 cm long) yielded 3.5 oven-dry tonnes/hectare/year (ODT/ha/yr), one-year-old plants 7.5 ODT/ha/yr and the two-year-old ones 9 ODT/ha/yr. Both the stems and the branches reached a maximum diameter of 4 cm.

On the basis of practical experience acquired so far, we can state that in fertile soils the production differences among the three types of planting stock material tend to decrease. Unless the rotation is longer, one-year-old plants are always better than cuttings, because the short growth cycle does not allow the smaller starting stock to catch up. On the contrary, the production differences between one-year-old and two-year-old plants are very small and often negligible.

There is no doubt that, for technical reasons, SRIC plantations require the use of cuttings, but for plantations having a density ranging from 1,000 to 2,500 plants per ha, it is often better to use one-year-old plants or, alternatively, unrooted one-year-old shoots from coppice nurseries. With this type of material, in addition to higher production, easier weed control is also achieved.

Two-year-old plants are decidedly less suitable for this kind of plantation, especially in view of their high production costs and of the associated planting expenses.

The same care is needed for the production, preparation and preservation of unrooted cuttings and plants for nurseries and conventional poplar plantations respectively.

The cultivation of a special nursery, in Italian "barbatellaio", for the rearing of one-year-old stems to be used for the production of cuttings is described here. It is possible to use the cuttings obtained from these nurseries to establish biomass plantations, but they are usually used for the establishment of nurseries.

Growing cuttings

Soil preparation is done, preferably in summer, by ploughing 40-50 cm deep, in order to both eliminate weeds and to physically and chemically transform the soil.

The soil should be disk harrowed to prepare a good planting-bed for cuttings.

The selection of cuttings should be done carefully, as the aim is the production of good propagation material.

The cutting diameter varies according to the clone and is usually between 10 and 30 mm. For *P. deltoides* the minimum is 15 mm as the pith is very thick.

A good criterion is to obtain cuttings that do not bend easily when inserted into the soil. It is important to keep dormant buds, near the top of the cutting, in good condition.

When planting cuttings, the best results are achieved using a planting machine that was built some years ago. This machine inserts the cutting completely into the soil. Only in small farms or with limited quantities are the cuttings planted by hand.

The density in a cuttings production nursery is about 77,000 plants per ha, in single or double rows. Average production is about 5 or 6 cuttings per stem, or 350,00-400,000 cuttings per ha, or even 500,000 cuttings per ha in the best situations.

The choice of spacing depends on the dimensions of the available machinery: single rows for small tractors and double rows for large ones.

The nutrition level of the one-year-old plants from which the cuttings are obtained plays a key role. These plants should be cultivated in a deep soil with a sandy texture, rich in nitrogen, phosphorus and potassium, and a pH in the range of 6.5 to 7.5. A good fertilization with manure is also useful. It should be done for poplar culture or, even better, for the crop which precedes it, because of the positive influence that the organic matter has on the physical characteristics of the soil.

The mineral nutrition of these plants has been studied. The absorption rhythm of minerals during the vegetative season and mineral removal at the end of the annual cycle have been considered. The absorption of the nutrients is very precocious. It has been shown that at the beginning of August at a biomass production level equivalent to 45% of the annual total production, the nitrogen absorption had already reached 72%, that of phosphorus 66% and that of potassium 85% of the total amount. Nitrogen, phosphorus and potassium are absorbed early due to a particularly intense utilization of these elements by young plants.

The quantity of nutritive substances taken from the soil is fairly high and is similar to that of a wheat culture.

If we adjust the maintenance fertilization to balance the removal of nutrients, the quantities needed are about 100 kg/ha of P_2O_5, K_2O and N_2. The quantity of nitrogen may seem insufficient but is aimed at favouring a better C/N ration in the tissues which should not be too low as it would negatively affect lignification. After coppicing, as the production of dry matter increases, the quantity of fertilizing elements should increase by 20-25%.

Young plants in stool-beds need continuous care. Weed control, fertilization, irrigation and pesticide treatments are very important.

Weed control is done both by using chemical products and conventional cultivating equipment such as clod breakers and rotary tillers.

Pre-emergent chemical weed control is done using products based on trifluralin + linuron (Nemifest or Trinulan) with doses of 0.8 + 0.4 kg/ha added to other products based on alachlor (Lasso) or metalachlor (Dual) with doses of 1.4 or 1.0 kg/ha respectively (e.g. 3.5 kg of Trinulan + 4.0 kg of Lasso per hectare or 3.5 kg of Trinulan + 2.5 kg of Dual per hectare).

Once the herbicides lose effect, about one month after application, the weeds growing along the rows are removed through hoeing and the weeds growing between the rows through mechanical work of the soil, including frequent discings, or tillage (in the soft soils). This work is done two or three times during the vegetative season, depending on the degree of weed infestation.

Control of the following insects is done: Gypsonoma, the dusky clearwing moth (*Parenthrene tabaniformis*) and the poplar weevil (*Cryptorhynchus lapathi*). For diseases, only *Marssonina brunnea* is controlled for susceptible clones.

A top dressing fertilization is done by applying the nitrogenous fertilizer (ammonic sulphate, ammonium nitrate or urea) (100 kg/ha of N) at two different times: the first time the fertilizer is spread beside the rows (when the stems are 30-40 cm high) and the second time on the whole surface (when they are about 1 m high).

