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Nursery production and stand establishment of broad-leaves to promote sustainable forest management

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Preface

Over recent years, the level of new forest planting has increased considerably. This is primarily due to the commitment in many countries to extend the forest area or to rehabilitate degraded forest ecosystems and to reclaim disturbed sites for forestry, also with the aims to maintain and increase biodiversity, to mitigate global climate changes.

In addition, the market of the forest nursery stock has changed: nurserymen are requested to produce planting stock of high quality standards, of a wide variety of species, of native species and local provenances, and of broad-leaves rather than conifers.

The conference held in Rome in 2001, whose proceeding we have the pleasure to edit, brought together scientists, forest managers, policy advisors, private nursery entrepreneurs and producers of nursery equipments. The proceedings present biological results and technical solutions regarding nursery production and stand establishment of forest broad-leaves from projects and activities all over the world.

With participation from 20 different countries the conference and this proceeding will be a landmark for people interested in nursery production and stand establishment of broad-leaves in order to promote sustainable forest management.

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A. NURSERY OPERATIONS

1. A machine to cut poplar sets into cuttings

P. Balsari[1], G. Airoldi[1] and G. Facciotto[2]

Summary

The establishment of short rotation forestry (SRF) plantations for the production of biomass: a) allows the reduction of excessive production of food crops and b) from the environmental point of view, makes the production of energy sustainable (at preesent 90% of energy is produced by the traditional fossil fuel throughout the world). The economical sustenance of this type of cultivation requires low cost techniques during and after the establishment of the plantation. One of the most demanding operations when establishing poplar plantations for Short Rotation Forestry is cutting sets into cuttings.
A little over 600 cuttings · h^{-1} (5 s · $cutting^{-1}$) were produced using traditional techniques (taking into consideration the position of the buds). This level of productivity is acceptable on small surfaces like the ones used to produce cuttings in nursery. It is however considered too low in the case of establishing poplar SRF plantations.
In order to increase productivity, the Mechanical Division of the DEIAFA, together with the Istituto di Sperimentazione per la Pioppicoltura and the Berni Company, and with the financial support of ENEL-CRAM, designed and developed a machine to produce cuttings, taking into consideration the safety of the operator.
The system of producing cuttings is schematically made up of: a) a plastic wrapper which encircles some sets automatically; b) a circular saw, provided with a 500 mm diameter blade with necessary protection; c) a feeding system; d) a pre-determining system of cutting lengths and e) a spraying system to paint one end of the cuttings so that they can be inserted in the transplanting machine correctly.
The machine can produce cuttings of different lengths from 20 to 40 cm, put together in 15-20 units which are dropped in special containers.
During a series of tests carried out with one-year old poplar sets the machine produced over 3000 cuttings·h^{-1} which corresponds to 1,2 s · $cutting^{-1}$.
If this machine were used for SRF in a 100 ha, 8-year rotation plantation, the cost of producing cuttings would drop by 22% when compared to the traditional system.

Keywords: short, rotation forestry, cuttings, poplar, machine.

Introduction

Short rotation forestry (SRF) plantations for the production of biomass have a double target: reducing surplus agricultural production and, from the environmental point of view, provide an alternative source of energy (Christopherson, 1989), 90% of which is generally provided by the traditional fossil fuel throughout the world. Following the regulations of the European Community, which are aimed at reducing the excessive production of food crops, about 800.000 hectares of this type of production will be gradually eliminated during the next few years in Italy. A specialised type of forestry that provides an alternative source of energy

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should cover these surfaces. This solution will increase the income of farmers and the local economy will benefit all around. At the same time, utilizing alternative energy will determine considerable environmental advantages which include a significant reduction of CO_2 in the air (Paine et al., 1996; Bruzzi et al., 1996; Rosch e Kaltschmitt, 1999).

This renewed alternative energy source which can be obtained from SRF for the production of woody biomass is only at the preliminary stages in our country, whilst in North European countries (Danfors, 1994; Toivonen e Tahavanainen, 1998) it is a reality. The Scandinavian countries set up a technique in growing trees at high density (8000-10000 cuttings · ha^{-1}), using a completely mechanised method of planting cuttings and harvesting woody biomass crops (Danfors, 1992).

The realisation of this type of plantation with poplar clones has not been very easy as far as preparation and planting of cuttings is concerned (Facciotto and Schenone, 1998). The methods or equipment used to obtain cuttings from sets are characterized by low productivity and although they can be considered sufficient for nurserymen, they do not meet SRF requirements. After carrying out an evaluation of the productivity of the equipment actually used to subdivide sets into cuttings, a special machine has been set up to increase this parameter complying with regulations regarding the safety of the operator.

The machines presently used to produce poplar cuttings

In order to evaluate the working capacity for the subdivision of sets into cuttings, the following equipment was utilised: a) pneumatic shears; b) alternating blades; c) band sawing machine.

The working period of both machinery and labour force was determined following the CIOSTA method for a period of about 2 hours in the case of the alternating blades machine and 30 minutes in the case of other equipment.

Garden shears could be used to obtain cuttings from sets and pneumatic shears could be used to decrease fatigue for the worker. This type of equipment facilitates the cutting according to the position of the buds and the operator freely chooses the length of each cutting, which is parameter difficult to standardise. This equipment was characterized by a work capacity of a little more than 500 cuttings per hour of labour (7,2 $s \cdot cuttings^{-1}$).

The utilisation of alternating blades machine allows to even dimensions of cuttings. Such equipment is composed of two cutting elements (one on each side of the machine), a swinging blade and a fixed counter blade placed can be operated by means of a crank moved by a three-phase electric engine with a nominal power of 0,5 kW. Each of these cutting elements is composed of two fixed blades found at a reciprocal distance of 19,5 cm. The workers who have to conduct this operation (one for each type of cutting) place the sets and the blade in a position equal to a distance of 1,5-2 cm from the first bud. The work capacity of this machine was of 630 $cuttings \cdot h^{-1}$ (5,7 $s \cdot cuttings^{-1}$).

In both the equipments analysed, the time factor is acceptable for producing cuttings for nurserymen, but decidedly too much for the establishment of a plantation.

The use of a band sawing machine allows to reach a productivity near 2.700 $cuttings \cdot h^{-1}$ when operating on bundles of 15-20 sets without taking into consideration the position of each bud. However, the use of this type of equipment cannot be proposed as it is not in conformity with the laws in force regarding safety measures for the operator.

The machine developed

In order to achieve productivity levels similar to those obtained by the band sawing, a machine was designed and developed in collaboration with the Berni Company and with the financial support of ENEL-CRAM. The equipment was designed in accordance with the laws in force regarding safety measures for the operator.

The production system of cuttings is composed of a wrapping machine, a circular saw, provided with a 500 mm diameter blade which functions with an engine of 6 kW, equipped with

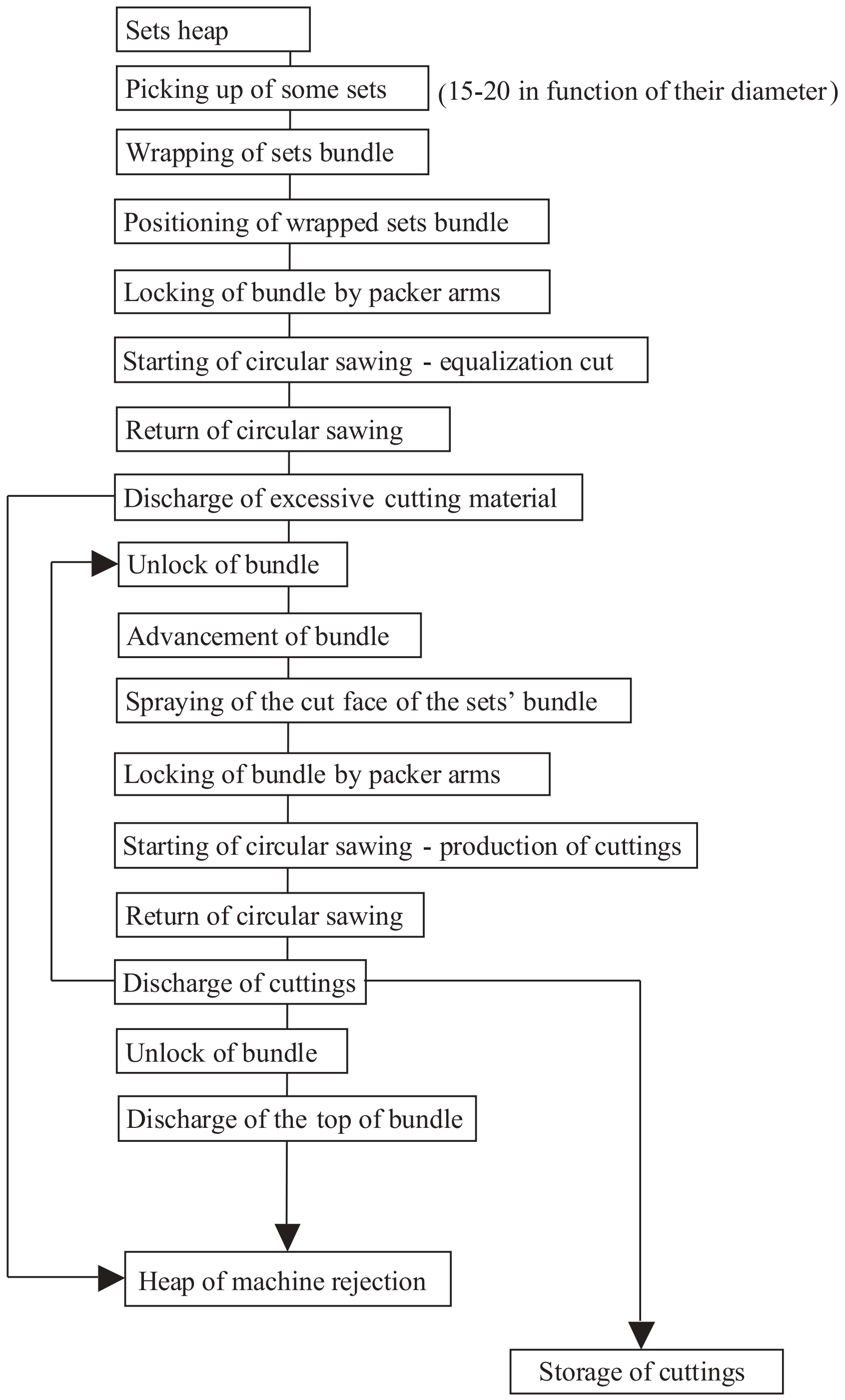

Figure 1: Work sequence necessary for the production of cuttings with the prototype made by the Berni Company.

the necessary protection, a feeding and predetermination of cutting lengths system. The machine operating procedure is pointed out in Figure 1.

After having taken 15-20 sets, the operator inserts them into the wrapping machine, which covers the sets with a plastic film.

These are then placed on a roller conveyor and transported towards the cutting system. The system for the determination of the length of cuttings makes it possible to vary the terminal po-

sition of the bundle with respect to the circular blade and in this way cuttings of various lengths (from 20 to 40 cm) can be obtained. The cutting machine is turned on by means of two press buttons, placed on the sides of the control board, and both hands of the operator are occupied on the board while the blade is operating. An electronic device starts off a series of mechanisms controlling the blocking of the bundle and the spraying of natural colour on the basal part of it. At this point the circular blade starts to operate cutting the bundle and the cuttings are then dropped on the ground or in a special container (Figure 2).
During a series of trials, this equipment reached a working capacity of more than 3.000 cuttings·h^{-1}, with a productivity increase of 10% with respect to band sawing and 5 times more to that obtained from the system which produces cuttings according to the position of the bud (Figure 3).
The painting of the basal part of the bundle is very important for the positioning of each cutting in the application device of the planting machine. This determines time reduction during the operation up to 15% with respect to the unpainted cuttings. It is easier to handle bundles of cuttings instead of single cuttings (Figure 4).

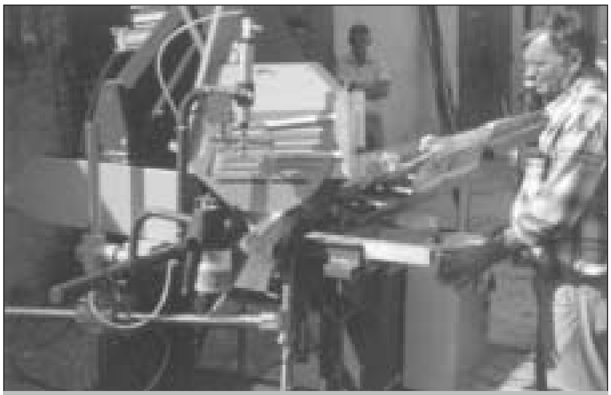

Figure 2: A particularity of the cutting of a bundle of sets wrapped in plastic film.

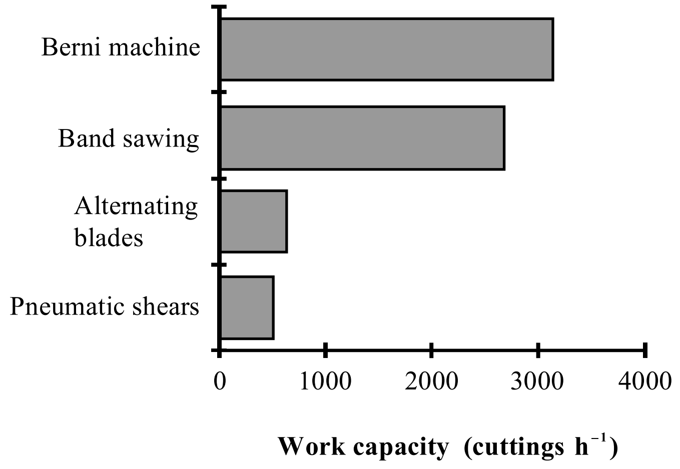

Figure 3: Comparisons on the work capacity of the equipment used for the subdivision of sets into cuttings.

Figure 4: A particularity of the bundle of cuttings wrapped in plastic film and painted on the bottom face.

Conclusions

This machine can produce 30 cm cuttings instead of 20 cm (the present standard size) which can improve rooting and the production of woody biomass. However using 30 cm cuttings reduces the number of cuttings that can be obtained from a set (from 5-6 to 3-4).
On the other hand the use of this ma-

chine in a SRF plantation with a surface of 100 hectares having a rotation of 8 years and taking into consideration a market price of 7,500 *EUROS*, can reduce the actual production costs from 4,4 *EUROCENTS* cutting^{-1} to 3,5 *EUROCENTS* cutting^{-1} (22% less).

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2. Operative and economic evaluation of machines for planting cuttings

P. Balsari[1], G. Airoldi[1] and G. Facciotto[2]

Summary

In order to determine suitable machinery for planting cuttings in a Short Rotation Forestry (SRF) poplar plantation, a two-year experimentation with *Populus canadensis* 'I-214' was conducted in a typical poplar area located on the West side of the River Po Valley. In the trial different transplanting machines were compared as for quality and capacity of work and relative costs.
Four different types of machines were tested during the trial: a Rotor semi-automatic transplanter, a Quick-wood forest planting machine, a Salix Maskiner step planter and a Berto planting machine.
All four types were used on the same field having sandy soil, previously ploughed and harrowed. The field was sub-divided into smaller plots 7,2 m wide (four rows) and 250 m long. All the machines were set to operate with spacing of 180x70 cm, corresponding to a total establishment of 8.000 cuttings$\cdot$ha^{-1}. The cuttings were planted in such a way that they did not emerge from the ground for more than 2 cm. Twenty cm long cuttings, cut just above the first bud, were utilised for the Rotor, Quick-wood and Berto planting machines. The Salix Maskiner was fed with sets and was regulated to plant 20 cm cuttings.
Rooting rate, determined 90 days after transplanting, was near 83% in the case of the Rotor machine and under 63% for the other transplanters. The Salix Maskiner Step planter was able to plant over 6.300 cuttings in one hour, while the working capacity of the other machines was significantly inferior (under 1.300 cuttings $\cdot$ h^{-1}). In brief the experimentation pointed out the technical and economical validity of the Rotor semi-automatic planting machine, especially when used on smaller surfaces (2-7 ha). The Salix Maskiner step planter is far more interesting as it is more convenient when used for planting poplar sets on larger surfaces (7 ha).

Keywords: transplanting machine, poplar, work capacity, cost.

Introduction

The mechanization of cultivating coppices in Short Rotation Forestry (SRF) requires specific cultivation techniques. Due to the low value of the material produced (used only as a source of energy), the costs of production and transport weigh heavily on the balance of these crops. For this reason, researches conducted in North European Countries were directed towards the development of cultivation techniques and equipment that would limit costs of production by reducing work requirements. In many countries prototypes and commercial models of equipment for harvesting the product were examined, as the mechanization of harvesting, owing to the small size of the boles, is of significant importance for this type of cultivation (Lyubomir, 1988). Unfortunately, very little importance was given to the production of cuttings and the establishment of the plantation. The most interesting solutions on this subject were discovered and applied in North European Countries (Pitterie, 1992 and Doehrer 1995), with vegetative

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material (*Salix* genus in particular) and in environmental conditions (climate and soil) very different from those found in Italy.

The cost of the production of propagation material and the cost of establishing plantations significantly affect the global production cost of woody biomass as this type of cultivation is characterized by a considerable investment of plants (from 3.000 to 20.000 per ha). Furthermore, it is advisable to take into account the nature and requirements of the operations to be carried out before and after establishment of the vegetative material, the outcome of which is of fundamental importance for a successful cultivation (Christopherson, 1989 and Friedrich, 1995).

In order to determine suitable machinery for planting cuttings in a Short Rotation Forestry (SRF) poplar plantation, a two-year experimentation with *Populus canadensis* 'I-214' was conducted in a typical poplar area located on the West side of the Po Valley.

Materials and methods

Four different types of transplanters were examined:

- Rotor semi-automatic transplanter;
- Quick-wood forest planting machine;
- Salix Maskiner step planter;
- Berto planting machine.

All four transplanters were used in the Experimental Farm 'Mezzi' of the Istituto di Sperimentazione per la Pioppicoltura (ISP) at Casale Monferrato, on the same sandy field, which was previously ploughed and harrowed. The transplanters were used in plots 7,2 m (4 rows) wide and 250 m long.

The cuttings of *Populus canadensis* 'I-214' were planted on April 4 1997. The planting machines were set so that the cuttings were planted with a spacing of 180x70 cm for a total of 8.000 cuttings · h^{-1}.

The cuttings used for the Rotor semi-automatic transplanter, the Quick-wood forest transplanter and the Berto transplanter, were 20 cm long and were cut just above the first bud. The Salix Maskiner was fed with sets and arranged in order to plant 20 cm long cuttings at a distance of 70 cm.

The **Rotor** semi-automatic transplanter is composed of a track chain made of 42, 10 cm wide, track shoes, each with a cylinder having a diameter of 5 cm. In each cylinder there is a piston with a 23 cm stroke with 2 pulleys. The track is stretched by the recoil spring idlers driving the track and connected to the machine frame. When the track shoe is on the upper part of the track chain, the piston slides down, owing to its weight, allowing the operator to introduce the cutting in the cylinder. While the tractor pulls the machine, the track plates are moved towards the truck roller and the pulleys linked to the pistons start rolling on the inclined rail connected with the truck roller shield. So the piston moves down pushing downwards and inserting the cutting in the soil. The spacing on the row can be varied with a step of 10 cm by blocking a certain number of pistons. The machine is equipped with two seats and two holders for the cutting cases (each containing about 500 cuttings). During the trials the machine was attached to a tractor having a nominal power of 44 kW. For the establishment of a SRF plantation with a distance of 70 cm between cuttings 6 pistons out of 7 were blocked. In such operating conditions a crew of 3 people were necessary – the driver, a man on the machine to put the cuttings in the cylinders and a third person at the headland to fill the cases and supply the planting machine with cuttings (Figure 1).

The **Quick-wood forest transplanter** was expressly developed to plant forest species in compact soil. It is a rear mounted machine and is equipped with a hydraulic system operated by the tractor PTO. The planting element consists in a furrow maker, with a wing on each side of the shovel and a pair of prehensile fingers in the rear side of the straight steel bar. The planting element is driven by a double effect hydraulic cylinder - controlled, thanks to a foot lever, by the operator - and may assume a filling position (parallel to the ground) and a planting one, with a forward rotation of 90 degrees. In the rear of the frame, 2 press wheels determine

Figure 1: The Rotor cuttings transplanter used in the trial.

the depth of the furrow and pack the soil at the sides of the cuttings. On the left side of the machine there is the seat for the operator and the support for the case in which cuttings are placed. The distance between the cuttings varies depending on the tractor speed and the planting frequency (Figure 2).

The **Salix Maskiner step-planter** is characterized by 2 planting units, operated by a central transmission shaft, driven by the PTO of a tractor of at least 60 kW. The distance of the cuttings along the rows is controlled by the variation of the position of a pulley with respect to the centre of a clutch disc, in order to change the planting frequency (Figure 3). This machine operates directly with sets, which are inserted between two rubber belts that lead them towards the planting shoes, in the lower part of the system. The sets are then cut into cuttings by the machine, which pushes them vertically in a narrow slot opened by a disc opener. Behind the planting unit two press wheels close the slots. Cutting lengths can vary from 10 to 20 cm with steps of 2 cm. The diameters of the sets should range from 8 to 20 mm while the length should be of 800-2.500 mm. The feeding of a cutting and planting system unit requires the presence of an operator to bring the sets one after the other in the planting device.

Figure 2: The Quick-wood forest transplanter used in the trial.

The **Berto planting machine** is equipped with one working unit only. This transplanter can be used for cuttings and seedlings up to 55 cm in length and with a diameter up to 30 mm. The planting unit, composed of a drive wheel with prehensile fingers to hold cuttings, operates when lowered to the ground. The cuttings are placed in a furrow, made by a furrow maker; the soil is then packed firmly by adjustable press wheels. Every Berto planting unit – furrow maker, planting wheel, press wheels, operator seat and cuttings cases – floats independently in its frame, so that the unit can adjust itself automatically to the irregularities of the ground (Figure 4).

The working time of both machines and labour for-

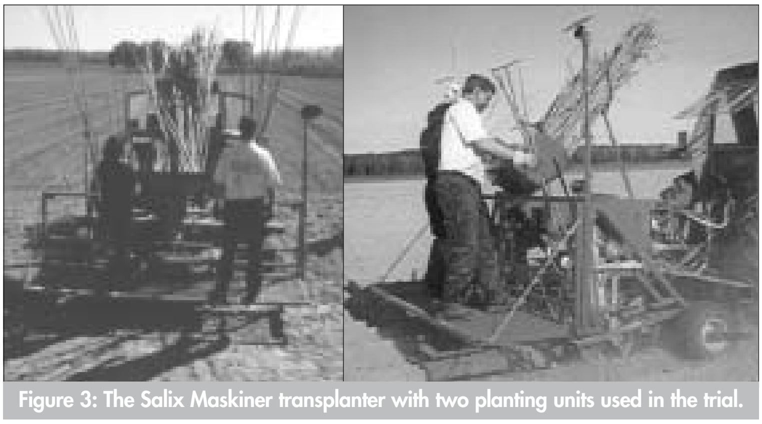

Figure 3: The Salix Maskiner transplanter with two planting units used in the trial.


Figure 4: The Berto transplanter used in the trial.

ce were recorded on the field, following CIOSTA (Comité International d'Organisation Scientificue du Travail en Agricolture) indications, on areas of at least 5.000 m², and for period not shorter than 2 hours.

The work quality was expressed as rooting percentage of cuttings planted by each machine, determined 90 days after planting, and in terms of production of oven dry (OD) biomass at the end of the second growing season.

In the case of the Salix Maskiner the following parameters were recorded:

- distance between cuttings planted;
- size of cuttings;
- distance of the first bud from the top of the cutting;
- number of cuttings damaged.

As regards the economic evaluation, the cost of each machine per hour was determined using the method proposed by Ribaudo (1977), with prices updated in 2000.

An annual utilization of 500 hours was adopted for tractors, and the power requirement was calculated by taking into consideration data recorded during experimentation and the drawbar pull and power absorption under different operating conditions in which the tractors were used. The cost of tractors per hour was determined considering each cost item, labour cost included, and applying the computing procedure implemented by the Mechanics Section of DEIAFA (Piccarolo 1989).

In particular, it was determined that the Rotor machine can be utilized with only one operator for positioning the cuttings (work capacity 1650 $m^2 \cdot h^{-1}$ and 3 workers). For the Salix Maskiner, a model with only one working unit was assumed (working capacity 4.600 $m^2 \cdot h^{-1}$ and 3 workers).

Results obtained

Working capacity of machines

The **Rotor machine** reached a working capacity of nearly 1.300 cuttings · h^{-1}, required 49,2 work-hours · ha^{-1} and during the trials did not reveal any problems.

The **Quick-wood forest transplanter** presented significant problems in adjusting to operative requirements, particularly because it lacked an efficient system for determining distance between the cuttings, and was characterized by a slow upward and downward movement of the planting device. Both these factors resulted in a low working capacity (680 cuttings · h^{-1}) and, subsequently, a high labour requirement (about 70,2 work-hours · ha^{-1}).

Even though the **Salix Maskiner step-planter** demonstrated a high working capacity (over 6.300 cuttings · h^{-1}, 4-5 times superior to the other transplanters used in the trial) and a low request of labour (10 working-hours · ha^{-1}), it presented several operative problems, such as:

- the planting system required a series of adjustments in function of the tractor speed and PTO rpm to operate with the required planting distances;
- the system to determine the length of cuttings was not efficient, as it produced cuttings of different sizes;
- the excessive speed of the planting device often resulted in cutting breakage in dry soil during experimentation;
- the belts transporting the sets to the cutting and planting system caused the loss of some buds.

During the trials this machine planted cuttings characterized by a length of 20,5 cm (±2 cm), the first bud with 3,4 cm (± 1 cm) far from the top cut and with a spacing of 71 cm (± 6,6 cm). About 20% of cuttings, especially those with small diameters, were broken or damaged.
With the **Berto transpalter** a working capacity of 1.250 cuttings · h^{-1} was obtained (Table 1).

Table 1: Operative characteristics of the planting machines utilized

	Rotor	Quick-wood	Salix Maskiner	Berto
Rows distance (m)	1.8	1.8	1.8	1.8
Cuttings distance (m)	0.7	0.7	0.7	0.7
Forward speed (km^{h-1})	1	0.5	4	1
Workers (n)	4	3	4	3
Working capacity (m^2h^{-1})	1626	854	8028	1567
Total time TU	100.0%	100.0%	100.0%	54.5%
Avoidable loss time TME	3.8%	2.0%	3.1%	2.0%
Net working time TO	96.2%	98.0%	96.9%	52.5%
Effective time TE	90.3%	94.9%	55.8%	47.5%
Turning time TAV	3.8%	2.0%	15.5%	4.0%
Provision time TAS	2.2%	1.1%	25,7%	1.1%
Working capacity (cuttings h^{-1})	1290	678	6372	1244
Required time (s. cutting^{-1})	11.2	15.9	2.3	8.7

The main problem noted during the trials was the blockage of the furrow maker when the equipment was lowered suddenly, for example after turning headland. This movement required a lot of attention and this reduced the working capacity of the machine.

Technical and economical evaluation of the machines utilised

The rooting percentage 90 days after planting was of about 83% with the cuttings planted by the **Rotor** machine whilst it was always below 60% with the other machines. The low rooting level (normally in the Farm 'Mezzi' the percentage of rooting of *P. canadensis* 'I-214' reached 98% with the Rotor machine) was caused by the particularly adverse environmental conditions during the trial. The soil water content was very low at planting and the first rainfall of that year was at the end of May. The results obtained with the **Berto** and **Quick-Wood** machines were even worse because during the planting operations these machines moved the soil near the cuttings and this caused a further reduction of the water content in the soil (Figure 5).
The reduced rooting level of the cuttings planted with the **Salix Maskiner** machine was due to cutting lengths (which were not always regular), random cutting of the sets (without taking into account the position of the bud) and damage of cuttings. The biomass obtained at the end of the second growing season once again demonstrated the technical superiority of the Rotor semi-automatic machine; in fact an average production of a little more than 10 ODt $ha^{-1}year^{-1}$ was registered (Figure 6).
As regards working capacity, the highest productivity level was obtained with the Salix Maskiner planting machine – with over 6.300 cuttings planted in one working hour. The other machines clearly showed a lower working capacity – less than 1.300 cuttings · h^{-1} (Figure 7).
From the economical point of view, the Rotor machine proved to be the most remunerative in the case of SRF planted areas between 2 and 6,5 ha·$year^{-1}$ with a cost of 7,1 and 4,8 *EU-*

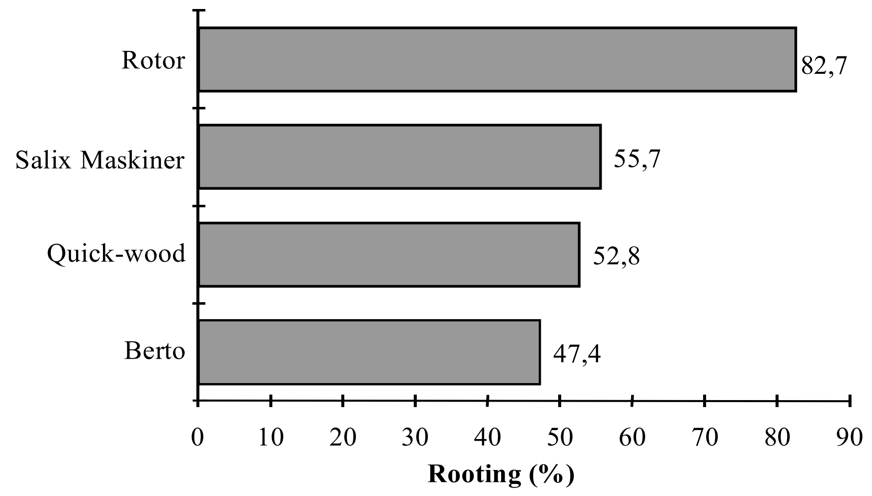

Figure 5: Rooting percentage with references to the different machines utilized.

Figure 6: Biomass production at the end of the second growing season.

ROCENT cutting^{-1} respectively. For larger areas it is more convenient to utilise the Salix Maskiner with a planting cost of 4,8 and 2,5 *EUROCENT*·cutting^{-1} respectively for 6,5 and 20 ha of SRF planted every year (Figure 8).

Conclusions

The research carried out (even though it refers to one year and one site) demonstrated how thanks to the utilization of suitable equipment it is possible to considerably reduce the costs for planting cuttings in poplar SRF.
The comparison of the different types of planting machine presently available on the market showed the technical and economic validity of the Rotor semi-automatic machine, especially when it is utilised in small areas (2-7 ha).
The Salix Maskiner – designed for planting whole willow sets – resulted, from the mechanical point of view, very interesting and also valid under the economical profile for planting poplar sets on areas bigger than 7 ha.

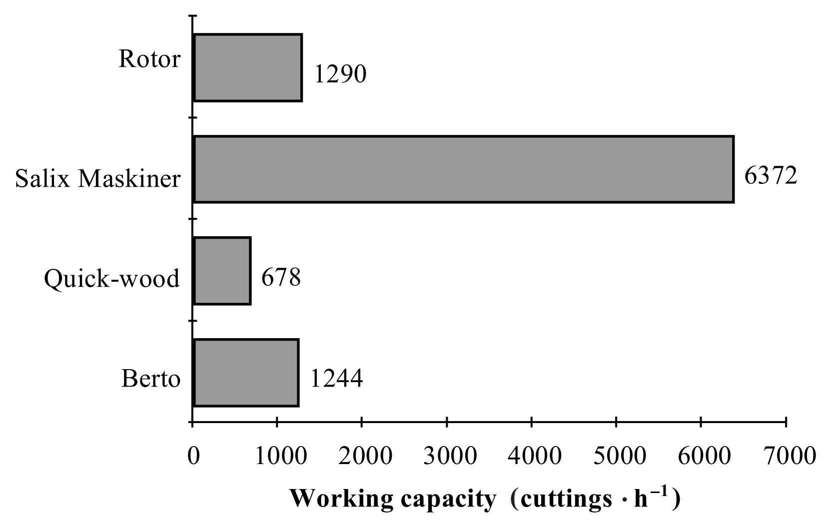

Figure 7: Work capacity of the machines during trials.

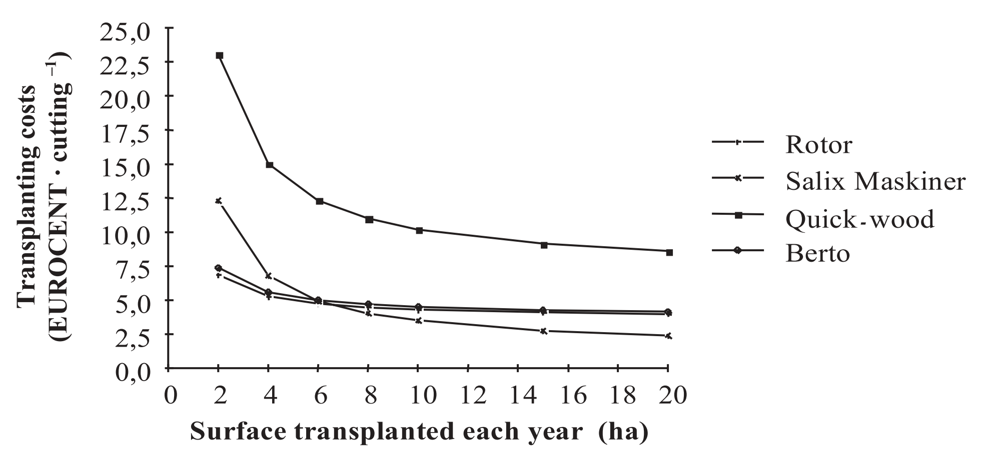

Figure 8: Costs of planting cutting of the four machines.

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3. The use of a compost activator to overcome seed dormancy in *Rosa canina* L.

P. Belletti[1], J. Cullum[2], F. Gorian[3], I. Monteleone[1] and B. Piotto[4]

Summary

Seeds of *Rosa canina* possess a complex dormancy mechanism which normally requires protracted periods of natural stratification before germination is possible. As an alternative pretreatment it is shown that the compost activator, Garotta, is able to break seed dormancy when incorporated into the stratification mixture.

In the absence of Garotta 0.5% of seeds germinated after a stratification treatment of 13 weeks at 20°C + 12 weeks at 4°C. In contrast, when the compost activator was used germination rates increased to between 39.0% and 50.25% depending on the level of Garotta added. Germination was also more rapid and more uniform in the Garotta treated seeds.

It would appear from the germination results obtained when alternating temperatures (5°C/25°C) were used that increased germination would have resulted from a longer period of cold treatment.

Future experiments in which the moisture content is reduced during the cold stratification period in an effort to delay radicle emergence, during pre-treatment, are suggested.

Keywords: compost activator, *Rosa canina*, seed dormancy, stratification.

Introduction

The seeds of many temperate trees and shrubs are of the orthodox type. They can be stored for long periods at low temperature and low moisture content (< 5-10%) and exhibit marked periods of dormancy to allow seed germination to be timed to favourable periods of the year (Bewley & Black, 1994). These dormancy mechanisms are frequently complex and have been the subject of much research by seed physiologists and plant raisers alike.

The genus *Rosa* has many species in which the seeds (achenes) exhibit complex dormancy mechanisms: these include a hard woody pericarp, chemical inhibitors and the requirement for both warm and cold periods of stratification. With *Rosa* species raised commercially from seed, for example in rootstock production, the traditional method of overcoming dormancy is by natural stratification in the open (stratification pits). This relies on seasonal changes including chilling to overcome the various dormancy mechanisms (Gordon & Rowe, 1982). However, the process is protracted and can give variable results. More artificial methods of breaking rose seed dormancy have been used, including treating dry seeds with concentrated acid to scarify the thick pericarp (Blundell & Jackson, 1971). Acid scarification can be effective, but successful treatment requires careful timing of the endpoint and there are safety concerns when using acids on the nursery.

Textbooks on tree seed dormancy often claim that in natural conditions microbial decay is responsible for breaking down hard seedcoats and releasing seeds from dormancy (McMillan, 1979). Surprisingly there is little or no evidence to support this claim. In an effort to examine this widely held view experiments which aimed to investigate the effect of enhanced microbial activity on hard-coated seeds were started at Writtle College, England (Cullum *et al.*, 1991).

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Garden vegetable waste is often converted to useful compost and mulch by using a compost activator. These products can be of inorganic or organic origin and are claimed by the manufacturers to increase microbial rotting of plant material. The British made product 'Garotta' (William Sinclair Horticulture, Lincoln, UK) has been shown to significantly increase seed germination of the rootstock *R. dumetorum* 'Laxa' (Cullum *et al.*, 1991). Other proprietary compost activators have also been shown to be effective. For example the German product 'Radivit' increased seed germination in a number of rose species including *R. canina, R. canina* 'Pfanders', *R.gallica,* and *R.jundzillii* (Feuerhahn & Spethmann, 1995) and the Dutch compost activators 'Asef' and 'Luxan' were very effective on seeds of *R. canina* 'Inermis' (den Besten *et al.*, 1995). The action of 'Garotta' has been studied and enhanced microbial populations and increased degradation of cellulose has been demonstrated when a compost activator is added to the pre-treatment medium (Morpeth *et al.*, 1997).

This paper describes the use of a compost activator, 'Garotta', to overcome seed dormancy in seeds of *R. canina.* When replanting wild species it is important to encourage growers to use seed of local provenance, but also to seek methods which ensure high germination rates so that the genetic diversity of the wild plant population is maintained and replanted into wild environments. The use of a compost activator in the pretreatment of *R. canina* seeds allows these objectives to be more easily achieved.

Materials and methods

Seeds used in the experiments were supplied by the Forest Seeds Processing Plant of the Italian Ministry of Agriculture and Forests Policies: they were collected in north-east Italy (Monti Lessini) during the autumn of 1999. On receipt, the moisture content of the seeds was about 12%. Before use, the seeds were soaked in water for 24 hours and those floating on the water surface were discarded.

Stratification was performed by mixing seeds with moist vermiculite (prepared by adding 100 g vermiculite to 160 ml deionised water and stirring thoroughly): 10 g seeds were added to 25 g of the stratification mix. Afterwards, compost activator was added. Different amounts were evaluated: 0 (control), 0.5, 1, 1.25 and 1.75 g Garotta per 10 g seeds. The final mixtures were stored within polyethylene bags, tied loosely to permit gas exchange with the external environment. Twice a week each bag was shaken to aerate the mixture and distilled water added to return the bag to its original weight.

Stratification was divided in two periods: warm (20°C) and cold (4°C). The duration of the warm stratification was 12 or 13 weeks, while cold stratification duration ranged from 10 to 14 weeks.

After stratification, seed germination was assessed by placing seeds in Petri dishes containing moist filter paper and kept in darkness. Two different germination temperatures were evaluated: constant 20°C and alternate 5/25°C (for 8 and 16 hours respectively). Germination was recorded regularly over a period of up to 70 days. Four replicates of 100 seeds each were used. Data from germination tests were analysed by using the software SeedCalculator, provided by Plant Research International from Wageningen (The Netherlands). The following parameters were scored: PG (percentage of germination), TMG (mean germination time, calculated by integration of the fitted curve and proper normalisation), T_{50} (the time required for germination of 50% of total germinability), UG (uniformity of germination, the time between 75% and 25% of total germinability), VS (viable seeds, obtained by adding to the germinated seeds those ungerminated seeds considered viable in the biochemical test with tetrazolium).

Results

The use of compost activator proved to be essential to permit seed germination after the stratification process. It was shown that the rate of Garotta added was not significant (Table 1).

Table 1: Effect of compost activator Garotta on Rosa canina seed germinability after 13 weeks of warm stratification and 12 weeks of cold stratification. Germination tests performed at 20°C on 4 replicates of 100 seeds each. PG is the percentage of germination, TMG the mean germination time in days, T50 the days required for germination of 50% of total germinability, UG the uniformity of germination in days and VS the percentage of viable seeds. Means in columns carrying the same letter are not significantly different at p = 0.05 level, according to Turkey's test

Treatment	PG	TMG	T_{50}	UG	VS
Control (without Garotta)	0.50 a	11.35 a	7.88 a	12.48 a	80.00 a
Garotta (0.5 g/10 g seeds)	50.25 b	2.28 bc	1.80 bc	2.08 bc	84.25 a
Garotta (1 g/10 g seeds)	39.00 b	2.66 b	1.84 bc	2.92 b	84.00 a
Garotta (1.25 g/10 g seeds)	39.00 b	2.87 b	2.31 b	2.60 b	81.75 a
Garotta (1.75 g/10 g seeds)	46.75 b	1.71 c	1.19 c	1.88 c	89.00 a

The length of the cold stratification period affected considerably the seed germination (Table 2): 10 weeks allowed on average 23.75% of seeds to germinate, while after 14 weeks the percentage of germination was as high as 39.25.

Germination tests performed under alternating temperatures allowed seeds to almost double their germination percentage (52.29 *vs* 28.28 obtained at 20°C constant), although the germination process was much slower (mean germination time of 14.85 and 4.80 days respectively) and less uniform (uniformity of germination of 13.60 and 4.57 days respectively) (Table 3).