The amount of water needed for growth during the vegetative season (from April to September) varies from 500 to 600 mm. In the Po Valley the average rainfall is 300 mm, thus irrigation should provide at least 200mm, distributed regularly during the vegetative season according to need. Sprinkler irrigation and flooding are the methods used.

Stool-beds allow the production of shoots of uniform dimensions, with no or few sylleptic branches, suitable for the production of cuttings with good sprouting and rooting abilities.

It is advisable to re-establish stool-beds every year in order to obtain shoots with uniform development, with many dormant buds, and that are healthy and in good physiological condition.

Coppicing can be used for a few years for the clones producing a stem with no or few sylleptic branches. Generally speaking, clones of *P. deltoides* produce many sylleptic branches, while some *P. x euramericana* clones produce only a few.

Harvesting of shoots or branches can take place anytime after leaf fall. However, it should not be done too early, unless a cool room is available where the material can be stored for several months. Decreased rooting ability and survival percentage of cuttings obtained from material collected in December and stored outside has been observed.

Collection of whips from stool-beds is done mechanically. They are cut with a circular blade at 5 cm from the ground. Whips are roughly classified according to their height and then bundled for transportation, reduction to cuttings and storage.

The optimal mean diameter of cuttings is 18-20 mm but cuttings with diameters of 15-17 mm and 21-23 mm are frequently used with good results. Cuttings having these measurements can be planted by machine. Cuttings with a diameter below 15 mm (and as low as 10 mm) or above 23 mm, are used with good results but they should be planted by hand. Cutting dimensions are not completely independent of clone or the techniques used in the production of planting stock material. *P. nigra* clones supply fairly thin whips; while *P. deltoides* clones produce very big ones, particularly after coppicing.

Cuttings can be made by hand using secateurs or mechanically with pneumatic or hydraulic scissors, or with a dedicated machine, as at the S.A.F. farms and in big nurseries. Cuttings should be prepared with a clean cut and therefore the tools should always be very sharp. The top cut should be made preferably 1-2 cm above a dormant bud in good condition and should be horizontal; the cut on the bottom should be a slanting one in order to make insertion into the soil easier.

The preparation of cuttings usually begins at the end of February for planting in March. Cuttings can be cut and then immediately planted, however, it is often advisable to separate the two operations. In order to take advantage of good soil preparation and the choice of the right time for planting, a practical solution is to store cuttings in a cool room between -2 and +2°C. The cuttings can be stored also at +4°, but only until the end of March. Cuttings of the clone

ERIDANO begin to sprout much earlier than those of the euramerican clones, at a temperature of about 4-5°C, as do most of the balsam poplars. These genotypes should be kept at lower temperatures.

It is advisable to take the material out of the cool room about one week before planting and to check their hydration condition. Dehydrated cuttings are almost always at risk of failing, particularly if the planting soil is not ideally humid. Immersion in water for at least one week can be a good remedy, as it stimulates rooting. Balsamic poplars, however, are more sensible to asphyxia. Therefore, it is necessary to avoid leaving them in water for too long a time (3-4 days are sufficient).

PLANTING DESIGN

Comparisons made on poplar plantations of the clone I-214, with densities decreasing from 10,000 plants per ha (1.60 x 0.60 m spacing) to 4,500 (1.50 x 1.50 m), 2,500 (2 x 2 m), 1,600 (3 x 2 m), 1,100 (3 x 3 m), 830 (4 x 3 m), 550 (6 x 3 m), 410 (6 x 4) and, finally, to 330 plants per ha (6 x 5 m), showed that the yearly usable wood mass produced decreases when spacing is increased but, at the same time, the percentage of valuable wood mass increases (Prevosto, 1984).

The results of a series of spacing tests carried out in plantations where cuttings were set at 18 increasing distances, on divergent rows, following the Nelder design, confirm the above as regards yields. The available area for each tree ranged from 0.807 to 30.75m^2. On a six-year rotation, production sharply decreased when density was reduced. With a density of 6,500 trees per ha, production totalled 19.65 kg/m^2 (196.5 tonnes/ha), and decreased to 12.7 kg/m^2 (127 tonnes/ha), at a density of 2,770 trees per ha. Production, expressed as biomass, is approximately 14.5 and 9.5 ODT/ha/year respectively.

It is interesting to note that production changes only moderately from a density of 2,770 trees per ha (3.61 m^2/tree) to a density of 1,176 trees per ha (8.50 m^2/tree). This result is quite important from a practical point of view as it permits operations in a sufficiently wide spacing range. For example, a density of 2,770 trees/ha can be obtained with a 3 x 1.20 m spacing and that of 1,176 trees/ha with a 3 x 2.80 m spacing. 3 m spacing within the rows is used, allowing, among other things, the employment of the most common cultivating machinery. The possibility of changing the spacing within the rows from 1.20 to 2.80 m without significant production losses, allows the use of clones with different requirements or the production of logs with varying diameters, that increase as spacing becomes greater. In fact, going from the first to the second spacing distance, the mean diameter per tree at breast height, six years after planting, ranges, on average, from approximately 10 to 15 cm, with an increase of from 20 to 70% of wood suitable for the paper industry.

In the conditions of the Po Valley, the first rotation lasts 5-6 years as do the ones following coppicing.

After coppicing it is necessary to remove all the coppice shoots except the one kept for the development of the stem. The trimming should be done before the second vegetative season following coppicing.

Two coppice shoots can be left instead of one, but the dimensions they will reach during the rotation will be proportionally smaller. The choice of leaving one or two coppice shoots depends on the end product.

For biomass, monoclonal plantations are recommended in order to increase production and to provide homogeneous material with respect to both the size of the trees and the physical and technological characteristics of the wood produced. This is very important for material used for the pulpwood and chipboard industries, but is not so important for fuel wood.

Keeping a large range of species and clones is necessary to allow the establishment of a mosaic of monoclonal plantations of limited size with the aim of reducing phytopathological risks.

SITE SELECTION AND PREPARATION

To evaluate the site it is necessary to consider soil texture, depth, availability of water and nutrients and pH.

For SRIC it is necessary to select a deep, medium-textured soil with high fertility and a pH in the range of 5.5 to 7.5. The soil should be well drained and have good water reserves (water table accessible to roots) or be easy to irrigate during the growing season.

Cultivated lands and bottom lands are suitable, while easily flooded lands are to be avoided because of the damage water could cause to the culture in the first year after planting or coppicing.

Cultivated lands are normally cleared and reasonably well-drained and they need only be ploughed at the end of summer or even just before planting, physical soil conditions and weather permitting.

Fertilization should correct any lack of nutrients, usually nitrogen, but often also phosphorus and less frequently potassium. These last two nutrients should be spread before ploughing. Ploughing should be followed by disk harrowing to prevent regrowth of weeds and to obtain a well-aired and finely textured soil, which favours the development of roots.

Poplar plantations with high densities and short rotations give high production results. After coppicing, in the rotations following the first one, production often increases because the stumps have a well-developed root system. The combination of high density, e.g. 1,000 plants/ha, with rotations of 5-6 years, regeneration via coppicing allows, in suitable sites, a production of 10 to 20 tonnes/ha/year of oven-dry woody biomass.

Coppicing is carried out in order to avoid replanting expenses (always very expensive), profiting from the resprouting ability of the stumps. Vigour and longevity of stumps are very important for the adoption of this technique.

Nevertheless, coppicing has some negative aspects:

- a larger insect diffusion on stumps, such as with the poplar borer (*Cryptorhyncus lapathi L.*) and the large poplar borer (*Saperda carcharias*);
- the on-set of physiological imbalance in competition among plants, which, in the conditions of the Po Valley, makes them more sensitive to water stress;
- diffusion of PMV, particularly among the *Populus deltoides* clones;
- the exacerbation of the phenomenon of iron deficiency in calcareous soils, particularly for the clones most sensible to this physiopathy.

In order to avoid or reduce these drawbacks it is advisable to choose the most suitable clones and soils. Very calcareous, permeable soils and soils with drainage problems should be avoided. Acid soils (pH 4-5), in which the growth of poplars is limited are not suitable. Liming the soil to correct the acidity is very expensive and previous experience has shown that it has limited efficacy.

Also the correction of iron deficiency is too expensive to justify the biomass yielded.

PLANTING

Planting methods

In the Po Valley the most suitable season to plant cuttings is mid-February to March, but this period can be extended to the whole month of April if the material is kept in cold storage at a temperature of -2 to 2°C. For one-year-old sets, both the period from the end of November to the end of December and that from mid-February to mid-March, are suitable for planting clones with good rooting abilities, while the latter is to be preferred for clones with any rooting difficulties (e.g. *P. deltoides*).

One-year-old plants are inserted into holes 60 to 80 cm deep and 15 to 20 cm in diameter, dug by an auger driven by a tractor.

Cuttings of normal length (20 to 25 cm) are planted by hand or with machines, used to plant cuttings in nurseries, while the longest ones (50 cm) are inserted into holes dug by an auger driven by a tractor.

TENDING

Weed control

Weed control is very important and includes the use of herbicides and mechanical cultivation with conventional equipment.

For 5 to 6 year rotation coppice plantations, the times at which weed control is most required are the first and the second year after planting and/or after coppicing. In following years, the thicker canopy shades out any serious competition from weeds.

Pre-emergent herbicides are used, immediately after the planting of cuttings or after coppicing but before flushing. For dicotyledons, good results are obtained with products made of trifularin + linuron (0.8 + 0.4 kg/ha) in most soft soils, or pendimethalin + linuron in more compacted soils. Other products made of alachlor (1.4 kg/ha) or metolachlor (1 kg/ha) are added to combat graminaceous plants. The herbicides are usually active 30 to 40 days. Afterwards, only methods for mechanical weed control are used.