Table 2. Effect of cold stratification duration on Rosa canina seed germinability after 12 weeks of warm stratification. Germination tests performed at 20°C on 4 replicates of 100 seeds each. Data reported are the average of different Garotta doses. PG is the percentage of germination, TMG the mean germination time in days, T50 the days required for germination of 50% of total germinability and UG the uniformity of germination in days. Means in columns carrying the same letter are not significantly different at p = 0.05 level, according to Tukey's test

Treatment	PG	TMG	T_{50}	UG
10 weeks	23.75 a	5.93 a	4.96 a	5.24 a
14 weeks	39.25 b	4.18 b	3.22 b	4.00 b

Table 3. Effect of temperature on Rosa canina seed germinability after 12 weeks of warm stratification and 13 weeks of cold stratification. Germination tests performed at 20°C on 4 replicates of 100 seeds each and at 5/25°C for 8/16 hours respectively on 4 replicates of 100 seeds. Data reported are the average of different Garotta doses. PG is the percentage of germination, TMG the mean germination time in days, T50 the days required for germination of 50% of total germinability, UG the uniformity of germination in days and VS the percentage of viable seeds. Means in columns carrying the same letter are not significantly different at p = 0.05 level, according to Tukey's test.

Treatment	PG	TMG	T_{50}	UG	VS
20°C constant	28.28 a	4.80 a	3.73 a	4.57 a	88.80 a
5/25°C	52.29 b	14.85 b	11.53 b	13.60 b	91.34 a

Discussion

The use of a compost activator proved to be essential to allow seeds of *Rosa canina* to germinate after the various warm and cold stratification periods. The Garotta dose proved not be a limiting factor, providing the threshold of 0.5 g per 10 g of seeds is exceeded. Garotta did not show any phytotoxic effect: germinated seeds proved to be able to produce normal seedlings after transplantation (data not reported), while the number of viable seeds (as determined by biochemical test with tetrazolium) did not decrease after any treatment.

A similar pattern of results was recorded at each of the 3 laboratories involved in the research. The benefit of adding Garotta to the pre-treatment mixture is clearly evident (Figure 1).

It is probable that the cold stratification periods evaluated in our experiments were not long enough to allow all seeds to break their dormancy. An insufficient amount of cold seems to be confirmed by the results of germination tests performed under different temperatures: at 5/25°C many more seeds overcame dormancy, although this process period could allow many seeds to germinate within the stratification mixture: after 13 weeks of cold stratification it was possible to observe about 1% of pre-germinate seeds and these numbers would probably dramatically increase with longer cold stratification periods. A possible solution is the cold stratification of seeds with limited moisture content, in such a way that the dormancy breaking process can occur, while seed germination is prevented. Experiments in this direction are at present being carried on at the Institutions involved in the research project.

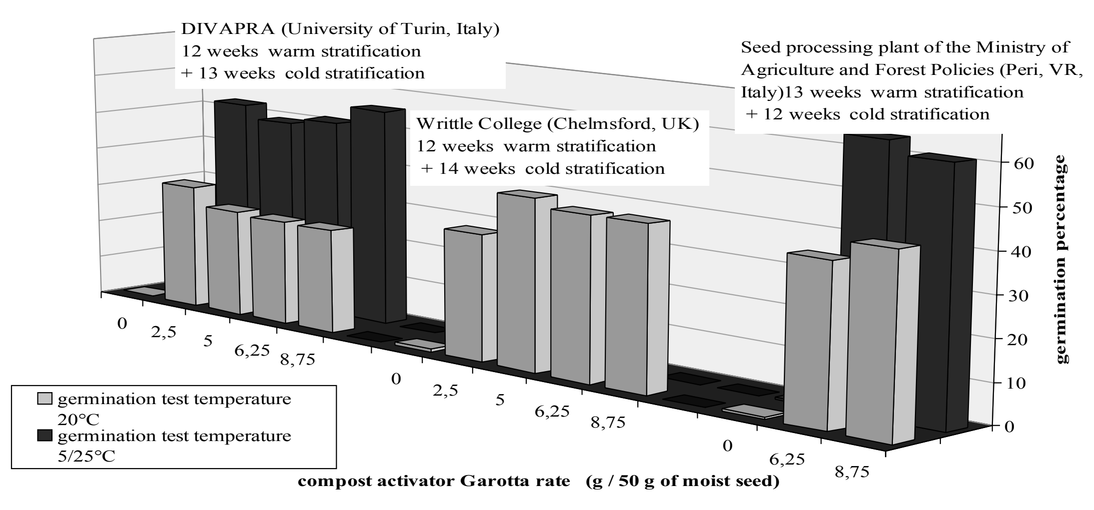

Figure 1. The most interesting results obtained by the 3 laboratories using the compost activator Garotta to overcome *Rosa canina* seed dormancy.

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4. Cork-oak and stone-oak seed management aimed at implementing nursery production of seedlings

*P. Belletti, I. Monteleone and M. Cartarasa**

Summary

Cork-oak and stone-oak are important species for Mediterranean regions, where they play an important role in the economy of marginal areas. However, efficient reforestation is hampered by inadequate supplies of high quality seedlings.

Oak seeds are recalcitrant and therefore cannot be desiccated. This hamper seed storage, as it would be necessary to sow acorns during the spring following harvest. The moisture content that seeds should not overcome to maintain high viability ranged from 35 to 37%. Below 15-18% moisture content acorns all died. Concerning seed storage, moisture content higher than 40% proved to be better than lower values, while temperature of 0°C was better than higher and lower temperatures. After 9 months of storage at 0°C, acorns with 42% moisture content were still fully viable.

Although cork-oak and stone-oak seeds show a slight dormancy, stratification treatments proved not to be able to improve seed germination. Only in a few cases it was possible to speed up seed germination, but saved time is much less than treatment duration.

Thermotherapy proved to be highly efficient in keeping under control insect infestation of seeds. Treatment in water at 45°C for 30 minutes killed all larvae present inside seeds while not decreasing seed germination performance.

Keywords: *Quercus ilex*, *Quercus suber*, reforestation, seed harvest, seed stratification, thermotherapy.

Introduction

Cork-oak (*Quercus suber* L.) and stone-oak (*Quercus ilex* L.) have great ecological and naturalistic importance for Mediterranean regions, where these species are essential part of agri-silvicultural and pastoral systems and plays an important role in the economy of marginal areas. However, most of the stands are old, since reforestation has been hampered by rural depopulation. Moreover, in case of stone-oak, stands have been transformed in coppice forests and show decay symptoms. Efficient reforestation is hampered by inadequate supplies of high quality seedlings.

The paper presents some of the results achieved within the European Community research programme FAIR5-3480, "Optimisation of cork-oak seed management in support of Community policies for reforestation and cork production". The research is carried on by Research Centres and nurseries from The Netherlands and the Mediterranean countries where the species are diffused (Italy, Spain and Portugal) and it is co-ordinated by the University of Turin.

The general objective of the project is the implementation of the methods for cork-oak and stone-oak seedling production, thus enabling efficient reforestation and/or rejuvenation of stands in Southern Europe. This general objective is pursued through the identification of the optimal storage conditions and treatments for uniform germination of high quality seeds, including methods for the protection of seeds and seedlings against the most harmful pests and diseases which affect the species. The treatments and storage conditions developed are evaluated for their applicability on a large scale in the cork-oak seedling producing industry in Portugal, Spain and Italy.

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Harvest techniques

Different harvest techniques have been evaluated for their effect on seed quality, including collection of acorns on the ground after natural drop and collection of acorns on nets after forced shedding. In general, it has been observed that acorns collected on the ground show a higher moisture content and therefore their germination is faster. On the other hand, acorns collected on nets are characterised by a higher germinability (Figure 1). Therefore the use of nets is recommended when the sowing does not follow immediately seed harvest.

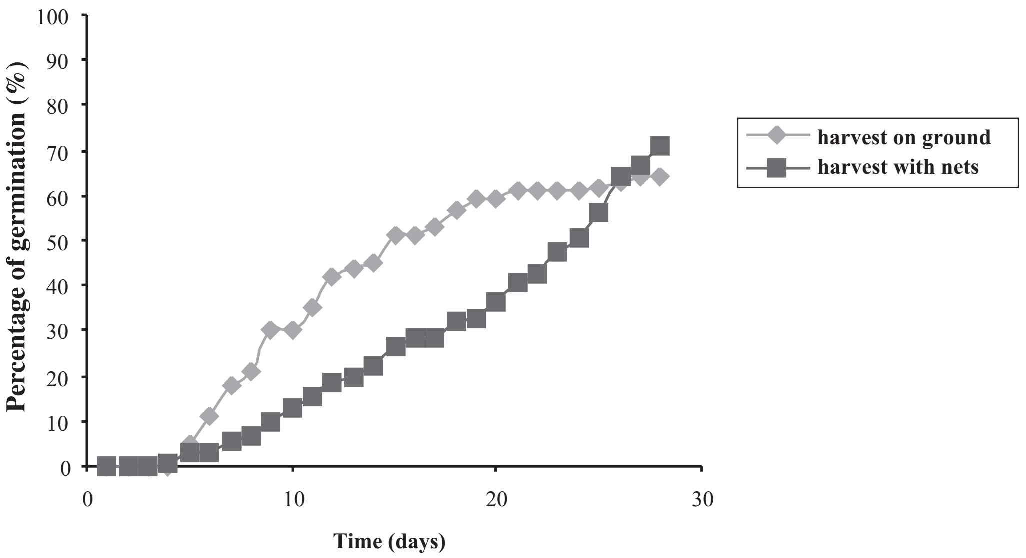

Figure 1: Comparison of stone-oak seed germination following different harvest techniques.

In any case, after harvest, seed moisture content has to be carefully controlled, in order to avoid seed pre-germination (that occurs at m.c. of about 42-45%) as well as seed deterioration due to desiccation (seed germination is negatively affected at m.c. lower than 35-37%).

Seed storage

Cork-oak and stone-oak seeds show recalcitrant behaviour (Roberts *et al.*, 1984) and therefore cannot be desiccated below an high level of moisture content. This hampers the possibility of medium and long-term storage, as it would be necessary to sow acorns during the optimal season (spring, that is about six months after harvest). The critical moisture content, that is the value that seeds should not overcome to maintain high viability, has proved to range from 35 to 37%. Below 15-18% moisture content acorns all died, whatever the drying procedure (Figure 2). Seed storage experiments under different temperatures and moisture contents combinations have been carried on. High moisture contents proved to be better than values lower than 40%, while temperature of 0°C was more favourable than higher and lower temperatures. After 9 months of storage at 0°C, acorns with 42% moisture content show values of germinability and emergence comparable with those of fresh material (Figure 3). Storage at 3°C allowed seeds to pre-germinate, while temperatures below 0°C have proved to be totally unreliable, due to seed death during the first months of storage.

Stratification

Dormancy is a natural mechanism aimed at timing seed germination to favourable periods of the year (Bewley & Black, 1982). It has been reported that oak seeds show dormant behav-

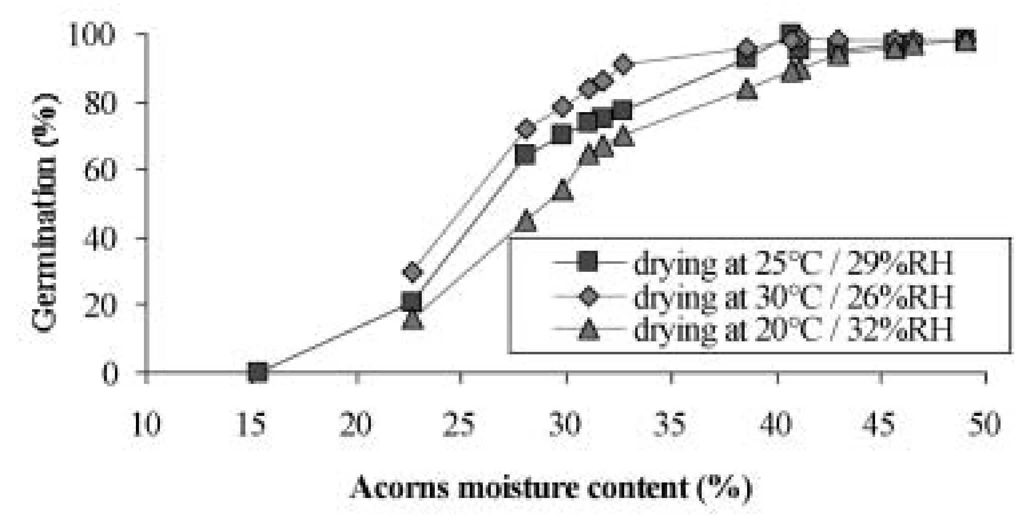

Figure 2: Effect of drying method applied to Quercus suber acorns on the percentage of germination.

iour, although variable among species (Santos, 1994). Although cork-oak and stone-oak seeds are not fully dormant, their germination is not uniform and it is expected to be improved after stratification (storage for some months at low temperature). However, stratification treatments and phyto-hormones applications proved not to be able to improve substantially seed germination. Only in a few cases it was possible to speed up seed germination, but saved time is much less than treatment duration (Table 1).

On the whole, the best stratification treatments were the ones performed at 0°C: in fact, temperatures higher than 0°C allowed seed to pre-germinate during the treatment, while negative temperature strongly damaged the seeds.

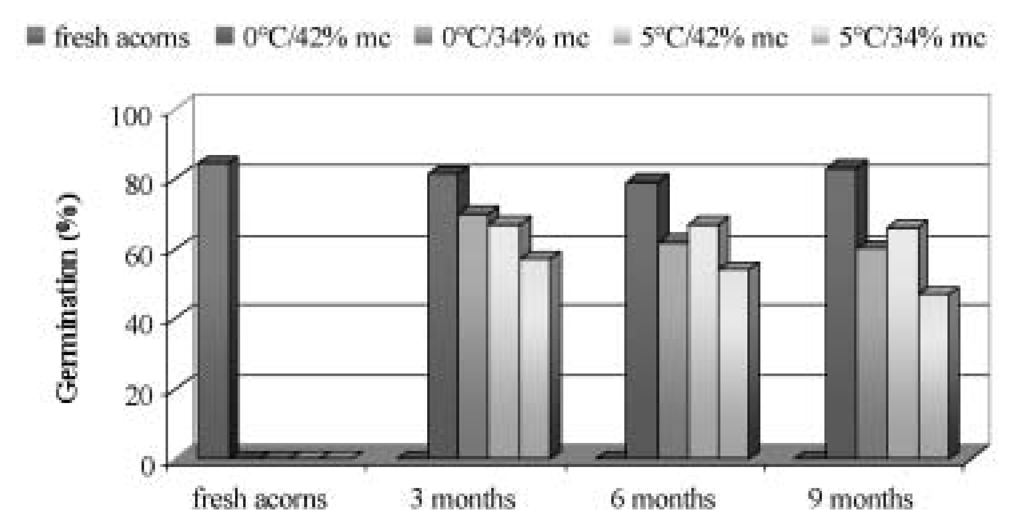

Figure 3: Germination of *Quercus suber* acorns stored for up to 12 months at different moisture contents and temperatures.

Thermotherapy

Several insects attacks cork-oak and stone-oak acorns, laying eggs inside the ripening fruits. The most dangerous insects are *Coleoptera Curculionidae* (namely *Curculio elephas*), *Lepidoptera Tortricidae* (*Laspeyresia splendana*) and, limited to some areas, *Imenoptera Cinipidae*. After egg hatching, larvae feed with seed tissue, namely cotyledons, and at harvest many

Table 1: Results of stratification treatments on cork-oak seeds for 42 days. Seed moisture content before stratification was arranged at about 40%

	Moisture content (%)	Germination percentage (d)	Mean Germination Time (d)	Uniformity of Germination (d)	Seedling emergence (%)
Control	49	98	5.3	3.2	85
Stratification with substratum					
- 5°C	44	22	9.1	4.2	13
- 2°C	42	77	5.7	3.4	68
0°C	47	98	2.9	2.1	98
3°C	50	71	3.9	2.3	-
Stratification without substratum					
- 5°C	41	50	6.8	3.8	42
- 2°C	40	81	6.5	4.0	76
0°C	41	87	5.2	3.8	77
3°C	40	49	7.8	4.4	-

seeds are affected by insects. In case of acorn storage, larvae can seriously damage the seeds, since the relatively high storage temperature is not able to block their metabolic activity.
The spread of chemicals against insect is not fully efficient, due to their localisation inside seeds. Moreover, environmental and sanitary problems related to insecticide use are far from being solved.

An interesting alternative, lacking in environmental concern, is the thermotherapy. Acorns of both cork-oak and stone-oak proved to clearly withstand a treatment in hot water at 45°C, not showing any decrease in germination (Table 2). To the contrary, all larvae present inside the seeds were killed after the treatment.

Table 2: Effect of thermotherapy treatment on stone-oak seed viability and larvae survival

Thermotherapy	Moisture content (%)	Germination percentage (%)	Mean germination time (d)	Uniformity of germination (d)	Larvae survival (%)
Control	38	71	19.1	10.8	100
2 h/45°C	40	62	19.1	8.5	0
30 min/45°C	38	71	19.1	10.8	0

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5. Does autumn climate affect the applicability of shoot frost hardiness as an operational test parameter for storability of pedunculate oak (*Quercus robur* L.) seedlings

*P. Brønnum**

Summary

Recent studies have indicated that shoot frost hardiness at –20°C is useful as an operational test parameter for assessing storability of pedunculate oak (*Quercus robur* L.) seedlings. The aim of the present study was therefore to evaluate the applicability of the test in two Danish nurseries (A and B).

In 1998 bare-rooted oak seedlings were lifted in week no. 40, 41, 43, 44, 47 and 51 in both nurseries, except for week no. 40 in nursery B. At each occasion, a seedling sample from each nursery was cold stored, until they were outplanted in May 1999. At the same time, seedlings were collected for testing of shoot frost hardiness. Frost hardiness was calculated as $\mathrm{SEL}_{\mathrm{diff}\text{-}20}$, i.e. the difference in mean shoot electrolyte leakage of shoots frozen to –20°C and non-frozen control shoots. The stored seedlings from nursery A were planted on former agricultural land at the Research Station in Aarslev and seedlings from nursery B were planted in a field in that nursery. First-year field performance at both sites was assessed the following winter as survival and height increment.

The lifting season was characterised by extraordinary great precipitation during October. Nursery A and B respectively received approximately 240% and 220% of the average rainfall in this month. This wet period was followed by a relatively dry and cold period of frost with temperatures down to ca. –12°C. The very wet field conditions may have affected seedling physiology, as a transient stagnation or increase in shoot electrolyte leakage was observed in seedlings from both nurseries during October. However, in spite of these abnormal weather conditions, shoots from both nurseries developed the anticipated frost hardiness at –20°C by the middle of November (week no. 47), indicating that lifting for cold storage would be safe from this week. The altered physiological state of seedlings lifted in October seemed to have had no effect on storability. Shoot frost hardiness appeared to be an acceptable indicator of oak seedling storability, but the effects of other factors (rough handling, planting site conditions) may overrule the effects of lifting time. The procedure of mailing shoot tips overnight for laboratory testing was generally safe provided that shoots were sampled under 'normal' weather conditions.

Keywords: pedunculate oak, bare-rooted seedlings, frost hardiness, lifting time, storability.

Introduction

In Denmark nurserymen often report poor storability of pedunculate oak (*Quercus robur* L.) and difficulties with determining correct lifting time for storage. Mild or wet weather conditions during the lifting seasons have often been suspected as the reason for poor storability. As a consequence, some nurseries avoid to cold store oaks in years with excessive autumn rainfall, although it is still not quite clear what effect weather conditions have on storability.

The negative effects of early autumn lifting of seedlings for long term cold or frozen storage have been known for several years (Winjum 1963; Lavender & Wareing 1972), and have been extensively studied for conifer forest trees, while less attention has been given to decid-

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uous trees (e.g. Lindqvist 1998). A major practical problem has always been to determine the moment when seedlings are ready for storage, i.e. in a physiological condition where they are sufficiently resistant to tolerate the stresses they suffer by being out of their natural environment for up to several months (Sønderhousen & Bøvre 1980, Ritchie 1986).

In practice nurserymen have used foliage colour changes and leaf drop as indicators of physiological maturity in deciduous species, and thus making their decision about lifting time on a subjective and non-physiological basis. A small number of physiological tests of storability have been developed over the years, but they have until now been used relatively little by nurseries in Denmark and probably most of Europe.

In conifers, storability has been related to both shoot dry matter content (SDM) and shoot frost hardiness in a number of studies (e.g. Rosvall-Åhnebrink 1985, Colombo 1990). SDM and shoot frost hardiness are also known to be related in deciduous species (Calmé *et al.* 1995), but studies by Jensen *et al.* (1993) and Brønnum (unpublished data) have suggested that SDM during the period when oak seedlings become storable is only poorly correlated with storability. Colombo (1990) found a linear relationship between shoot frost hardiness and freezer storage injuries in black spruce (*Picea mariana* (Mill) B.S.P.). A recent study by Brønnum (in prep.) showed a similar correlation between shoot frost hardiness and storability in pedunculate oak, suggesting that storability can be determined on the basis of shoot frost hardiness assessments in deciduous species as well.

The objective of the present study was to repeat the experiment mentioned above in another year. A second objective was evaluate the possibility of setting up a mail-based laboratory test service, by involving two Danish nurseries (called A and B) in the experiment. Several practical restrictions, however, made it necessary to have different experimental approaches in the two nurseries. In nursery A lifting and sampling was done by research staff in order to repeat the experiment of the previous year with the same provenance as used earlier. In nursery B lifting and sampling was done by nursery staff and with a different provenance. Direct quantitative comparisons of results from the two nurseries are therefore difficult. The evaluation of the "operational approach" (nursery B) as compared to the "experimental approach" (nursery A) will therefore mainly be qualitative. Furthermore, the autumn lifting season in that year was characterised by excessive precipitation, and made it possible to investigate the hypothesis that poor storability is related to wet weather conditions.

Materials and methods

Sampling

Seedlings of pedunculate oak (*Quercus robur* L.) were lifted during autumn of 1998 in two Danish nurseries A and B. The seedlings in nursery A were a Dutch provenance and the seedlings in nursery B were a Danish provenance. Liftings occurred in week no. 40, 41, 43, 44, 47 and 51 in both nurseries, except for week no. 40 in nursery B. At each occasion, a sample of 100 seedlings were lifted for cold storage until May 1999 at +4°C (from December at –1°C) and another 50 seedlings were sampled for frost tolerance testing. Seedlings in nursery A were lifted by research staff and transported to the Research Station in Aarslev, where they were frost tested and cold stored. Seedlings from nursery B were lifted by nursery staff and stored in the nursery cold storage facilities. Shoot tips for frost testing from nursery B were sampled by nursery staff and sent overnight by express mail to the laboratory at the Research Station.

Freezing tests

From each of the 50 seedlings a 3-cm long stem segment (shoot tip) was cut out just below the apical bud. The shoot tips were washed in tap water and afterwards carefully rinsed in deionized water to avoid contamination with surface ions. Each shoot tip was put into a 25-ml plastic bottle and capped. 25 shoot tips were frozen in a programmable freezer to -20 °C at a rate of 2°C per hour and held at this temperature for one hour before thawing. The remaining 25 shoot tips were held at +4°C as control.

Cell membrane injury in control and frost samples was evaluated using the electrolyte leakage method: after thawing to room temperature 20 ml of deionized water, with a known low electrical conductivity (C_0), were added to each bottle and the samples were left to leak in darkness at room temperature for 24 hours. After shaking the samples briefly, the conductivity of the water (C_1) was measured with a conductivity meter. The samples were then autoclaved at 110 °C for 60 minutes to achieve maximum possible electrolyte leakage. A second measurement of the conductivity (C_2) was made after the samples had cooled to room temperature. The shoot electrolyte leakage (SEL) was calculated as:

$$\text{SEL} = (C_1\text{-}C_0) \;/\; (C_2\text{-}C_0) \cdot 100\ (\%)$$

Shoot frost hardiness was expressed as $\text{SEL}_{\text{diff -20}}$ in order to eliminate the effect of membrane damage caused by environmental factors in the nursery and during lifting and handling. $\text{SEL}_{\text{diff} \div 20}$ is defined as the difference in SEL of samples frozen to -20 °C and the respective control samples, kept at +4 °C, in accordance with Lindström and Håkansson (1996).

Field performance

The stored seedlings from nursery A were planted on former agricultural land at the Research Station in a randomized complete block design, with 5 blocks of 20 seedlings per lifting week. To simulate weed competition in a controlled manner, 60 cm wide strips of grass (*Festuca rubra* 'Tamara' and *Agrostis castellana* 'Highland', ratio12:1), were sown between the seedling rows leaving a 30 cm wide weed free area around the seedlings. Grass height was kept at 5-10 cm by regular moving. Seedlings from nursery B were planted in a field at the nursery, using the same experimental design, but without grass strips. Weed control in this field closely resembled operational management, with combined mechanical and herbicide control. First-year field performance at both sites was assessed the following winter as survival, height and stem diameter increment.

Results

Freezing tests

Shoot electrolyte leakage of control (SEL_{+4}) and frozen (SEL_{-20}) shoot tips from both nurseries decreased significantly during the lifting period. (Figure 1). The SEL_{+4} was in the same range for both nurseries while SEL_{-20} was generally higher in nursery B. A transient stagnation (nursery A) or increase (nursery B) in SEL was observed during October. The difference in SEL between frozen and control samples ($\text{SEL}_{\text{diff-20}}$) decreased from approximately 20 and 30 percent in the first lifting week to values below 5% in week 51 and 47 for nursery A and B respectively. $\text{SEL}_{\text{diff-20}}$ was generally lower in nursery B than in nursery A. The transient stagnation or increase in SEL in October had only little influence on the decrease in $\text{SEL}_{\text{diff-20}}$ values.

Field performance

Seedling survival assessed after the first growing season was very high (96-100%) for all lifting dates in both nurseries (data not shown). Seedling height growth differed between lifting dates and nurseries (Figure 2). First-year height increment of seedlings from nursery A increased gradually as lifting was delayed and reached a maximum value from week no 47.

In nursery B there was no significant differences in height increment between lifting weeks except for week 41 which was considerably lower than the later weeks. Also the performance of seedlings lifted in nursery B in week 51 was lower than expected. Height increment was generally greater in nursery A than in nursery B. The correlation between field performance and SELdiff-20 at the time of lifting was rather good in nursery A (r = -0.93; p = 0.007), but poor in nursery B (r = 0.60; p = 0.28).

Weather conditions

The lifting season was characterised by extraordinary great precipitation during October (Figure 3). This was the second highest recorded in Denmark since 1873. The regions where nursery A and nursery B are situated received an average rainfall of 150 mm (normally 62mm) and 210 mm (normally 94 mm), respectively, during October. The wet period was followed by a relatively dry and cold 3-week period with night temperatures down to ca. – 12°C. (Anonymous 1998).

Discussion

The frost tolerance during the period was generally better in seedlings from nursery B, which had lower $SEL_{diff-20}$ -values than nursery A seedlings. Since climate and other environmental conditions are not very different in the two nurseries, this is probably probably due to provenance differences (Deans & Harvey, 1996). The seedlings from nursery B are of Danish provenance and thus originates from a more northern climate than those from nursery A (Dutch provenance).

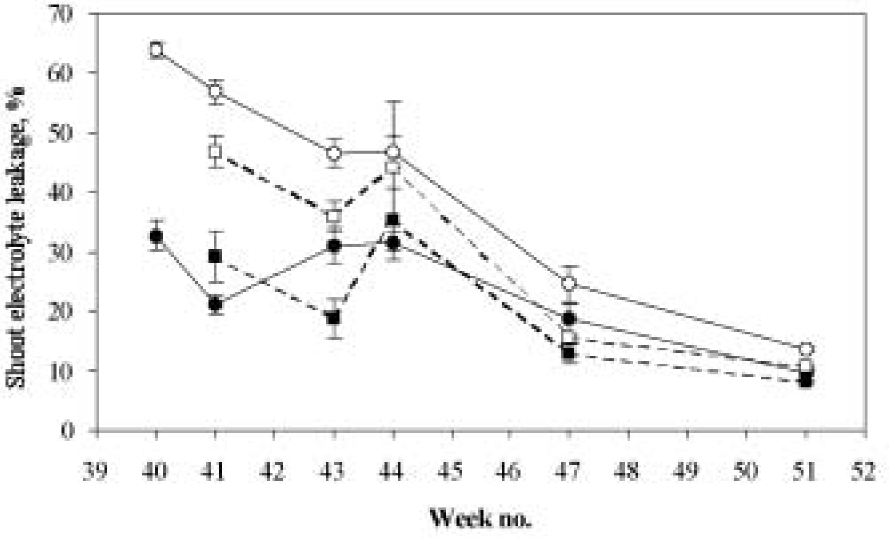

Figure 1: Electrolyte leakage of pedunculate oak (Quercus robur) shoot tips frozen to −20°C (open symbols) and non-frozen control (black symbols). Each point represent mean electrolyte leakage as a percentage of autoclaved values from 15 samples at the time of lifting in nursery A (solid lines) and B (broken lines) during autumn and early winter 1998. Vertical bars indicate standard error of means.

The very wet field conditions apparently affected seedling physiology more or less in both nurseries, as a transient stagnation or increase in SEL was observed in seedlings from both nurseries during the wet period in October. McKay (1993), likewise, reported fluctuations in root electrolyte leakage of Sitka spruce (*Picea sitchensis* (Bong.) Carr., Douglas fir (*Pseudotsuga menziesii*, (Mirb.) Franco), and Japanese larch (*Larix leptolepis* (Sieb. & Zucc.) Gord.) that could result from a period of high temperatures and rainfall prior to lifting. In the present study, the greater electrolyte leakage values measured in shoot tips from nursery B compared to nursery A in week 44 could, however, be due to extraordinary membrane injuries caused by mailing the shoot samples. In most weeks mailing seemed to have little or no effect on the excised shoot tips, suggesting that the mailing procedure is rather safe under normal circumstances, but the greater injuries observed in shoots from nursery B in week 44 indicates that care should be taken if are shoots are sampled and sent by mail during periods with much precipitation.

The experiment conducted in the previous year showed that oak seedlings were storable when $SEL_{diff-20}$ -values were around 5% or less, which generally corroborates with the findings of Colombo *et al.* (1982) and Lindström and Håkansson (1996) for conifers. In spite of the excessive rainfall in October, shoots from both nurseries developed the anticipated frost hardiness ($SEL_{diff-20}$ around 5% or less) by the middle of November (week no. 47), indicating that lifting for cold storage would be safe from this week. The weather conditions and the altered physiological state of the shoots observed in October seemed therefore to have little or no effect on storability (i.e. next year field survival and height growth). Height growth of seedlings lifted in nursery B in week 51 was surprisingly low. The relatively low night temperatures in November that followed the wet period could have had an negative impact on the roots of seedlings lifted in week no 51, either during lifting and handling in the field or during storage. However, the exact cause remain unclear, since shoot frost hardiness indicated that seedling were storable, and also because the negative effects were only observed in nursery B.

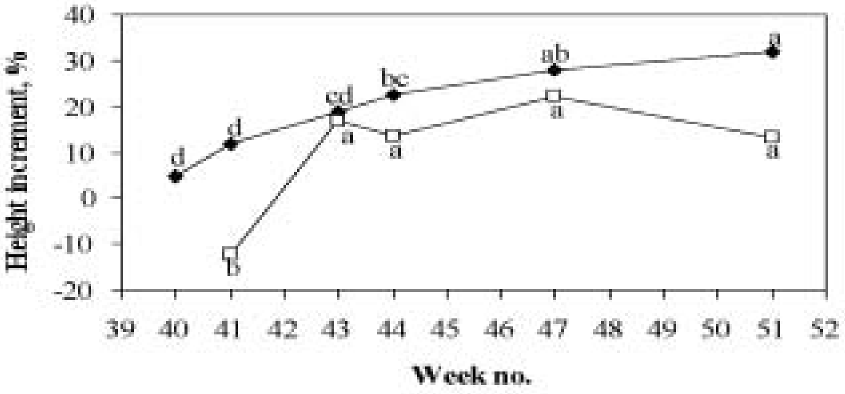

Figure 2: First-year height increment as percentage of initial height of pedunculate oak (*Quercus robur*) seedlings lifted in nursery A (black symbols) and nursery B (white symbols) during autumn and early winter 1998 and cold stored until planting in spring 1999. Height increments of seedlings from the same nursery sharing the same letter are not significantly different ($p \leq 0.05$).

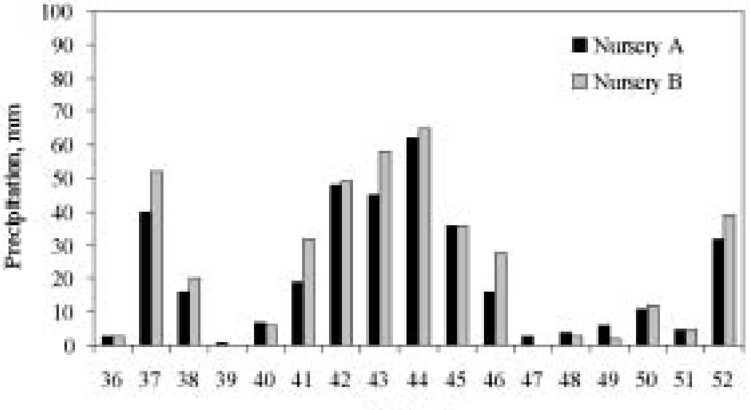

Figure 3: Mean weekly precipit ation (mm) during the period from September until December 1998 of the regions where nursery A and B are situated (Anonymous 1998).

Although it can not be said for certain, planting procedures and planting site conditions may have played a relatively greater role on first-year field performance than lifting time. Seedlings from nursery A were planted under relatively uniform and controlled weed competition, while seedlings from nursery B were planted under more severe weed competition. This is probably the reason for the more stable increase in height increment with later lifting weeks of nursery A seedlings compared to the rather unstable and variable increments of nursery B seedlings. The site condition factor could therefore also explain why a better correlation was found between frost hardiness at the time of lifting and field performance in nursery A compared to nursery B.

In conclusion, the results of this study indicates that wet autumn weather condition may affect SEL-values of oak seedlings, but apparently not storability, meaning that the nurseryman should take the current weather conditions into account when interpreting results of freezing test. Oak seedlings seem to be storable when shoot tips are frost hardy at −20°C, i.e. when $SEL_{diff-20}$ values are around 5% or less. Mailing shoot samples overnight for laboratory testing seems to be generally safe, but there is a risk that the samples under certain conditions will suffer from the transportation. The freezing test used under operational conditions were less precise in predicting field performance potential as compared to a test conducted under experimental conditions. The major reason for the less precise results obtained in the "operational approach" appears to be other disturbing factors occurring under operational conditions (rough handling, planting site conditions), which may overrule the effects of lifting time.

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6. Influence of the sampling time, type of cutting and indole-3-butyric acid (IBA) on cutting rooting of *Viburnum tinus* L.

*M.A. Cocozza Talia, F. La Viola and G. Cristiano**

Summary

This paper is about the results of agamic propagation trials in *Viburnum tinus* L.
The propagation material, consisting of apical and subapical cuttings 6 cm long, was sampled at two different times from a spontaneous plant.
For both cuttings, the rhizogenic treatment was effected using a solution of indole-3-butyric acid at the concentrations of 1000 and 2000 p.p.m. by dipping the cutting basis.
For apical cuttings, the rhizogenic treatment was performed for each concentration for 1 hour and for 12 hours, respectively; for subapical ones, the treatment was applied only for 12 hours.
Measurements concerned the rooting percentage (%); the mean number of roots per cutting (n°) and the maximum and minimum lengths (cm) of roots.
As to the sampling time, from the first results, it seems that the sampling effected in October induced a higher rooting percentage.
For the type of cutting, the apical ones have shown a quicker response to rhizogenesis.
For both cuttings, it seems that the lower concentration (1000 p.p.m.) enabled better results than the higher one (2000 p.p.m.).

Keywords: *Viburnum tinus*, cuttings, indole-3-butyric acid, rooting.

Introduction

Viburnum tinus L., belonging to the family of *Caprifoliaceae* is a spontaneous species in the Mediterranean environment; widespread in holm oak plantations and in evergreen woods, it can be found from the sea-level up to 800 m a.s.l.
It is an evergreen shrub that reaches till 3 m height and which has a quite compact habit. Its leaves are entire, dark and glossy and its white flowers are grouped in apical inflorescences (corymb-like tops) that are pink-coloured at the stage of buds.
The flowering, very prolonged through the year (from October to June) is followed and sometimes overlaps with fruit-setting with persistent drupes which take a metal-blue colour at ripening.
Viburnum has a great ornamental and ecological value because, thanks to the long permanence of flowers (for all winter) and fruits, it is a feeding source for insects: it is indeed a nectar-bearing species craved for by bees and which is also suitable for nest-building.
From an ornamental point of view, this species has been mostly used as garden species, but its growing also yields a niche product to be used as green cut plant with flowers and fruits.
Given its poor temperature and cultural requirements, it is suitable for windy areas, it resists to drought periods and to poor and heavy soils and also to pollution; hence it yields a product able to enable the development of marginal areas (Dalla Guda *et al.*, 2001).
To obtain a product that keeps a good commercial standard, the propagation of this species should be agamic, partly because the obtention of seedlings is quite difficult due to the complex dormancy of seeds (Hartmann & Kester, 1990) which can generally germinate in a long period, even after about 8 months.

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Agamic propagation is usually effected using cuttings taken in late springtime (Hartmann & Kester, 1990), although good results have also been obtained by taking them in August and November; in the latter case, the use of growth regulators enables an increase in rooting percentage (Piccioni *et al.*, 1996).

Cuttings should have – as pre-requisite – poorly lignified tissues; therefore techniques promoting the etiolation of mother plants (shadowing and banding) (Ferrini *et al.*, 1998) are used so as to enable taking non-lignified cuttings suitable for the formation of a good rooting system (root quantity and quality) that is extremely important for the survival of rooted cuttings (Singh, 1993a).

The use of root-inducing substances, usually synthetic growth regulators, favours an increase in the rooting percentage (Vezzosi, 1998); among these substances, the auxin compounds are the main promoters of such a process (Alpi *et al.*, 1992) and in particular, the most largely used is the indole-3-butyric acid (IBA) that enables obtaining not only an increase in rooting for some species that are not suitable for agamic propagation (Shim *et al.*, 1993) but also allows the formation of an adventitious rooting system with better characteristics (Sohair & Taleb, 1995; Spethmann & Hamzah, 1988; Singh, 1993b; Keever *et al.*, 1995).

The IBA treatment of cuttings can be applied either as talcum powder formulate or as a solution, with better results being obtained in the latter case (Dawson & King, 1994; Chong & Hamersma, 1995). The solution may have different concentrations as a function of the cutting features, the more or less accentuated lignification of tissues and thus of the sampling time (Souidan *et al.*, 1995) or as a function of the treatment duration; it would seem, however, that the concentration of 1000 p.p.m. (Yoo YongKweon & Kim KiSun, 1996; Fouda & Schmidt, 1995a) enabled achieving excellent results.

Moreover, the application can be effected together with other compounds to favour the translocation of the active ingredient (Bir & Barnes, 1995) increasing its effect, or with treatments made to induce the disinfection of the propagating material, as has been observed for different ornamental tropical species (Hara *et al.*, 1994; Hata *et al.*, 1994).

Given the importance of *Viburnum tinus* L. on the flower and nursery market, the present work is intended to check the influence of the sampling time, the cutting features, the indole-3-butyric acid treatment (different concentrations and durations) on cutting rooting.

Materials and methods

Cutting propagation trials were run.

In the first trial the following treatments were compared:

- 2 sampling times every two months: 2nd decade of October and 2nd decade of December;
- 2 types of cutting: apical and subapical;
- 2 concentrations of the indole-3-butyric acid solution: 1000 and 2000 p.p.m.

The solution was applied by immersion of cuttings for 12 hours.

In the second trial, the following treatments were compared:

- 2 sampling times every two months: 2nd decade of October and 2nd decade of December;
- 2 concentrations of the indole-3-butyric acid solution: 1000 and 2000 p.p.m..
- 2 dipping times of cuttings in the solution: 1 and 12 hours.

In the second trial apical cuttings were used.

After the IBA treatment, cuttings were placed in paper pots using as substrate a mixture of leaf mould and pearlite in a 60:40 ratio; then they were left for rooting in a cold glasshouse.

The measurements included the rooting percentage (%), the mean number of roots per cutting (n°), the maximum and minimum length (cm) of roots.

The split-plot design with three replicates per treatment was used; data were submitted to the analysis of variance.

Results

First trial

As to the rooting percentage, a 68% mean value was obtained and, as shown in Table 1, it has been significantly affected by all tested treatments.

Between the two sampling times, the best results have been obtained from the first, effected in October, with a 21% increase as compared to that effected in December; instead, for the type of cutting, the most suitable were the apical ones that induced an 18% increase. Lastly, for the rhizogenic treatment, the highest rooting percentage was obtained with the lower concentration (1000 p.p.m.) of the solution that induced a 19% increase.

For the quantity and quality features of the newly formed rooting system, Table 1 shows an interaction between the different factors compared.

Table 1: Rooting percentage of Viburnum tinus L. cuttings and biometric parameters (1st trial)

Principal effects	Rooting percentage (%)	Roots/cuttings (n°)	Root lenght (max – cm)	Root lenght (min – cm)
Sampling time				
13 Oct 00	74.6*	9.9**	5.0**	0.9**
14 Dec 00	61.6	6.7	1.6	0.4
Type of cuttings				
Apical	73.7*	9.0**	4.3**	0.7
Subapical	62.5	7.6	2.4	0.6
Concentrations of IBA solution (p.p.m.)				
1000	74.2*	8.4	3.6	0.8**
2000	62.0	8.2	3.1	0.5

Significantly different from the other value at 0.01P (**) and at a 0.5 P (*)

As to both the average number of roots per cutting and their maximum length an interaction was observed between the sampling time and the cutting type. The cuttings sampled in October, in particular the apical ones, are actually more prompt to rhizogenesis since they emit the highest number of roots (10 per cutting, on average) and reach the highest length (7 cm on average) (Figures 1, 2).