In one-year-old plantations only a small area around the tree is treated. Where a normal harrow cannot manage, chemical treatments are used with good results:

- annual weeds are treated with products made of paraquat (0.9 - 1 kg) or diquat (1-1.2 kg/ha) mixed with other products made of trifluralin + linuron or pendimethalin + linuron in the doses mentioned earlier;
- in the case of perennial and mixed species a first treatment is done using paraquat when weeds are growing and a second treatment containing:
    - 2-4D (0.15 kg/hl) mixed with white oil in those soils where there are mainly wide-leaved weeds, possibly adding clopyralid (0.005 kg/hl) if there is any Cirsium;
    - dalapon + oxyfluorfen (0.65 + 0.21 kg/hl) in the case of perennial graminaceous plants;
    - glyphosate (0.25 - 0.4 kg/hl) for an almost total and rather long lasting cleaning, particularly with largely diffused *Artemisia*, *Solidago* or any other weeds which are hard to control if the other herbicides are used;
- in the case of shrubby weeds (*Rubus*, *Amorpha*, *Robinia*, *Clematis*, etc.) a suspension of fosamine ammonium (0.48 kg/hl) can be sprayed at the end of August.

To destroy weeds between the rows, disk harrows are used two or three times during the growing season according to the extent of the infestation and the type of weeds.

Chemical weeding should be limited to the first two years and to a narrow strip along the row, while mechanical weeding should be extended to all years and to all areas between rows.

During the second half of the first rotation and particularly during the rotations following coppicing it would be useful to compare the usual harrowing with mulching, a much simpler operation. A thick layer of leaves and other vegetable material on the ground would make it harder for weeds to sprout.

It is important to make sure that the above mentioned herbicides are also suitable for newly selected clones and to find new chemical products in order to widen the range of products useful for weed control in SRIC.

Removal of nutrients from the soil

On the basis of tests carried out in plantations of the clone I-214 we can state that the quantity of nutrients removed from the soil depends essentially on the percentage of bark and therefore varies according to the dimensions of the stems which, in turn, depend on the densities and rotations adopted. For example, a tonne of leafless biomass can contain the following quantities of nutrients:

Density (trees/ha)	Rotation (years)	N_2	P_2O_5 (kg/O.D.T.)	K_2O	CaO
75,000	1	6.9	3.1	5.2	9.0
10,000	2	5.6	2.1	4.2	7.5
277	13	1.6	0.7	2.4	5.7

We can reasonably expect that for a density of 1,000-2,500 trees per ha and rotations of 5-6 years, a tonne of woody biomass (oven dry) should contain approximately 3.5 kg of nitrogen, 1.5 kg of P_2O_5 , 3.5 kg of K_2O and 6.5 kg of CaO.

These data can be of use for an approximate definition of the maintenance fertilization needed by SRIC plantations. Obviously, it is necessary to verify these data because the quantities of nutrients removed from the soil can vary as a function of soil fertility and of clonal requirements.

Irrigation

As far as irrigation is concerned, in the Po Valley, there usually are long dry periods in July and August when, if the water table is low, it is necessary to irrigate the plantation with a total volume of about 150 mm water two or three times. The method of irrigation will obviously depend on the site, on the available equipment and water sources.

Irrigation is often an expensive operation, particularly if we consider that the wood material produced has small economic value. Unfortunately in Italy there are few areas which could be cultivated with poplars without irrigation and this represents a limit to the expansion of biomass plantations.

ENTOMOLOGICAL AND PATHOLOGICAL RISKS

Productivity of plantations for biomass production can be affected to a remarkable degree by several biotic adversities. Their effect is directly related to the specific characteristics of cultivation and to the microclimatic conditions of the plantations, as well as to the end-use of the wood material produced.

High density plantations and the resulting humid microclimate are favourable to the proliferation of parasites, such as the woolly poplar aphid (*Phloeomyzus passerinii*) and the scales (*Diaspis pentagona, Chionaspis salicis, Quadraspidiotus* spp.), which compromise the vitality of cortical tissues and therefore the survival of young shoots. Humid environments are also suitable to defoliators such as *Phyllodecta vitellinae* and to foliar fungi such as *Melampsora* spp., attacks of which result in important production losses.

Coppicing allows the establishment of a great population of harmful bark and wood boring insects on the stumps, among which the most important ones are the European goat moth (*Cossus cossus*) and poplar clearwing borer (*Parenthrene tabaniformis*). These insects are attracted by the healing tissues and cause a remarkable weakening of the tree. The large poplar borer (*Saperda carcharias*), causes similar damage. The poplar and willow borer (*Cryptorhynchus lapathi*), is considered to be serious because of the extent of damage it causes on young stems. The delicate shoots that develop after coppicing are the favourite food of *Melasoma populi*, which causes defoliation during the delicate vegetative phase of the tree.

If culture is aimed at the production of material of adequate dimensions for use in the paper industry, the poplar shoot borer (*Gypsonoma aceriana*), which is constantly present at high population levels, can cause appreciable damage, preventing development of the leader, so that a "witches broom", formed by smaller twigs, takes its place.

Finally, there are numerous parasites able to damage the poplar regardless of the culture type. Among these are the bark and wood boring insects *Agrilus suvorovi populenus* and *Melanophila picta*, frequently found on trees suffering from water stress, and the defoliators *Hyphantria cunea* and *Byctiscus* spp. Also, in the climatic conditions of the Po Valley, *Marssonina brunnea* and *Venturia populina* fungi, can cause repeated defoliations on the most sensitive clones.