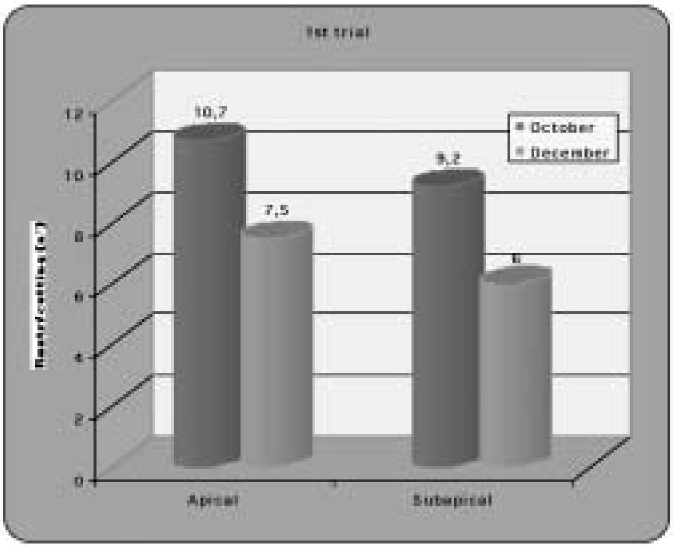

Figure 1: Interaction of the sampling time and cutting type on the number of emitted roots.

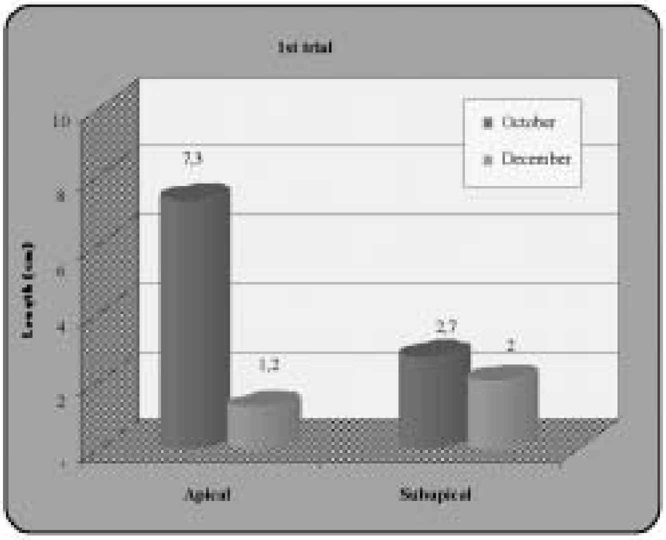

Figure 2: Interaction of the sampling time and cutting type on the root maximum length.

Second trial

Table 2 shows a mean rooting percentage of 83%.

Table 2: Rooting percentage of Viburnum tinus L. cuttings and biometric parameters (2nd trial)

Principal effects	Rooting percentage (%)	Roots/cuttings (n°)	Root lenght (max – cm)	Root lenght (min – cm)
Sampling time				
13 Oct 00	86.8	11.1**	7.7**	1.1**
14 Dec 00	79.7	8.7	1.4	0.4
Concentrations of IBA solution (p.p.m.)				
1000	86.8	9.4	4.8	0.9**
2000	79.7	10.4	4.4	0.6
Iba dipping duration				
1 h	92.8**	10.7	5.0**	0.8
12 h	73.7	9.0	4.2	0.7

Significantly different from the other value at 0.01P (**)

No differences were observed between the cutting sampling times and the IBA solution concentrations.

Moreover, statistically significant differences were found between the dipping times of cuttings into indole-3-butyric acid solution: indeed, the dipping for 1 hour induced a 26% increase in rooting percentage as compared to that of 12 hours.

In any case the cuttings taken in October emitted a higher number of roots, statistically significant as compared to the cuttings taken in December.

As to the other biometric parameters measured on roots, in particular at the maximum length (Figure 3), an interaction was observed between the sampling time and the dipping duration: the higher number (as for the Ist trial), 8.3 cm, on average, was obtained from the cuttings taken in October and dipping for 1 hour in the solution.

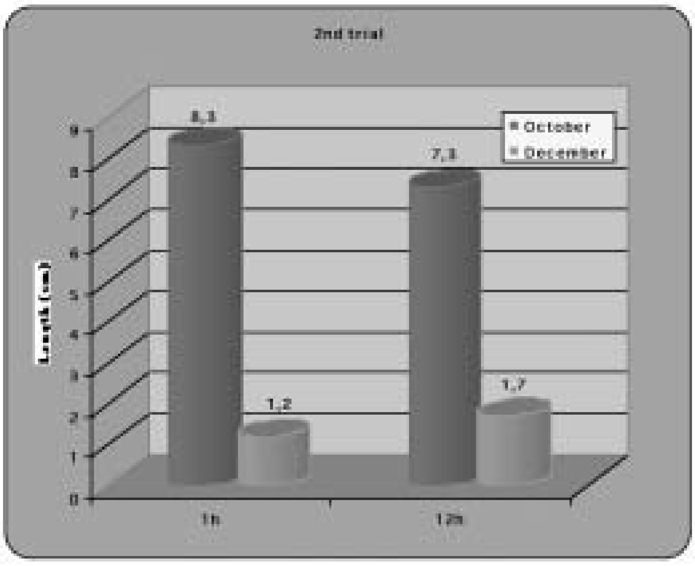

Figure 3: Interaction of the sampling time and IBA dipping duration on root maximum length.

Conclusions

The above research pointed out that for the agamic propagation of *Viburnum tinus* L., the best results were obtained taking cuttings in October, notably with apical cuttings, as it had been observed for other species (Ruta *et al.*, 1997).

This is presumably due both to the lower lignification of tissues and to the higher endogenous levels of auxins that stimulate rhizogenesis more quickly.

As to the indole-3-butyric acid concentrations, also for *Viburnum tinus* L., the best results have been obtained at 1000 p.p.m. concentration, as found for some rose species (Fouda & Schmidt, 1995b).

After all for *Viburnum tinus* L. resorting to the concentration and duration of the lower treatments, it is possible, in agreement with other authors (Wilkinson, 1993; Piagnani & Bassi, 2000), to achieve better results (higher rooting percentage and better quanti-qualitative properties of the newly formed system), probably in synergy with the conditions that occur when apical cuttings are taken in October and are subjected to 1-hour dipping in an IBA solution at a concentration of 1000 p.p.m.

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7. How to Improve the Quality of Broadleaved Seedlings Produced in Tree Nurseries

*S.J. Colombo**

Summary

Broadleaved seedlings grown in tree nurseries contribute to forest sustainability in three ways. First, commercial plantations established from nursery stock provide wood products used by society and associated economic benefits. Secondly, seedlings used to establish community forests support the need for wood that is consumed locally or is manufactured and sold to the direct benefit of those in the community. Thirdly, broadleaved nursery stock production can also promote forest sustainability by conserving local genetic sources of indigenous species that might otherwise be lost.

Producing nursery stock of a desired size requires balancing environment conditions between those favouring growth and those which hold growth back, while avoiding severe infestations by harmful insects and disease. Nursery stock needs to meet certain size targets to be successful after planting, however, physiological properties are at least equally important to field performance. Nonetheless, practices to produce seedlings possessing desirable physiological traits remain beyond the reach of most nursery managers. Physiological criteria of stock quality are available but their adoption as grading standards seldom occurs without the support of those who are responsible for tree survival after planting. The development of morphological and physiological standards that are based on field performance and related back to nursery production practices is an important element of the improvement of reforestation success using broadleaved tree species.

Keywords: nursery stock production, forest sustainability, target seedling, standard, field performance.

Introduction

It is questionable whether forests could be managed sustainably without the planting of seedlings grown in tree nurseries. Forest management can be said to be sustainable if it provides "generational equity" (Fox 2000). With generational equity, forest management is sustainable if it meets the present needs of society without compromising the ability of future generations to obtain the same levels of benefits from the forest (American Forest and Paper Association 1999). Tree nurseries provide planting stock that helps ensure desired tree species are regenerated rapidly following disturbance. Three areas can be identified in which the nursery production of broadleaved tree seedlings produced in nurseries contribute to sustainability: plantation forestry for industrial wood production, community forests where the benefits of the forest are realized locally, and for the preservation of rare or threatened species and genetic sources.

The demand for forest products is increasing in tandem with global population while the area of forest in the world is declining (Hee 1993). To satisfy the growing demand for forest products from a shrinking forested landbase, countries will increasingly turn to intensively managed forest plantations. Plantation forests provide jobs, improve national economies, and provide wood that might otherwise come from natural forests. Plantations are usually established using seedlings or cuttings produced in tree nurseries and using seedlings with high growth potential helps maximize wood production.

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In contrast to industrial plantations, community tree nurseries produce seedlings to satisfy local needs for forest products. Community nurseries are usually smaller than nurseries producing seedlings for industrial plantations, the former growing hundreds or thousands rather than millions of seedlings in the latter. The seedlings grown in community nurseries produce trees for planting to provide building materials, food, and wood for fuel.
Forests also provide benefits that are not usually accounted for in financial terms. Forests protect watersheds, provide homes for wildlife, and act as a reservoir or preserve for native plant and animal species. In addition it is increasingly being recognized that many forest dwelling plants and animals contain biochemicals with properties valuable to society (Kimmins 1997) or have genetic properties that have value for breeding purposes or as a source of genes for other species (Namkoong 1986). Nascent efforts in ecological restoration and genetic conservation can be supported by nurseries which have the ability to produce tree seedlings of a wide range of forest plant species (Landis et al 1993, Edson et al 1994). While nursery propagation of rare species is not a replacement for habitat preservation, efforts in restoration will be aided by an improved understanding of the seed germination and nursery cultural requirements of the many infrequently grown species.
The practices employed to produce nursery stock can affect survival and growth after planting (Duryea 1985). Although the importance of sound nursery practices to sustainable forestry is often implicit, there is a direct link between nursery practices and whether many of the objectives of sustainable forest management are achieved (Persson 1991). Nursery practices may vary in intensity depending on whether trees are grown for industrial plantations, community forests, or to preserve species and genetic resources. Regardless of the end-use of the trees, there are common aspects of nursery practices inherent to a sound approach to seedling production.

Nursery stock production

Nursery stock production can be categorized into four phases and a number of attendant steps (Figure 1). As defined here, this process includes the planning for production and shipping, and is not limited to steps that are directly involved with germination and growth of seedlings. Detailed information on each phase is described elsewhere (e.g., Armson & Sadreika 1974, Landis et al 1995). This paper will highlight some key aspects of nursery stock production that are essential for the success of tree seedling production and reforestation.

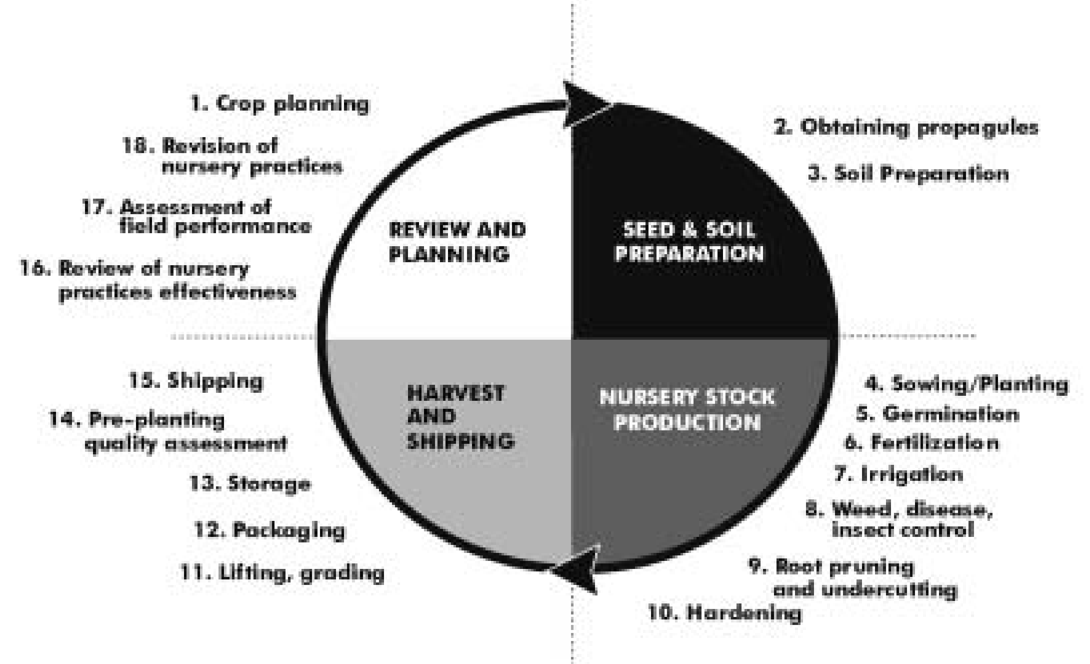

Figure 1: The nursery stock production cycle divided into four phases and component steps.

Soil preparation and seed germination

The two major preparatory steps in producing tree seedlings are to prepare the soil for planting and to obtain viable seed (or vegetative propagules if plants are being grown vegetatively). Mismanagement of either of these steps will usually create major impediments to the production of vigorous tree seedlings.

Whether seedlings are grown in containers or bareroot nursery fields, in order to grow vigorous trees the soil must provide adequate water, inorganic nutrients, and aeration. Armson and Sadreika (1974) stated "the growing of trees in a nursery involves an intensive form of management, particularly when the nursery is to be in continuous production for many years. Although all phases of production are important, it is the soil and the practices dealing with it that are the core of any management program." While proper soil preparation is vital, soil properties are more easily controlled than seedling properties since soil reactions are based on physical and chemical characteristics.

In the case of seed, physiological processes regulate viability and dormancy. Seed that is nonviable will not germinate; viable seed that is dormant will not germinate rapidly or uniformly. Slow germination is a problem if the trees do not reach the size desired for planting.

Slow germination is often accompanied by germination that is spread out over a long period of time. A wide spread in the time of germination among seedlings can create serious nursery crop management problems if it causes large size disparities among seedlings in a nursery crop. Small initial differences in size due to variable germination can lead to large size differences at the time of shipping. Seeds that germinate later may produce seedlings that are overtopped by earlier germinating seedlings, reducing light levels and therefore limiting photosynthesis in the smaller trees, leading to yet greater differences in size.

In a container nursery, differences in time of germination within a crop can lead to large differences in leaf area and therefore transpiration, which cause differential rates of container drying. The driest containers can determine the watering rate in a crop. Since all containers in a crop are usually watered at the same time, the larger seedlings will be watered closer to their optimum and the growing medium of the plugs of shorter seedlings will tend to be too wet. This situation is exacerbated by two factors: being in an understory the shorter seedlings transpire less because of lower light levels, This also tends to keep the growing medium in the container wetter. Secondly, if overly wet the growing medium may become anaerobic due to flooding which causes stomata to close and seedling transpiration to be restricted. Finally, the cooler, wetter understory environment experienced by the smaller seedlings in a crop favour disease that can have serious consequences for crop management and seedling quality.

Seedling growth

As for seed and seed germination, the science that underlies the growth of seedlings in a nursery is very complex, although the act of growing seedling crops is not viewed that way. This complexity is illustrated in Figure 2, which shows some of the overlapping and, in part, interconnected growth events that take place in typical northern temperate hardwood tree seedlings during the growing season. Cold hardiness declines in the spring and root growth commences prior to bud break. With bud break the predetermined leaves and telescoped shoot tissues inside the bud enlarge. For species in which the shoot grows from predetermined tissues, the terminal bud begins to form while the current year shoots are elongating. Budscales form, leaf primordia that will expand in the following year are initiated inside the bud, and a periderm develops on the exterior of the stem as the current year's shoot ceases elongation. Often, there will be an autumn resurgence of root growth in broadleaved seedlings when shoot growth ends. These complex and interconnected, growth processes occur as a result of biochemical and physiological that are ultimately governed by genetic responses to seasonal environmental cues.

One of the reasons nursery stock production is not viewed as highly complex is that seedlings "grow themselves", with relatively little effort on the nursery manager's behalf. As a result, producing a crop of seedlings does not require that one be aware of all the steps that a tree passes through during a growing season. In general nursery management practices are mainly intended to control the size and relative balance of shoot and root tissues by varying fertilization rates, watering, shoot and root pruning, and in the case of seedlings grown in greenhouses, the daylength and temperature.

An ability to control the size and balance of a crop of seedlings is the minimum that should be expected of a nursery manager. However, enough is known about the physiological traits important for planting success that nurseries can potentially produce seedlings with particular physiological traits. That this is not standard practice is the result of a variety of factors and there are notable exceptions (Sloan 1994).

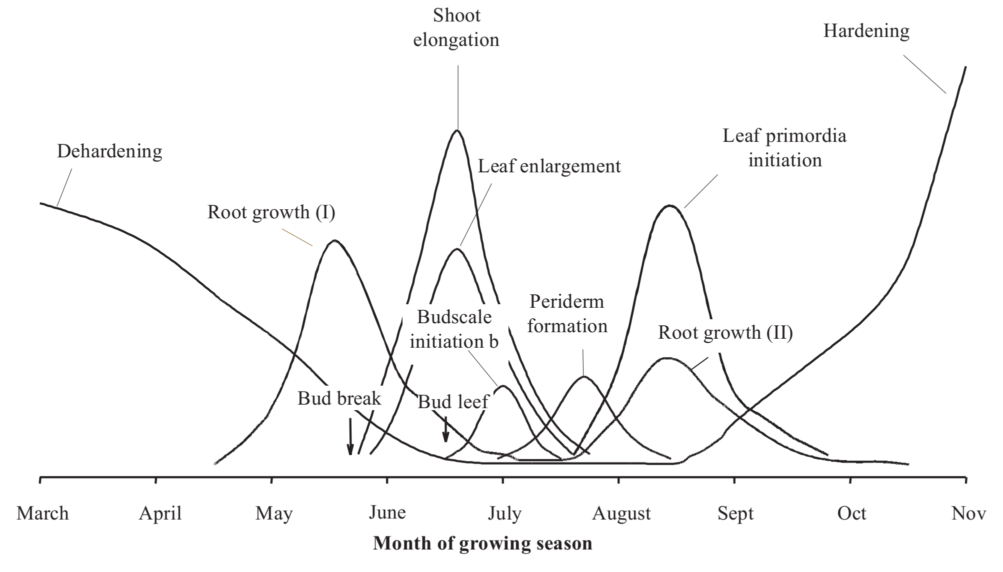

Figure 2: Growth processes that a typical temperate zone broadleaved tree seedling passes through during the growing season. Lines represent the relative intensity of the process it depicts.

Among the most factors impeding the production of seedlings with specific physiological traits is a tendency to view the time seedlings are shipped from the nursery as the end rather than the continuation of the nurseries responsibility that is then shared with those that plant trees.

Ideally, nursery managers will have a sound understanding of the relationship between the physiological responses of trees to the nursery environment. A basic background in horticulture can provide much of this knowledge (Landis 1994). However, those who plant trees, including most foresters, usually have only a rudimentary training in ecophysiology. Thus, most foresters lack the knowledge to be able to relate the properties of nursery stock to the site and environmental conditions into which the trees are planted. As a result there is little chance of feedback from the field to the nursery to improve the properties of seedlings being planted (Colombo & Parker 1999).

Shipping and planting

Trees lifted at the completion of the seedling production phase are either stored or shipped immediately for planting. Many of the problems affecting seedlings occur during this time, especially with bareroot seedlings because the roots are exposed and may dry after lifting and long roots are cut off. If lifted seedlings are to be stored indoors overwinter it is essential that they acquire sufficient hardiness before being removed from the nursery beds. This requires an understanding of the processes that lead to high levels of cold hardiness in roots and shoots as well as a means of determining when seedlings can be stored.

Pre-planting quality assessment should be the keystone event in nursery production. Nursery practices determine seedling size and physiological characteristics. The link between nursery practices and the quality of seedlings should be obvious, yet this relationship is often overlooked. Part of the reason for it being overlooked may be that the economics of production focuses attention towards producing **more** seedlings, rather than on producing **better** seedlings. The other cause of a lack of focus on quality is that most foresters receiving seedlings are only concerned that the trees meet minimum criteria for size. Pre-planting quality assessment is a means of evaluating aspects of seedlings that go beyond size.

Table 1 lists some of the more commonly evaluated seedling quality attributes (Colombo et al. 2001). These attributes can be broadly classified as those based on morphology and those based on physiology. Puttonen (1987) spoke in favour of morphological attributes as a predictor of field performance, in part because morphological characteristics are widely measured and are known to bear a relationship to field performance (Thompson 1985). However, as noted by Duryea (1985), stocklots that have the same size seedlings may differ in important physiological characteristics (in the extreme case, one group may contain undetected damage or even dead trees and yet have the same morphology). Some physiological tests can discern damage as well as indicate the vigour of nursery stock. Nursery mangers should seek to produce seedlings that have desirable morphological properties and also perform well in physiological tests.

Root growth potential and chlorophyll fluorescence are physiological tests that can be used both to detect damage and to rate healthy seedlings into vigour classes. Root growth potential is probably the most commonly measured physiological quality assessment method. It integrates the ability of the roots to conduct water and the shoot to photosynthesize, two crucial aspects affecting seedling performance after planting (Ritchie & Simpson 1997).

Chlorophyll fluorescence takes place when a beam of light is shone on green plant tissues. The amount of light fluoresced and its pattern over time indicates whether chlorophyll molecules are intact and the photosynthetic mechanisms are active and undamaged. This is also an attractive test because it is non-destructive, the results are instantaneous, and the test simple to conduct (Sampson et al 1997, Colombo et al 2001).

The measurement of stress-induced volatile emissions (SIVE) is a promising pre-planting test for detecting stock with viability problems or tissue damage (Sampson et al 1997, Colombo et al 2001). Trees and other plants respond to a damaging stress by producing characteristic gases (Kimmerer & Kozlowski 1982). One of these gases, ethanol, is a byproduct of anaerobic respiration. Damage to the aerobic respiratory pathway or a lack of oxygen can lead to anaerobic respiration. Correlations between ethanol production by seedlings and damage to them have been demonstrated (Templeton & Colombo 1995).

Electrolyte leakage is another method that can detect tissue damage (Murray et al. 1989, McKay & White 1997). Damaged tissues leak electrolytes from cells that show up as increased electrical conductivity if the tissues are immersed in water. Electrolyte leakage has been used extensively to detect post-freezing damage which indicates the level of cold hardiness and readiness for frozen storage (Glerum 1985, Deans et al 1995). Electrolyte leakage has also been used as a viability test to detect damage to tissues prior to shipping seedlings for planting (McKay & Mason 1991, O'Reilly et al 2000).

Relationships between field performance and the physiological and morphological properties of nursery stock need to be established separately by species. By tying nursery stock properties to field performance and nursery cultural practices it is possible to implement practices that will more consistently produce nursery stock possessing higher levels of desirable attributes. Unfortunately, it has been argued that the failure of stock quality tests to infallibly predict field performance is reason not to use such tests as a grading procedure (e.g., Binder et al 1988). Such pernicious arguments disregard the benefits to regeneration programs that come from morphological and physiological grading of nursery stock. Although the field performance of any particular stocklot is not highly predictable (because of variability in handling, planting, and field conditions), stocklots with high root growth potential and chlorophyll fluorescence should on average perform better after planting. Certainly, it is difficult to imagine many foresters willingly accepting nursery stock with lower root growth potential and chlorophyll fluorescence if such stock is provided at a competitive cost.

Table 1: Seedling attributes that can be measured to characterize the suitability of nursery stock for planting. Revised from Colombo et al. (2001)

Physical characteristics		Physiological performance		Chemical attributes		Pest status
Morphology	Bud development	Directly measured	Indirectly evaluated	Inorganic compounds	Organic compounds	
Diameter	Bud initiation	Chlorophyll fluorescence	Bud dormancy status	Micro-nutrients	Amino acids	Insects
Dry weight	Leaf primordia	Electrical impedance	Cold hardiness	Nitrogen	Carbohydrates	Pathogens
Height		Photosynthesis	Damage expression	Phosphorus	Plant growth regulators	
Ratio measurements		Plant moisture status	Root growth potential	Potassium		
Root system size			Stress-induced volatile emissions			

Review and planning

Review and planning need to take account of what takes place in the nursery as well as how seedlings perform after planting. Through review and planning it is possible to link results not just between one nursery crop and the next but also between the nursery and the field. Improvement over time requires good record keeping and a review of those records alongside evidence of field performance.
There are three components of Review and Planning identified in Figure 1.

- The review of nursery regime effectiveness involves a retrospective analysis within the nursery that relates the size and condition of seedlings achieved in light of the practices that were employed. It relates, for example, whether seedlings met prescribed sizes and were ready for shipping when needed.
- Field performance is assessed to determine how well the seedlings met the objectives for which they were grown. It is important for the nursery manager to determine what role the manner in which the trees were grown and the condition of the seedlings when shipped played in the success of the stock after planting.
- Crop Planning is done by the nursery manager taking into account the practical, day-to-day human, financial and biologial considerations that affect how a crop if seedlings will be grown.

Landis (1994) states that seedlings belong to the customer, not to the nursery where they were grown. Therefore, planning needs to be done foremost from the perspective of the person who will be receiving the trees and only thereafter from the perspective of the nursery manager. Field performance, therefore, needs to be a critical part of planning, although in practice this is too often overlooked.

Relating field performance to nursery practices

One way to promote the use of nursery practices that improve seedling physiological and morphological traits is to draw explicit links between the manner in which nursery practices affect these traits and how the traits affect survival and growth after planting.
The field performance of planted tree seedlings can be considered in light of Liebig's Law, which states that the productivity and ultimately the survival of a complex system that is dependent on a number of essential inputs are limited by the single variable in least supply. This concept was restated by Odum (1971) for ecological systems and by Landis (1993) for tree seedling production. This concept can also be applied to the issue of seedling performance af-

ter planting (Figure 3). Unrestrained by external factors, the growth of a seedling is limited only by the genetic potential to utilize carbon dioxide, water, and mineral nutrients. However, planted seedlings seldom achieve their genetic potential as growth is usually subject to a number of limiting factors. The relationship between seedling quality and field performance shown in Figure 3 is represented in terms of staves in a barrel. The top of the barrel is seedling genetic potential, while seedling performance after planting is shown by the height of water, which is determined by the shortest stave in the barrel. Nursery managers should produce stock where seedling quality is not the factor limiting field performance.

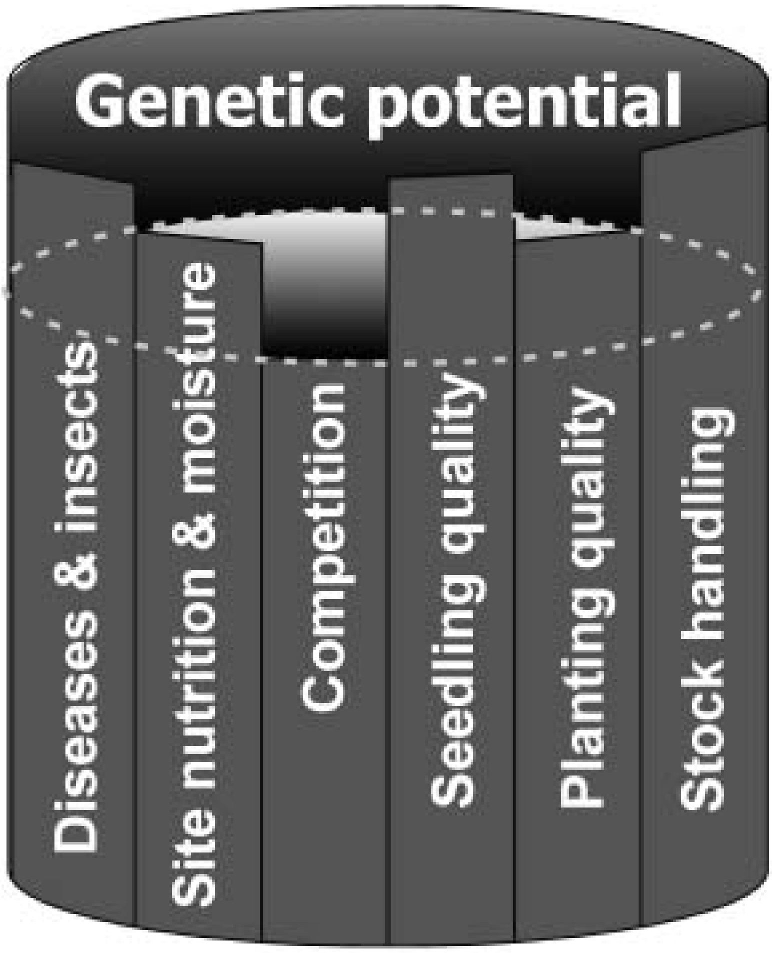

Figure 3: A barrel and staves representation of Liebig's Law of the minimum as it pertains to factors limiting the performance of seedlings after planting. The factor most limiting is the one that determines the level of performance of a planted seedling.

To evaluate whether seedling quality is limiting to field performance it is necessary to: a) understand the relationship between seedling quality traits and performance under a range of field conditions, b) have a program where seedling quality is monitored prior to planting, and c) collect data on field performance and relate it back to seedling quality. In practice, these three steps are seldom all carried out. Consequently, the relationships between nursery practices, seedling quality, and field performance are usually not well understood.

One of the impediments to understanding how field performance is affected by nursery practices is the variation in field environments that obscures such relationships. As a result, seedlings of similar quality may perform very differently when the field conditions they are planted into are dissimilar. In the alternate situation, seedlings of diverse quality may perform similarly under certain field conditions; either very harsh conditions, where all stocklots are li-able to perform poorly regardless of quality, or very forgiving conditions, where almost all stock will perform well. The majority of research on seedling quality and field performance has been conducted using conifer nursery stock. While the principles are likely the same the specific relationships between seedling quality and field performance undoubtedly need to be verified and fine-tuned for broadleaved species. Three approaches that can be used to reveal relationships between seedling quality and field conditions are: a) evaluating seedling performance under limiting environmental conditions in test environments; b) planting seedlings with a known gradient in quality on a semi-controlled site; and c) boundary line analysis of field performance data from operational stocklots.

In the limiting conditions approach, seedlings are evaluated after planting in an artificial harsh environment. Seedlings that perform better in this harsh test environment are concluded to be better adapted to the anticipated non-ideal site condition. This approach, proposed by Timmis (1980) and applied by Grossnickle (Grossnickle et al 1988, Grossnickle & Folk 1993), has been used to evaluate the performance potential of seedlings in controlled environments mimicking expected limiting field conditions (e.g., hot or cold, dry or wet).

The limiting conditions approach is similar to the vigor testing procedure developed at Oregon State University (McCreary & Duryea 1985). The OSU vigor test is based on the premise that less vigorous and damaged seedlings can be killed or further damaged by stresses experienced during planting and establishment. These susceptible stocklots can be detected prior to planting by applying an artificial stress and monitoring the stock for survival in a growth room. Good correlations have been found between survival of the OSU stress test and field survival and growth (McCreary & Duryea 1985), although in planting years with non-stressful weather poorer stock has been found to survive and grow adequately.

A second approach used to relate seedling quality to field performance is to compare the performance of seedlings with a gradient in a chosen stock quality attribute. In this way a range of seedling sizes or physiological conditions is created while attempting to remove other variations in seedling quality or planting site conditions that may obscure the relationship There are two keys to relating a quality gradient to performance potential of a stocklot. One requirement is that the gradient in quality be broad enough to produce a wide range of a difference in performance potential. If the stock is all of about the same quality then much of the data will be clustered together and correlations will not be evident (McCreary & Duryea 1985). The second key to using the gradient approach is to minimize interference from extraneous factors that might obscure the relationship between the measured quality attribute and field performance. For this reason such tests are often conducted using a single stocklot and partially controlled conditions where extreme competition or environmental conditions can be avoided. An example of this approach is shown in Figure 4, where a range of root growth potential levels was created by storing and/or moisture stressing the trees before planting. Seedlings were from the same stocklot and planted at the same time, so that differences in field performance could be deemed to be due to differences in root growth potential. This data demonstrates a significant relationship between RGP and survival after planting (Figure 4). Similar relationships have been produced for other species and attributes (Mullin & Christl 1982, Ritchie 1985).

A third means of determining the relationship of seedling attributes to field performance is through boundary line analysis (Webb 1972). Boundary line analysis can be used to identify a functional relationship amidst variation due to unidentified factors by isolating the top-performing points in each seedling quality class. According to boundary line theory, the level of a variable, *y*, which is dependent on a second variable, *x*, can be reduced from its optimal level by unidentified factors. Boundary line analysis has been used to determine relationships where the unidentified factors cannot be adequately known and their cumulative effects are not quantifiable (Kitchen et al. 1999).

Figure 5 shows an example of boundary line analysis. This example uses data from a trial where white spruce bareroot seedlings were graded into a range of size classes based on root length prior to planting. Tree heights were measured five years after planting. Figure 5a shows the correlation derived from individual tree data, which produced a large cloud of points and a weak correlation (r^2=0.167). Figure 5b shows the correlation produced using average root length classes rather than individual tree data. The increase in the value of the correlation coefficient (r^2=0.667) reflects the reduced variation due to averaging and produced essentially the same equation for the relationship as the individual tree data. In comparison, using boundary line analysis (Figure 5c) a regression line was fit to the topmost individual-tree data points in each root length class. This boundary line relationship was significant (r^2=0.876) and the larger slope indicated a stronger dependence of field performance on the root length of seedlings at planting. Boundary line analysis is a means of analyzing the large amounts of field performance and seedling quality data that are sometimes available from plantations established for industrial purposes. The technique offers a means of sorting through the variability in nursery stock performance that occurs under operational field conditions and stocklots from a range of genetic sources and raised and planted in different years.

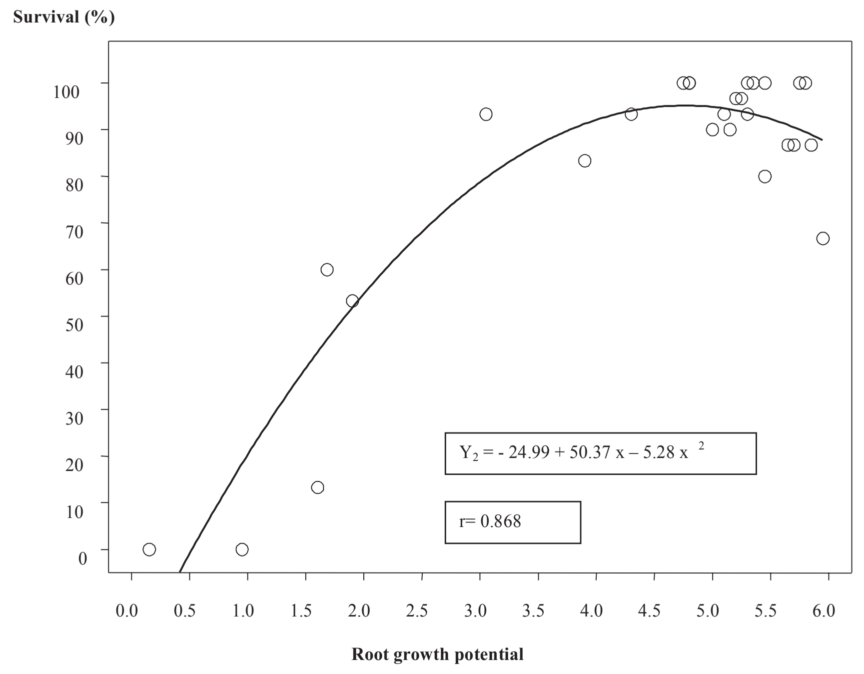

Figure 4: Survival of black spruce bareroot nursery stock possessing different levels of root growth potential at the time of planting. Seedlings, planted together on a cultivated site, were from the same nursery stocklot from which sub-samples with different levels of root growth potential were induced by quality reducing treatments (Colombo, unpublished data).used to determine relationships where the unidentified factors can not be adequately known and their cumulative effects are not quantifiable (Kitchen et al 1999).

Recognition that what takes place in the nursery affects seedling performance after planting is not new (Shirley 1939, Wakely 1949). Attempts to improve field performance have been the main spur to implementing or refining morphological standards for planting stock (Thompson 1985), although such size standards often have been based on perception rather than demonstrated relationships between size and field performance (Sutton 1980). While seedling morphology is widely used to grade nursery stock, physiological standards have seldom been adopted (Dunsworth 1997). Sutton (1980) concluded that "attempts to improve planting stock quality will succeed only by unlikely chance unless they are based on adequate physiological knowledge". More widespread acceptance by foresters and nursery managers of the need for physiological standards is a prerequisite to the development of nursery practices that favour better physiological quality.

Conclusions

The greatest emphasis on planning nursery operations and on seedling quality often occurs in nurseries producing seedlings for industrial purposes. This reflects the greater capital avail-

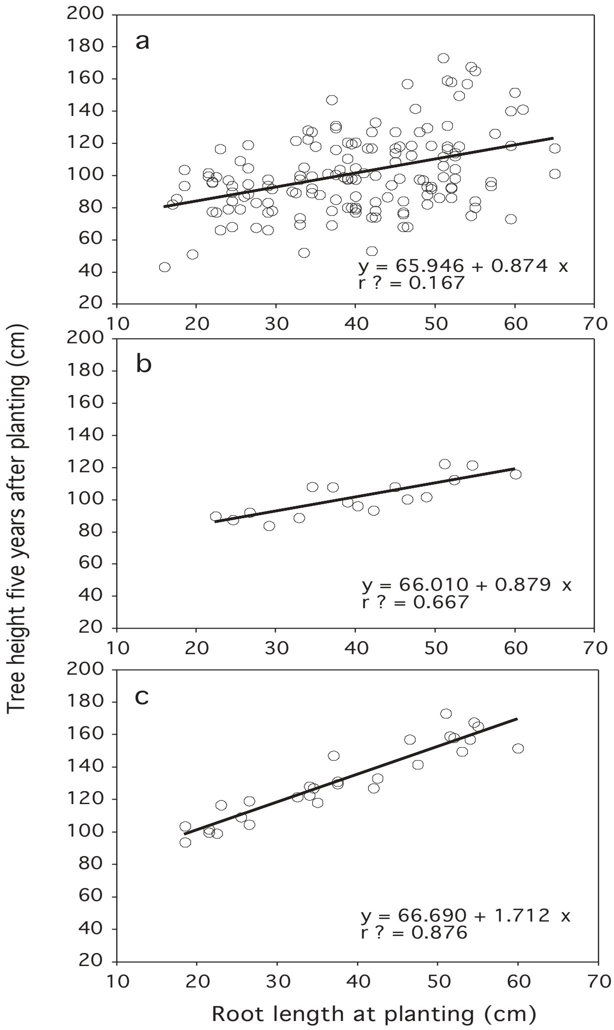

Figure 5. Correlations between height growth five years after planting and the length of the roots of bareroot white spruce seedlings at the time of planting. a) individual tree data; b) group mean data; and c) boundary line data. The data is drawn from the original data set on which a paper by Mullin & Christl (1980) is based.

able there for seedling production and in general, a better trained workforce. Probably the least sophisticated nursery practices are employed in community-based tree nurseries. However, in many cases the smaller number of seedlings in community nurseries may allow for closer attention that partially makes up for less advanced nursery technology.

There is room for improvement in practices in even the most advanced nurseries, especially insofar as gaining an understanding of the relationships between nursery practices and field performance is concerned.

Attempts to use tree nurseries to regenerate non-commercially valuable species is daunting given the potentially large number of species that can be confronted, many with unique or unknown biological needs for germination and seedling growth. Broadleaved species have important roles to play in sustaining the natural environment, providing economic benefits through forest plantations, and supporting indigenous populations who rely directly on forests for wood and other products. Clearly, the efficient nursery production of broadleaved seedlings that will survive and grow vigorously is an important component of forest sustainability. The improvement of reforestation success using broadleaved tree species relies on the development of morphological and physiological standards that are based on field performance and related back to nursery production practices.

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8. Promoting germination of native species using smoke for land restoration and nursery production in Australia

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Summary

Western Australia is well known for the high biodiversity of its flora, particularly the south-west region. This area has a typical mediterranean-type climate and possesses 5710 published species of vascular plants 79.2% of which are endemic to the area. With such a strong presence of endemic vascular flora the most effective and efficient method of reintroducing native flora is through the propagation of local native seed.

For most disturbed areas such as urban bushland, road verges and mining areas, failure to recruit native species from respread topsoil, broadcast or nursery-sown seed is often due to dor,ancy residing in the seeds. Seed dormancy limits the re-establishment of many species reducing the return of species and afecting the orginal local vegetation cover.

There are many different methods to break seed dormancy, some of which are species-dependent and produce irregular results. Plant-derived smoke, however, has been used to improve germination for approximately 60% of Western Australian species, including species form the Myrtaceae, Rutaceae and Proteaceae families. Smoke as a dormancy breaking treatment in not limited to species from fire-prone habitats as it has been shown to alleviate dormancy in species from alpie vegetation (Tasmania, Australia).

Without the use of heat, smoke can be applied in an aqueos form called smoke water ('bubbling' of smoke in water for 1 hr) or in an aerosol form. The mechanism of smoke in the alleviation of dormancy is unknown, but could be associated with physical and chemical actions.