Phytosanitary control in biomass production plantations causes a number of problems (not only economic) mainly due to the culture characteristics themselves. The high density prevents the easy operation of machines and a satisfactory distribution of chemical products on the stem and crown. In addition, bark and wood boring insects living in the stumps are unlikely to be reached by insecticides and are therefore able to reinfest the crop itself as well as adjacent poplar plantations.

It is advisable to control *C. lapathi* because of its highly damaging effects, by chemical spraying of the stems at the time of sprouting. Measures against the other parasites are economically and technically impossible. Their damage can be limited by carefully choosing planting sites and by carrying out, where possible, adequate tending in order to maintain the trees in a sufficiently vigorous condition, so that they can better endure the attacks.

The use of resistant poplar species and clones can be of great help in controlling abiotic adversities. For this purpose, *Populus alba*, among the indigenous poplars, shows a very high resistance to the woolly poplar aphid and to several foliar diseases, as well as a good tolerance against bark and wood boring insects (Delplanque *et al.*, 1986). Among exotic species, *Populus deltoides* is generally resistant to the aphid and to *Marssonina brunnea*. Among the hybrids, those of *P. deltoides x Populus trichocarpa* and x *Populus ciliata* give higher guaranties of resistance against *P. passerini* and *M. brunnea* than the hybrids of *P. deltoides x P. nigra*. However, it is still possible to select some interesting clones from among these hybrids.

MACHINERY FOR SRF

Equipment for making cuttings

Machinery exists for making cuttings. With this machinery it is possible to obtain cuttings with a slanted cut on the bottom and a straight clean cut on the top. The cuts are made using two opposite blades at adjustable distances. The machine works electrically and makes 27 cuts per minute. It is driven by two operators and its work capacity is 2,500 cuttings per hour.

Planting

Semi-automatic equipment is used for the planting of cuttings (Figure 1). The basic element is a track chain, with track shoes.

As it is possible to vary the chain composition, the establishment distance between cuttings on the row can be varied at will.

The machine works as follows:

On the track chain (1) the track shoes which contain the cuttings (2) are placed at fixed intervals; the operator takes the cutting from a case (4) and puts them by hand into the upper holes (3) of the boxes.

The track shoe (2) remains still once in contact with the soil. It is kept in the soil by a grip tooth. The tractor proceeds, dragging the machine frame, which causes the piston rollers to expel the cutting (7). In this way the cutting is pushed downwards and is inserted into the soil (8). The machines are equipped with a cutting shield (6). The equipment can be supplied with one or two tracks (5).

The machine is dragged and lifted (5) by a tractor having between 50 and 100 HP. The output is about 1200 cuttings per hour per each track.

Establishment of one-year-old plants

One-year-old plants, or coppice shoots, with average heights of between 2.50 and 4.50 m, are planted in holes with diameters of 15-20 cm and depths of 60-80 cm. The holes are made with an auger driven by a tractor.

This equipment is the same as that used for poplar plantations establishment in Italy.

Machines for pest control

There are two main types of equipment used in poplar plantations for pest control and they are known as "dusters" and "sprayers".

a) Dusters (Pressure dusters with oriented jet)

The most common dusters consist of a tank, a liquid circuit, and nozzles.

The pumps on the dusters have an average flow of between 20 and 60 L/min and the resulting pressure varies between 5 and 50 kg/cm.

It is necessary to use dusters for the control of the poplar weevil (*Cryptorhyncus lapathi L.*), the large poplar borer (*Saperda carcharias L.*) and the woolly aphid (*Phloeomyzus passerinii Sign.*) and in general against parasites that attack the trunks of poplars. Dusters are used for trees of small dimensions (1 to 3 years at most) or when localized treatments are required. During the first few months in a one-year old nursery, for example, before the plants reach a height of 0.8-1.2 m, it is possible to dust 4 rows at the same time using a lever with nozzles located at the width of the interrows.

b) Sprayers

While dusters only have a liquid circuit, sprayers also have an air circuit. They are very similar to dusters but, instead of ejecting droplets directly on the plant they supply air through a fan (axial, centrifuge, etc..) which sprays them onto the plant. The sprayers commonly used are of two types: pneumatic sprayers; and mechanical sprayers.

Sprayers are preferably used when extended land areas are to be treated against insects, leaf and branch diseases, both in poplar plantations (after the second or third year) and in nurseries (from the second half of the first year on). They are not suitable for treatments on single trunks, small plants or in widely-spaced plantations because of the waste of chemical.

In biomass plantations these machines can be used where the plant density is high. It is necessary to study possible adaptations for better efficiency in biomass plantations.

Spraying equipment for weed control

After the establishment of cuttings and before flushing, the whole soil surface is treated with spray equipment. The work capacity is about 1 ha/hour. The herbicide is effective from about one month, to at most 40 days. Mechanical weed control is then done with disk harrows.

At the beginning of the second growing season and in following ones, only a strip beside each row is treated with herbicide, using band spraying equipment. The work capacity of this equipment is about 1.0 ha/hour. After this treatment mechanical operations are used.

Machines for the cutting of sets in nurseries and for extraction of one- or two-year-old plants

Stems of one- or two-year-old plants are cut with hydraulic scissors set on a lifter arm of a tractor.

A special plough is used for the extraction of one-year-old plants.