At Kings Park and Botanic Garden, in Perth Western Australia, smoke is regularly used for the nursery production is not only due to higher levels of germination, but also earlier and more uniform emergence of seedlings. Most of the stock produced in the nursery is then used for restoration projects with similar levels of survival as conventionally produced plants.

For natural recruitment and consequently, optimal establishment, smoke can also be used *in-situ*. Smoke can be applied directly to topsoil with significant improvement in recruitment of native species from the soil seed bank results.

Smoke treatment of the soil seed bank has advantages in terms of rapid germination, good establishment and high survival of plants.

Keywords: Australia, native species, seed dormancy, smoke.

Dormancy

For disturbed areas such as urban bushland, road verges, degraded habitat and mined areas, failure to recruit native species from respread topsoil, broadcast or nursery-sown seed is often due to dormancy residing in the seeds. Seed dormancy limits the re-establishment of many species reducing the return of species and affecting the original local vegetation cover. Post rehabilitation sites suffer the absence of important key families and consequently reduction of plant and associated microorganism diversity (Table 1).

Dormancy is defined as the absence of germination of (viable) seed in conditions deemed favorable for germination (Nikolaeva 1969). Dormancy mechanisms have evolved in plants to

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Table 1: Key families which often fail to regenerate in plant rehabilitation programs

Class	Family
Monocotyledons	Cyperaceae Juncaceae Poaceae Restionaceae
Dicotyledons	Dilleniaceae Epacridaceae (sensu Ericaceae) Proteaceae (some taxa) Rutaceae

maximise the success of seedling establishment and survival in the plant's local environment (Bewley & Black 1994; Baskin & Baskin 1998).

Dormancy has two forms, based on the source of dormancy imposition. The first being inorganic dormancy: where unfavourable environmental conditions impose dormancy; and second being organic dormancy; where dormancy is imposed by the seed itself.

Most dormancy research has been undertaken on species of the northern hemisphere from deciduous forests, boreal coniferous and temperate alpine zones and arctic and temperate-zone alpine tundra. Mediterranean-type ecosystems are vastly different (Baskin and Baskin 1998). Chilling and drought stress, which represent key processes in vastly different ecosystems are known to impose similar water restriction mechanisms on plant and possibly seed tissues (Taiz and Zeiger 1991). However, it is likely that dormancy release is as divergent as the ecologically diverse parent floras in which a species resides. For example, for autumn germinating mediterranean species, high temperature conditions associated with summer, the season preceding the growing season, rather than chilling, which is often prescribed for spring germinating species from temperate to cool climates, would play a role in dormancy release.

Fire

Fire plays an important role in the regeneration and growth in many plant communities of mediterranean-type ecosystems. The Californian chaparral has a rich flora with different mechanisms for cueing germination to post-fire conditions (Keeley 1991; Kelley & Fotheringham 1998b), in fire-dependant plant communities in South Africa, fire regime plays a role in succession (Kruger 1984), increased germination after fire (Naveh1975) together with vegetative regrowth (Piotto *et al* 1999) has been documented in the Mediterranean basin region.

The germination of many Australian species is known to be limited to post-fire periods.

These include heath species of southern Australia (Specht *et al*. 1958; Specht 1981), hard seeded leguminous species (Cavanagh 1980; Auld and O'Connell 1991; Whelan 1995; Bell *et al*. 1993; Bell 1999), fire ephemerals (Hobbs and Atkins 1990; Smith *et al*. 1999) and perennials which are difficult to propagate (Meney *et al*. 1994; Curtis 1996; Schatral 1996). Fire and appropriate moisture levels are therefore highly favoured as the two most important germination cues, ensuring germination occurs under favourable environmental conditions (Bell 1999).

Heat from fire releases the physical seed coat dormancy of many legume species and a few non legume species (Bell *et al*. 1993; Koch *et al*. 1996). Fire can trigger the opening of serotinous fruits which then release the seed onto the post-fire seed bed. In many of these species, the woody fruit provides the dormancy mechanism as well as preventing post and pre-dispersal predation (e.g. *Banksia* spp.). The seed, once released, has limited dormancy, with germination proceeding once soil wetting has occurred. Seed banks accumulate either in serotinus cones and fruits, where seeds are maintained in a quiescent state within the canopy, or in the soil, where deep dormancy delays germination until fire. Many species have evolved barriers to germination that are normally overcome by fire-related cues. (Keeley J.E & Fotheringham 1998a).

Smoke

Smoke is another by-product of fire and has been a recent discovery as a dormancy breaking cue (Brown *et al.* 1997). Seeds of a substantial number of species from the mediterranean type ecosystems of southern Africa (de Lange and Boucher 1990; Brown *et al.* 1993; 1994; 1995), California (Keeley and Fotheringham 1998a;b) and Australia (Dixon *et al.* 1995; Roche *et al.* 1997a, b; Enright *et al.* 1997; Read and Bellairs 1999; Tieu *et al.* 1999, 2001) have been shown to germinate in response to plant derived smoke at significantly higher levels than untreated seed. Smoke also overcomes dormancy in species without an obvious requirement for fire for germination of vegetable seeds such as celery (*Apium graveolens* L.) (Thomas and van Staden 1995), lettuce (*Lactuca sativa* L. cv. Grand Rapids) (Drewes *et al.* 1995).

Use of Smoke in Western Australia

There are many different methods for breaking seed dormancy, some of which are species-dependent and may produce irregular results. Plant-derived smoke, however has been used to improve germination in approximately 60% of the more then 300 Western Australian species tested, including species from the Myrtaceae, Rutaceae, Proteaceae and Restionaceae families (Figure 1).

Smoke as a dormancy breaking treatment is not limited to species from fire-prone habitats as it has been shown to alleviate dormancy in species from Tasmanian alpine vegetation (Marsden-Smedley *et al.* 1997). Smoke, without heat, can be applied in an aqueous form called smoke water ('bubbling' of smoke in water for 1 hr) or in an aerosol form. The smoke is generated in a large metal drum by slow and controlled combustion. The smoke is forced into water to capture the soluble active components or into a tent to allow the smoke to settle directly on the soil containing seeds or treating seeds disposed in trays (Figure 2).

Materials combusted to produce smoke to effectively break seed dormancy range from fresh and dry plants, hay, cellulose and tabacco. Commercial smoke food flavourants also promote seed germination.

In fire-prone plant communities such as kwongan and *Banksia* woodland, on site application of smoke alone is equally effective as a wildfire in promoting seed germination (Dixon *et al.* 1995; Roche *et al.* 1997a). (Figure 3).

Figure 1: The application of smoke can be use to improve the germination of many species which are difficult to germinate using conventional methods. eg. Loxocarya gigas.

It is also more effective than nutrients (Figure 4) and soil disturbance (Figure 5) resulting in higher germinants and number of species.

In Jarrah (*Eucalyptus marginata*) forest of Southwest Western Australia (Roche *et al.* 1997b) the application of aerosol smoke induced a 48-fold increase in the total number of germinants and led to a 4-fold increase in species diversity.

The timing of smoke application is important. Smoke applied in autumn will maximise the period that the germinants have to become established prior to the possible next summer drought. The application of smoke in other mediterranean environments to stimulate soil seed banks should also be in autumn so that the applied smoke will gently leach into the soil

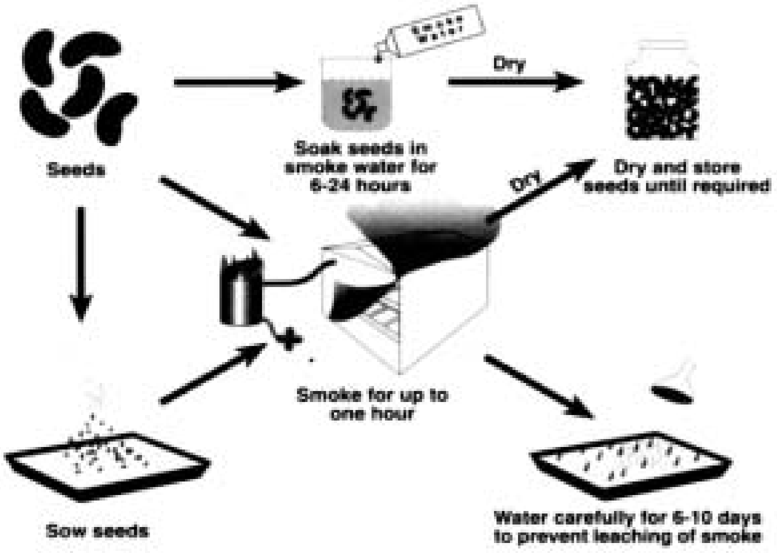

Figure 2: Use of the smoke for nursery germination.

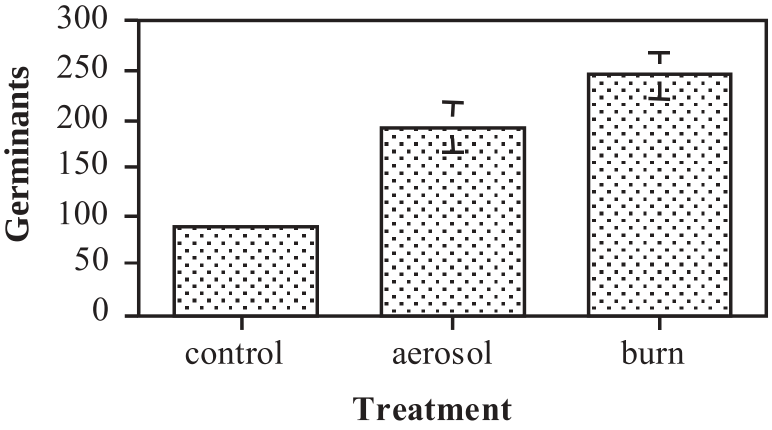

Figure 3: Applied smoke is as effective in breaking dormancy in heatland species as a wildfire.

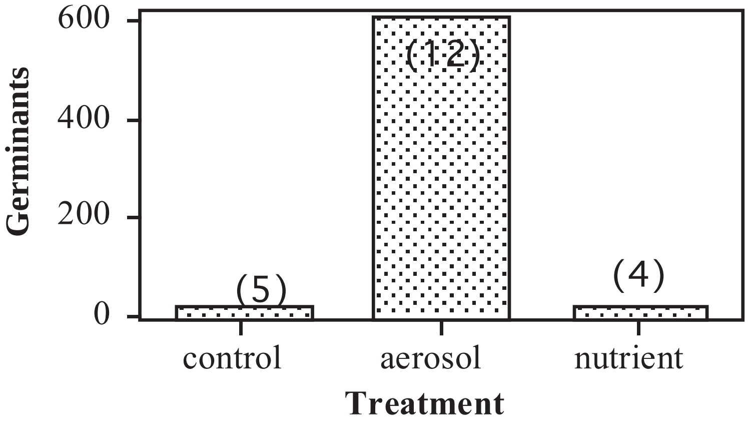

Figure 4: Comparison of smoke vs nutrient application to knowngan heat to stimulate germination. In brackets number of species.

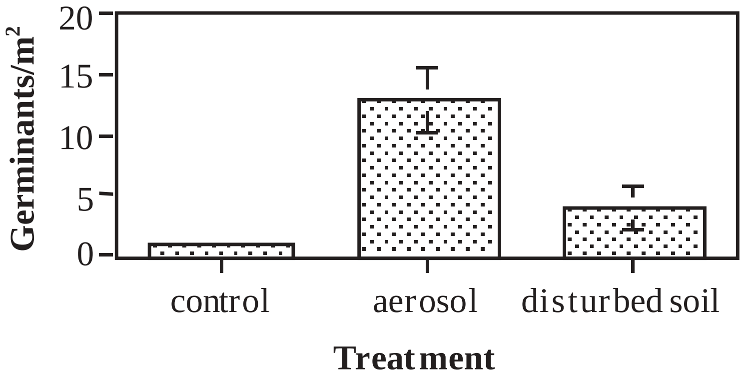

Figure 5. Evaluation of the effects of disturbance and aerosol smoke on seedbank germination within knowgan heatland.

profile with the first rains so seeds receive the dormancy breaking cue. In Australian species, more than 100 genera (in phylogenetical distant families) of a total of 159 studied in both glasshouse and habitat conditions have shown smoke-responsive germination (Dixon *et al.* 1995; Enright *et al.* 1997; Grant and Koch 1997; Roche *et al.* 1997a;*b*; Ward *et al.* 1997; Read and Bellairs 1999; Smith *et al.* 1999) (Table 2).

Response to smoke is independent from, taxon, post-fire regeneration strategy, life form or seed size (Dixon *et al.* 1995).

At present, the mechanisms of the action of smoke are not clearly understood but there have been preliminary investigations which exclude physical degradation of the seed coat or nutritive support as a role for smoke (Baldwin *et al.* 1994). The active constituent is soluble in water (de Lange and Boucher 1990; Dixon *et al.* 1995) and does not involve heat, another component of fire. Baldwin *et al.* (1994) suggested that smoke may trigger germination by chemically interacting with inhibitors or promoters in the seed coat, endosperm, embryo or combinations of these seed tissues. Egerton-Warburton (1998), in addition, showed that smoke acted on the seedcoat by increasing the permeability of the sub-testa cuticle to solutes. Smoke can replace the light requirement and overcome dormancy in lettuce (Drewes *et al.* 1995) and celery (Thomas and van Staden 1995) and the active compound(s) of smoke appears to parallel the action.

The active compound that triggers germination is clearly volatile and is produced when plant material is heated to around 200° C (Jager *et al.* 1996). To this present day the active chemical(s) have not been isolated.

Restoration and nursery

At Kings Park and Botanic Garden, in Perth Western Australia, smoke is regularly used for the nursery production of native plants. The success of the use of smoke in mass production is not only due to higher levels of germination, but also to earlier and more uniform emergence of seedlings. Most of the stock produced in the nursery is then used for restoration projects with similar levels of survival as conventionally produced plants.

For natural recruitment and consequently, optimal establishment, smoke can also be used *in-situ*. Smoke can be applied directly on site with significant improvement in recruitment of native species from the soil seed bank results.

On site application and sowing of pre-treated seeds with smoke is now widely adopted, with successful results, in mine sites and land restoration.

The advent of smoke, as a germination stimulant for Australian plants, has opened up opportunities to study and utilise Western Australian species (Dixon *et al.* 1995, 1996; Roche *et al.* 1997a;*b*; Roche *et al.* 1998) previously deemed ungerminable or with low germination and considered impractical for use in horticulture and land restoration.

Table 2: Australian genera which are responsive to smoke for germination under nursery or field conditions

- Acacia *
- Acanthocarpus
- Acrotriche
- Actinostrobus
- Actinotus
- Adenanthos *
- Agonis
- Agrostocrinum
- Allocasuarina *
- ,Alyxia
- Amphipogon
- Andersonia
- Anigozanthos
- Arthropodium
- Astartea
- Astroloma
- Baeckea
- Banksia *
- Billardiera
- Blancoa
- Boronia
- Bossiaea *
- Brunonia
- Burchardia
- Bursaria
- Caesia
- Callitris
- Calytrix
- Chamaescilla
- Chieranthera
- Clematis
- Codonocarpus
- Comesperma
- Conospermum
- Conostephium *
- Conostylis
- Crassula
- Cryptandra
- Cyathochaeta *
- Dampiera *
- Desmocladus *
- Dianella
- Diplolaena
- Drosera
- Epacris
- Eriostemon
- Eucalyptus *
- Exocarpus
- Gahnia
- Geleznowia
- Georgiella
- Gompholoblum *
- Gonocarpus
- Grevillea
- Gyrostemon
- Haemodorum
- Hakea
- Hemigenia *
- Hemiphora
- Hibbertia
- Hovea *
- Hyalosperma *
- Hybanthus
- Hydrocotyle *
- Hypocalymma
- Isopogon
- Isotoma *
- Johnsonia
- Kennedia *
- Lachnostachys
- Lasiopetalum
- Laxmannia
- Lechenaultia
- Leptomeria
- Leptospermum
- Leucopogon
- Levenhookia *
- Lobelia
- Lomandra
- Loxocarya
- Lysinema
- Macropidia
- Melaleuca *
- Mitrasacme
- Myriocephalus
- Neurachne
- Opercularia *
- Orthrosanthus
- Patersonia
- Persoonia
- Petrophile
- Phyllanthus *
- Pimelea
- Pityrodia
- Platysace
- Pomaderris
- Poranthera *
- Ptilotus
- Ricinocarpus
- Rulingia
- Scaevola
- Siegfriedia;
- Sollya
- Sowerbaea *
- Sphenotoma
- Spyridium
- Stackhousia;
- Stipa *
- Stirlingia
- Stylidium
- Tersonia
- Tetraria
- Tetrarrhena
- Tetratheca
- Thysanotus
- Trachymene.*
- Trichocline
- Tripterococcus
- Trymalium *
- Velleia
- Verticordia'
- Waitzia *
- Xanthorrhoea *
- Xanthosia

*(*smoke response under field)*

At present researcher in Kings Park and Botanic Garden are investigating the effect of smoke on a number of key species of the Mediterranean basin flora.

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9. Effect of different methods of producing poplar cuttings on rooting ability and plant growth

G. Facciotto[1], G. Mughini[1], P. Balsari[2] and G. Airoldi[2]

Summary

During studies on Short Rotation Forestry (SRF), four different methods of producing poplar cuttings were examined:

a) the widely-used method of producing cuttings (sprouts cut at an angle at one end and straight at the other - 20 cm long and 1-2 cm above the buds);
b) sprouts cut straight at 10 cm intervals (regardless of buds);
c) sprouts cut straight at 20 cm intervals (regardless of buds);
d) sprouts cut straight at 30 cm intervals (regardless of buds).

These methods were then compared to the planting of whole sets (3 m long) horizontally (method e) leaving about 10 cm above the surface. In this way the cutting of the sets can be avoided.

Trials were carried out at the farm belonging to the Istituto di Sperimentazione per la Pioppicoltura at Casale Monferrato on sandy soil, using a completely randomized block design with five replications (30 cuttings or 7 sets per plot), and placing the cuttings at 180 x 70 cm, which corresponds to a density of about 8.000 cutting·ha^{-1}.

Ninety days after planting the best rooting results (90%) were obtained from the 30 cm cuttings, produced by sets cut at random and not taking into consideration the position of the buds. Similar results were obtained with traditional cuttings (oblique at one end and transversal at the other).

In the other plots (10 and 20 cm cuttings produced by sets cut at random), rooting was considerably inferior and statistically different (about 3% and 56% respectively).

After the first vegetative season, the best results of plant growth were obtained planting whole sets with an average height of 341,5 cm. With regard to biomass production the best results were obtained using 30 cm cuttings and planting whole sets: 3,91 ODt ha^{-1} and 3,68 ODt ha^{-1} respectively.

Keyworks: short rotation foresty, poplar, cuttings, rooting.

Introduction

Poplars are normally propagated by means of cuttings obtained from stems of one-year old plants or from one-year old shoots grown on stools. In suitable sites, plants of *Populus canadensis* 'I-214', produced from cuttings, can grow from 2,50 m to 3,50 m during the first growing season, whilst shoots produced from stools often grow from 3.5 to 4.5 m (Frison and Piotto, 1984). Each shoot can produce 5-10 cuttings which are 18-23 cm long.

In fact, sets with diameters from a minimum of 10 mm to a maximum of 30 mm (taken at 50 cm above soil) can be utilised. The finer ones, insufficiently lignified, and the bigger shoots

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with too many branches should be eliminated only if they are established with planting machines which have set diameter limits (AA.VV., 1996).
The widely-used method of producing cuttings is to cut the stripling oblique at one end and transversal at the other, 1-2 cm above the buds and 20 cm in length. This method is adopted to facilitate and promptly recognise which end of the cutting is to be planted (Frison, 1996).
The position of buds on sets influences rooting and growth, with values decreasing from the base to the top. This was attributed to the distribution of latent roots along the set, which are numerous at the base and in the middle part of the sets, and become scarce towards the top.
The diameter of cuttings also influences plant growth. The results obtained from cuttings having diameters from 15 to 30 mm appear to be excellent (Frison, 1996). On the other hand, the results obtained from diameters under 15 mm are not so good and the lack of growth of those under 10 mm is evident.
The growth of young poplars depends on the length of cuttings, especially during the first year of vegetation. For example, in order to maintain regular growth the cuttings should be 35 cm with the *P. canadensis* 'Luisa Avanzo' and 25 cm with the *P. canadensis* 'Bellotto' (Frison and Facciotto, 1985).
This type of cutting production is inadequate for Short Rotation Forestry (SRF) owing to the reduced work capacity during the preparation of cuttings and subsequent establishment. To investigate the effect of cuttings production on shoots growth, 5 different methods of poplar plantation were compared.

Materials and methods

Four different methods of producing poplar cuttings were examined:

a) the widely-used method of producing cuttings (sprouts cut at an angle at one end and straight at the other - 20 cm long and 1-2 cm above the buds);
b) sprouts cut straight at 10 cm intervals (regardless of buds);
c) sprouts cut straight at 20 cm intervals (regardless of buds);
d) sprouts cut straight at 30 cm intervals (regardless of buds).

These methods have been compared with the planting of whole sets (3 m long) placing them horizontally about 10 cm under the soil. In this way cutting of sets can be avoided.
Trials were carried out at the farm belonging to the Istituto di Sperimentazione per la Pioppicoltura at Casale Monferrato on a sandy soil, using a completely randomized block design with five replications (30 cuttings or 7 sets per plot). The cuttings were placed at 180 x 70 cm, corresponding to a density of about 8.000 plants per hectare.
The cuttings were hand planted on April 3, 1997 in furrows about 15 cm deep, in a field previously ploughed and harrowed. All the cuttings were planted in a vertical position with the topmost bud facing skyward, and the soil packed firmly around them. The 10 cm cuttings needed furrows 10 cm deep whilst whole sets were laid horizontally in furrows about 10 cm deep (Figure 1).
A week later herbicide treatment was carried out with a boom sprayer. The mixture, made up of water and the equivalent of 0,4 $kg\cdot ha^{-1}$ of linuron, 0,8 $kg\cdot ha^{-1}$ of trifluralin and 1,4 $kg\cdot ha^{-1}$ of alachlor, was distributed all over the surface (Vietto and Giorcelli, 1997). Owing to lack of rain from January to the end of May, which is unusual in the Po valley, sprinkler irrigation was carried out twice – the first on April 13 and the second one on April 28.
At the end of the vegetative season the rooted cuttings and the number of plants which had developed from each set were counted. Subsequently height and double diameters of all the plants were measured at breast height (1,30 m from the ground); 6 plants per plot were cut to determine the amount of biomass produced.

Figure 1: Placement of the whole sets in 10 cm deep furrow.

Results

At the end of the growing season the best rooting results were obtained from the 30 cm cuttings which were produced by cutting the sets at random (90% rooted) (Figure 2).

As noted the 20 cm cuttings cut at random from sets had lower rooting values (56%) while the 10 cm cuttings rooting value was just a little over 3%.

Results not statistically different were obtained with cuttings normally utilized at the farm (Figure 3).

The whole sets produced 23,2 (± 9,6) shoot per plot, corresponding in our test condition to a rooting of cutting of about 80%. An average of 3 plants per set were obtained. Budding was not particularly homogeneous and decreased from the base towards the top of the set. It was therefore necessary to reduce the length of the set to be planted by at least one meter from the top part so that budding became homogeneous.

From whole set

From cutting

Figure 2: Shoot roots development.

With regard to the development of young plants, the best results of height and diameter were obtained by whole sets.

In detail, whole sets allowed the development of plants with an average height of 341,5 cm. Results not statistically different were obtained from 30 cm long cuttings cut at random (313,3 cm), with traditional 20 cm cuttings (302,6 cm) and with 20 cm long cuttings, obtained from sets cut at random (290,0 cm). The development of the plants from 10 cm long cuttings was significantly inferior and statistically different with respect to the other techniques (218,0 cm high) (Figure 4).

As regards plants diameter, the best results were obtained from whole sets with an average diameter of 22,2 mm. Results not statistically different were obtained from 30 cm long cuttings cut at random (20,6 mm), from traditional 20 cm cuttings (19,5 mm) and with cuttings 20 cm long, obtained from sets cut at random (18,6 mm). The 10 cm long cuttings produced shoots with a diameter considerably inferior and statistically different with respect to other methods (11,1 mm) (Figure 5).

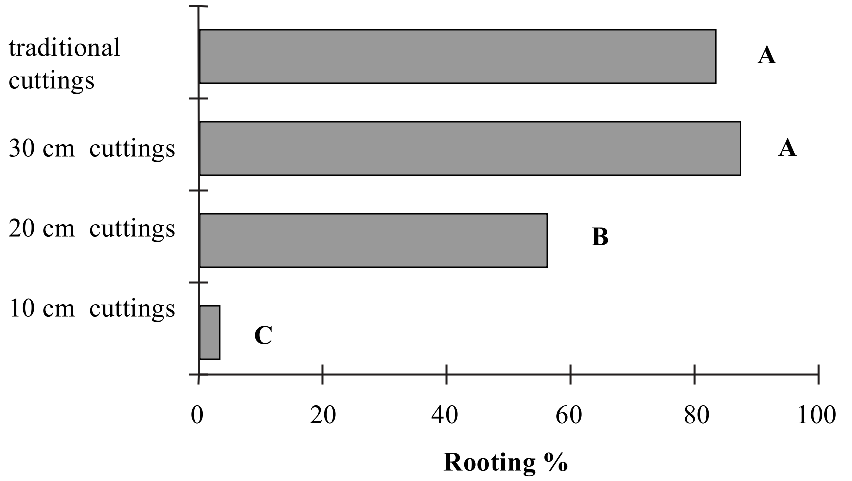

Figure 3: Mean rooted cuttings for different production systems. Measures taken on 29.01.1998. Values with the same letters are not statistically different (Duncan test P≤ 0,01).

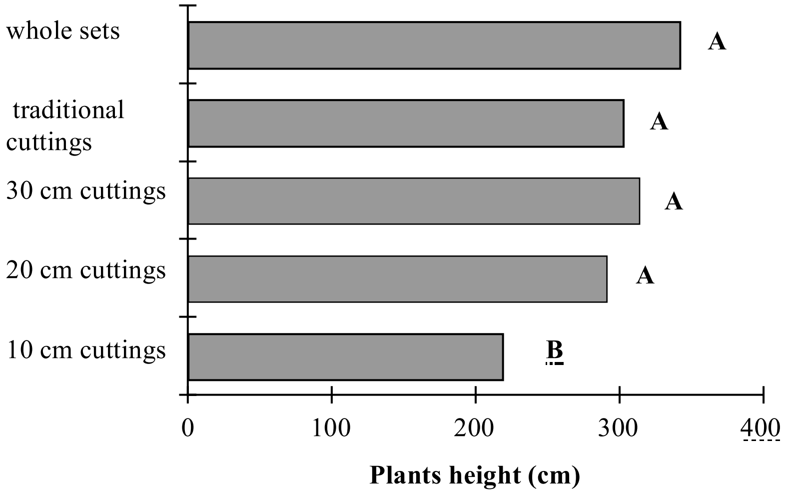

Figure 4: Height of plants obtained from different methods. Measures taken on 29.01.1998. Values with the same letters are not statistically different (Duncan test P≤ 0,01).

The production of woody biomass was calculated taking into account the average diameter and the height of plants, their fresh and dry weight and rooting percentage of the cuttings. Major production of oven dry (OD) biomass was obtained from plants grown from 30 cm long cuttings, cut at random (3,91 ODt·ha^{-1}), followed by those obtained from whole sets (3,68 ODt·ha^{-1}) and those obtained from 20 cm long cuttings normally utilised at the farm (3,36 ODt·ha^{-1}).

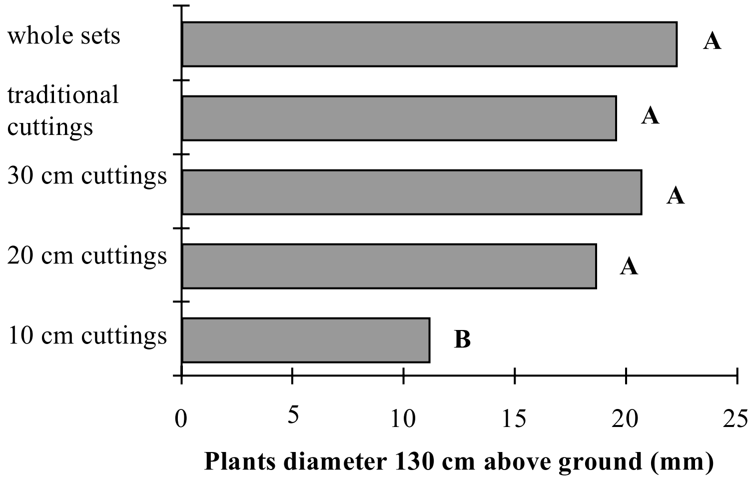

Figure 5: Diameters of plants measured at 1.30 m from ground during trials. Values with the same letters are not statistically different (Duncan test P≤ 0,01).

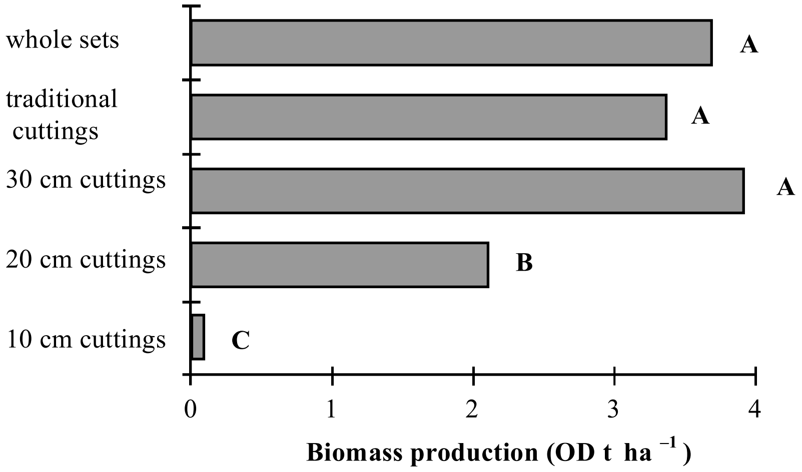

Figure 6: Oven dry biomass per hectare obtained in different methods at the end of the first growing season. Values with similar letters are not statistically different (Duncan test P≤ 0,01).

Significantly inferior results were obtained from 20 and 10 cm long cuttings cut at random with 2,1 ODt·ha^{-1} and 0,08 ODt·ha^{-1} respectively (Figure 6).

Conclusion

Although the trial was conducted for only one growing season, it revealed a potentially interesting alternative method for the plantation of poplar SRF in Western Po Valley conditions. The results obtained using 30 cm cuttings cut at random and whole sets were not statistically different from those obtained using the traditional method.
The possibility of establishing a poplar plantation, at a short rotation cycle, for the production

of biomass using sets, placing them horizontally in the soil under the surface, is particularly interesting and encouraging as it could reduce the costs of production and establishment. Even though it was characterized by a lesser number of root suckers per hectare, the method of planting whole sets was particularly interesting as the shoots produced as much dry biomass as the plants obtained from 30 cm long cuttings cut at random. This result is probably due to more reserve substances and water contained in whole sets as compared to a cutting. This system of planting requires extremely simple machinery: a plough to open the furrows and two press wheels to cover and to pack the soil firmly around the sets. This system would further reduce both time and costs for establishing a poplar plantation.

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10. Effect of inorganic and organic NPK fertilizers on the growth of three tropical hardwood seedlings grown in an ultisol

*J.A. Fagbenro**

Summary

Nature and components of potting mixtures used in the forest nurseries often have direct influence on the quality of the planting stock. Three series of nursery potting experiments to study the effect of inorganic (15: 15: 15) and lignite-based organic fertilizers (19: 7: 5) on the growth of two indigenous (*Ceiba pentandra and Parkia biglobosa*) and one exotic (*Gmelina arborea*) tree species were conducted in Ibadan, Nigeria. The plants were grown for 3 months in top soils (0-30cm) collected from an ultisol (acid soil) in southern Nigeria. Five levels of the fertilizers, viz, 25, 50, 100, 200 and 250 mgNKg^{-1} were added to the soil. The results indicated that the three tree species responded significantly to fertilization. Growth rates, height, stem diameter, leaf production and dry matter yield increased in most cases, significantly (P=0.05) over the controls. Irrespective of fertilizer type, Ceiba always responded more to fertilization than did either Parkia or Gmelina. Effects of adding inorganic fertilizer beyond 25mgNKg^{-1} for Ceiba and 100mgNKg^{-1} for both Parkia and Gmelina were less beneficial. As for organic fertilizer, application rates up to 250mgNKg^{-1} still appeared to be beneficial to the three tree species. Irrespective of plant type, no significant correlation was established between rates of inorganic fertilizer application and plant height, stem diameter, leaf count and dry matter yield. However, rates of application of organic fertilizer were significantly positively correlated with plant parameters except for *Parkia biglobosa* where no significant positive correlation was found between plant height and leaf count.

Keywords: growing media, nursery stock, fertilization, growth.

Introduction

At the beginning of forest exploitation in Nigeria, the country depended primarily on the natural forests for the bulk of its timber and other wood supply (Abu et al., 1989). But with the rapidly growing population and the unprecedented expansion of economic activities in the early sixties, severe pressure has been imposed on the country's forest resources to meet the attendant upsurge in the demand for forest products for domestic consumption and export. As a result, emphasis was shifted from natural regeneration to artificial regeneration which gave rise to the establishment of several hectares of forest plantations of both exotic and indigenous tree species, including *Ceiba pentandra Parkia biglobosa* and *Gmelina arborea*.

Research results have however convincingly shown that one of the plant characteristics that affect growth rate and biomass production of trees in plantations is the quality of planting stock. One of the important factors that have direct influence on the quality of the planting stock is the nature and component of potting mixture used in the nursery for their production. According to Wilde (1958), a nursery soil should have at least 2% of organic matter and appreciable quantity of plant nutrients. But Nigerian foresters are not always lucky to have nursery sites or soils with the desired amount of organic matter and nutrients for the production of healthy and vigorous planting stock. Consequently, they either rely on the use of inorganic fertilizers or organic materials for the improvement of their nursery potting mixtures. As a result, there have been variations in the type of potting mixtures being used in forest nurseries in dif-

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ferent parts of the country due to variation in materials available in a given locality and partly to tradition in a particular nursery (Jackson et al., 1970).

However, inorganic fertilizer is rarely used in the country to raise tree seedlings. Where it is used, it has been kept to the barest minimum. Apart from the economic cost, nursery seedlings of maximum weight produced by heavy applications of mineral fertilizers has been reported to have succulent tissues, unbalanced top-root ratio and other unsatisfactory properties which lower their ability to survive on cut-over lands (Fagbenro & Olunuga, 1989). Besides, Wangari & Sanford (1984) have observed that inorganic fertilizer can only supply the specific nutrients it contains to the soil, but cannot provide the additional effects of organic matter for the prevention of erosion, run-off and leaching, improvement of cation exchange capacity and water holding capacity of the soil.

So, over the years, the productivity of permanent forest nurseries in Nigeria has become dependent upon the supply of organic materials, particularly animal manure, for the improvement of the physical condition of soil and as a supplier of plant nutrients (Olagunju & Ekwebelam, 1985). However, animal manures are not available in every locality in the country for use in forest nurseries. In addition, they neither contain constant nor balanced nutrients. The use of immature animal manures also produce ammonia that is detrimental to the tender roots of plant seedlings. Yet, the country has abundance of other organic materials, notably lignite, which can be processed and utilized to produce high quality nursery planting stock (Fagbenro, 1988). Here in Nigeria, there have not been systematic investigations on the possibility of producing lignited-based organic fertilizers and on their effects on plant growth. Preliminary studies have indicated that lignite-based fertilizers are a viable and cost-effective alternative to inorganic fertilizers (Fagbenro & Olunuga, 1989; Fagbenro & Afuwape, 1992; Fagbenro et al., 2000). This investigation is therefore one of the series of studies to compare possible effect of a lignite-based organic fertilizer with that of its inorganic counterpart on the growth of seedlings of three economic tree species.

Materials and methods

Bulk topsoil (0-30cm) was collected from an abandoned agricultural farm formerly grown to cassava and plantain at the Forestry Research Institute of Nigeria experimental station, Sakpoba in Edo State. It was air-dried, ground and sieved through 2mm sieve. Some physical and chemical properties of the soil were determined and are presented in Table 1a.

The inorganic fertilizer (15: 15: 15) was purchased from Oyo State ADP while the lignite-based NPK organic fertilizer (19: 7: 5) was developed by the author of the paper (Table 1b) using local raw materials. The fertilizers were applied at the rate of 0, 50, 100, 200 and 250 mg NKg^{-1}. Each fertilizer type was thoroughly mixed with 2kg sieved soil, the mixture put in a black 3-litre plastic pot having two draining holes at the bottom.

Ceiba pentandra, Parkia biglobosa and *Gmelina arborea* seedlings of similar height were transplanted at 2-leaf stage into the polypots at one per pot. The pots were left in the greenhouse for one week after transplanting to overcome initial shock. Thereafter, the pots were removed outside the green-house and put on benches. Random numbers were used to determine the position of each pot on the nursery bench. Watering with deionised water was done once or twice a day as necessary when it did not rain. The plants were grown outside the greenhouse to simulate nature. The statistical design adopted was a completely randomised one, while the treatments were replicated three times.

At fortnightly intervals, seedling height was measured with a ruler from the soil surface to the seedling tip while the stem diameter was measured with a micrometer at the crown line to the nearest mm. The leaf count was also recorded fortnightly.

At the end of 12 weeks the experiment was terminated. The shoots and roots were oven-dried at 70^{0}C until constant weight was obtained. Total dry matter and nodule weights were then determined.

Particle size analysis of the < 2mm soil sample was determined by the improved Bouyocous (1962) hydrometer method while all chemical analyses were done according to Fagbenro et al. (1994).

Analysis of variance was conducted and least significant differences at the 5% level of probability estimated to test for significance of results. Data from seedling growth parameters were subjected to simple correlation analysis to determine the extent application rates of fertilizers were related to the growth variables. Students t-test was used to examine differences between the fertilizer types.

Table 1a: Some properties of the soil sample (0-30cm) used for the fertilizer experiments

Property			Value
Texture:	Sand	(%)	89.0
	Silt	(%)	3.4
	Clay	(%)	7.6
pH		(H_20)	4.8
Organic C		(%)	0.93
Total N		(%)	0.06
Av. P		(ppm)	5.25
Ca		(cmolKg-1)	1.46
Mg		(cmolKg-1)	1.04
K		(cmolKg-1)	0.14
Na		(cmolKg-1)	0.02
Al		(cmolKg-1)	3.66
Ex. Acidity		(cmolKg-1)	0.76
TEB		(cmolKg-1)	2.66
ECEC		(cmolKg-1)	7.10

Table 1b: Fertilizers used for the experiments

Property	Fertilizer type	
(%)	Inorganic	Organic
N	15	19
P205	15	7
K20	15	5
OC	-	24.1
EHS	-	18.8
HA	-	15.9
FA	-	2.9
Other nutrients	-	ND

EHS: Extractable humic substances; HA: Humic acid; FA: Fulvic acid; ND: Not determined.

Results

Growth rate

For the three species, result indicated that fortnightly seedling height, stem diameter growth rates and leaf count in the control were high initially but decreased gradually thereafter. Seedling growth rates varied greatly with rate of fertilizer application. Growth rates were always more rapid in the early part of the growth period for seedlings grown in treatments having inorganic fertilizer. For both inorganic and organic fertilizers, height growth rates seemed to be at the peak at the end of 8 weeks of growth at every fertilizer application level.

Effect of inorganic fertilizer

Inorganic fertilizer had varying effects on height, stem diameter, leaf production and dry matter yield of Ceiba, Parkia and Gmelina seedlings (s. 1-4). For a given plant type, all treatments that had fertilizer addition produced seedlings that were significantly superior to the control for all the plant parameters measured except at 25-mgNKg^{-1} level where no significant difference was found between the control for stem diameter, leaf production and dry matter yield for Parkia and leaf production for Gmelina and at the highest application level of 250mgNKg^{-1} where Parkia produced seedlings that were inferior to those of the control in terms of stem diameter growth.

For *Ceiba pentandra*, effect of adding NPK inorganic fertilizer beyond 25mgNKg^{-1} was less beneficial in term of height growth (Figure 1) while 100mgNKg^{-1} appeared to be the optimum for both *Parkia biglobosa* and *Gmelina arborea* for this plant parameter. Irrespective of level of application, inorganic fertilizer always influenced height growth of Ceiba more than those of Parkia and Gmelina.

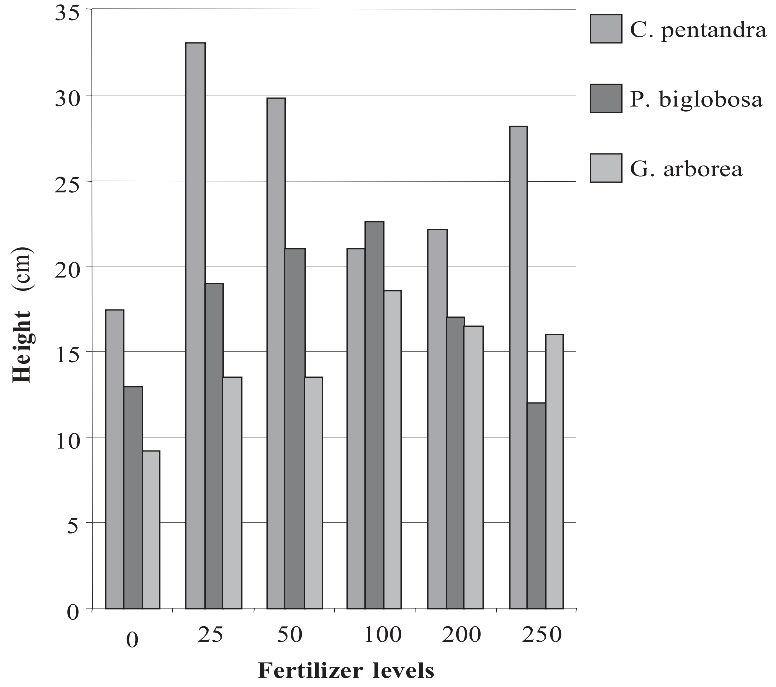

Figure 1: Effect of inorganic fertilizer on the height growth of C. pentandra, P. biglobosa and G. arborea seedlings.