Machine for soil discing

In widely-spaced plantations, 3 x 3 m for example, disk harrows are used. These machines allow the discing of the total surface, including between plants in a row. In this way a second discing across rows is not required.

Machines for stump extraction

There are two types of machines used in Italy for stump extraction:

a) half-destroying cylinder. Once put on the stump it extracts the inner part of the stump and no soil. This part of the stump can be used by wood industries. The remaining part of the stump (roots included) is then broken into pieces and these pieces are left on the site. The half-destroying cylinder has an internal working diameter of 350 mm, while the external breaking is done for a diameter of 1200-1300 mm.

b) auger. Once put on the centre of the stump it breaks it into pieces and the pieces are then left on the site. This machine has a working diameter from 900 mm to 1500 mm.

The technical features of the equipment follow:
power absorbed: 100-110 HP
weight: 2950 kg
mean number/hour extraction: 70-80
mean number/hour breaking: 60-80.

Machines for harvesting operation

The same equipment adopted for conventional plantations is used for plantations having densities between 1,000 and 2,500 trees per ha and 5-6 year rotations. These include the chain saw for felling, buckets for loading logs and pitchforks for amassing branches.

In Italy this mechanization is not very advanced; an improvement of efficiency and a reduction of costs are therefore necessary.

ECONOMIC SITUATION FOR SRF

For the time being, it is rather complex in Italy to evaluate the economic outlook of short rotation poplar culture aimed at producing material of small dimensions. It is, in fact, difficult to foresee how industry will react to a new product which is being offered to the market in a substantially different way from that which has been done so far. The most commonly adopted cultivation models strictly respond to the requirements of the market. The wood destined to the manufacture of pulp for paper production or chipboard can be considered as "by-products" of the production of timber suitable for the veneer industry (Borelli, 1989). The economic features of these materials would presumably be different if they were placed on the market as real "products". The monetary return to poplar growers would probably change as a result of an activity specifically aimed at the production of small-size material.

It is worth trying to examine the ability of the market to absorb these products, on the basis of available data concerning the wood consumption of industries manufacturing pulp and paper and chipboard (R.E.S.S., 1984).

If we take into account only industries producing mechanical pulp, where poplar wood consumption reaches significant values, we can observe how strongly Italy depends upon foreign supply. Italy imports 204,000 tonnes out of the approximately 416,000 tonnes used. The most important reason for these industries to import timber is the insufficient level of domestic production, not price competition. Therefore, there are sufficiently large opportunities to use suitable poplar material from internal production.

The situation of the chipboard industry is completely different: in this case poplar wood, representing a little more than 50% (924,000 tonnes) of the total consumption, comes almost exclusively (869,000 tonnes) from domestic supplies. However, it is interesting to observe that round wood represents 55% of this value, while the remaining quota comes from waste from other conversion industries. It is probably within this consumption quota that it will be possible to sell round wood, produced for the purpose, provided the price is competitive.

If we examine Table 1, based on the above mentioned research by R.E.S.S., it is possible to observe a substantial homogeneity in the way poplar wood is distributed according to classes of purchase price. The use of chips and residues could be explained by an insufficient quantity of logs rather than by economic convenience.

Taking the above considerations into account, we believe that there are real chances to place poplar material of low dimensions coming from SRF cultivation on the market; 500-600,000 tonnes per year could be the maximum quantity. Assuming an average production at rotation of approximately 150 tonnes/ha, this means, in terms of area, that we need approximately 3,600 ha to be felled yearly and therefore, for rotation lengths of 6 years, the total area covered should be at least 21,000 ha.

This is a large area, considering the Italian poplar culture reality, especially if we consider the present unfavourable conditions that have caused, in the last ten years, a continuous decrease in plantations. It is therefore evident that large investments will only be made if these are highly profitable crops, especially with respect to competition from other valuable crops for fertile soils. These conditions make it economically impractical to dedicate plantations for the production of fuel wood.

It is therefore necessary to examine the cost-benefit ratio of this particular cultivation model. This is particularly difficult in the absence of reference points, not only for the intensity of tending to be carried out but also the interest rate, and the sale price of the final product.

The values used in Table 2 refer to well known examples of poplar farms in the Po Valley; therefore, the results obtained have to be considered as merely indicative. The table shows that the economics of a short rotation poplar plantation are not favourable, especially because of the high planting costs. Even if these costs were drastically reduced in successive cycles as a result of coppicing, poplar tree growers would have to support a heavy liability. The use of cuttings would certainly reduce the costs, but a concurrent reduction in production would also occur.

Only on the best sites, with yields of approximately 270 tonnes/ha, would it be possible to have positive annual land revenues estimated around 500,000 and 1,000,000 thousand lire per ha at the end of the first and second rotation respectively.

These economic estimates, although only speculative, do not allow one to reach an optimistic conclusion on the possibilities of developing short rotation poplar culture. It is not practical in the present market situation of poplar wood. The establishment of professional agreements between producers and users could guarantee a minimum price to the producer which would have to be at a level sufficiently high to guarantee an income comparable to that of other crops. On the other hand, sale prices would also have to be comparable to similar raw materials, produced with different systems, in order to be competitive on the marketplace. For the time being, the margin separating these two values is so high as to make it very hard to foresee a positive future for the development of SRF models on a large scale.