Similar trend was observed for stem diameter except that inorganic fertilization of Parkia at the highest application level of 250mgNKg^{-1} did appear to have significant detrimental effect on the tree parameter (Figure 2).

As for the leaf production, inorganic fertilization significantly increased it for Ceiba at 25mgNKg^{-1} while Parkia produced its greatest number of leaves in treatments that received 100mgNKg^{-1} whereas, inorganic fertilization did not have any significant effect on leaf production by Gmelina (Figure 3).

Figure 4 shows the effect of inorganic fertilizer on dry matter yield by the three hardwoods. The trend was similar to the height, stem diameter and leaf production. But unlike height, stem diameter and leaf production that were highest at 25mgNKg^{-1} for Ceiba, the tree produced the heaviest seedlings at 100mgNKg^{-1} fertilization level just like Parkia and Gmelina.

Effect of organic fertilizer

The results are presented in Figures 5-8. Figure 5 shows that all treatments having organic fertilizer, like its inorganic counterpart, produced seedlings that were in most cases significantly taller than those grown in the control. Height increase was observed for the three tree species throughout all the fertilizer application levels. Maximum increment of 19% was recorded for Ceiba between 25 and 50mgNKg^{-1} application levels, 77% for Parkia between the control and 25mgNKg^{-1} and 35% for Gmelina between 200 and 250mgNKg^{-1} application levels.

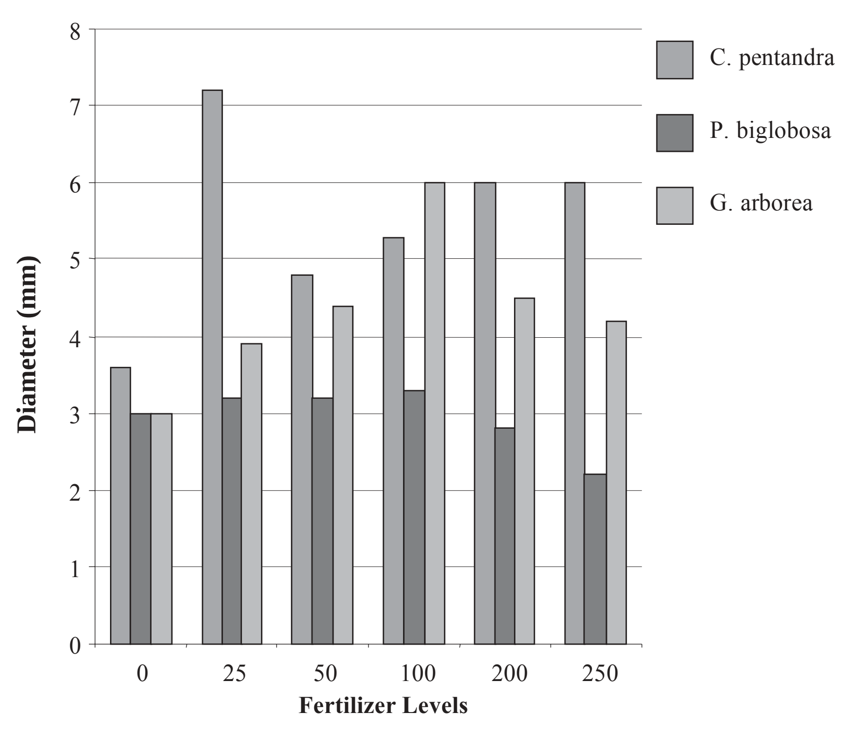

Figure 2: Effect of inorganic fertilizer on leaf production by C. pentandra, P. biglobosa and G. arborea seedlings.

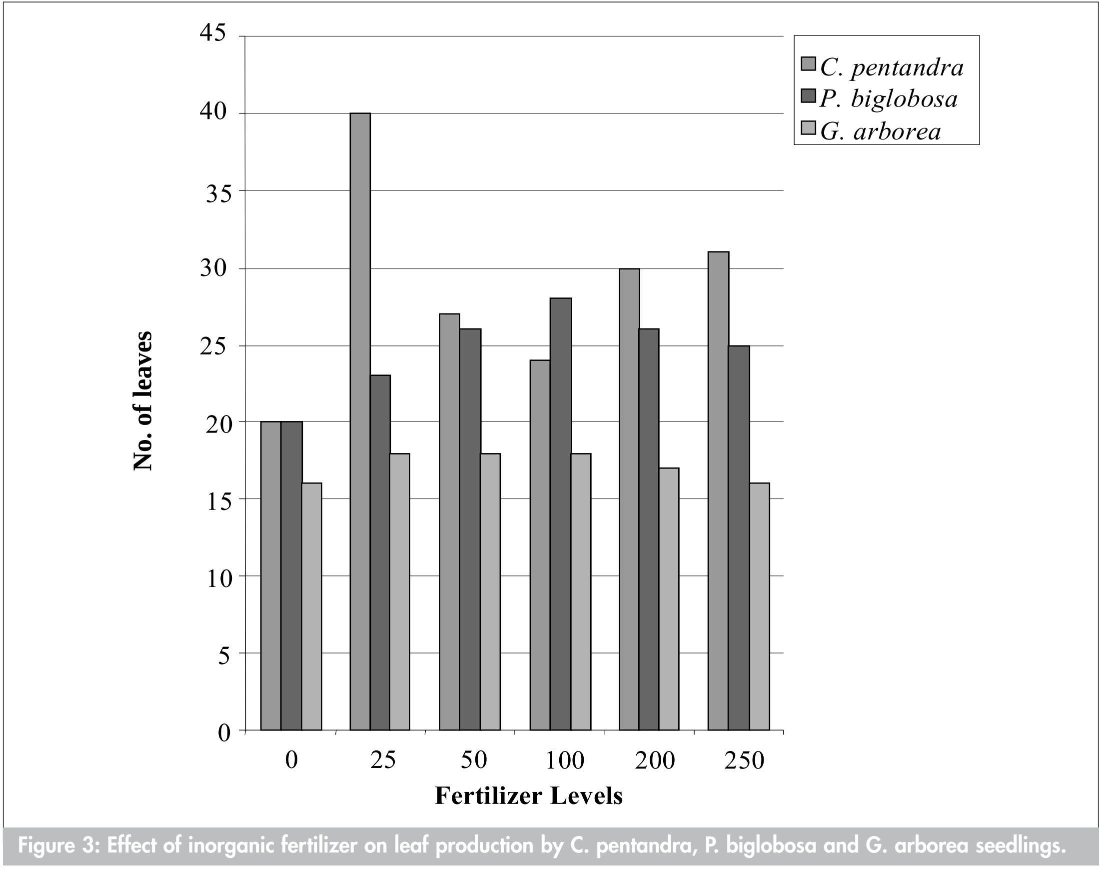

Figure 3: Effect of inorganic fertilizer on leaf production by C. pentandra, P. biglobosa and G. arborea seedlings.

The trend observed for height growth was similar to that of stem diameter. Increase in organic fertilizer application generally led to increase in stem diameter growth by three hardwoods

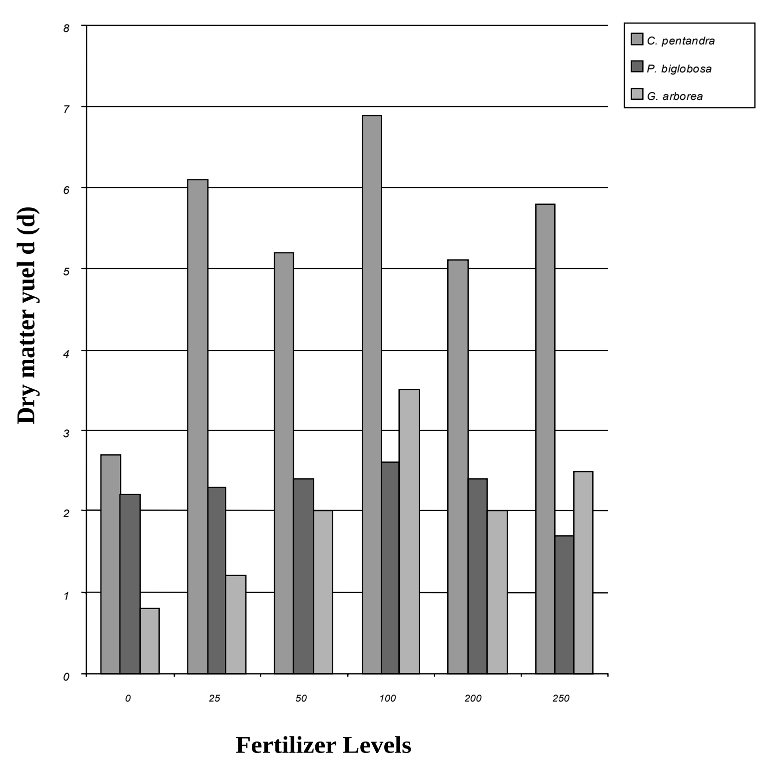

Figure 4: Effect of inorganic fertilizer on dry matter yield by C. pentandra, P. biglobosa and G. arborea seedlings.

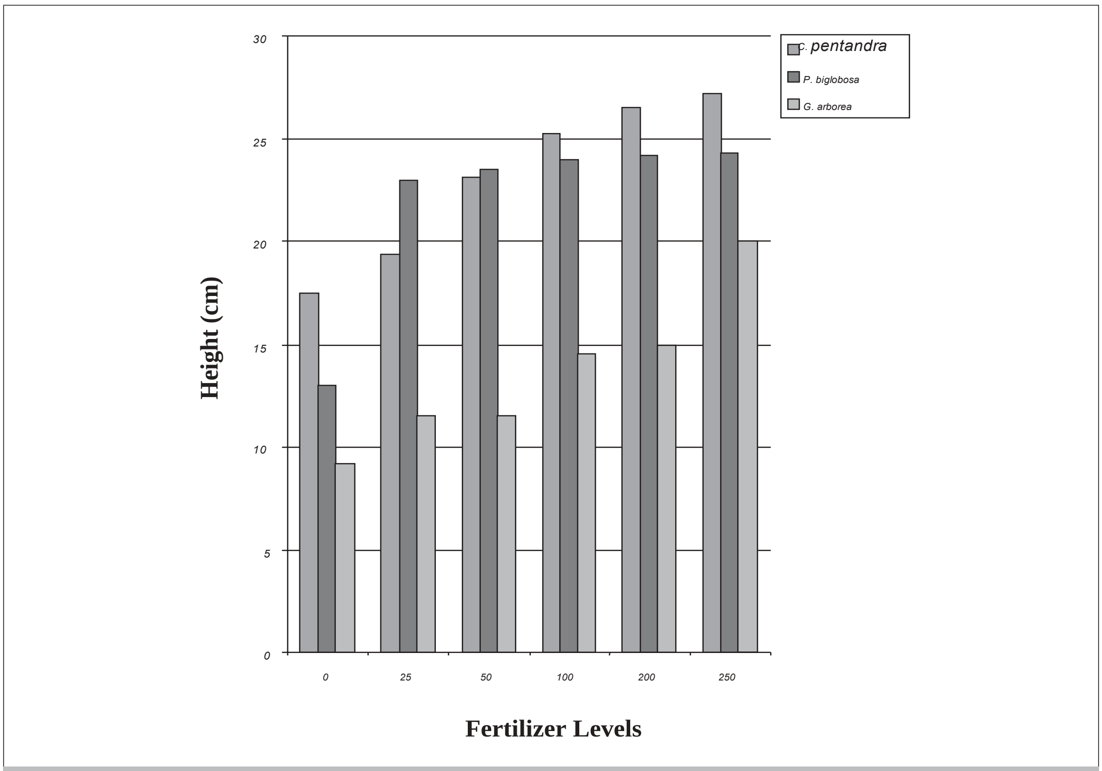

Figure 5: Effect of organic fertilizer on the height growth of C. pentandra, P. biglobosa and G. arborea seedlings.

(Figure 6). Like the height growth, Ceiba responded more to organic fertilizer in terms of stem diameter production while the response of both Parkia and Gmelina appeared to be similar. Leaf production by the three tree species also increased with increasing organic fertilizer ap-

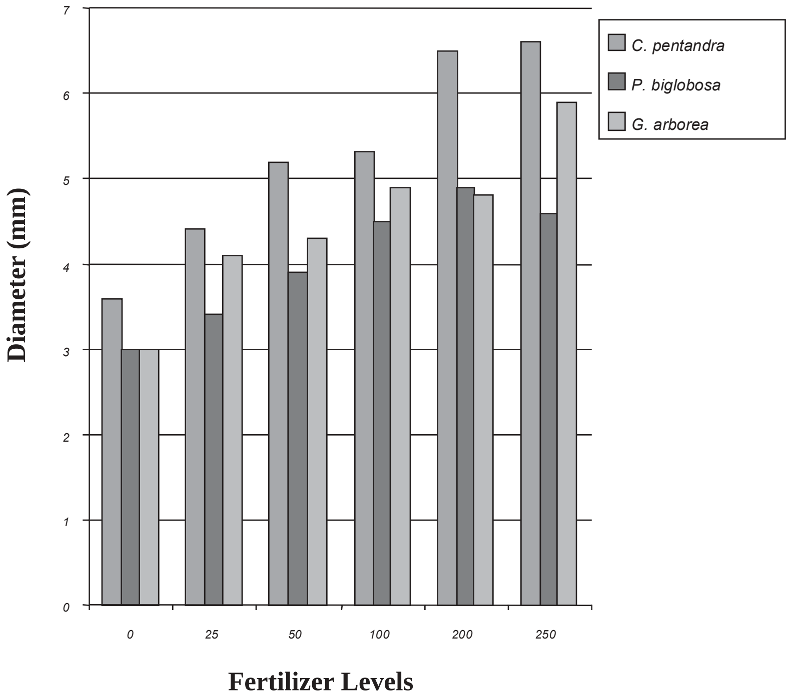

Figure 6: Effect of organic fertilizer on stem diameter growth of C. pentandra, P. biglobosa ang G. arborea seedlings.

plication (Figure 7), with Ceiba producing the highest number of leaves, followed by Parkia while Gmelina produced the least number. The differences at different fertilizer levels were however in most cases not statistically significant.

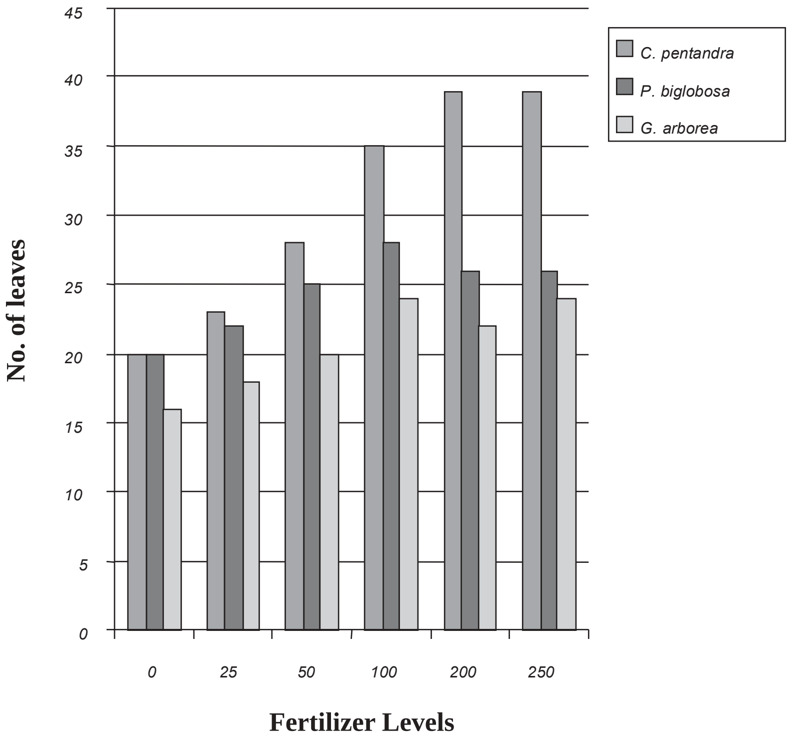

Figure 7: Effect of organic fertilizer on leaf production by C. pentandra, P. biglobosa and G. arborea seedlings.

Figure 8 shows the effect of NPK organic fertilizer on the dry matter production by the tropical hardwoods. Like the three plant parameters already examined, dry matter yield also increased with increasing organic fertilizer application, with Ceiba also producing the heaviest seedlings. Maximum increment of 63% was recorded for Ceiba between the control and 25mgNKg^{-1}, 15% for Parkia between 50 and 100mgNKg^{-1} and 63% for Gmelina between the control and 25mgNKg^{-1} application levels.

Comparative effect of inorganic and organic NPK fertilizers

As shown in Tables 2-4, inorganic fertilizer generally produced taller, bulkier, more leaves and heavier Ceiba and Gmelina seedings especially at the low and intermediate levels when compared with its organic counterpart. But at the high application levels of 200 and 250mgNKg^{-1}, organic fertilizer appeared to be superior to inorganic fertilizer in stimulating the growth of these two hardwoods.

As for Parkia, organic fertilizer was evidently superior to its inorganic fertilizer in terms of height, stem diameter growth, and dry matter production at all levels of application. The two fertilizer types however tended to have similar effect on the number of leaves produced by Parkia. When data for all the measured parameters for each tree species were subjected to t-test analyses, the observed differences between the two fertilizer types were however not statistically significant except for stem diameter of Parkia where organic fertilizer produced seedlings that were significantly bulkier than those produced with inorganic fertilizer.

Table 2: Comparative effect of inorganic and organic fertilizers on *Ceiba pentandra.*

Treatment (mgNKg-1)	Height (cm)		Stem diameter (mm)		Leaf count		Dry Wt. Yield (g)	
	Inorg.	Org.	Inorg.	Org.	Inorg.	Org.	Inorg.	Org.
0	17.5	17.5	3.6	3.6	20	20	2.7	2.7
25	33.0	19.4	7.2	4.4	40	23	6.1	4.4
50	29.8	23.1	4.8	5.2	27	28	5.2	4.5
100	21.4	25.2	5.3	5.3	25	35	6.9	5.0
200	22.1	26.5	6.0	6.5	30	39	5.1	5.3
250	28.2	27.2	6.0	6.6	31	39	5.8	5.4
LSD at 5%	**3.8**	**2.1**	**1.2**	**0.8**	**4**	**4**	**1.0**	**1.0**

Table 3: Comparative effect of inorganic and organic fertilizers on *Parkia biglobosa.*

Treatment (mgNKg-1)	Height (cm)		Stem diameter (mm)		Leaf count		Dry Wt. Yield (g)	
	Inorg.	Org.	Inorg.	Org.	Inorg.	Org.	Inorg.	Org.
0	13.0	13.0	3.0	3.0	20	20	2.2	2.2
25	19.0	23.0	3.2	3.4	23	22	2.3	2.3
50	21.0	23.5	3.2	3.9	26	25	2.4	2.6
100	22.6	24.0	3.3	4.5	28	28	2.6	3.0
200	17.0	24.2	2.8	4.9	26	26	2.4	2.9
250	12.0	24.3	2.2	4.6	25	26	1.7	2.9
LSD at 5%	**3.2**	**1.9**	**0.9**	**0.8**	**3**	**4**	**0.3**	**0.4**

Table 4: Comparative effect of inorganic and organic fertilizers on *Gmelina arborea.*

Treatment (mgNKg-1)	Height (cm)		Stem diameter (mm)		Leaf count		Dry Wt. Yield (g)	
	Inorg.	Org.	Inorg.	Org.	Inorg.	Org.	Inorg.	Org.
0	9.2	9.2	3.0	3.0	16	16	0.8	0.8
25	13.5	11.5	3.9	4.1	18	18	1.2	1.3
50	13.5	11.5	4.4	4.3	18	20	2.0	1.5
100	18.5	14.5	6.0	4.9	18	24	3.5	2.0
200	16.5	15.0	4.5	4.8	17	22	2.0	2.1
250	16.0	20.2	4.2	5.9	16	24	1.5	2.1
LSD at 5%	**2.0**	**1.5**	**0.7**	**0.7**	**2**	**3**	**0.3**	**0.3**

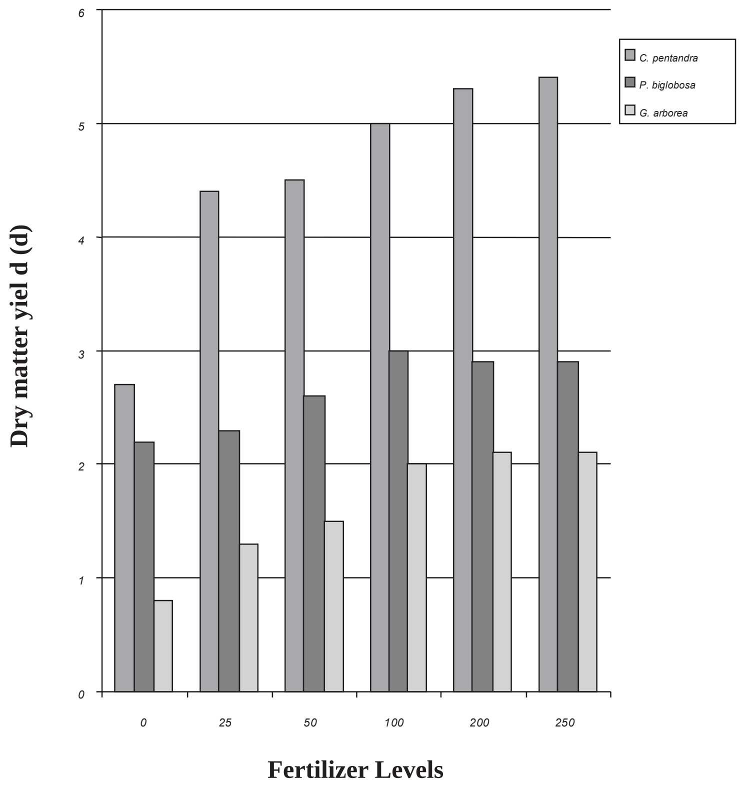

Figure 8: Effect of organic fertilizer on dry matter yield by C. pentandra, P. biglobosa and G. arborea seedlings.

Relationship between seedling growth parameters and supply of inorganic and organic NPK fertilizers.
The linear correlation coefficients indicating the relationship between rates of fertilizer application and plant height, stem diameter, number of leaves produced and dry matter yield for the three tree species and the fertilizer types are presented in Table 5.

Table 5: Relationship between some growth parameters of three tropical hardwoods and application levels of inorganic and organic fertilizers.

Source of comparison		Correlation coefficient (r)	
	Ceiba pentandra	Parkia biglobosa	Gmelina arborea
Inorg. Fert. Vs Height	0.22	- 0.33	0.66
Inorg. Fert. Vs Stem Dia	0.36	- 0.48	0.32
Inorg. Fert. Vs Leaf count	0.17	- 0.31	- 0.36
Inorg. Fert. Vs. Dry matter	0.36	0.48	0.23
Org. Fert. Vs. Height	0.87**	0.57	0.94**
Org. Fert. Vs. Stem Diam	0.95**	0.88**	0.89**
Org. Fert. Vs. Leaf count	0.93**	0.67	0.81*
Org. Fert. Vs. Dry Matter	0.80*	0.75*	0.95**

* *significant at 5% probability level*

** *significant at 1% probability level*

Irrespective of plant type, no significant correlation was established between rates of inorganic fertilizer application and plant height, stem diameter, number of leaves produced and dry matter yield. Height, stem diameter and number of leaves produced by Parkia were even negatively correlated with rates of inorganic fertilizer. On the other hand, rates of application of organic fertilizer were significantly positively correlated with plant parameters except for Parkia where no significant positive correlation was found between plant height and number of leaves produced.

Discussion

The apparent higher seedling growth rate in the control during the first 3 weeks of growth as compared to the subsequent weeks could be due to the initial flux of nutrients already present in the soil. This was probably followed by rapid nutrient depletion caused by the growing plants and this probably resulted in the observed reduced growth rate during the weeks that followed. Differences in growth rates by *Ceiba pentandra, Parkia biglobosa* and *Gmelina arborea* could be attributed to differences in the inherent growing capabilities of the tree hardwoods and their degree of tolerance to soil acidity.

The significant seedling growth in treatments that had inorganic fertilizer as compared to the control and the increasing seedling height, stem diameter, leaf production and dry matter yield by the three tree species as a result of increased level of application of inorganic NPK fertilizer up to 100 mgNKg^{-1} might be due to adequate availability of nutrients in the potting mixtures up to this level of application. These results confirm the fact that tree plants also require nutrient elements for adequate growth (Fagbenro & Aluko, 1987). The depressed height and stem diameter growth and leaf production by Ceiba beyond application level of 25mgNKg^{-1} of inorganic fertilizer probably indicated a low tolerance of the tree species to inorganic fertilizers in acid soil and seems to suggest that one should not apply inorganic NPK fertilizer to Ceiba seedlings beyond 25mgNKg^{-1} level in this soil type to ensure good growth. But the fact that the hardwood produced heaviest seedlings at a higher level of 100 and not at 25mgNKg^{-1} implies that further investigation is required to determine inorganic NPK application rate for optimal response by this tree species.

The reduced seedling growth of Parkia and Gmelina beyond application level of 100mgNKg^{1} was likely to be as a result of too much nutrients in the potting mixtures. This probably led to reduced root growth and nutrient uptake in the presence of active mobile aluminium in the soil. The result seems to suggest 100mgNKg^{-1} application level of the inorganic fertilizer as the optimum for these two tree species.

The increased growth of seedlings of Ceiba, Parkia and Gmelina due to increase in the supply of lignite-based NPK organic fertilizer first indicates that manufactured organic fertilizer type could also have stimulating effect on plant growth. Secondly, the increasing height, stem diameter, leaf production and dry matter yield by the three hardwoods throughout the five application levels of the organic fertilizer implies that the tree species could tolerate a high dose of organic fertilization in this acid soil as against its inorganic counterpart. The reason for this is not apparent. It might be due to the presence of high amount of humic substances (HS) in the organic fertilizer (Table 1b) which probably complexed the exchangeable Al in the acid soil to make its toxicity less effective in damaging plant roots and in making plant nutrients difficultly available to the plants. Aluminium toxicity is one of the major factors limiting plant growth on acid soils (Bell & Edwards, 1987). Organic materials (crop residues) have been reported to ameliorate infertility of acid soil with appreciable quantity of inorganic monomeric aluminium (Larsen, 1997). It could also be due to the hormonal properties of HS that have been reported to stimulate plant growth (Freeman, 1975; Fagbenro & Agboola, 1993; Fagbenro et al., 1999). According to Flaig (1975), the effect of physiological active substances, such as HS, is to improve plant yield if one or several growth factors are in deficit or in excess. Further investigations are however required to determine optimal response by the seedlings to the organic fertilizer in this soil type since all the four plant parameters measured in this study continued to increase throughout the five fertilizer application levels.

Reasons for the superiority of inorganic NPK fertilizer over its organic counterpart in stimulating higher growth of Ceiba and Gmelina seedlings at the low and intermediate application levels are not very clear. One of the reasons may be because of the quick release of nutrients into the potting mixtures by inorganic fertilizer, resulting in rapid seedling growth. Organic fertilizer, on the other hand ,is a slow nutient-release preparation and hence did not release plant nutrients quickly into the planting media for rapid seedling growth especially within the short period of three months that the seedlings were grown.

The fact that Parkia responded more positively to organic fertilizer than to inorganic type was probably because the tree species is more sensitive to the negative effect of Al in the acid soil and which the HS in the organic fertilizer counteracted to some degree. This is probably so when one considers the very significant increases in plant parameters between the control and treatments that had organic fertilizer.

The observed positive correlations between fertilizer (organic and inorganic) supply and growth of the three tree species further confirms the beneficial effects of fertilizers on plant growth. Fagbenro et al., (1999) also found positive correlations between rates of inorganic and organic fertilizer application and growth of Leucaena and Gliricidia in the acid soil. The non-significant positive correlations recorded between plant parameters and inorganic fertilizer supply suggests that the fertilizer type may not be ideal for the seedlings of these hardwoods at least in the acid soil. Therefore, the organic fertilizer that was positively significantly correlated with the plant parameters should be preferred to its inorganic counterpart to enhance plant growth. Reason for the negative correlation between inorganic fertilizer supply and growth of seedlings of Parkia was not apparent. It could be because inorganic fertilization in the acid soil negatively affected an important growth aspect of the plant possibly N_2 fixation. Fagbenro et al., (1999) reported negative correlation between weight of nodules produced by two nitrogen fixing plants, Leucaena and Gliricidia, and supply of inorganic NPK fertilizer. In this study, the inorganic fertilizer probably had similar effect on Parkia which is also a legume. Further investigations are however required to confirm all these reasons.

In conclusion, data presented in this paper indicate that fertilization is beneficial to the seedling growth of *Ceiba pentandra*, *Parkia biglobosa* and *Gmelina arborea* in the acidic soil used. It is however suggested that lignite-based organic fertilizer should be preferred to its inorganic counterpart to enhance plant growth. Given the important and projected increase in the use of organic fertilizers (including animal manures and compost) in the Nigerian forest nurseries, plantations and agroforestry systems, further studies on the optimal response of trees to fertilizers - organic, inorganic or organic/inorganic combination using different soil types need to be carried out.

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11. Hardwood seedling production techniques in the Southern United States

*K. Mc Nabb**

Summary

Deciduous hardwood species account for less than 3 percent of the 1.2 billion bare root seedlings produced annually in the southeastern United States. The numbers are misleading, however, because hardwoods cost more to grow, bring a higher price, satisfy a large customer base, and account for significant species diversity in nursery production. Typical management techniques begin with methyl bromide fumigation prior to fall or spring sowing, preemergent herbicide application, heavy nitrogen fertilization and watering. Other cultural treatments include undercutting, lateral root pruning, and top pruning. All hardwood species are manually lifted after undercutting, although machines have been developed to lift and place the seedlings on top of the soil. Most seedlings are shipped in kraft paper bags, but may be stored for several weeks at 5°C when lifted dormant.

Keywords: hardwood planting stock, Southern United States, management techniques, storing.

Introduction

The southern United States produces approximately 1.2 billion forest tree seedlings each year. By far the largest portion is pine, which accounts for around 95% of total production. The remaining 5% consists of a number of hardwood species from multiple genera, including *Acer, Carya, Fraxinus, Juglans, Liquidambar, Platanus, Populus,* and *Quercus*. Very few seedlings are grown in containers and only one species, *Populus deltoides*, may be shipped from the nursery as a cutting. Hardwood seedling nurseries in the Southern United States, therefore, produce 1-0 bare root planting stock of multiple genera and species. This planting stock is produced for the most part in public nurseries operated by the individual 13 southern states (Lantz 1997). Private nurseries produce around 20% of hardwood planting stock. The principle reason that public nurseries more commonly produce hardwoods is that they have a public service mandate and can better justify the multiple species and small shipping quantities characteristic of hardwood nursery production.

The importance of hardwood seedlings to the nursery program in the southeastern United States is not indicated by their small fraction of the total seedling production. Although hardwoods are only 5% or less of overall production, they can contribute significantly to nursery profits. Pine seedlings typically sell for around $40 per thousand seedlings of 1-0 stock. Hardwood planting stock will sell from $150 to $350 per thousand seedlings. For example, the Tennessee Forestry Commission nursery produces a total of 30 million seedlings per year with hardwoods only 15% of this total, or 4.5 million trees. But because hardwoods sell for $200 per thousand on average and pine sells for $40, hardwoods are almost 50% of nursery income. In addition, hardwoods are important to several environmentally oriented programs such as the Wetland Reserve Program, Conservation Reserve Program, and others that give emphasis to wildlife or restoration objectives. Hardwood production is good for maintaining public relations, as they tend to sell small numbers of seedlings across a large number of customers.

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Seed and Sowing

Most seed used for hardwood planting stock production comes from wild sources. Seed are collected by private operators wherever they can find it, but usually within the same state as the nursery. This is not always the case, however, and when seed are scarce either for an individual species or within a particular state, seed will be shipped from other areas of the region. Quality seed is a problem for nurseries. Little is understood about the factors affecting the variability in production between individual trees, years, and locations. Moreover, because so much of the seed comes from wild sources, seed are subject to disease, insects, and mammal predations all of which affect seed availability and quality. A great deal of research is needed on seed production and storage. Recalcitrancy continues to be a difficult problem for some species, particularly for the white oak family.

Seed size varies greatly between species. Even so, virtually all hardwood seed are machine sown in the South. The design and manufacture of these machines is accomplished "in-house" or may be copied from another nursery. Seed are sown in either four or five drills in a raised bed that is 1.2m wide and 15 cm deep. Sowing spacing varies considerably depending upon seed size and germination. Generally speaking, hardwoods are grown at between 50 to 150 seedlings per square meter. Larger seeded species such as *Quercus*, *Juglans*, and *Carya* will be sown at the wider spacings, while smaller seeded species such as *Liquidambar*, *Platanus*, and *Fraxinus* will be sown at the closer spacing. Fall sowing is preferred by most nurseries when possible. Seed sown in the fall has the advantages of not requiring stratification prior to sowing and also allows the nursery staff to concentrate on pine sowing in the spring. Currently, nursery managers are not treating seed with fungicides or animal repellants prior to sowing. Small mammal and bird predation is thwarted through vigilance and shooting.

Seed are covered with a mulch after sowing, but most managers use screened bark or sawdust. Larger seeded species that are planted from 2-4 cm deep may require no mulching, while lighter seeded species require a mulch of 5-10 mm depth. Some nursery managers use "living mulch." In the fall they sow wheat, oats, or rye grass in the beds with the tree seed. The grass soon germinates and provides a cover for the soil. This grass is then sprayed with glyphosate herbicide the following February or March prior to seed germination. The seed germinate into a grass mulch 15 to 20 cm high which provides good weed control, soil protection, and water retention.

Pest Management

Weed Control

Because of a general lack of effective herbicides, the foundation for weed control in hardwood nurseries is fumigation with methyl bromide. Two formulations have been commonly available for nursery soil fumigation; 98% methyl bromide and 2% chloropicrin, and 66% methyl bromide and 33% chloropicrin. The 98% formulation is preferred because (1) chloropicrin more severely impacts endomycorrhizae that are typically associated with hardwoods, and (2) a higher rate of methyl bromide may be applied. Fumigation is especially important for nutsedge (*Cyperus* spp.) control as nursery managers do not have good chemical options for control of these troublesome weeds Application rates are usually around 540 kg/ha ai of methyl bromide. Even so, some weed species, *Ipomoea* spp. and *Cassia* spp., for example, are not affected and may actually increase in germination when fumigated. The soil is covered with plastic sheeting during application and remains covered for several days. Applications are made once during a rotation, before the first seedling crop. Hardwood crops are usually grown on a 2:2 rotation; two successive years of seedlings followed by two years of cover crop. This is quite variable, however, and some nurseries produce crops using a 1:2 rotation (seedlings:cover crop) or even one year of pine followed by one year of hardwoods.

The availability of effective pre-emergent herbicides for weed control in hardwood seedling beds is very limited. Only four pre-emergent products are commonly used for hardwood production in the southern U.S.: oxyfluorfen, napropamide, prodiamine, and trifluralin (Table 1). Oxyfluorfen, trade name Goal®, can be used pre-emergent to the seedling crop only on large seeded species such as *Juglans*, *Quercus*, and *Carya* either in the fall or spring. Oxyfluorfen can damage small seed species such as *Platanus* and *Liquidambar*. Pre-emergent herbicides may also be applied to hardwood seedbeds after seedlings are around 15 cm in height. Prodiamine, napropamide, and trifluralin may be applied over the top of young seedlings for weed control, but must be applied to bare soil (pre-emergent to the weeds). Therefore, hand weeding may be needed to remove already established weeds. The importance of fumigation becomes even more apparent as it significantly contributes to keeping beds clean, particularly for small seeded hardwood species. Crop species variability is probably the most difficult aspect of developing a strong herbicide-based weed control program for hardwood seedbeds. Individual species can vary considerably as to their selectivity for an individual product, and while a number of products are available on the market, complete testing of efficacy across species, soil types, and application rates remains a challenge for nursery research.

Post-emergent herbicides are very important herbicide options for hardwood seedling culture. Fluazifop-p-butyl, sethoxydim, and glyphosate are used routinely. None of these have any pre-emergent or soil activity and must be applied directly to physiologically active weeds. Fluazifop-p-butyl and sethoxydim provide grass herbicide activity only, but have the distinct advantage of application over the top of seedlings. Both compounds provide good control of both annual and perennial weeds although caution must be exercised when applying to very young seedlings with succulent leaves. Glyphosate, on the other hand, must be directed and is phytotoxic to all green tissues. Glyphosate is commonly applied as shielded sprays between the drills. It may also be applied by hand as directed sprays, as well as using a rope wick. In the latter case the weeds must be taller than the seedlings so that herbicide does not touch seedling leaves.

Table 1: Herbicides commonly used in hardwood seedling culture in the southern United States and recommendations for use

Common name	Trade name	Application Reccomandations
fluazifop	Fusilade®	Post-emergent grass herbicide with no pre-emergent or soil activity. Applied 0.3 - 0.45 L/ha ai broadcast over the top, or 1% solution directed, any time grasses are physiologically active. Precautions: Over the top applications
glyphosate	Roundup®	Broad spectrum post-emergent weeBroad spectrum post-emergent weed control with no soil or pre-emergent activity. Directed sprays of 1-2% ai solution applied to actively growing weeds. Precautions: No crop selectivity and must be used with caution. Effectiveness can be reduced by dirty or muddy water
napropamide	Devrinol®	May be applied year round as a pre-emergent broadcast treatment over young nursery stock or a directed application to weed-free soil at 1.7 kg/ha ai. Precautions: Napropamide does best when incorporated with irrigation/rainfall.
oxyfluorfen	Goal®	Used for broad spectrum weed control applied pre-emergent to recently sown large seeded hardwood species (eg. Quercus, Juglans, and Carya) at 0.56 kg/ha ai. Precautions: Not to be used on small seeded hardwood species
prodiamine	Barricade®	May be used for broad spectrum pre-emergent weed control immediately after fall sowing large seeded species as well as over the top applications in the spring after seedlings are well established at 0.7 - 1.7 kg/ha ai. Precautions: Incorporate with at least 5 mm of irrigation.

segue

segue

Common name	Trade name	Application Reccomandations
sethoxydim	Poast®	Post-emergent grass herbicide with no pre-emergent or soil activity. Applied 0.3 - 0.6 L/ha ai broadcast over the top, or 1% solution directed, any time grasses are physiologically active. Precautions: Some formulations have a surfactant and may damage very young hardwood foliage.
trifluralin	Treflan®	Pre-emergent weed control of small seeded grasses and broadleaves applied (1) immediately after fall sowing large seeded hardwoods, (2) after fall sowing small seeded hardwoods but before mulching, or (3) weed free soil in early spring to fall sown hardwoods. Application rate is 1 L/ha ai. Precautions: Do not use on Platanus. Should be tested on individual species before use. Must be incorporated.

Mechanical weeding machines are commercially available but are not commonly used in southern hardwood nurseries. Hand weeding, however, is a common practice, with the amount of hand weeding varying considerably from nursery to nursery and year to year. Factors that affect the amount of hand weeding include: effectiveness of the fumigation, time since fumigation, weed species, overall nursery sanitation, crop species, and the type of mulch.
Mulches can often bring in weed species, particularly if they have been stored for any length of time. Nursery sanitation through aggressive weeds control along roads, irrigation pipes, and around structures will contribute to reducing hand weeding requirements. Finally, a well managed weed control program for the cover crop also helps reduce weed seed reserves in the soil.

Insect and Disease

Integrated pest management is the cornerstone of successful pest management in hardwood nurseries. Generally speaking, hardwood seedlings do not typically have significant insect or disease problems. This is primarily due, however, to the constant vigilance of the nursery manager. Soil insects such as mole crickets and cutworms can be a problem for very young seedlings if allowed to go undetected. There are also a number of defoliating insects, aphids, and mites may occur. Insecticides used to combat these various pests include dimethoate, malathion and esfenvalerate.
The necessity for constant vigilance required for insect control, goes double for disease control. Again, while not typically a serious problem, disease can spread quickly if not controlled. The most common foliar disease is powdery mildew, usually treated with chlorothalonil. Soil borne root pathogens such as *Phytophthora* and *Cylindrocladium* can be treated using chemicals as well, but crop rotation combined with subsoiling will significantly contribute to control.

Irrigation and Fertilization

Hardwood crops tend to use more water than do pine crops. Smaller seeded species such as *Platanus*, *Ulnus*, and *Liquidambar*, require a large quantity of water during the germination phase to maintain high soil moisture contents. During the rapid growth and leaf expansion phase of late spring and early summer, hardwoods also require relatively higher amounts of irrigation, although this may not be true on soils of finer texture. On sandy soils, which is the more common situation for nurseries in the southeastern U.S., hardwoods have higher water requirements than do pine. Once the seedlings achieve a desired height, usually in mid to late summer, nursery managers tend to reduce the irrigation to slow seedling growth.
Fertilization recommendations are based on annual soil analysis and standards set nearly 30 years ago (Table 2). Little hardwood fertility research has been done during that time. Phosphorus and potassium are usually applied as a plowdown prior to bed shaping and sowing. A typical plowdown application might be 30 kg/ha of elemental P and 50 kg/ha of elemen-

tal K, usually triple super phosphate and potassium chloride, respectively. Nitrogen is applied as a top dressing during the summer months as liquid or granular ammonium nitrate.
The linear correlation coefficients indicating the relationship between rates of fertilizer application and plant height, stem diameter, number of leaves produced and dry matter yield for the three tree species and the fertilizer types are presented in Table 5.
Occasionally ammonium sulfate is used. Top dressings are usually made every two weeks for as few as five applications or as many as 10, depending upon management philosophy. Total elemental nitrogen application for hardwoods (204 kg/ha, Table 2) is more than the typical pine fertilization regime of of 170 kg/ha per crop.

Seedling Conditioning

Most hardwood nurseries top prune seedlings in order to keep them from getting too tall and to “release” smaller seedlings in the bed that are being shaded. Some nurseries will not prune alternate branching species for fear of resulting in the lack of a dominant leader and producing a poor form. Other managers feel that even alternate species will show no signs of top pruning several years after planting. Seedlings are pruned one or two times depending upon rate of growth, and generally managers try to cut them to about 50 cm height. Ideally, only green or succulent material is pruned, although this is not always possible and cutting into woody tissue is common. Seedlings are not top-pruned immediately prior to lifting, although there are a number of possible advantages such as easier packing, storage, and transportation, along with the possibility of increased survival with no loss of growth after several years (South 1996).

Table 2: Nursery Soil Fertility Standards (Davey 1973 as cited by Stone 1980) and average elemental application rates (South & Zwolinski 1996)

Attribute	Acceptable range	Average application rates
Acidity	pH 5.6 - 6.8	
Nitrogen		204 kg/ha
Available P	56 - 168 kg/ha	19
Available K	168 - 336	24
Available Ca	672 - 1,344	0.8
Available Mg	56 - 168	0.1
Availagle Mn	11 - 224	
Organic matter	greater than 1%	
Total soluble salts	**less than 1,000 ppm**	

Root pruning is rarely practiced in hardwood nurseries and is used only when seedling growth cannot be controlled with top pruning. Some studies have indicated that undercutting increases the number of first order lateral roots, which then translates into increased field survival (Schultz & Thompson 1997). Seedlings are only undercut in southern nurseries immediately prior to lifting to facilitate handling.

Lifting and Storage

Hardwood seedlings are lifted using a Fobro machine which lifts the seedlings, shakes the soil loose from the roots, and lays the trees on the surface of the ground. Seedlings are then manually retrieved and placed into plastic coated paper bags. Nursery workers cull seedlings in the field according to the standards of that particular nursery and then place a specified number of seedlings in each bag - usually 150, 200 or 250 depending upon the species and size of seedling. Some nurseries transport the seedlings to a packing shed where they are counted and culled. Seedling quality standards for hardwood seedlings are not well researched. Some nurseries use a single height criteria, usually around 40 cm, although this varies by

species. Most nurseries use a minimum diameter of 1 cm as the principle culling criteria. Following transport to the storage area, seedlings are sprayed with a water absorbent gel before placing in cold storage at 2-5^{0}C.
Dormant hardwood seedlings keep very well in cold storage. No adverse affects of 6-10 weeks have been observed for a number of species. Even so, most nursery managers prefer to move their seedlings from storage to the planting site as soon as possible and storage periods of 1 to 3 weeks are typical. Many will coordinate seedling requests with lifting schedules to minimize the amount of time seedlings will remain in storage.

Final considerations

While hardwood production in the southern United States is relatively small in relation to pine seedling production, its importance for the regeneration program in the region cannot be overemphasized. Unfortunately, most research and technology transfer has concentrated on pine issues and there is a great deal of work that could be done to improve hardwood seedling culture. Certainly, seed production, processing, and storage is a serious problem. Basic weed control and fertilization programs are founded mostly on experience and limited field trials. Seedling quality is yet to be well defined in relation to seeding conditioning practices such as root and top pruning, spacing, and fertilization. Given the number of species and even the number of genera, the problem is daunting. Hopefully, future researchers will be able to more completely address some of these issues.

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12. Modernization of forest tree seedling production system in India and its impact on seedling health, stand establishment and productivity

*C. Mohanan**

Summary

In India, about 100 broad-leaved species are being utilized for various afforestation and reforestation programmes. Of these, *Tectona grandis, Eucalyptus grandis, E. tereticornis, Dalbergia sissoo, Acacia auriculiformis, A. mangium, Paraserianthes falcataria, Gmelina arborea, Terminalia crenulata, Lagerstroemea speciosa*, etc. are the important ones and the annual planting rate is about 1.78 Mha. Seedling production, stand establishment and stand productivity are affected by various limiting factors, of which diseases play a major role. Due to high humid conditions prevailing in many parts of the country, diseases affect the seedling crop and pose practical problems in nursery management as well as planting programmes. Recently, rootrainer technology was introduced in forestry sector which has had a tremendous impact on production and protection of planting stock. The rootrainer seedlings and clonal plants produced are almost free from diseases and the technology offers production of large number of disease-free, uniform sized planting stock within a short period (maximum 90 days). The rootrainer technology offers other advantages over the conventional seedbed and polypot nursery system, especially on root spiraling of seedlings. However, the technology has to be further optimized depending on the tree species, potting media used, local climatic conditions, and planting technique followed. A survey on the stand establishment, growth and incidence of diseases in plantations raised with rootrainer seedlings revealed that the present technology is very suitable for eucalypts and acacias, however, for *Tectona grandis* and other broad-leaved fast growing species, it needs to be further optimized. The new technology also offers improvement of seedlings and clonal plants by easy manipulations of mycorrhizae, biofertilizers, and biopesticides. Experiments with *Pisolithus tinctorius*, an ectomycorrhizal fungus in rootrainer eucalypts seedlings and clonal plants yielded very good results. The paper highlights the modernization of planting stock production system and its impact on nursery management, stand establishment and stand productivity.

Keywords: rootrainer seedlings, seedling health, establishment, stand productivity

Introduction

In India, forests have been playing a vital role in the socio-economic development, as they have been an important source of subsistence, employment, revenue earnings and raw materials to the cottage as well as modern industries. Their role in ecological balance, environmental stability, biodiversity conservation, food security and sustainable development has also been widely recognized particularly after the enunciation of National Forest Policy, in 1988. The forest resources of the country have been under mounting pressure owing to increasing human and livestock population. Excessive withdrawals are much beyond the carrying capacity which have resulted in the depletion, degradation and endangering natural regeneration of the forests. At present the total forest cover which includes dense forest, open forest and mangrove is estimated to be 633,397 km^2. This constitutes 19.27% of country's ge-

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ographic area. As far as timber species are concerned, of the 320 species available in India, 65 species are of major importance, 106 have fair demand and others are less preferred. Most of these timber species have been raised on a large-scale in production forests, tree lands and village forests to meet the demand from the traditional as well as modern sectors. As there is no further scope to extend the area under production forestry, augmenting the productivity of existing plantations by intensive management has been taken up. Recently, large-scale planting has been taken up under different afforestation and reforestation programmes which requires large quantities of planting stock of different tree species each year.

Even though, forest tree seedling production system has been revolutionized in many countries, in India, production of planting stock is still largely depended upon conventional methods. Although, different types of containers have been experimented to raise the seedlings by various agencies like forest industries and institutions, since 1985 onwards, the rootrainer technology has been introduced in forestry sector very recently. Employing this technology, planting stock of selected broad-leaved species has been raised on a large-scale. Due to the tropical climate prevailing in many States in India, diseases and pests cause major havoc, which often play as a major limiting factor for raising and maintaining the nursery stock. Under conducive microclimatic conditions, seedling crops of any forestry species may succumb to one or more diseases and pest attacks. In India, climatic conditions range from temperate in northern region to tropical warm humid in north-eastern and southern peninsula and hence incidence and severity of diseases and pests in nurseries exhibit tremendous variation. Accordingly, pathogens and pests causing epidemic and epizootic problems in northern region of the country may not be of much importance in southern region , and *vice versa*, mainly due to the climatic variation and also difference in host species raised. However, in general, disease and pest outbreak in forest nurseries in high rainfall areas often become drastic and most species raised become seriously affected. As the disease and pest hazards in forest nurseries become very common which often upset the entire planting programme, systematic studies and management of economically important diseases and pests have been taken up during 1980s and 1990s and nursery management practices for important forestry species standardized (Mohanan 1997,2000a,b; Sharma *et al.* 1985, Sharma & Mohanan 1991).

In forest nurseries, from 1970 onwards polythene containers of different sizes have been used on a large-scale for direct seeding as well as transplanting the bare root seedlings. Though, the technology in vogue is most economical, root spiraling or coiling is one of the disadvantage of the polythene container raised seedlings. The rootrainer technology has been developed to overcome the root spiraling problem. Apart from this the technology offers many other advantages too. At present, most of the State Forest Departments and Forest Corporations in India are employing the rootrainer technology to raise planting stock including ramets. Development of appropriate potting media suitable for the forestry species is also initiated recently. At present many organic media such as coir pith, forest weeds (compost), etc. and inorganic media such as vermiculite, perlite, sand, etc. (for clonal nursery) have been used in rootrainers.

The technological changes in raising seedlings in rootrainers rather than in seedbeds and polythene containers has had a major impact on seedling production system. Soil-borne diseases which pose major threat in seedbed nurseries seldom occur in rootrainers where the growing medium is generally free from pathogens. With the increases in environmental concern on use of pesticides in delicate ecosystems like forest nurseries, nursery managers are being instructed to use cultural and biocontrol measures and biofertilizers, as far as possible, for managing the nursery diseases and boosting the seedling growth. Modernization of seedling production system has also made tremendous impact on stand establishment and stand productivity.

Seedling production system in India

The quality of planting stock in forest nursery warrants not only the successful field establishment but also subsequent excellent growth and high yield. Thus, forest nurseries play a vital role in any afforestation/reforestation programmes. Raising nurseries requires technical skills including careful planning for all the major components such as selection and preparation of nursery site, quality seed, appropriate potting media, containers, organizing the work force, nursery hygiene and protection, etc. All these factors are equally important for producing healthy, vigourous quality planting stock. The outcome of planting stock quality is reflected in the stand productivity. In India, the forest nurseries become operational either through out the year or during December to June, depending upon the climatic factors of the locality, planting technique employed and the tree species raised. The forest seedling production system in India can be broadly grouped into two: conventional and modern.

Conventional Nurseries

Usually, the nurseries are raised by the State Forest Departments in suitable sites in each year during the dry period (December/January). Seedlings are grown in seedbeds of standard size (12x1.2x0.30m) and for the first 45 to 60 days, a shade pandal of thatched coconut leaves or jungle leaves is provided to protect the seedlings from sun scorch. The seedbeds are watered at regular intervals with a prescribed quantity of water. In seedbed nurseries, regulation of shade, water and seedling density is carried out depending up on the tree species and the planting technique to be followed. When seedlings attain a height of 10 to 15 cm, they are pricked out into polythene containers (18x12 cm) filled with sieved soil (forest soil) during February/March; for the first two to three weeks the container plants are kept under shade. The container plants are maintained till they are planted out during June-July (south-west monsoon). Thus, maintenance of seedlings of most of the tree species required for at least six months. However, this period is much longer in the case of teak (*Tectona grandis*), where 12 to 18 month-old seedlings are used for preparing stumps, which are planted out directly during May-June.

Polypots/polybags or polythene containers are widely used for raising seedlings in forest nurseries since 1970. Polypots of different sizes are used for either direct seeding or transplanting the bare root seedlings from the seedbeds. Even though, the polythene containers are handy and economical, they have inherent problem of root coiling or root spiraling which influences considerably the establishment, growth and survival of the out planted seedlings. Tendency of spiraling the seedling roots inside the container is one of the most serious problems in container nurseries. Seedling roots grow geotropically but if they do not meet any physical obstruction, they may tend to grow laterally around the side of the container. Root spiraling will not adversely affect the growth of seedlings in nursery, but it can seriously reduce the seedling quality after out planting. Spiral roots adversely affect field establishment and survival. Even though, it can occur in almost any type of containers, root spiraling is most serious in flat bottomed, smooth walled polythene containers. To overcome the problem of root coiling in polybag- raised seedlings, rootrainers have been found to be very effective.

Modern Nurseries

In temperate countries, during the past 25 years, many different types of containers have been developed and tested to suit the mechanization in seedling production as well as field planting. New types of containers are still being designed and tested, but the perfect container for raising tropical broad-leaved species has yet to be developed. In reality, no single container is yet to satisfy the requirements of every nursery because of the differences in tree species raised, nursery operations, planting technique followed, planting site, etc. The rootrainer is a specially designed cylindrical container made up of opaque material with two open ends of which the lower end tapers gradually with a smaller open end, to provide favourable condition for the root development. Inside the rootrainer, four to six ridges or ribs are provided which run longitudinally from one end to another, to prevent root coiling. When a root starts to touch ridge it immediately changes its course and traverse down thus avoiding coiling.

The Principles of rootrainer technology include: providing appropriate environment to attain rapid development of primary roots and subsequent secondary roots; allowing early natural pruning of primary tap root and induce secondary root system so as to attain 'forced multiple taproots'; maintaining acute angle of secondary and tertiary root tips and its subsequent pruning, so as to keep downward movement to attain network of massive root system. The above principles aim at training of root in desirable direction, enhancing the surface area for absorption with least or without any injury or disturbance to tender roots. Appropriate training of root system is achieved through providing porous, easily penetrable, nutrient rich potting medium with free drainage and proper aeration. Limited quantity of growing medium induce root competition and thereby optimum utilization of the medium in the cells. Natural pruning of primary and secondary roots occurs by exposing the growing tips to sunlight and air, and thus induces strong vigorous multiple tap roots. Maintaining the angle of inclination in such a way that lateral roots should tend to develop downward, and providing taper in the bottom of rootrainers, the available space for root development tapers down or gets restricted and resultantly, downward inclination is maintained.

The primary function of any container is to hold a discrete supply of growing medium, which in turn supplies the seedling roots with water, air, mineral nutrients, and physical support while the seedling is still in the nursery. As the tree seedling survival and growth are directly related to the ability of the root system to promptly regenerate new roots, known as root growth potential (RGP), and grow out into the surrounding soil, many tree seedling container features are designed to encourage the seedling to form a good root system in the nursery and to protect these roots until the seedling is out planted. The relative health and vigour of the root system is also reflected in the morphology and growth of the seedling shoot.

In India, although, different types of rootrainers are available to grow seedlings of different broad-leaved species, reusable trays containing cells from which seedlings/ramets can be removed at the planting site are the most preferred ones. Single cell and styrofoam blocks or composite trays are being widely used. Both seedlings and ramets (clonal plants) are raised on a large-scale in rootrainers. For clonal nursery, single cell rootrainers are the most preferred ones. The size of the container for a particular seedling crop depends on both biological and economical features. Usually, cell volume in the rootrainers for raising broad-leaved species, ranged from 150 cc to 300 cc. However, optimum container size varies according to many different factors, including growing density, seedling species, size of seedling desired, type of growing medium, environmental conditions, and length of growing season. The distance between the individual cells in the block generates seedling growing density, one of the most important container characteristics affecting seedling growth. The spatial arrangements of cell within the block also has economical implications, however, tree seedling requires a certain minimum amount of growing space, which varies with species and age. In general, rootrainer seedling quality increases with a corresponding decrease in growing density. Since the rootrainer technology is only recently being introduced in India, a number of factors are yet to be determined for the optimization of the technology to suit the particular climatic conditions, tree species and planting techniques followed.

The rootrainer nursery has certainly many advantage over the conventional or polypot nursery, not only in production of quality seedlings but also in overall nursery management. Some of the advantages are: rootrainers can be easily filled with potting medium, easy to regulate the moisture regime in the container, easy to apply fertilizers, biopesticides, biofertilizers, etc., easy to make casualty replacement, easy to handle and transport, air pruning of roots produces actively growing rot tips, produce uniform sized hardy planting stock (seedlings/ramets), seedling shock due to transpotation/ outplanting less, nursery maintenance period less (maximum 90 days), etc. Presently, seedlings of *Eucalyptus tereticornis, E. grandis, Tectona grandis, Terminalia paniculata, T. bellerica, T. crenulata, Acacia auriculiformis, A. mangium, Albizia lebbeck, A. procera, Paraserianthes falcataria, Gmelina arborea, Cassia fistula, Cassia siamea, Pongamia pinnata, Dalbergia sissoo, D. sissoides, Azadirachta indica, Lagerstroemea speciosa, Hardwickia binata, Xylia xylocarpa,* etc. are raised on a large-scale in rootrainers. In Kerala State alone about 3.2 million rootrainer seedlings have been raised during March-June 2001.

Clonal nursery

Exploitation of the potentials of clonal forestry has resulted in increased productivity of eucalypts in countries like Brazil, South Africa and Congo. The potential of clonal propagation in eucalypts for improving the yield was realized when Aracruz Florestal in Brazil could increase the yield from 36 $m^3ha^{-1}yr^{-1}$ to 64 $m^3ha^{-1}yr^{-1}$ in *E. grandis* (Zobel 1993). Mean annual increment (MAI) of eucalypts plantations in Brazil, prior to initiation of clonal forestry in 1967 was only 15m^3ha^{-1} yr^{-1} at 7 year rotation. With the use of further improved clones under intensive management, the yield could be boosted even up to 100 m^3 $ha^{-1}yr^{-1}$.

In India, clonal forestry on a large-scale was started in Andhra Pradesh State by ITC Paper Boards Ltd. during 1980s. *Eucalyptus tereticornis* (hybrid) plus trees were selected from plantations and ramets were prepared on a large-scale for raising plantations under farm forestry and regular forestry programmes. So far, clones from more than 45 fast growing, disease resistant trees are being multiplied through rooting of cuttings. Productivity is expected to be 20-25 m^3 ha $^{-1}yr^{-1}$ by 7th year which is nearly four-fold increase in yield over plantations raised from seedlings (Lal, 1993). In Kerala State also clonal forestry initiated recently and many disease resistant clones of *Eucalyptus tereticornis* and *E. grandis* were identified and ramets were prepared on a large-scale for supply mainly to the State Forest Department (Balasundaran *et al.*, 2000).

Eucalypts seedlings and ramets or clonal plants can be conveniently grown in rootrainers. However, the method of production of ramets differs slightly on account of use of coppice cuttings as reproductive material. Single cell rootrainers of 150 cc are usually used for raising the ramets. Various rooting media such as vermiculite, perlite and soil/sand mixtures are being used. Rooting hormones usually employed are: Indole acetic acid (IAA), Indole butyric acid (IBA), Naphthalene acetic acid (NAA), 2,4 Dichlorophenoxy acetic acid (2,4 D). Of these most commonly used hormone is IBA and it is used as dip method, quick dip method and dry-dip smear method. Of these, dry dip method is most commonly used for eucalypts and IBA (4000 ppm) mixed with inert talcum powder is used for stimulating the root formation. The rootrainers with the cuttings are initially transferred to the mist chamber subjected to intermittent mist for 4-5 weeks until a good root system is developed and top growth starts. After initiation of sprouting, the rootrainers are transferred to hardening units provided with sprinklers and shade nets to reduce sunlight and temperature. Nutrients (DAP and NPK mixture) are supplied to the ramets and average plant height of 30-45 cm is maintained. The technology offers production of uniform sized, disease-free, healthy planting stock leading to higher and uniform wood yield from the plantations.

Potting media

The potting medium physically supports the growing seedling and stores and supplies nutrients, water, and air to the root system. The better the medium, the better will be the development of a healthy, fibrous root system and the quality of the seedling produced. As there are not many natural materials with all the elements required for healthy root growth, potting media are usually blends of different elements. In general, for obtaining good results, potting medium should be with good porosity, light in weight, well-drained but with good water holding capacity, slightly acidic with good cation exchange capacity (CEC), etc. Porosity is one of the most important physical properties of the medium because it determines the space available for air, water and root growth. Poor aeration affects adversely the root form and structure which leads to decreased seedling vigour. Even though, good drainage is desired, the potting media should have high water holding capacity. Organic materials in medium provide a large number of micro-pores which help to retain water. In general, the total porosity of a good medium should exceed 50% and the aeration porosity should range from 20 to 35% depending on the medium. Overall balance of both micro and macro-pores is necessary for high quality potting medium. The pH, cation exchange capacity (CEC), and fertility are the chemical properties which determine suitability of the medium. The desired pH of most of the media ranges from 5.5 to 6.5 (slightly acidic), however, the pH for optimal seedling growth is species dependent. When pH levels are not within the desired range, nutrients either become unavailable or toxic and chemical additives like lime or sulphur are required to control the pH. A high level CEC is required to continually supply the nutrients to the seedlings and hence, the greater the addition of organic matter or compost, the higher the CEC of the potting mix. Management of nutrient supply to seedlings is extremely important irrespective of the fertility of the individual component which make up the potting medium. Potting medium can be either composed of a single substrate or mixtures of various organic and/or mineral components. Mixtures of various components with complementary physical and chemical properties yield superior potting medium.

In India, the common organic materials used in potting medium include: coir pith, sugar cane waste, rice hulls, saw dust, tree bark, forest weeds, paddy straw, wheat syraw, water weed, etc. Most of these organic materials, except rice hulls benefit from composting and balances the ratio of carbon to nitrogen in the material. Inorganic components used in potting mix for improving the drainage and aeration are vermiculite, perlite, pumice, sand, etc. Composted organic material has all the chemical and physical properties of an ideal potting medium. Even though, any organic material is suitable for composting, the most vital factor for compostability is its C/N ratio, i.e. ratio of carbon to nitrogen present in the raw material. The optimum range is 25-30:1 and at C/N ratio above 30, nitrogen must be added in the form of nitrogenous fertilizers like urea or ammonium sulphate. In different States, forest weeds (*Chromolaena odorata, Lantana camera, Andropogon* s*p.Combretum* sp.,), wheat straw, coir pith, water weeds, tea and coffee waste, etc. are used for composting. Usually, Berkeley's method is followed for making the compost. In different States, slight modification of the process is being made in accordance with the availability of the compostable organic materials. Usually, the succulent shoots of desirable forest weeds are cut manually and transported to the chopping site where manually operated chopper machine equipped with double blades chop the materials to a size of 5-10 mm. Prior to placing charge in compost shed, 50% water by weight of total weight of the mixed material is added, to have homogenous mass and to expedite the microbial activity. Then the mixture is placed in compost shed layer by layer sprinkling with water. After a week when the temperature of the heap reaches about 55^{0}C, the heap is turned over and thoroughly mixed. In no case temperature is allowed to exceed 60^{0}C to avoid death of microorganisms. The period for completing the process depends on the plant species and the organic matter used. However, usually for forest weeds, within 30 to 45 days composting will be completed. The final product looks dark brown and having a greasy feel and earthy smell. Depending on the tree species potting media are prepared by mixing the compost with soil and sand in different proportions.

Impact of rootrainer technology on seedling health and stand productivity

During the past few years, forest nursery practices in India have undergone a tremendous modifications based on various microclimatic, edaphic and biotic factors, including host, pest and pathogen association. Consequently, seedling health has been given more importance which further widened the scope of phytosanitory problems. However, introduction of rootrainers in forestry sector and thereby the technological changes in seedling production has had a major impact on nursery management. Under the new seedling production system, protection of seedling crop from pests and diseases becomes less significant. As soil less or soil free potting media are used in rootrainers, common soil-borne diseases like damping-off, seedling blight, wilt, etc. seldom occur in rootrainer nurseries. However, the conventional nursery system which caters the larger part of the requirement of planting stock, still suffers severely from the disease havoc. *Rhizoctonia solani* and *Cylindrocladium quinqueseptatum* are the important pathogens affecting the seedling crop of different tree species. Under the conducive tropical climate, maintaining the nursery crop for a longer period is one of the most serious problems confronting the nursery managers. During this period, diseases and pest problems occur in succession and if timely intervention is not done the entire seedling crop may be devastated by one or other diseases and pest attacks. However, in rootrainers, the broad-leaved species require a maximum period of 90 days of growth and hence a rigorous management is possible during this comparatively shorter period of maintenance than in conventional nurseries, where the maintenance period ranges from six months to 18 months. For example, eucalypts seedlings have to be maintained in the seedbed nurseries for 3-4 months and thereafter in polypot nurseries for 2-3 months. During this period, diseases like damping-off, seedling blight, web blight, stem infection and foliage infections caused by different fungi affect the seedling crop and often epidemic outbreak occurs (seedling blight caused by *Cylindrocladium* spp.) devastating the entire seedling crop. In rootrainer nursery, even if foliage disease occurs, the affected seedling/s can be easily removed from the blocks and replaced with other healthy seedlings, thereby avoiding the spread of the disease in nursery. Similarly, seedlings showing poor or stunted growth or deformity can be easily replaced or corrected by application of appropriate nutrients. Since, the rootrainer seedlings exhibits uniform growth performance, prophylactic pesticide treatment, if required, and maintenance of seedling quality are easier than in conventional nursery system. Under the planting stock improvement programmes, disease resistant and fast growing ramets can be produced on a large-scale employing the rootrainer technology. Screening of efficient clones for disease resistance at nursery level can also be performed very efficiently employing the new technology. The new technology is very efficient and suitable for planting stock improvement using mycorrhizal, biofertilizer and biopesticide manipulation, since the rootrainer technology gives more emphasis to healthy root system of the seedlings. In eucalypts, planting stock improvement using *Pisolithus tinctorius*, an ectomycorrhizal fungus, has been carried out employing rotrainer seedlings. Application of fungal spore slurry and mycelial and spore pellets was found very easy and handy in this system. In teak (*Tectona grandis*), planting stock improvement through arbuscular mycorrhizal fungal manipulation carried out employing the rootrainer seedlings also showed very good results and the rootrainer technology offers quick assessment of mycorrhization of root system. Introduction of inoculum of biopesticides as well as biofertilixers and screening their efficacy are also much easier efficient in rootrainers. As far as other nursery parameters like seedling density, shade over the nursery, water regime, etc. are concerned, the system offers enough flexibility in operations. Seedling density can be controlled at desired level at various growth phases of seedlings by emptying the cells in blocks in non-destructive method. Similarly, seedlings of different tree species can be kept under shades of different intensity and duration. Control over water and nutrient regimes is also easy and handy in this system.

Plantations employing rootrainer seedlings of different species, especially *Eucalyptus tereticornis, E. grandis, Acacia auriculiformis, A. mangium, Tectona grandis,* etc. have been raised in different States during 1999 –2001. As far as plant health is concerned, eucalypts plantations raised with rootrainer seedlings show resistance to most of the stem canker and foliage diseases. However, a new bacterial wilt disease caused by *Ralstonia solanacearum* was recorded in most of the rootrainer raised *Eucalyptus tereticornis, E. grandis* and *Tectona grandis* plantations and seems to be transferred from nursery to the field through diseased planting stock. Although, plantations of eucalypts and acacias raised with rootrainer seedlings exhibit very high field establishment and growth performance, it is too early to make any prediction on the stand productivity. However, the present field data indicate that plantations raised with rootrainer seedlings are performing much better than those raised with conventional polypot seedlings.

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13. Artificially induced male competition to produce seeds for bioremediation purposes

S. Mugnaini[1], M. Nepi[1], L. Cresti[1], B. Piotto[2] and E. Pacini[1]

Summary

We report the development of a new technique, called "assisted pollination", to obtain plant populations with a high genetic variability. The technique consists in pollinating with an abundance of pollen collected from geographically distant donors. The strong male competition between pollen grains for fertilising the ovules results in a better quality of the progeny. Assisted pollination may be useful to overcome the low genetic variability of isolated plant populations or to obtain plants for bioremediation purposes.

Keywords: land reclamation, genetic diversity, assisted pollination.

Introduction

Seedlings used to recolonise or reclaim disturbed land are produced by cutting or seed (Schütz, 1990). In the case of cuttings, the new population has no genetic diversity, unless cuttings from many donors are used (Figure 1). Plants arising from seeds collected in the wild have greater genetic diversity, but their reproductive success is uncertain (Figure 2).
To obviate this, we developed a technique which we named "assisted pollination"; it consists in pollinating with an abundance of pollen from a number of plants growing at large geographical distances (Figure 3). This creates strong male competition between pollen tubes travelling along the style. Only the pollen grains with "better" genes will fertilise the ovules. The progeny should therefore be of better quality (in terms of viability and vigor) because the large overlapping of gene expression between the male gametophytic phase (pollen) and the sporophytic one (from seedlings to plants) (Ottaviano and Mulcahy, 1989).

Materials and methods

The degree of competition is directly proportional to the number of pollen grains landing on the stigma and inversely proportional to the number of ovules/ovary (Ottaviano and Mulcahy, 1989; Lisci et al., 1994) (Table 1). To optimise the technique, it is necessary to know the various phases and characteristics of the reproductive cycle of the plants, and the biotic and abiotic factors that could affect them.

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Table 1: Competition in relation to certain reproductive characteristics. Most of the characters considered favour strong competition of only one sex, few favour both. Of all the characteristic considered, the number of pollen grains falling on the stigma is the most determinant

Competition-related reproductive characteristics	Competition	
	Male	Female
A high number of pollen grains on stigma	strong	
Number of pollen grains on stigma close to number of ovules/ovary		strong
A high number of ovule/ovary		strong
One or few ovules/ovary	strong	
Very long style	strong	
Reduced stigma area	strong	strong
Brief male receptivity	strong	strong *
Brief female receptivity, ovary with many ovules	strong	strong

** Only if the number of ovules/ovary is great*

Results and discussion

This technique (Figure 3) can be applied to angiosperms and gymnosperms, especially those with seeds of low quality due to problems of pollen transport and viability (ISTA 1995, 1996). Assisted pollination is also useful for increasing seed production in dioecious plants; in nature, these plants may be isolated or far from plants of the opposite sex.

The technique is currently being tested with various species of juniper and broadleafs (*Pistachia lentiscus, Phillyrea latifolia, Daphne sericea, Myrtus communis*). Here we report the case of *Juniperus communis*.

Juniper, especially the species *Juniperus communis* and *Juniperus oxicedrus*, are pioneer plants that colonise natural and disturbed environments (Lee et al. 1995). This had led to their use to restore vegetation in areas such as abandoned quarries and trampled beaches. *Juniperus communis* can be used to promote re-establishment of forests because its prickly foliage shelters seedlings. *Juniperus oxycedrus ssp macrocarpa* is salt-resistant and can be used to consolidate coastal dunes, a threatened habitat. Indeed, the degree of disturbance of dunes is inversely correlated with the abundance of juniper (Garcia Mora et al. 1995).

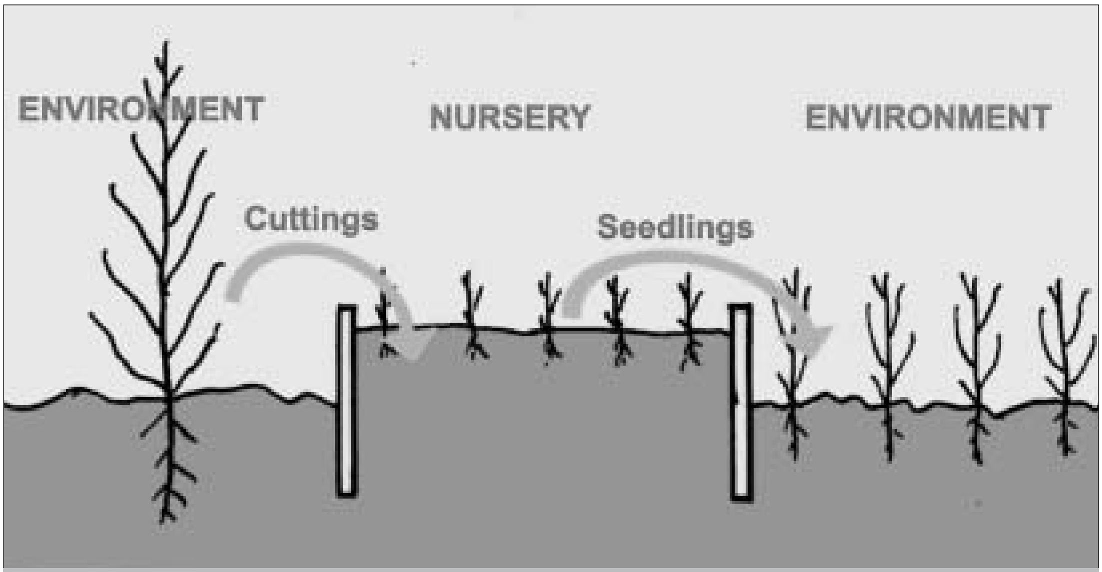

Figure 1: Seedlings obtained by vegetative reproduction (cutting). Results: 1) reduced variability; 2) few seeds if the species is self-incompatible; 3) Plants vulnerable to pathogens; 4) High mortality rate.

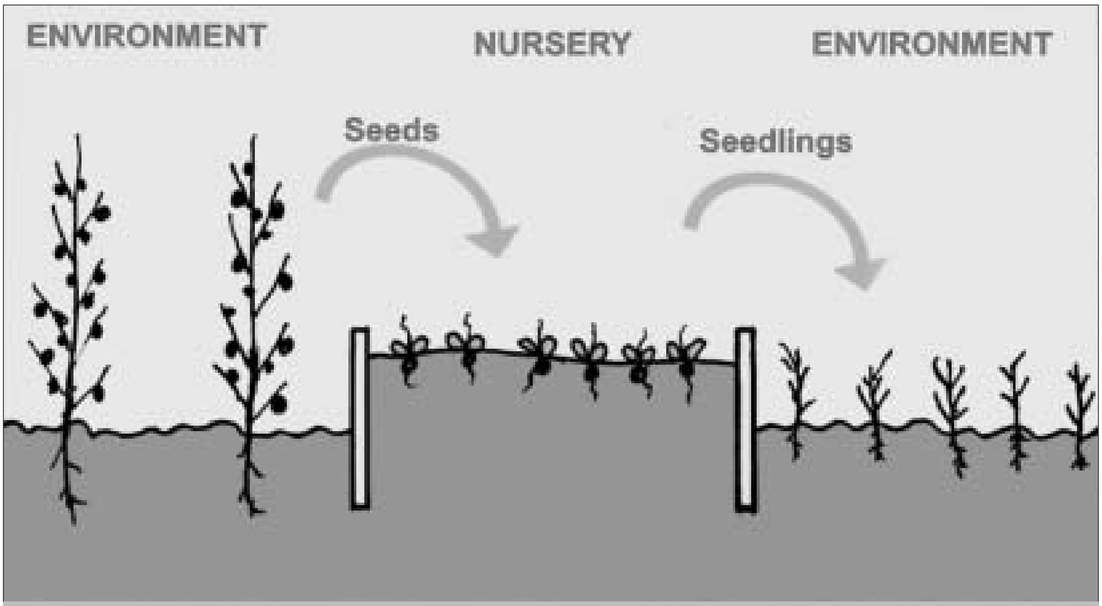

Figure 2: Seedlings obtained by sexual reproduction and free pollination. Results: 1) Genetic variability is uncertain because it depends on mode of pollination. Trees and plants with anemophilous pollination generally have greater genetic variability than small shrubs. 2) If the plant is self-incompatible and has vegetative reproduction, it produces few seeds; 3) resistance to pathogens depends on the genetic variability of the population; 4) Mortality rate variable.

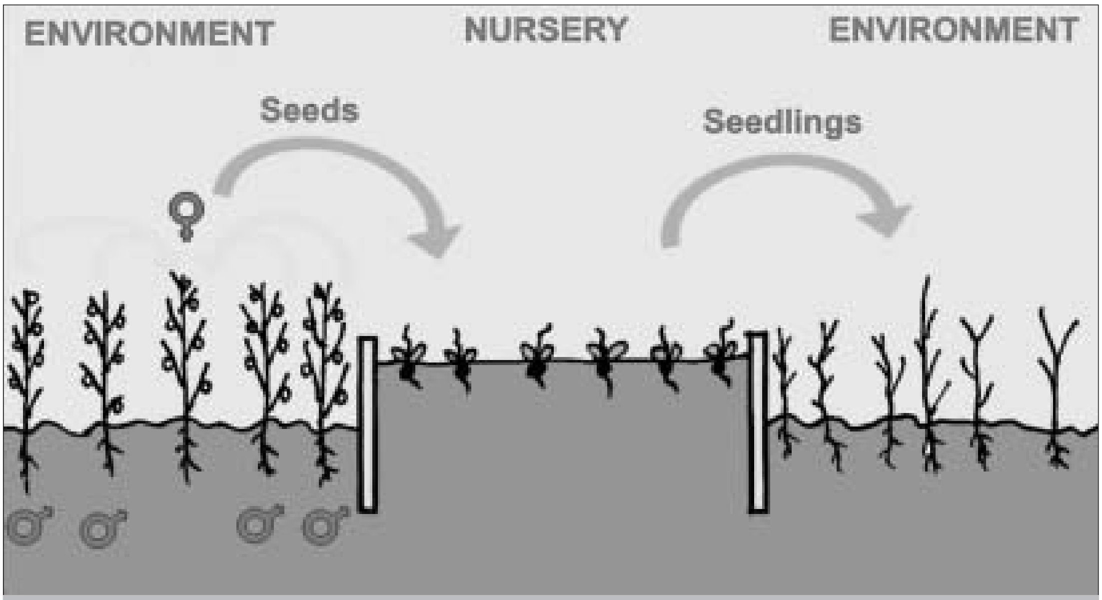

Figure 3: Seedlings obtained by sexual reproduction and assisted pollination. Results: 1) High genetic variability; 2) Self incompatibility no problem; 3) some genotypes pathogen-resistant; 3) low mortality rate.

Although they are pioneer plants, these two species have poor reproductive efficiency, producing a low percentage of viable seeds (Lee et al., 1995). Reasons for unviable seeds may include: 1) dioecy creating problems at the time of pollination due to an unfavourable male-female ratio or relative position (Jordano 1991); 2) production of fruits with sterile seeds even in the absence of pollination. Combined with a long reproductive cycle and poor seed germination, this means that the plants used for bioremediation are often obtained by vegetative reproduction, severely limiting the genetic variability of individuals. In order to increase the percentage of viable seeds with high genetic variability, we developed a technique of induced male competition which consists in pollinating with a large load of pollen from various, geographically distant individuals. Male competition increases because an abundance of genetically different pollen grains reaches the micropyle. Increased male competition should theoretically lead to higher quality progeny, manifesting as more vigorous seeds and seedlings. To optimise the technique, it is necessary to know the various phases and characteristics of the reproductive cycle of the plants, and the biotic and abiotic factors that could affect them. The reproductive cycles of *Juniperus communis* and *Juniperus oxycedrus* are long (2 or 3 years, respectively), and consist of three stages: 1) pollination (autumn or spring) and delayed fertilisation in the first year; 2) growth of fruit; 3) maturation of fruit in second or third year. In order to learn more about these plants and find parameters influencing reproductive success, we are studying the various phases of the reproductive cycle in different populations of juniper. So far it has been found that certain characteristics of mature fruits and seeds (water content, sugar content, mean number of viable seeds) differ between populations and vary during the period that the fruits are on the plants.

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14. Nursery production – a responsible contribution for sustainable forest management

I. Neves[1], *V. Paiva*[2]

Summary

The Aliança Florestal and Furadouro nurseries are five independent nurseries belonging to separate *Eucalyptus* pulp and paper Portuguese companies. Together, they produce around 25 million tree plants per year, which represents around 30% of the total Portuguese forest nursery production. They are engaged in providing forest managers with top quality planting stock, meeting the demanding challenges of sustainable forest management.

In Portugal, around 3.3 million ha of land are occupied with forest, of which 56% are broad-leaves and 44% are occupied with conifers.

Portuguese forests are essentially planted or cultivated. These plantations have been made with both production and protection objectives. These programmes and their management had already, in its base, some of the principles of the sustainability concept.

One of the big problems of Portuguese forest is the ownership structure: small estates (85% with less than 5 ha) and more than 400.000 private forest owners.

It is for the more marginal situations of the Southern Europe, facing greater ecological degradation risks, that is essential to produce and use adequate planting stock. Sustainable forest management requires correct soil preparation and establishment practices are used. In particular, this means a need for better plant quality to support competition with natural vegetation. Research and development on genetics and silviculture have an important role in a more global strategy for the conservation and maintenance of natural forests.

In all cases, the quality of stock material and plant production are of key importance to guarantee a sustainable forest management.

Keywords: sustainable forest management, nursery production, seedling, cutting, Portuguese forests.

Viveiros da Aliança Florestal and Viveiros do Furadouro are Portuguese independent nurseries belonging to two large *Eucalyptus* based pulp and paper companies. They are both part of two large *Eucalyptus* pulp and paper companies. These nurseries produce around 25 million forest seedlings and cuttings per year, which represents around 30% of total production of the most representative forest species in Portugal. Aliança Florestal has four nurseries and belongs to Portucel group and Viveiros do Furadouro, with one nursery, belongs to Celbi Stora Enso group.