EXTENSION IN SRF

Within the framework of the International Poplar Commission of the FAO, the Italian National Poplar Commission (NPC) was constituted in 1969 under the supervision of the Ministry of Agriculture and Forests.

The main aim of the NPC is to promote the development and the improvement of poplar culture. Specifically, the NPC:

a) advises poplar growers on how to choose planting and propagation stock material: studying and implementing rules for varietal testing and to control the identity and quality of material;
b) studies and promotes, legislative and administrative measures necessary to encourage and to protect poplar culture;
c) encourages and co-ordinates research and experimentation activities, promotes exchange of information on results obtained by research institutes or by private poplar growers;
d) promotes the best cultural techniques stressing the importance of more extensive and effective mechanization and the efficient control of parasites; promotes the establishment of growers associations, according to the regulations of the EC Council to reduce production costs; directing production towards the needs and the demands of industry;
e) promotes co-operation agreements among poplar growers and the industries which utilize wood and promotes market research in order to determine the product prices;
f) proposes to the International Poplar Commission of the FAO the registration of new clones after testing the identity, bio-ecological and technological characteristics using established procedures;
g) co-operates with the International Poplar Commission of the FAO and with the national poplar commissions of different countries and takes part in all research, scientific and economic-industrial investigations aimed at promoting the development of poplar growing;
h) participates in the standing Executive Committee and in the meetings of the International Poplar Commission of the FAO; and
i) organizes meetings and study tours in Italy and participates in similar activities abroad.

Regional poplar committees have been set up by the respective regional councils, with the goal of promoting these initiatives at the regional level, in those regions particularly interested in poplar growing (Piemonte, Lombardia, Veneto, Emilia-Romagna, Friuli-Venezia Giulia). For each regional Committee one member is appointed from among the ISP researchers by the SAF.

In Italy the production for sale and the sale of propagation and planting stock material for the establishment of poplar plantations are regulated by law. Poplar clones are registered in the National Register of Forest Clones. For this purpose poplar clones must meet cultural, biological and technological requirements before they can be distributed for reforestation and for wood plantations. These requirements are outlined in law. This law also issues general guidelines to be followed in the testing of propagation materials.

The identification, behaviour and production characteristics to be examined have been determined by the Minister for Agriculture and Forests following the advice of the National Poplar Commission; they are listed below:

- morphological characters
- production and growth
- rooting of woody cuttings
- rooting of plants
- adaptation to the environment
- response to cultural practices
- resistance to climatic adversities
- resistance to biotic adversities
  . infectious diseases
  . insects
- wood characteristics.

Experimental guidelines are outlined for the execution of tests and the following Institutes are appointed:

- Istituto per la Ricerca sul Legno, Firenze (I.R.L.)
- Istituto Sperimentale per la Selvicoltura, Arezzo (I.S.S.)
- Centro di sperimentazione Agricola e Forestale, Roma (C.S.A.F.)
- Istituto di Sperimentazione per la Pioppicoltura, Casale Monferrato (Poplar Research Institute, P.R.I.)

The third and the fourth institutes listed are run by SAF (Società Agricola e Forestale per le piante da Cellulosa e da Carta) and they carry out research activities for the E.N.C.C. (Ente Nazionale per la Cellulosa e per la Carta). E.N.C.C. is controlled by the Industry Ministry and is financed through a contribution from money earned from paper and carton chipboard destined to the national market.

Research projects on poplar are coordinated by the Poplar Research Institute. Until 1988 research activities in south-central Italy were carried out by the CSAF in Rome. However, other national research institutes co-operate with the Poplar Research Institute, particularly as far as specific problems are concerned. The P.R.I. participates also in international projects.

In the past, assistance to poplar growers by E.N.C.C. throughout Italy was free and was provided by the research institutes. With the passage of authority for forestry from the State to the Regions, the E.N.C.C. stopped assisting the poplar growers directly and the funds destined for this purpose are directly managed by the Regions. The Regions use these funds to make contributions to poplar growers both for establishment costs and for the control of pests, particularly *Marssonina brunnea*. The funds can also be used for other kinds of interventions such as the establishment and tending of demonstration poplar plantations that can be of great interest for the acquisition of technical information.

ISP is playing a leading role in extension through the establishment of pilot and experimental plantations on private farms. It selects farms that represent the environmental conditions of a specific area. This network of poplar plantations stretches over most of the representative poplar growing areas of the Po Valley. The pilot polyclonal plantations are visited by poplar growers and the technical information regarding appropriate choice of clone, tending operations and control against pests is available.

By request of the Poplar Growers Associations, researchers from the Poplar Research Institute give lectures on technical topics. By request of single growers, P.R.I. researchers give assistance and advice regarding specific problems.

Inspections are preferably made on farms buying propagation and planting stock material from the S.A.F., but sometimes are also performed at private farms that are not customers of the S.A.F., even if though this assistance is the responsibility of the Regions. Regions often do not have workers skilled enough for these tasks and therefore assistance is actually given by the staff of the S.A.F., research Institutes and particularly by the P.R.I.

As for diseases, poplar growers also consult experts of regional observatories for plant diseases.