These nurseries produce and supply not only *Eucalyptus globulus* seedlings and cuttings for the companies' own forest operations but also other species, including broad-leaves and conifers, which are widely used in all afforestation projects, including for protection purposes. In addition, plants are sold to other Portuguese and Spanish customers, including *Pinus pinaster*, *Pinus pinea*, *Eucalyptus globulus*, *Quercus suber*, *Quercus rotundifolia*, *Castanea sativa*, *Cupressus lusitanica* and others.

As mentioned before, total production of these nurseries is around 25 million containerised seedlings and cuttings per year, with 15 million broad-leaves (including eucalyptus) and 10 million conifers (Table 1).

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Table 1: Seedlings and cuttings annual production (10^6 plants)

	Furadouro	Aliança	Total
Broad-leaves	5.0	10.0	15.0 *
Conifers	3.5	6.5	10.0
Total	**8.5**	**16.5**	**25.0**

** Includes 5 millions genetically seedlings and cuttings of Ecalyptus globulus*

These nurseries are committed to provide forest growers with top quality planting stock, meeting the demanding challenges of a sustainable forest management. Their production is submitted to external auditing for independent certification in accordance with morphological criteria for quality.

Portugal total area is around 9 million ha, of which 3.3 million ha are occupied with forest: 56% are broad-leaves (1.9 million ha) and 44% are occupied with conifers (1.4 million ha). 58% of these 3.3 million ha are used for wood production and the remaining 42% for other purposes including cork and fruits production. Agriculture occupies 3.0 million ha and 2.6 million ha have other uses, including social (DGF, 1998)

According to the 1995 National Forestry Inventory, the Portuguese land use is (Table 2).

Table 2: Area by forest occupation

Species	Area (ha)
Maritime and Stone pines	1.140.000
Cork and Holm oaks	1.200.000
Eucalyptus (Blue gum)	700.000
Other oaks	180.000
Other broad-leaves	90.000

Source: 1995 National Forest Inventory

From the end of XIX century till now, the forest area in Portugal has increased from 640.000 ha to 3.3 million ha (DGF, 1998) (Figure 1).

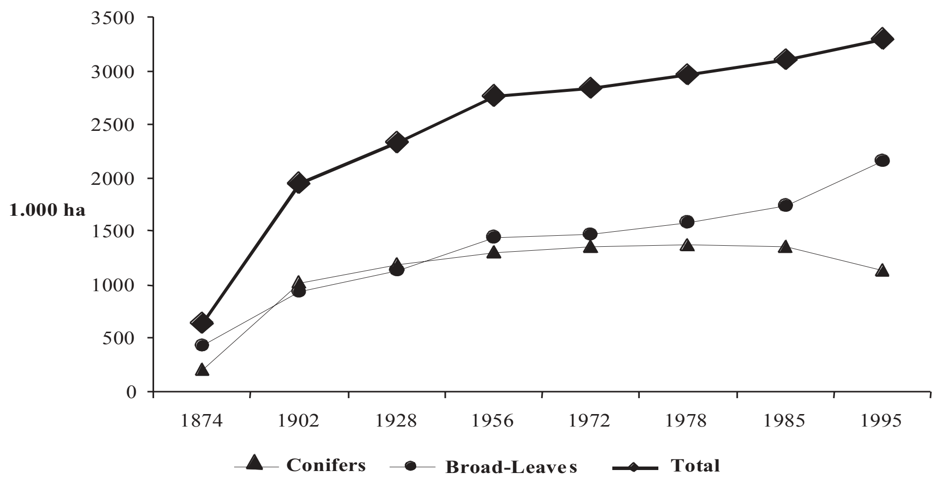

Figure 1: Forest area evolution.

Some comments can be made about this. As we can see from the Portuguese forest expansion in the last century, our forest is not essentially natural but most of the area is planted or cultivated. Also, we can say that a big plantation effort was made, with production or protection objectives, including in dunes, mountains and burned areas. Risk of forest fire is large: the annual burned areas in the last years have been more than 50.000 ha (DGF.1998).

Concerning forest ownership, most Portuguese area is private – about 87% is owned by private owners, including those managed directly by the pulp and paper industries. 3% of the forest area is state owned and 10% are communal forests. Number and area of forest ownerships also have particular characteristics: mainly small estates, 85% with less than 5 ha and only 1% with more than 100 ha. This last 1% represents actually about 55% of the total forest area (DGF; 1998). Here is one of the big problems of Portuguese forest: more than 400.000 private forest owners (in a total population of 10 million inhabitants) with a lack of forestry tradition. On the other hand, people are not always convinced of the fact that an active management of their lands can result in a positive return on their investment.

The increase in area that occurred in the last years has been due mainly to European Union financial subsidies to forest investment, reaching an average value of 15.000 ha per year (net increment). Also we have seen an increase in forest species diversity, with the use of indigenous species such as *Quercus* sp., *Castanea sativa*, *Juglans* sp., *Prunus avium*, etc.

The contribution of top quality seedlings and cuttings as part of a sustainable forest management strategy is evident from the following considerations. The success of forest establishment begins with appropriate seed or plant. Second, with increasing demand for forest products and services (economical and social), it is necessary to reach an increased productivity and an overall improvement in the forests. This implies we have to manage it in a sustainable way. This also means an improvement in the vigour and adaptation of seedlings or cuttings, in the reforestation of burned areas, areas of difficult of deficient natural regeneration and other potential areas for forest expansion, including abandoned farmland and uncultivated land. Thirdly, in Portugal as in other Southern European conditions, in spite of the observed high productivities, in general the climatic conditions, with a prolonged dry period with high temperatures and concentrated rain in a few cold winter months, means that planting operations have to be concentrated in a very short period. It also means frequently adverse conditions for the young seedlings and cuttings soon after planting as a result of shortage of available water during the initial development phase.

In Southern Europe there are large areas facing ecological degradation, particularly with fragile soils, which in many situations do not allow forest to regenerate naturally. It is precisely under these extreme situations that is essential to produce and use adequate planting stock (either seedlings or cuttings), including their subsequent nutrition, health conditions, root system development (much dependent on container type), plant size, adequate root and shoot ratio and appropriate hardening conditions. The later is essential for a good adaptation to final plantation conditions as well as the homogeneity of the lots sent to the field.

Sustainable forest management implies that correct soil preparation and stand installation practices are used. In order to reduce erosion problems, native vegetation should be maintained between plantation lines, ecological corridors should be preserved and young seedlings should be protected from intense radiation and temperature, winds and soil evaporation. In most cases this means a need for stronger seedlings, able to support competition with natural vegetation.

Each specific Portuguese ecological condition needs a different "type" of plant adequate to that variability. In Portugal, the start-up of a regulation process included a morphological certification for forest seedlings and cuttings while they are in the nursery. This means, sometimes, an excessive imposition based only on external characteristics that may lead to inadequate solutions. There is also a concern about directly translating the certification criteria developed by the European Union directives for other conditions, in particular those concerned the use of containers based exclusively on their volume.

The origin of seeds and cuttings used in forest plant production is of great importance for the stand success and therefore for the maintenance of high yields. In some cases, it is particularly important to ensure the geographic proximity of seed sources, or similar environmental conditions between seed source and final plantation.

Research and development on the areas of genetics and silviculture are important components of a strategy for conservation and maintenance of natural forests. The increasing demand from industry and other end-users means an increasing need for forest products, goods and services. Therefore, the utilization of genetically improved seedlings and cuttings, result in an increased forest productivity, hence contributing to a reduction in pressure from natural ecosystems and sites with high conservational value. Seedlings and cuttings of *Eucalyptus globulus* currently being produced by Aliança Florestal and Furadouro ensure productivity gains of around 30% compared with unimproved seedlings This ensures higher productivity, a better quality raw material for the industry and no increase in land use.

In conclusion, one of the key issues in a strategy for the conservation and maintenance of natural forests is the sound establishment, maintenance and sustainable use of cultivated forests, meeting the demands from industry and other uses, who provide society with forest products, goods and services. A major concern should therefore be to ensure the high quality of stock material and plant production, essential aspects of a sustainable and economically viable forestry.

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15. Comparative study of physiological response of broadleaved species to transplanting stress

Y. Raftoyannis[1], Radoglou K.[1] and G. Halivopoulos[1]

Summary

Seedlings of *Acer pseudoplatanus* L., *Castanea sativa* Miller. and *Quercus frainetto* Ten. were planted in January 1997, in a field site on Vertiscos Mountain, 70 km north of Thessaloniki, at 900 m elevation. During the following two growing season the physiological responses of seedlings to site conditions were monitored. *Q. frainetto* exhibited the lower values of midday leaf water potential (Y_{mid}) for both years and for the most of season. Seedlings of all species showed high reductions in the middle of summer in both years, with particularly low values in 1998 which was drier than 1997. In both years, a sharp reduction in Y_{mid} was observed at the beginning of July. In September, Y_{mid} recovered but to values lower to those found in May and June. All plant species exhibited their lowest assimilation rate (A) by the end of July. In 1997, assimilation rates recovered after the July depression to values even higher than those recorded in June. However, in 1998, only *Q. frainetto* and to a lesser degree *C. sativa* recovered from July high depression. Species reached their highest assimilation rates by the end of August in 1997 and in June during 1998. In general, stomatal conductance and transpiration rates followed the A patterns. In 1997, the seasonal course of effective quantum yield ($DF/F_{m'}$), for all plant species followed a rise-and-fall pattern with a peak at the beginning of July. In 1998, $DF/F_{m'}$ values were relatively high in June showed a deep depression during July. *Q. frainetto* and *C. sativa* recovered while *A. pseudoplatanus* continued to exhibit very low values.

Keywords: *Acer pseudoplatanus*, *Castanea sativa*, *Quercus frainetto*, physiological response, water potential, assimilation rate.

Introduction

Reforestation techniques have been improved over the past years in areas such as watering, site cultivation and weed control. However, reports of failed reforestation attempts still exist, especially in stressfull environments such as the degraded lands of Mediterranean areas. Reforestation failures are commonly reported in Greece. However, the factors responsible for these failures have not been studied. These failures might have been the result of poor root growth. It is well established that survival and growth of outplanted seedlings depend upon the rapid establishment of a vigorous root system (Margolis & Brant, 1990). Damage to root systems may occur by many external factors during the pre-planting period. Extreme temperatures, water imbalance and rough handling can cause severe damage to root systems (McKay, 1997). The successful establishment of seedlings depends on planting stock quality and the environmental conditions of the planting site. Phenological and physiological characteristics of seedlings determine their ability to overcome the transplanting stress.

Climate in Greece is characterized by moist mild winters and hot dry summers. Tree growth takes place primary during favorable conditions in spring and fall whereas metabolic activity becomes limited in most species as soil moisture stress and high atmospheric evaporative demand, coupled with high radiation, dominate summer time. Cold stress may occur during winter and may harm sensitive species. Summer drought seems to play the major role in limiting

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growth even in malacophyllous deciduous vegetation. Mediterranean species are adapted to climate and normally survive the summer drought but seedlings after planting suffer more. Stress effects on photosynthesis are shown to be primarily due to limitations in CO_2 influx to chloroplasts and stomatal closure is the major factor implied.
This study was designed in order to compare the physiological response to site environmental factors of three tree species commonly used for afforestation in the area.

Materials and methods

Experimental design

1. The following species were included in our study: two-year-old bare-root *Acer pseudoplatanus L.,* (origin: Drama), two-year-old container grown *Castanea sativa* Miller, (origin: Petrokerasa, Lagada), and two-year-old bare-root *Quercus frainetto* Ten. (origin: Vertiskos, Lagada). These species are commonly used in reforestation programs around the experimental site, in the area of Lagada, where there are many degraded wild lands. Seedlings were raised at the forest nursery of Lagada, 25 Km north of Thessaloniki (40°38′ N, 23°01′ E, altitude 100 m). Plant growing conditions at nursery, planting site preparation, planting method and post-planting care were identical to those used by the local reforestation service (Takos, and Merou, 1995). The nursery has a sandy loam soil type and the mean annual rainfall is 480 mm.
Seedlings were selected for uniformity and carefully lifted from the forest nursery of Lagada, on 28th of January 1997, placed in black polythene bags and transported to the experimental site (transportation time is half an hour). The experimental planting site was located in Krioneri, Lagada (23°18′ E, 40°50′ N) on the Vertiscos Mountain, 70 km north of Thessaloniki, at 900 m elevation. The natural tree vegetation of the area is dominated by *Quercus frainetto* trees mixed with *Quercus pubescens, Quercus petraea* and *Fagus sylvatica* trees at lower and higher elevations respectively. The experimental design was completely randomized blocks with three replications. In each block 30 seedlings from each species were planted (2 x 2 m, total block area = 72 m^2). A previously bare and degraded patch of public land, used for grazing, was selected for this experiment. Seedlings were shovel-planted and no fertilization or irrigation was applied to plants, following the usual practice of forest service in reforestation projects in the area. Environmental conditions were monitored with a weather station located within the experimental plot. Air temperature, air humidity and precipitation were recorded every hour. All sensors were connected to a data-logging device (DL2 Delta-T Logger, Delta-T Devices Ltd).

Measurements

During the growing seasons, the midday leaf water potential (_$_{mid}$) was measured using a pressure bomb (Wescor Inc., USA) at midday between 11:00 and 13:00 h, on six leaves per each species following the method described by Slavik (1974). Pre-dawn water potential was not recorded because the experimental site was remotely located and the access was difficult.
Leaf gas exchange measurements were made using a portable photosynthesis system (LI-6400, Li-Cor Inc., Lincoln, NE, USA). Leaves were enclosed in the cuvette until the values of assimilation rate (A), transpiration rate (E), intercellular CO_2 concentration and stomatal conductance (g_s) had stabilised (CV=1%, usually 15-45 sec). Environmental parameters such as air and leaf temperature (Tair, Tleaf), vapour pressure deficit (VPD), relative humidity (RH) and photosynthetic active radiation (PAR) were also recorded at the leaf surface. Observations were taken between 11.00 and 13.00 h. Net assimilation rate, stomatal conductance and transpiration were measured simultaneously. All measurements were made on one leaf of 6 plants per species. Fully expanded leaves with the same orientation and at the same layer in the crown (middle-top) were selected for measurement.
The saturation pulse method associated with the pulse-amplitude-modulation technique was applied for fluorescence measurements using a fluorometer MINI-PAM (Heinz Walz, Elleltrich, Germany). The tip of the fiberoptics was located 1.0 cm from and 60° to the leaf surface. Leaf temperature (Tleaf) and photosynthetic photosynthetic active radiation (PAR) were monitored

by the NiCr-Ni thermocouple and the quantum sensor integrated in the leaf-clip holder of the fluorometer. Unless otherwise stated, fluorescence measurements were made on sun-exposed, attached and fully expanded, current-year leaves. Measurements were taken on the same plants and leaves as in photosynthesis. The effective quantum yield was calculated as DF/Fm´= (Fm´ –F)/Fm´, where F and Fm´ are the fluorescence yield before and after the saturation pulse is applied on the leaf.

Percent survival was determined at eight different dates from June 1997 until September 1999 (8 June 1997, 20 July 1997, 11 September 1997, 28 May 1998, 27 July 1998, 10 September 1998, 4 June 1999, 10 September 1999. Plants with no leaves or alive buds were considered as dead.

Data analysis

All data were checked for normality of errors by plotting residuals versus predicted values, as well as using the Kolmogorov-Smirnoff test for goodness of fit. Variances of data were tested for homogeneity using the Bartlett and Levenne tests. Percent data did not always satisfy the assumptions of analysis of variance and subsequently they were subjected to the arcsine transformation for statistical analysis, but actual percentages are given in the tables and figures. When the assumptions of ANOVA were not satisfied even after transformations, the uses of nonparametric methods were employed. The Kruskal-Wallis test was used to test for difference among groups in single classification analysis and the Nemeyi test to compare the groups. All data were subjected to analysis of variance using General Linear Models (GLM) procedures and, when appropriate, means were compared with Tukey's multiple comparisons tests. All tests for significance were conducted at p=0.05, unless otherwise indicated.

Results

Rainfall during summertime was higher in 1997 and concentrated from mid-July to mid-August while in 1998 infrequent rains occurred and for the period from the middle of June to the middle of July almost no rain felled (Figure 1). Mean daily air temperature values were generally higher in 1998 than in 1997 and showed a gradual decrease by the end of the season. Mean daily relative humidity fluctuated around 70% during 1997, while in 1998 was around 50% until the end of August and then increased.

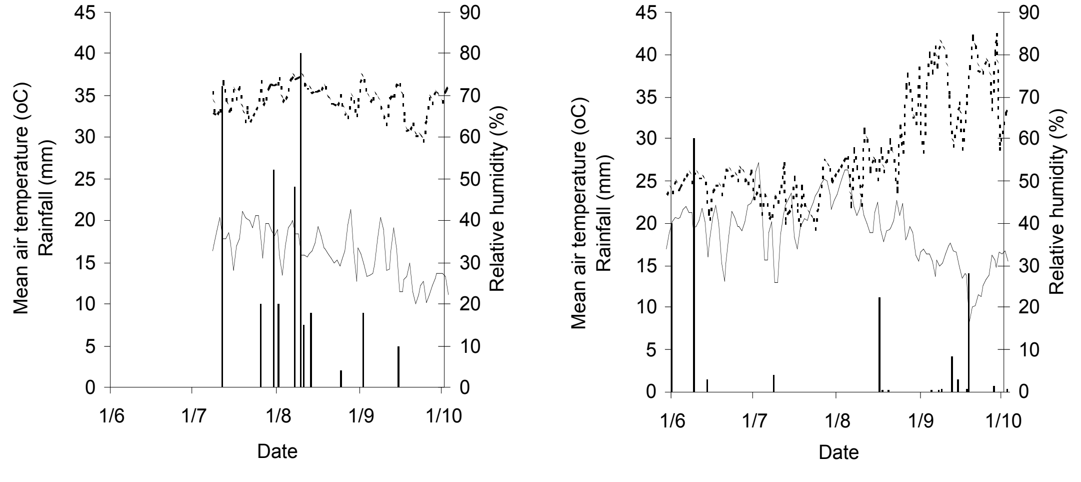

Figure 1. Seasonal courses of mean daily air temperature (full line), relative humidity (dotted line) and rainfall (bars).

Leaves emerged at the beginning of May and reached their final size in early June. *A.pseudoplatanus* came into leaf before *C. sativa* and *Q. petraea* and commenced net assimilation

(A) earlier. However, *A. pseudoplatanus* lost its leaves before the other two species. Figure 2 shows the seasonal pattern of midday leaf water potential (Y_{mid}) of the studied species. Seedlings of all species showed high reductions in Y_{mid} in the middle of summer in both years, with particularly low values in 1998 which was drier than 1997. In both years, a sharp reduction in Y_{mid} , lower than –2 Mpa, was observed at the beginning of July. In September, Y_{mid} recovered but to values lower to those found in May and June. *Q. frainetto* exhibited the lower values for both years and for most of the season (give values). *C. sativa* showed the higher values during 1997 and the first half of 1998. *A.pseudoplatanus* showed values between the other two species and higher than the other for August and September of 1998. Measurements were taken until the end of September because *A.pseudoplatanus* turned yellow.

Until 7th of August 1997, carbon assimilation rates (A) of all three species followed similar patterns and no significant differences among species were observed (Figure 3). On 12th of June 1997, mean A values of *A. pseudoplatanus, C. sativa* and *Q. frainetto* were 11, 12 and 13 _mol m^{-2} s^{-1} respectively. A slight increase of A was recorded for the two subsequent dates (3/7, 11/7) followed by a deep depression on 31/7 where mean values of all species were between

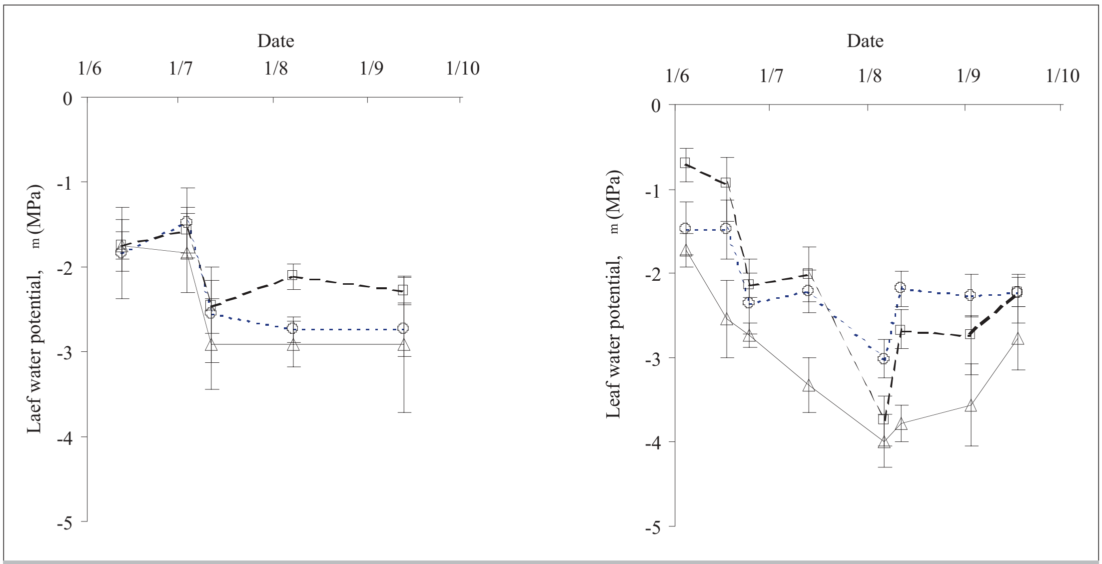

Figure 2: Seasonal courses of midday leaf water potential ($_{mid}$) for *Acer pseudoplatanus* (●), *Castanea sativa* (■) and *Quercus frainetto* (▲). Symbols represent means ±1 SD (n = 4-6).

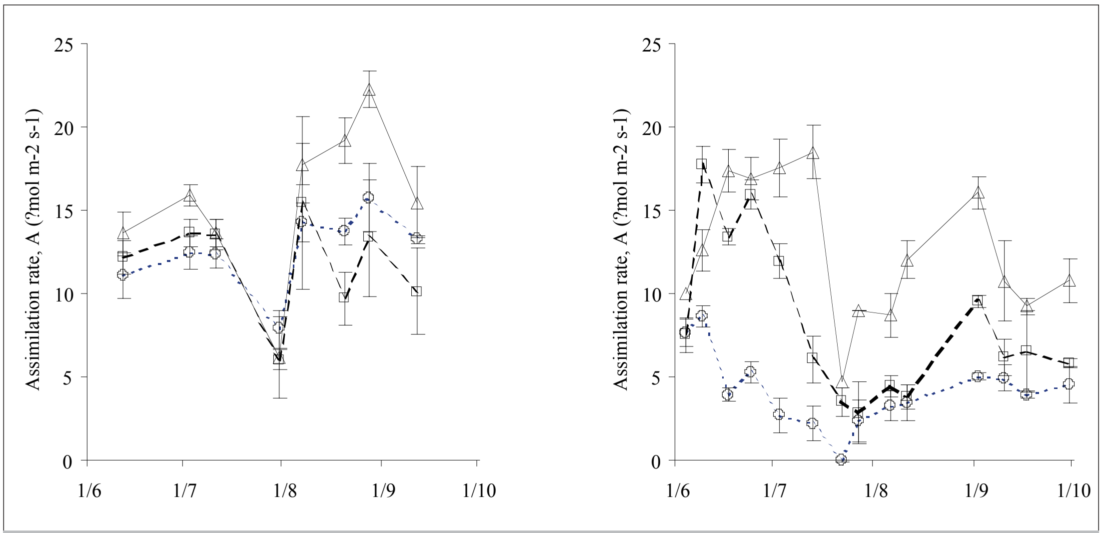

Figure 3: Seasonal courses of CO_2 assimilation rate (A) for *Acer pseudoplatanus* (●), *Castanea sativa* (■) and *Quercus frainetto* (▲). Symbols represent means ±1 SD (n = 4-6).

6 and 8 _mol m^{-2} s^{-1}. On 7th of August, photosynthesis recovered to values even higher than those recorded before the depression. On 20th of August mean values of A for *Q.frainetto* increased and were significantly higher from the other two species. A further increase in A of *Q.frainetto* was observed on 28/8 (22.3 _mol m^{-2} s^{-1}) while *A. pseudoplatanus* and *C. sativa* showed increasing rates but still significantly lower than *Q. frainetto.* At the last measurement day for 1997(12/9)all species showed a reduction in A compared to 28/8 and no significant differences among species were found. In 1998, A recovered quickly from July high depression while *A. pseudoplatanus* and *C. sativa* showed very low increase in A. Species reached their highest assimilation rates by the end of August in 1997 and in June during 1998. All plant species exhibited their lowest assimilation rate (A) by the end of July (Figure).
Stomatal conductance (g_s) showed different seasonal patterns in 1997 and 1998 (Figure 4).

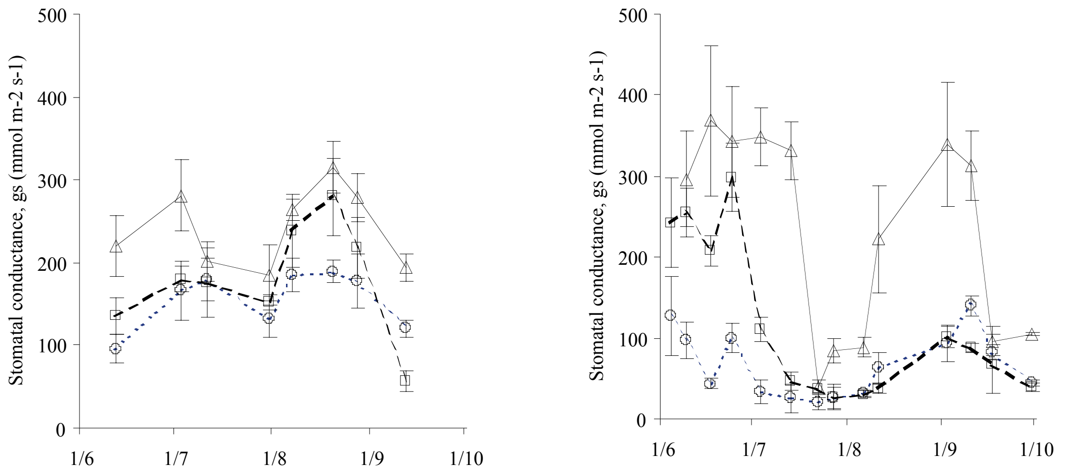

Figure 4: Seasonal courses of stomatal conductance (g_s) for *Acer pseudoplatanus* (●), *Castanea sativa* (■) and *Quercus frainetto* (▲). Symbols represent means ±1 SD (n = 4-6).

During 1997 all species showed g_s values higher than 100 with *Q. frainetto* having the higher values for most of the period while Y_{mid} was the lower. In 1998, *A. pseudoplatanus* and *C. sativa* showed g_s values lower than 100 from early July until the end of September and almost closed stomata. *Q. frainetto* showed similar low values only from the end of July until the beginning of August although Y_{mid} values were very low at the same period.
In 1997, the seasonal course of effective quantum yield (DF/F_m´), for all plant species followed a rise-and-fall pattern with a peak at the beginning of July (Figure 5). In 1998, DF/F_m´ values were relatively high in June showed a deep depression during July and some species (*Q. frainetto*, *C. sativa*) recovered while others continued to exhibit very low values. Regression analysis of _F/Fm´ and Y_{mid} showed a significant correlation (*A. pseudoplatanus*=0.66, *C. sativa*=0.18, *Q. frainetto*=0.49).
While seedling survival of all three species was almost 100% at the beginning of the growing season in 1997, a progressive reduction was observed during the experimental period (Figure 6). On 20/7/97 mean survival of all species was reduced and followed by a further reduction on 11/9/97. From the beginning of 1998, a sharp reduction in *A. pseudoplatanus* seedling survival (40%) was observed which continued until the last assessment of 1998 (15%). *C.sativa* showed a decline in survival from mid-summer until the final assessment of 1998 (45%). A slight reduction in *Q. frainetto* seedling survival was observed for 1998 (73%). No further significant reduction in seedling survival were measured in 1999, although a few plants were died during 1999.

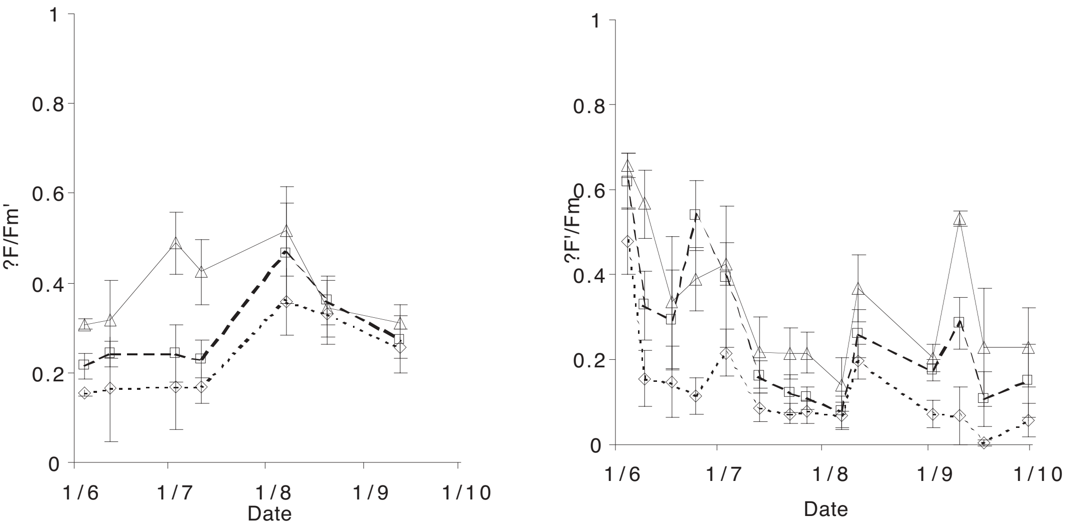

Figure 5: Seasonal courses of effective quantum yield (DF/Fm′) for *Acer pseudoplatanus* (●), *Castanea sativa* (■) and *Quercus frainetto* (▲). Symbols represent means ±1 SD (n = 4-6).

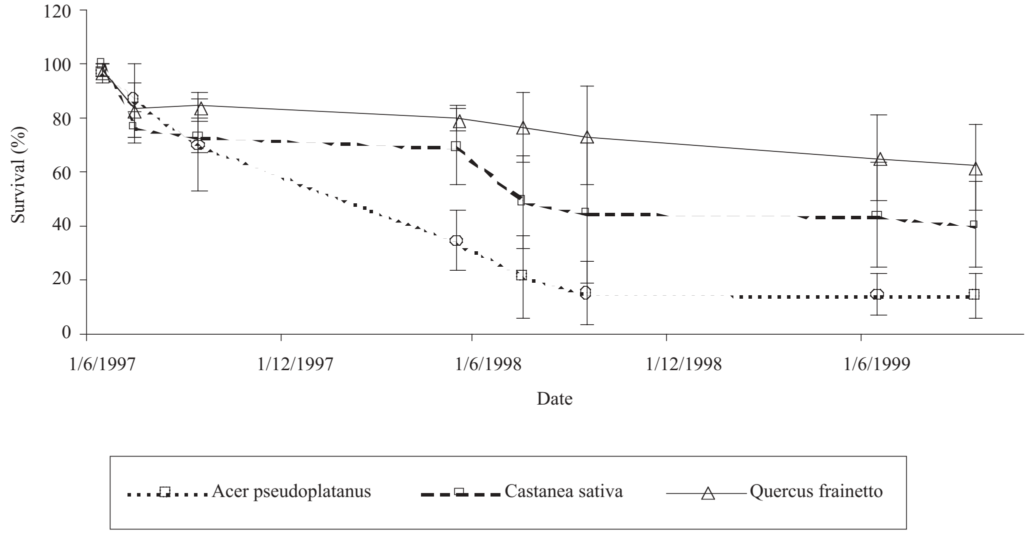

Figure 6: Seedling survival from 1997 to 1999, for *Acer pseudoplatanus* (●), *Castanea sativa* (■) and *Quercus frainetto* (▲). Symbols represent means ±1 SD (n = 30).

Discussion

Seasonal patterns of physiological parameters were similar to those observed in the same and other Mediterranean woody species. The mid-summer depression on assimilation rate and stomatal conductance is reported often and some plants may not overcome such a stress without detrimental effects. In our study, a high percentage of leaves of *A.pseudoplatanus* turned yellow during the water stress period, indicating irreversible cell damage and subsequent plant death as it was evidenced by survival rates. Kramer (1980) concluded that senescence of leaves is a mechanism for coping with extreme drought conditions. Broadleaf deciduous species in hot climates can assimilate carbon only for limited part of the growing season. Guehl *et al.* (1989) found that A, g_s and Y, of *Cedrus atlantica* seedlings, were affected by transplanting stress, but the decline of A was not a consequence of reduced gs, but was primarily determined by alterations of mesophyll photosynthesis. Recovery of A was strictly concomitant with root regeneration, but no evidence could be found to ascertain whether a functional linkage exists between these two parameters or whether they respond to a third, still unknown, factor. Fort *et al.* (1997) found that a gradual decrease in soil water content to 20% of field capacity affected both water relations and seedling growth of *Q. robur;* predawn leaf water potential declined and stomatal conductance, leaf expansion and root growth were severely reduced.

The low values of Y_m from July onwards, indicated that all species experienced a rather severe water stress. Most workers consider that tree seedlings are under water stress when Y_m falls below –2.0 Mpa, a condition experienced by our seedlings for both years after June. Fotelli *et al.* (2000) observed similar reduction of Y_m for *Q. frainetto* seedlings, with values reaching -6 Mpa while Damesin & Rambal (1995) observed similar values of Y_{mid} for *Q. pubescens*. Kaushal & Aussenac (1989) suggested that maintaining a high Y after transplanting is a key factor for the subsequent survival of forest seedlings; if it falls below a certain limit the chances of the seedling survival are reduced considerably and on reaching a certain level they are unable to recover. Under drought stress, no new roots develop which leads to a further reduction of Y and eventually seedlings die (Margolis & Brant, 1990; Burdett, 1990). Guehl *et al.* (1993) found that both development and survival of *Pinus nigra* ssp. *Laricio* var. *Corsicana* seedlings were related to their water status assessed at the beginning of the growing season and proposed that the carbon assimilation capacity of the transplanted seedlings was probably reduced as a result of the drought stress. However, in our study *Q. frainetto* showed the lowest values of Y_m for most of the season while its assimilation ability and survival rates were far better than the other two species. This outcome can only be related to species ability to survive at low water potential and keep stomata open, traits that show its adaptation to site conditions.

Seedlings of *A. pseudoplatanus* and *C. sativa* responded to drought conditions by stomatal closure, a mechanism reported by other researchers (Sala & Tenhunen, 1994). Drought induced a strong but not complete reduction of A on *Q. frainetto*, indicating that *Q. frainetto* can sustain significant CO_2 fixation during adverse water stress conditions. Epron *et al.* (1992) observed similar response of *Q.petraea* trees and they concluded that mesophytic oak species are able to maintain significant CO_2 fixation during periods of drought and may be considered rather drought tolerant. The same declining pattern of leaf conductance, over the season, was observed for *Q. pubescens* by Tognetti *et al.* (1999) and *for Q. ilex* (Sala & Tenhunen, 1994). Nardini & Pitt (1999) found that *Q. pubescens* seedlings are able to maintain high leaf relative water contents under water stress conditions. Tognetti *et al.* (1999) found that the effects of summer drought on *Q. pubescens* water relations, including whole-plant transpiration, were severe, but leaf conductance and water potential recovered to pre-drought values after major rainfall in September. Vivin *et al.* (1993) found that during water deficit, the pattern of reduction in gas exchange was similar for *Q.robur, Q. petraea* and *Q. rubra* seedlings. Thus, their ability to limit water deficit by reduction of transpiration was similar. We suggest that the differences in mortality between species are due to differences in tolerance to water stress, not in avoidance. Stomatal conductance (gs) decreased in conditions of high vapour pressure deficit (VPD). However, this did not decrease A as high VPD was associated with high solar radiation and the stimulation of photosynthesis caused by high photosynthetic photon flux density (PPFD) more than compensated for the reduction by VPD. A reduction in photosynthesis in response to water stress under natural conditions is probably the consequence of stomatal closure and possibly also high levels of irradiance and temperature. Dreyer *et al.* (1992) concluded that sensitivity of the photosynthetic apparatus to foliar dehydration in the absence of irradiance plays a very minor role in the adaptation of species to drought.

The maximum rates of CO_2 assimilation for the studied species were generally higher than those reported by other workers. Lauteri *et al.* (1997) reported that the mean assimilation rates of different populations of *C. sativa* seedlings, ranged between 6.6 and 9.5 mmol $m^{-2}s^{-1}$ in irrigated and 2.7 and 7.1 mmol $m^{-2}s^{-1}$ under drought conditions. The recorded maximum rate of A for *Q. frainetto* is higher than those observed in the field by Tretiach (1993) on *Q. pubescens* and *Q. ilex* (14 and 17.2 _mol m^{-2} s^{-1} respectively), by Epron & Dreyer (1993) for *Q. petraea* and *Q. robur* (around 15 _mol m^{-2} s^{-1}). The relative high values of A indicate a high photosynthetic potential when the environmental conditions are non-limiting. Morecroft & Roberts (1999) found that Amax of *A. pseudoplatanus* (3.5 μmol m-2 s-1) leaves was substantially lower than that of *Q. robur* (10.4 µmol m-2 s-1), despite *A. pseudoplatanus* being a fast-growing species.

The superiority of *Q. frainetto* is probably related to the fact that it was the only species native to the planting site. Failures of reforestation actions can often be the result of inappropriate selection of planting stock not adapted to a particular site. The use of native genetic material increases the chances of a forestation success. However, in recent years there is a tendency for centralization of nursery processes based purely on economic criteria. As a result, propagative material is usually collected from areas completely different to the planting site, seedlings are grown in completely artificial conditions and while seedlings might be of superb quality after lifting, they fail to establish in the planting site or their survival is reduced with time, particularly in extreme and stressful environments.

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16. Propagation of Mediterranean trees and shrubs by seed

*B. Piotto**

Summary

Nearly 27% of the Italian territory, mainly located in areas with Mediterranean climate and vegetation, is threatened by processes of soil degradation, erosion or desertification. Mediterranean vegetation needs particular attention: the role of plant cover is essential for mitigating desertification processes because vegetation and connectivity of 'green areas' strongly condition the quality and evolution of soil. The Mediterranean flora is well described from a botanical point of view but much less is known about their natural and artificial regeneration. This lack of knowledge is particularly serious because it represents a limit for multipurpose afforestation, restoration and reclamation and explains the fact that plantings are often carried out employing a narrow range of species which are easy to grow in the nursery. This practice greatly reduces levels of biodiversity.

The Italian Environment Protection Agency has published the handbook 'Propagation of mediterranean trees and shrubs by seed' as a contribution to the Italian Committee to Combat Desertification. The main target of this handbook is to offer essential information about seed biology of 120 Mediterranean trees and shrubs: ripeness and dispersal, factors affecting seed production, storage, dormancy, presowing treatments. Techniques to optimise nursery production, if available, are presented as well.

More than 30 authors, most of them Italians but also Spanish, English and Australian, have given their contribution to the volume.

Some chapters of the Italian version of the handbook are available in English on the web http://www.sinanet.anpa.it/documentazione/Pubblicazioni APAT/pdf/seedprop.pdf.

Keywords: Italy, Mediterranean vegetation, land degradation, planting, seed biology, propagation.

Presentation

The Italian Environment Protection Agency has prepared and published the handbook 'Propagation of mediterranean trees and shrubs by seed' as a contribution to the Italian Committee to Combat Desertification. It has been printed in Italian but it has partly been translated in English. The English version, is now present in the web (http://www.sinanet.anpa.it/documentazione/PubblicazioniAPAT/pdf/seedprof/pdf). Plainly we can say that the handbook is written for everyone who works with propagation of Mediterranean trees and shrubs. The first part includes chapters regarding the Mediterranean basin environment (vegetation, regeneration of vegetation after fires, reasons for vegetation decline, etc) and general methods of producing and handling seeds. The second part is a compilation of propagation data of 120 Mediterranean trees and shrubs.

The publication of the handbook gives a good chance to speak about the Mediterranean Ecosystem as well as about the seed problems of Mediterranean trees and shrubs, often neglected items.

The Mediterranean Ecosystem is undergoing a tropicalisation trend. In the last forty years

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there has been an increase of 20% in carbon dioxide in the atmosphere and in the last twenty years a noticeable increase of temperature has been recorded so that 'greenhouse effect' and 'desertification effect' can be considered as aspects of the same problem. Similarly there is enough evidence with respect to the high number of linkages between desertification, climate change and biodiversity (Calzolaio 2000).

Nearly 27% of the Italian territory, mainly located in areas with Mediterranean climate and vegetation, is threatened by processes of degradation, erosion or desertification.

Desertification in the European Mediterranean countries is linked to the following general characteristics of the region (Enne and Zucca 2000):

- highly vulnerable environment due to particular climatic and geomorphological characteristics combined with frequent unsustainable use of land;
- four thousand years of strong human pressure due to agricultural and pastoral activities, often in conjunction with phases of demographic growth and/or rapid economic development;
- increase of pressure from the '50s following major economic transformations which has led to intensification of mechanisation of agricultural practises, increase in water demand, increase of urban and tourist development, increase of soil and water pollution, concentration of human economic activities in coastal areas, fragmentation of landscapes;
- increasing aridity of the climate in the region (according to forecasts from advanced models);
- extensive forest cover losses due to frequent wildfires.