In Italy, none of the bodies in charge of the promotion and the defence of poplar cultivation (N.P.C., Poplar Regional Committees) nor the Poplar Growers Associations, take initiatives in favour of biomass plantations. Only the Poplar Research Institute has been working on a research project for ten years, in consideration of a future change to this situation. The aim of this project is to find out solutions for technical and biological problems related to biomass plantations.

In any case, it is clear that the solution of technical problems will not be enough to ensure the success of this type of plantation; only the market and therefore the economic profitability will decide the success or the failure of plantations for biomass production.

Taking into account this situation, it is obviously premature, in Italy, to begin a specific extension programme in SRF.

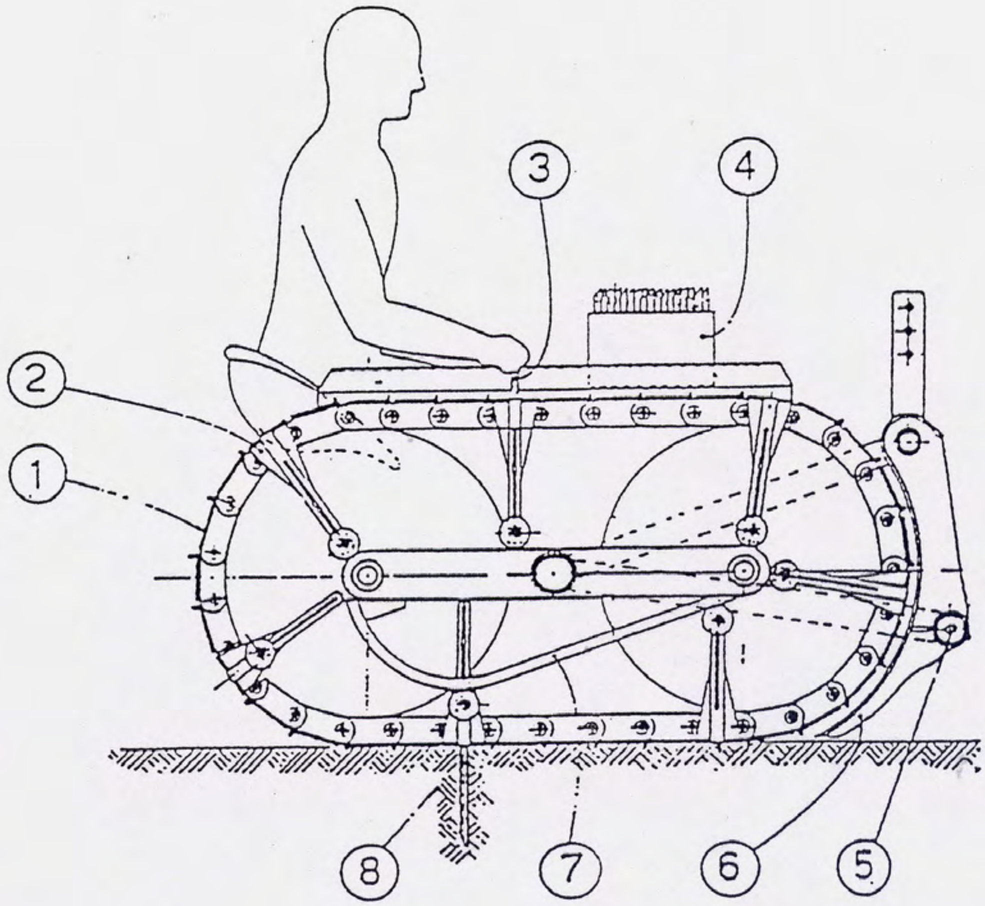

Figure 1. Semi-automatic planting machine for cuttings

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Table 1 Market price of wood in Italy in 1981 by species, wood product type and price class. Case frequency in census of chipboard industries.

CASE FREQUENCY

PRICE CLASS	Conifers L	Conifers C	Conifers R*	Poplars L	Poplars C	Poplars R	Other Broad-Leaved Trees L	Other Broad-Leaved Trees C	Other Broad-Leaved Trees R	Total
lire/tonne										
40,000	1	1	1	1	-	1	2	1	-	8
40-50,000	3	-	3	9	3	6	4	1	3	32
50-60,000	5	5	9	14	10	9	5	5	3	65
60,000	-	-	3	4	3	2	2	-	1	15
Total	9	6	16	28	16	18	13	7	7	120

*L = logs
C = chips
R = residues

Table 2 - Cultivation costs (in thousands of lire) for one hectare of densely-spaced poplar plantations.

	YEARS					
LIST OF COSTS	1	2	3	4	5	6
Site preparation	300					
Lay-out and hole -digging	500					
Stock purchase (£ 2,200 each)	2,860					
Delivery and planting	800					
Mechanical weed control	270	270	270	270	270	270
Chemical weed control	70	70				
Irrigation	450	300	300	300	300	300
Pest and disease control	50	130	130			
Fertilization	150		120		120	
TOTAL	5,540	770	820	570	690	570
CAPITAL AND COMPOUND INTEREST (r = 0.07)	7,644	1,009	1,004	653	738	570

TOTAL COST: £ 11,618,000
TOTAL PRODUCTION: 150 tonnes
AVERAGE VALUE: 50,000 £/tonnes
TOTAL INCOME: 7,500,000