In the Mediterranean region fire has always been part of the ecosystem since its presence was favoured by dry summer climate characterised by almost absolute lack of rainfall and presence of xeric vegetation (Basso, Pisante and Basso 1997). Mediterranean vegetation adapted itself to natural periodic fires with active and passive defence mechanisms but the high frequency of burnings in the last decades in many cases have led to soil degradation accelerated by rainfall water action. In fact, after a rain event there can be a migration of residual organic matter to the underlying horizon where waterproof repellent layers can develop. In presence of a certain slope a sort of slip sheet facilitates the falling down and loss of soil layers.

Chapter 3 deals with post-fire vegetation dynamics and regeneration in Mediterranean ecosystems. Understanding the role of fire in natural plant regeneration, especially the fire stimulation on seed germination, is extremely useful for artificial propagation. Example of this are studies carried out in Australia, South Africa and California which investigate the smoke or smoke extracts responsiveness of some germination patterns in areas with Mediterranean climate.

Deforestation, especially if followed by overgrazing with soil compactation, can be considered as the principal anthropic cause of groundwater loss in Mediterranean areas. Mediterranean woodlands, especially in arid areas, have diminished considerably and in many cases are degraded with large denuded surfaces characterised by thin soils alternating with outcropping rock. This means that the floristic and structural diversity of the natural vegetation, as well as the faunistic species richness and abundance, is constantly been reduced (Naveh 1995).

Unfortunately, the vulnerability of Mediterranean ecosystems allow a higher negative impact from factors that lead to any form of degradation.

In light of the above, the regeneration and management of woodlands in the Mediterranean needs particular attention: the role of plant cover is essential for mitigating desertification processes (Aru 1999) because vegetation and connectivity of 'green areas' strongly condition the quality and evolution of soil. Trees and shrubs in the Mediterranean areas show a multiplicity of functions.

- supply of organic matter to the soil;
- immediate and effective response to degradation caused by grazing, fire and deforestation;

- watershed protection;
- maintaining of biodiversity;
- production of wood, mushrooms, fruit;
- possibility of balanced extensive grazing;
- conserving landscape features of vast areas.

Mediterranean flora is well described from a botanical point of view. Abundant information is available for what concerns botanical and ecological characteristics, distribution and occurrence, value and use of many species but little is known about their natural and artificial regeneration. The absence of this information is particularly serious because it represents a lack of knowledge to address a multipurpose approach to forestation, restoration and reclamation and may explain the reason why plantings are often limited to a narrow number of species which are easy to grow in the nursery. This practice greatly reduces levels of biodiversity and it is even more worrisome with regard to shrubs and minor hardwood which are the greater part (60 to 70%) of the Mediterranean woody flora.

However, forest and conservation nurseries are being asked to propagate an increasingly number of Mediterranean plants. Learning how to properly propagate these 'new' plants properly, including those deserving a wider use as drought-tolerant ornamentals, can be a formidable challenge.

The main target of this handbook is to offer information about propagation by seed of 120 Mediterranean trees and shrubs. When available, the following items are focused within plant fact sheets for each species: fruiting and factors that can affect it, seed quality data (number of cleaned seeds per Kg, average germination percentage, etc.), seed ripeness, dispersal, storage, dormancy and presowing treatments to enhance and speed germination. Techniques to optimise nursery production, if known, are presented as well.

Gathering and processing these data was not easy because published information on how to propagate Mediterranean species is extremely limited and nursery workers, important sources of knowledge, just do not have the time to document what they know. More than 30 authors have given valuable contributions to the volume, most of them are Italians but also Spanish, English and Australian researchers have participated.

An item needing deep investigation is removal of dormancy in seeds dispersed by birds and small mammals. Seed dispersal by birds and small mammals is quite frequent in shade tolerant Mediterranean shrubs occurring in the understory, this habit being often associated with the presence of seed complex dormancies, removal of which is often unknown.

Storage of seeds has been examined in Chapter 10. Storability can be a great potential or, on the other hand, a heavy limitation for genetic resources conservation. In other words, if seeds of a given species do not allow medium or long term storage, its genetic variability could be threatened.

A large variation in storability is encountered between Mediterranean species. In seed handling terminology, seeds have been classified in two main groups according to their physiological storage potential: orthodox and recalcitrant seeds (Roberts 1973). Orthodox seeds can be dried to low (2-5%) moisture content and can, with low moisture content, be stored at low temperature (+3 to -18°C), generally for long periods. Seeds of recalcitrant species maintain high moisture content at maturity (often > 30-50%) and are sensitive to desiccation below 12-35% (depending on species). They also lose viability rapidly and, for this reason, storability is difficult.

Although the terms 'orthodox' and 'recalcitrant' seem to define opposite conditions, storage physiology of seeds seem to cover a more or less continuous spectrum, ranging from extremely recalcitrant (loss of viability in few days) to extremely orthodox (under optimal conditions viability is maintained for decades or centuries) (Farrant et al. 1988).

Storage of recalcitrant seeds is considered to be the most challenging problem in seed science today (Bonner 1996).

Success in short-term storage (3-4 years) of recalcitrant seeds of the temperate zone, primarily *Quercus*, has been achieved with both North American and some European species.

Unfortunately, the development of strategies and methodologies for the management and conservation of Mediterranean oaks genetic resources, including storage of recalcitrant acorns, have been afforded only recently (Frison et al. 1995). Within this group of long neglected species (disadvantaged for seed dispersal because of land fragmentation and lack of animal vectors in Mediterranean areas), an urgent priority has given to *Quercus suber* (cork oak). Cork is a regenerative raw material with high technological qualities combined with positive peculiar ecological characteristics; in many cases it has been defined as an *strategic material*. Since a couple of years storage of acorns of *Quercus ilex* (predominant tree in the *climax* phase of the sclerophyllous forest) is being studied as well.

The handbook reports updated current practices of storage of recalcitrant seeds which could be adapted to seeds of Mediterranean oaks. Storage of orthodox seeds is examined as well. Success of plantation establishment relies heavily on genetic variability, which allows adaptation to countless factors like climate, climate change, site conditions, drought, pests and diseases, thus permitting natural evolution of ecosystems. This is particularly necessary when artificial regeneration (afforestation or reforestation) aims at reclamation of disturbed land or at combating desertification.

Propagation techniques, involving collecting, processing, storing and pre-sowing treatment of seeds, culling seedlings, could erode genetic diversity, if they are not properly used. Risks related to adoption of wrong nursery programmes and, particularly, use of unsuitable propagation techniques are present even in high-developed countries. Nevertheless, many national nursery strategies are focusing on the propagation of a large number of neglected Mediterranean native species and, fortunately, recent research results are having positive effects.

Chapter 11 describes the usual presowing treatments employed in forest nurseries, the risks of genetic erosion that they could imply and the modern techniques that prevent diversity losses. In particular, those methods allowing dormancy breakage to occur in all seeds without ever permitting germination during pre-sowing treatment and avoiding unintentional selection of seeds requiring longer or more complex presowing-treatments.

Other chapters regard the Mediterranean flora (Chapter 1), the degradation of Mediterranean vegetation (Chapter 2), woody plants of Mediterranean melliferous flora (Chapter 5), natural vegetative propagation in Mediterranean plants (Chapter 6), harvesting and processing of seeds (Chapter 8) and seed testing (Chapter 10).

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17. Photochemical Reflectance Index: a novel tool for the assessment of seedling photosynthetical performance

S. Raddi[1] *and F. Magnani*[2]

Summary

The analysis of reflectance can be used to estimate foliar concentrations of photosynthetic pigments, thus providing information on the physiological status of green plants. Recently, the reflectance of leaves has been utilized for detecting their photosynthetic efficiency. This signal is captured by the photochemical reflectance index (PRI) given by the normalized ratio of reflectance at 531 and 570 nm. The relation between PRI and photosynthetic efficiency was assessed in several broadleaves (*Castanea sativa*, *Fagus sylvatica*, *Fraxinus angustifolia*, *Laurus nobilis*, *Quercus ilex* and *Quercus pubescens*) and it is strong enough to be used in nursery management. The use of reflectance indices to assess foliar content and functionality is also discussed.

Keywords: protosyntesis, photochemical reflectance index, nursery techique, planting stock evaluation.

Introduction

The evaluation of photosynthesis light use efficiency finds a large variety of applications in nursery management. It allows to assess if the environmental conditions (i.e., nutrient availability, water availability, air relative humidity, temperature) are optimal or not for plant growth. Following Monteith growth model, three variables describe well plant biomass production in non-limiting conditions: the quantity of incoming light used in the photosynthetical process (PAR), the amount of light intercepted by leaves that can be expressed through the leaf area index (LAI) and the efficiency of conversion of light energy to carbon, (Monteith, 1977). Moreover, the estimate of light use efficiency also allows to detect stress before any visual symptoms is noticed. In saturating light conditions the excess of energy has to be dissipated as heat in order to allow the photosystem II to remain functional under conditions of limited carbon uptake. Otherwise, photoinibitory damages occurs (Bjorkman and Demming-Adams, 1994; Demming-Adams, 1994).
Recently, the availability of low-price spectrometers allows people to take advantage of research studies and to use these techniques in the practice.

Materials and methods

Plant material

Leaves of potted seedling of *Castanea sativa* Mill., *Fagus sylvatica* L., *Fraxinus angustifolia* Vahl., *Laurus nobilis* L., *Quercus ilex* L. and *Quercus pubescens* Willd. were measured for gas-exchanges with an IRGA gas-analyser (CIRAS, PP-System). Simultaneously their reflectance spectra were acquired with a spectrometer (ZEISS MCS-501). Measurements with the gas-analyzer and the spectrometer were taken every minute on leaves exposed to saturating light

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condition at 1400-1500mmol PFD m^{-2} s^{-1}. Measurements were made on three dates: end of September, beginning of October 2000 and in February 2001.

Experimental measures

Ambient CO_2 levels was changed every 20 minutes with steps of 200 mbar covering the range from 100 to 1300 mbar. This experimental setup allow to plot assimilation rate (A, mmol CO_2 m^{-2} s^{-1}) to intracellular CO_2 (mbar) in order to evaluate gas-exchanges and to derive photosynthetical parameters (such as dark respiration, CO_2 compensation point, J_{max} and VC_{max}) by applying the Farquhar model (Farquhar et al., 1980).
In C3 plants at low intercellular CO_2 the response of assimilation rate to CO_2 is determined by the kinetic proprieties of the Rubisco (Farquhar et al., 1980). At higher concentration of CO_2, the maximum rate of photosynthesis is determined by the RuBP regeneration, that is the supply of ATP and NADPH by electron transport. This limitation can take two forms. Either the maximum capacity of the electron transport system limits synthesis of ATP and reductant or else the rate at which triose-P is utilized in product synthesis limits the rate of P_i-recycling to the chloroplast and that, in turn, limits photophosphorylation. Light use efficiency (LUE) was calculated by dividing assimilation rate (A, mmol CO_2 m^{-2} s^{-1}) by incident photosyntheticaly active radiation (PAR, mmol PPD m^{-2} s^{-1}).

Photochemical Reflectance Index (PRI)

This index is the normalized ratio of the reflectance at 531 nm (R_{531}) referred to reflectance at 570 nm (R_{570}):
PRI=[(R_{570}-R_{531})]/[(R_{531}+R_{570})], (Gamon et al., 1990).
The proposed functional basis of this index are: the non-radiative energy dissipation through inibition of phosphorilation that generates both a trans-thylakoid pH gradient and the conformational changes of chloroplasts on one hand, and the de-epoxidation of violaxanthin in the xanthophyll cycle on the other. The ZEISS-MCS501 spectrometer measures reflectance spectra with a sampling interval of 0.8 nm with a bundle of 150 optical fibers pointed at about 60° above the horizontal plane toward the leaf, external respect to the quartz window of the gas-analyser cuvette. The integration time of the spectrometer measures was 200 ms and 5 measures were averaged. Comparable reflectance spectrum are also obtained with an Ocean-Optics USB2000 with 5 ms integration time and 30 averages with a Savitzy-Golay smoothing (Figure 1).

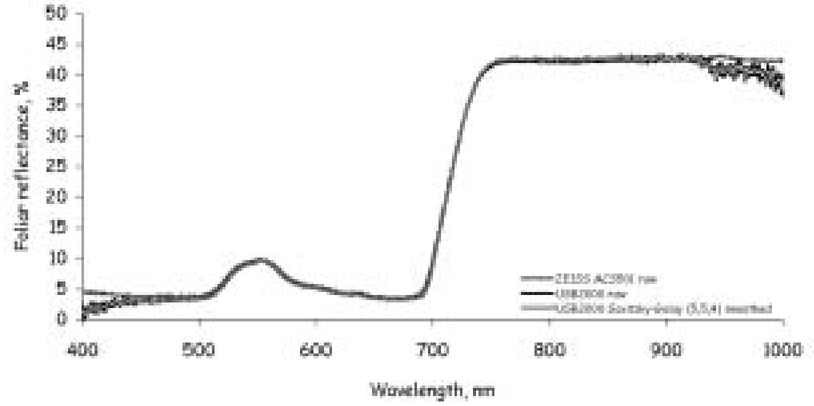

Figure 1: Comparison of a Quercus pubescens leaf spectrum obtained by a laboratory Zeiss MC501 and a portable Ocean Optics USB-2000.

Results

Changes in intercellular CO_2 concentration causes an assimilation rate changes and, therefore, changes in leaf reflectance in the range from 525 to 565 nm . Analysing the spectrum reported in Figure 2, it can be noted that the reflectance at 570 nm is only slightly influenced by light acclimatation or by assimilation rate. This wavelength was therefore chosen as reference to assess changes at 531 nm by the PRI index. On the contrary, reflectance at 531 nm is highly sensitive to assimilation rate changes.

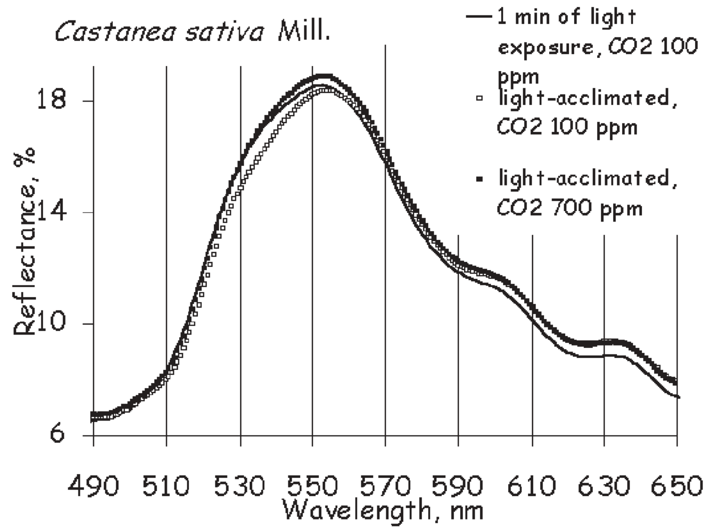

Figure 2: Acclimatation to light and CO2 in a leaf of chestnut (Castanea sativa Mill.).

The PRI index was modified respect to the formulation of (Gamon et al., 1990) standardising over a liner offset given by the reflectance minima in blue (at 420 nm) and red (at 660 nm) regions, where chlorophylls absorb:

$PRI_{\text{with linear offset}} = [(R_{570}-O_{570})-(R_{531}-O_{531})]/[(R_{570}-O_{570})+(R_{531}-O_{531})]$, where O_{570} and O_{531} are the linear offset at 570 and 531 nm.

Line equation is $y=a+bx$. The a and b line coefficients were calculated knowing the reflectance for the two wavelengths at 420 and 660 nm (where chlorophyll absorbtion is maximum) following:

$b=(y_2-y_1)/(x_2-x_1)$ and $a=y_1-b\cdot x_1$; where $x_1=420$ nm, $x_2=660$ nm, $y_1=R_{420}$ and $y_2=R_{660}$. Then, the reflectance offsets at 531 and 570 nm were easily calculated:

$O_{531}=a+b\cdot 531$; $O_{570}= a+b\cdot 570$

The species analysed showed a consistent linear relation between PRI index and instantaneous light use efficiency (Figure 3), on one hand and photosynthesis potential, as resumed by J_{max} (Figure 4), on the other. The determination coefficient (R^2) of this relationship was very high and higher than 0.8 for both instantaneous light use efficiency

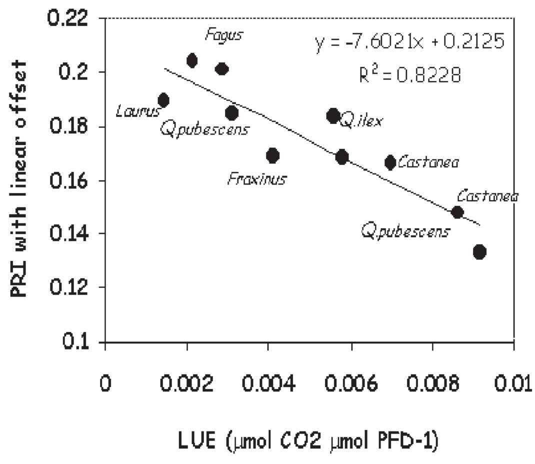

Figure 3. Linear relation between instan-taneous light use efficiency (LUE) and PRI at ambient CO_2.

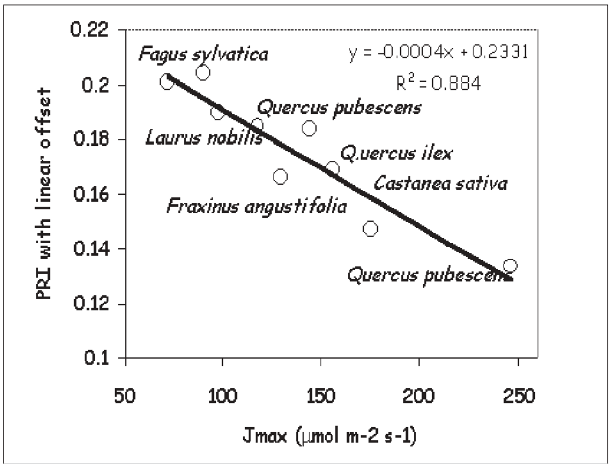

Figure 4: Linear relation between photo-synthetic potentiality (J_{max}) and PRI.

and photosynthetic potentials (R^2= 0.82*** and 0.88***, respectively).

Discussion

The analysis of reflectance spectra of leaves offers wide applications in plant science for assessing the biochemical contents and the structural and physiological status of the leaves (Penuelas and Filella, 1998).

A typical reflectance spectrum of a green and healthy leaf is showed in Figure 1. It has a low reflectance in the visible (VIS; 400-700 nm) given by the absorbance of photosynthetic pigments (mostly chlorophylls and carotenoids) and a high reflectance in the near infrared region (NIR; 700-1300 nm). The NIR reflectance results mainly from the distribution of intercellular spaces within the leaf and is therefore linked to leaf thickness, biomass and water content. Leaf dehydration causes the collapse of the spongy mesophyll and a reduction of the NIR plateau. Therefore, the reflectance spectrum of the leaf in the visible and near infrared regions (i.e. in the wavelength range from 400 to 1000 nm) can be used to monitor *in vivo* changes in the concentration of chlorophyll and photosynthetic accessory pigments such as carotenoids or anthocyanins.

Reflectance indices, which are simple mathematical expression derived from reflectance spectra, allow to express pigment content (such as, chlorophylls, xanthophylls and anthocyanins) reducing the large volume of data given by a spectrometer to a single value more suited for plotting, statistical analysis and evaluation. Moreover, a normalized index as PRI, where the difference between two reflectance bands is divided by the sum of the same two reflectance bands, prevents from problems that can derive from broad-band changes in reflectance, such as those produced by chloroplast movements (Brugnoli and Bjorkman 1992). It is worth to notice that index normalization when applied at the canopy on the whole only partly corrects for effects linked to geometry of illumination-observation system such as sun angle, canopy structure and leaf movements. For this reason, the use of a spectrometer connected with an optical fiber is highly recommended for estimating pigment contents in intact leaves.

The estimate of the light use efficiency, both in terms of instantaneous light use efficiency (LUE) or as photosynthetic potential (J_{max}) is a key-point for the pre-symptomatic detection of stresses. Instantaneous light use efficiency can be measured by means of Infra-Red Gas Analyser devices or by fluorescent emission. J_{max} expresses the maximum photosynthetic rate in light saturating conditions, or in other terms the photosynthetical potential. J_{max} value depends on the season and particularly on the average light environment experienced by the leaf in the five days before measurement, but it also depends on the nutrient and water availability. Unfortunately, the classical way of estimating J_{max} by A-c_i curves is very time consuming and not apt to the nursery practise. Light use efficiency is inversely related to dissipation of excess of light, that means that the higher the photosynthetical efficiency, the lower is the energy dissipated as heat by fluorescence. Moreover, several processes of dissipation of excess radiation by plants (such as xanthophyll pigment interconversion, trans-thylakoid pH gradient and chloroplast conformation changes) have been found to be related with changes in reflectance near 531 nm (Bjorkman and Demming-Adams, 1994). At leaf and canopy scales indices derived by reflectance at 531 nm (R531) correlate with the epoxidation state (EPS) of the xanthophyll cycle pigments and with light use efficiency (Gamon et al., 1992).

The reflectance changes at 531 nm is composed by two signals, one near 525 nm associated with the interconversion of the xanthophyll pigments, and one near 539 nm associated with reversible chloroplast conformational changes linked to the trans-thylakoid pH gradient (Gamon et al., 1990). These two reflectance bands appear to be equivalent to the absorbance

changes at 505 and 535 nm, respectively (Bilger et al., 1989). Heat dissipation and the associated absorbance changes at 505 and 535 adjust rapidly to excess photon flux density, providing a measurement of the efficiency photosystem II. Since reflectance varies inversely with absorbance in the visible region, it can also assess heat dissipation under condition of excess light in the field. The slightly different wavelengths of the signal as determined by reflectance or by absorbance could be explained by the different optical path of transmitted *vs* reflected radiation. The exact position of the signal might also depend upon the relative contribution of the two components (reflectance at 525 and 539 nm, respectively) in different species, environmental conditions, leaf anatomy and leaf morphology. Nevertheless, many plant species of widely varying habits, phenology, leaf anatomy and photosynthetic pathway all show reflectance changes upon increased illumination centered at or near 531 nm, suggesting a widely applicable index of photosynthetic function (Gamon et al., 1997) .
In conclusion, PRI is an index, which has a sound physiological basis, given by more than twenty years of physiological research on algal species, on chloroplasts and recently on leaves. The slight modification in the blue-green region of the reflectance spectrum peaked at 531 nm is bound to the interconversion of xanthophylls, whose de-epoxidation is involved in the dissipation of excess light energy. The relationships observed between PRI and instantaneous light use efficiency on one hand and between PRI and photosynthetic potentialities (such as J_{max}) on the other are strong enough to be used in the practice to assess plant vigor. Even economically reflectance measurements are more convenient for speed and price in respect to alternative techniques and methodologies for measuring photosynthetical efficiency and potentialities.

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18. *Quercus suber* L. and *Quercus ilex* L. nursery production in Portugal

*D. Ribeiro and H. Marques**

Summary

Cork oak and holm oak are two of the most important broad-leaves species in Portugal, covering one third of the total forested area. In the last few years, Portugal has been working in the improvement of the quality of these oak plantations. One of the fields where this work has been done is at the nursery plant production techniques. At the moment there are, in Portugal, 124 forest nurseries officially listed and 30% of them are producing cork and holm oaks tree seedlings using suspended rigid plastic containers. The substrate used to produce the planting stock it is, mainly, peat and composted or aged pine bark.

During the last three years the quantity and quality of cork and holm oaks tree seedlings has been increasing. As an example, the cork oak tree seedlings production was raised almost 26%, from 11 million plants to 13.8 million. Simultaneously, the application of European and National legislation, that defines some morphological and phyto-sanitary parameters for the marketing of planting stock, promoted tree seedlings quality. This work gives a global view of the evolution of cork and holm oaks production in Portuguese nurseries and the main problems related to nursery techniques.

Keywords: *Quercus suber*, *Quercus ilex,* nursery techniques, seedling production, Portugal.

Introduction

Cork and holm oak stands, pure or mixed, represent roughly one third of the forested area in Portugal. Most of the area occupied by these species, 720 000 ha for cork oak and 465 000 ha for holm oak, is in the southern part of the country. Most of the stands are exploited as agrosilvopastoral systems known as "*montados*". Both species grow in difficult ecological conditions characterized by: warm and dry summers, average temperatures of 21 to 25ºC in summer and 8 to 12ºC in winter; rainfall varies from 400 to 600 mm, mostly during winter, with a dry period of 4 to 5 months; poor and unbalanced soils with an high risk of erosion and limited use. Because of that, these systems are of substantial social, economic and conservationist importance at national and regional level. They are home to several biotopes, prevent soil degradation, and most of all provide most of the income of the population. Rationally exploited they can provide diversified productions: cork, wood, animal husbandry, beekeeping and game resources. It is this multiple use purpose that prevents the human desertification of the interior south of Portugal.

As it is well known cork is the most important product of cork oak stands, representing 3% of the Portuguese exports. Due to their value cork and holm oaks are protected species and strongly aided in order to increase their area. Only in the last five years 65 000 ha of new stands of cork oak and 23 000 ha of holm oak were cultivated with government subsidies.

One of the problems with new forestations is the difficulty in establishing them by natural regeneration. Cork and holm oak seeds are subject to a series of biotic and abiotic factors that inhibit their development: climate conditions are difficult for germination, they are eaten by rodents and other animals and deteriorated by insect and fungal attacks. Because of that ar-

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tificial regeneration has been the alternative. In order to minimize the harsh forestation conditions and guarantee plant survival seedling plantation with containerized plants is the favored method for establishing new stands.
The amount of plants needed increased the number of nurseries producing cork and holm oak plants leading the official forestry body to regulate plant quality.

Global overview of the sector

At the moment there are 14 State owned nurseries and 110 private nurseries officially listed. 30% of them produce cork and holm oaks tree seedlings. The largest nurseries are located in the central region of Portugal and they produce almost 67% of the total cork oak plant production (Table 1).

Table 1: Percentage (%) of cork oak plant production per region

Portuguese regions	97/98	98/99	99/2000
North	9	10	9
Centre	64	67	69
South	27	23	22

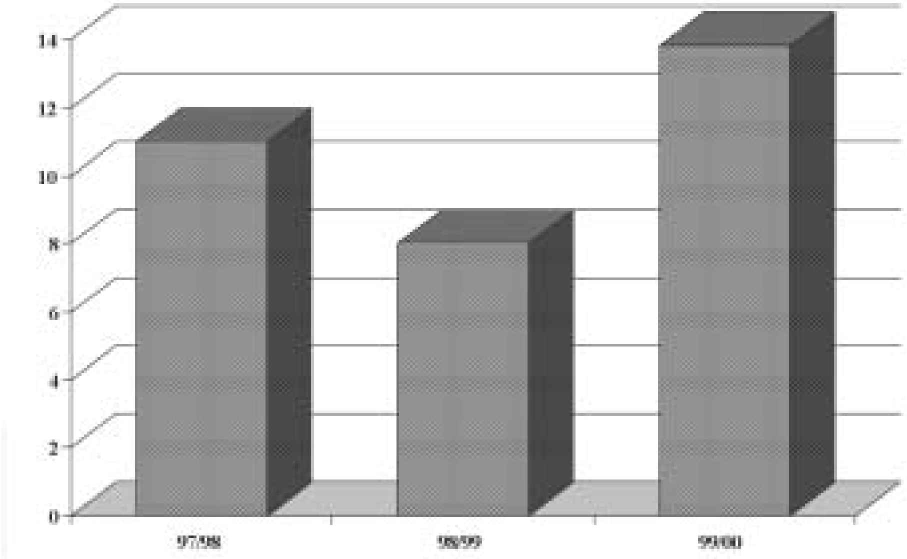

Figure 1: Cork oak tree seedling production (1997-2000).

During the last three years the quantity and quality of cork and holm oak tree seedlings increased. As an example, the cork oak tree seedlings production was raised almost 26%, from 11 million plants to 13.8 million (Figure 1).
The increase in quantity was linked with better quality. This was due to legislative measures, passed on 1998 that defined external quality of planting stock. Since 1997, the official body has assessed the external requirements of legislated species, which include cork oak. Until 2001, the percentage of plants that fulfil the external requirements has been raised (Figure 2).

Present nursery techniques

In Portugal, cork and holm oak plants propagation is basically made from seeds and all the plants are produced in containers. The use of containers allows precise control of nutrition, spacing, light and other cultural factors to maximise growth of the seedling at this very criti-

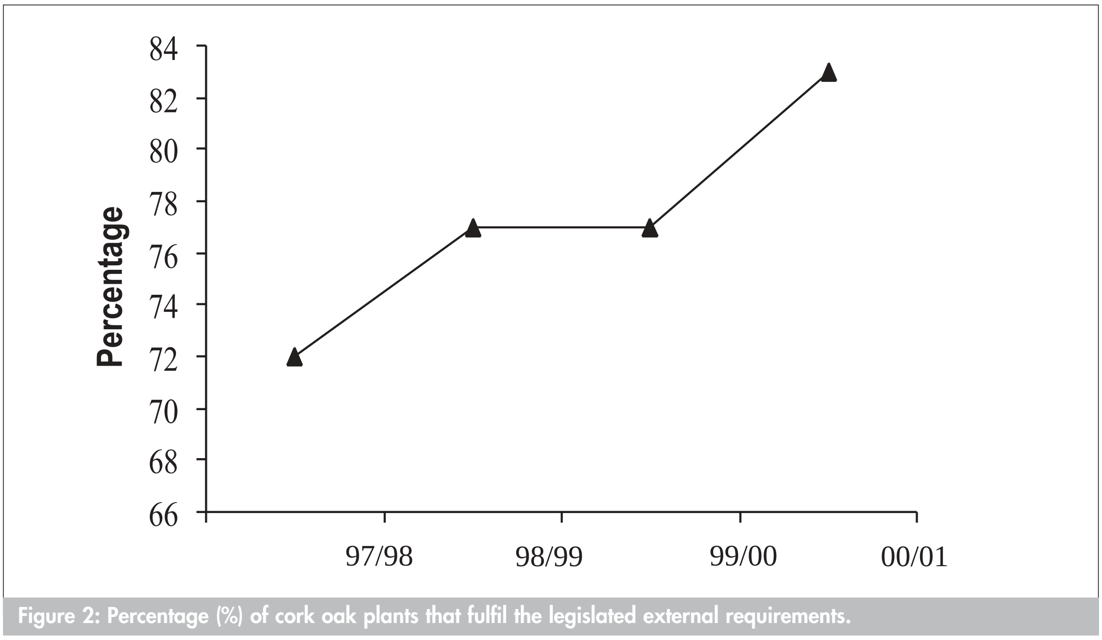

Figure 2: Percentage (%) of cork oak plants that fulfil the legislated external requirements.

cal stage. Since 1995 the rigid plastic containers have replaced the polyethylene bags. Most of the nurseries use suspended rigid plastic containers, which allows air-root pruning. There still are some that use rigid plastic containers placed directly on the ground, which causes some problems to the root system, namely the circling or strangling roots presence. It is standard procedure to use containers with 300 cm^3 but containers with 200 cm^3 and 250 cm^3 are also used (Figure 3).

The use of containers means that the nurseries need to use some kind of substrate to produce their planting stock. Until a few years ago soil and peat were widely used as themain substrate components for the production of tree seedlings in containers. However, in the last five years others have replaced these substrates. The use of soil showed problems related to the filling of rigid plastic containers and to physical properties, namely waterlogging and bad drainage. On the other hand, peat is a natural and non-renewable resource, and it has increased environmental concern about its extraction in great quantities. Moreover, peat is an expensive substrate and some nurseries are having some serious problems with its use, which have been attributed to residues of herbicides. Even though, peat is a substrate still used in cork and holm oak production. But, because of peat's problems other nurseries are already using others substrate components, like composted or aged pine bark and a mixture of peat with pine bark.

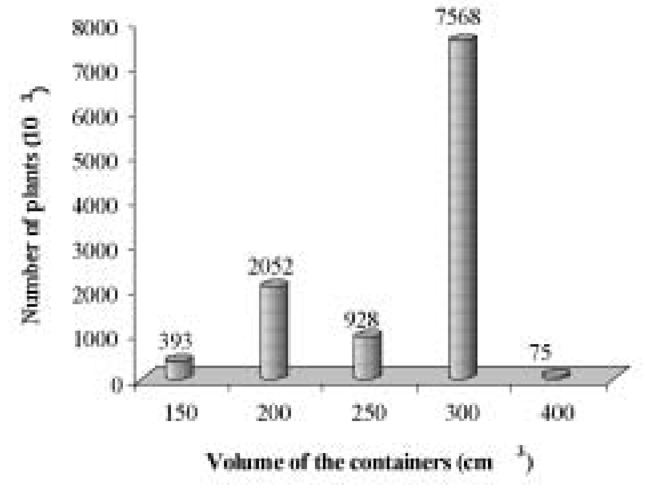

Figure 3. Number of cork oak plants produced related with the volume of containers (1999-2000).

In 1996, the Department of Agriculture and Environmental Chemistry of Instituto Superior de Agronomia and the General Directorate of Forests started a project which main purpose was to study the possibility of using different substrate components in the production of containerised tree seedlings. According to this study, the use of composted pine bark is a good alternative, but two problems should be avoided:

- Bad maturation of the compost and phyto-toxicity problems;
- High pH values as a result of the addition of high amounts of lime at the beginning of the composting process.

50% of the nurseries use a mechanised filling or sowing system. Sowing is carried out since November to March. Almost all the nurseries use sprinkling irrigation.The fertilization technique mostly used is the addition of controlled release fertilizer to the substrate.
Due to the great number of nurseries, there are considerable differences between bigger and smaller nurseries as far as production techniques are concern. The big nurseries have a mechanised production process while the small ones still use a familiar manual production process.

Main problems found in nurseries

The main problems detected in Portuguese nurseries are related to the seed supply and plant production techniques. Some nurseries have found the correct solution to these problems, but the others still have problems. The most usual problems are:

- Low seed production of Quercus suber and Quercus ilex in the last few years;
- The storage and conservation of the seed of these species for a long period are difficult;
- Use of containers with an unfit volume to the species, which produces an unbalanced shoot/root ratio;
- Use of containers placed on the ground, which can cause weed problems, root deformation and non-natural root pruning;
- Lack of knowledge about phyto-sanitary problems;
- Use of substrates without quality.

Parameters for the marketing of cork oak planting stock

The application of European and National legislation, that defines some morphological and phyto-sanitary parameters for the marketing of planting stock, promoted tree seedlings quality.
The requirements to be met by planting stock of cork oak, for marketing, are:

- Minimum age – 5 months ;
- Minimum height – 13 cm;
- Healthy leading shoot;
- Well balanced plants;
- Minimum root collar diameter- 3 mm;
- Healthy taproot;
- Straight and abundant roots;
- Uncurl root system;
- Strong and single stem, without injuries or unusual bending;
- Absence of desiccation, overheating, mould, decay or other harmful organisms.

Conclusion

The mutual efforts of nurseries and official body allowed a positive trend in cork oak plant quality as shown in Table 2. Even though there are no numbers for holm oak, because its marketing is not officially regulated yet, it will be in 2003, the trend was the same, since the techniques are the same and they have the same quality control.

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19. Large scale production of mycorrhizal broad-leaved forest seedlings in nursery for the improvement of early field performances

B. Robin[1] *and P. Combot*[2]

Summary

All tree species naturally develop symbiosis associations with a lot of fungal species. Both partners benefit from this association (mutual benefit). The fungus provide water and mineral nutrients to the tree and the tree for it part supply carbohydrate to its fungal partner.
Great improvement of forest trees outplanting performances resulted from genetic selection of tree provenances. Numerous scientific papers have evidenced the beneficial role of selected mycorrhizal strains on the growth, the survival, the nutrition and the disease resistance of associated host plant. Controlled mycorrhizal broad-leaved planting stocks is therefore a new and promising way to an additional and considerable improvement of early performances of forest tree seedlings.
The Robin nursery developed its own laboratory facilities to select mycorrhizal strains, to produce new generation of inoculum at industrial scale according to an original process and to control all steps of mycorhization at the nursery.
The Robin nursery has been involved in several European programmes in close co-operation with different public research institutes. Numerous field trials have been carried out from mycorrhizal seedlings supplied by the Robin company. Selected strains of *Hebeloma Crustiliniforme* (neutral and alkaline soils) and *Laccaria bicolor* (acid soils) improved significantly both survival and early growth of various broad-leaved host trees.
Nowadays the Robin nursery is the only European nursery able to produce, at large scale, forest planting stock mycorrhizal with several selected strains adapted to forest stand conditions. Moreover all the seedlings production is conducted under ISO 9001 quality system.
The Nursery could supply any reforestation programme with high quality planting stock mycorrhizal with custom made selected strains. The annual production is up to 4/5 millions 1+0 containerized seedlings.

Keywords: broad-leaved seedlings, simbiosis, fungi, mycorrhizal seedlings, quality standards.

Introduction

The mycorrhizal association is undoubtedly the most widespread symbiotic association on earth. A wide diversity of fungal groups form several morphological types of mycorrhizal association with 97% of plant species. The most common type, arbuscular endomycorrhizae (AM) is formed on many plant species by members of the endogonaceae and particularly on many hardwoods trees more especially of the rain forests. Only a few non specific species form mycorrhizal associations on a lot of different host plants.
Ectomycorrhizae are formed by many species of basidiomycetes and ascomycetes but only with members of the plant families Pinaceae, Betulaceae, Fagaceae, Salicaceae and Myrtaceae. It is only 3 to 5% of terrestrial plant species but they are of significant forest importance. More than 2000 fungal species develop mycorrhizal associations which are more or less specific and some species are of edible interest.
It has been shown that the symbiotic association between plants and fungi was a determining

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factor during evolution for the adaptation to terrestrial environment. Both partners benefit from the mycorrhizal association. The fungus provide water and mineral nutrients to the tree, and enhance his resistance to different stresses and diseases which results in better survival and growth promotion. In return the fungus is supplied in carbohydrates by the associated plant.

The nursery approach: improvement of broad-leaved performances

A great improvement of broad-leaved forest has resulted from genetic selection of provenances. A similar improvement can be expected from selection and control of the fungal partner. Successful inoculation of species forming both types of mycorrhiza has been achieved. Arbuscular mycorrhiza are obligatory symbiots and is only multiplied on host plant. The inoculum including spores, root pieces and growing substrate can be supplied by several companies in Europe and north America but the microbiological purity is hard to reach. From more than 2000 species involved in the ectomycorrhizal associations only a few ones can be considered as efficient candidates for inoculation. Indeed a succession of species occurs naturally in forest stands. Some species most of them non specific form mycorrhizal associations during the first 10-15 years of trees development and are successively replaced by other species . A limited number of the formers known as early stages species have been successfully grown "in vitro". The candidates should be searched out in the following genera: *Hebeloma, Laccaria, Paxillus, Tuber, Scleroderma, Pisolithus, Suillus, Thelephora*, *Cenococcum, Rhizopogon* etc… The nursery decided to develop the large scale production of mycorrhizal seedlings with selected fungal strain to improve survival and early growth performances in the field. Some mycorrhizal associations are formed naturally during the first growing season at any nursery and are typical of growth conditions. The fungal species involved depends on environmental conditions, cultural practices and host species cultivated. Most of them are adapted to high fertility conditions and intensive cultivation and disappear quickly once saplings are outplanted in the fields. Such associations are considered as useless either at the nursery or in the fields.

The production of mycorrhizal seedlings at the Robin nursery under the ISO 9001 quality label.

Except for the control of some soil-borne diseases controlled mycorhization is of low interest in modern nurseries since appropriate fertilization regimes allow good growth of plants and controlled mycorhization requires reduced fertilization rates. At the contrary positives effects in survival and early growth can be expected at outplanting sites if the fungal strains have been selected for adaptation to the field conditions. A lot of experimental studies reported beneficial effects all over the world. Very rare papers mentioned negative effects or no effect but in most case the soil conditions were not convenient to the fungal partner. Consequently controlled mycorrhizal seedlings represent undoubtedly a great progress for reforestation. So the Robin nursery involved in the mycorrhizal practical experiments for a long time (1960 in cooperation with Moser Austria) decided to develop large scale production of high-performance seedlings more than ten years ago. They first developed a laboratory specially designed for mycorrhizal studies. A staff specially trained is in charge of all steps of controlled mycorrhization programme which must comply the following principles:

- Select and grow both partners for site adaptation
- Formulate inoculum
- Bring partners together in appropriate conditions which favour their association
- Monitor closely growth parameters and environmental conditions
- Identify mycorrhizal association, control, approve and register mycorrhizal plants

Arbuscular mycorrhizal inoculum is usually supplied by specialised companies under the form of spores or root fragments or cultivation substrate. Ectomycorrhizal inoculum of selected strains is produced at the nursery laboratory under various vegetative forms (artificial inoculum). Inoculum under solid form obtained after fermentation on porous material soaked in liquid culture medium is achieved for *Pisolithus tinctorius, Hebeloma crustuliniforme, Laccaria laccata, Paxillus involutus, Suillus sp., Rhizopogon sp.* etc… Second generation of inoculum from mycelium grown in liquid culture is achieved *for H. crustuliniforme, Laccaria laccata, Suillus sp. Lactarius sp.* It is much more efficient and can be store more than one year but it is not convenient for all species.

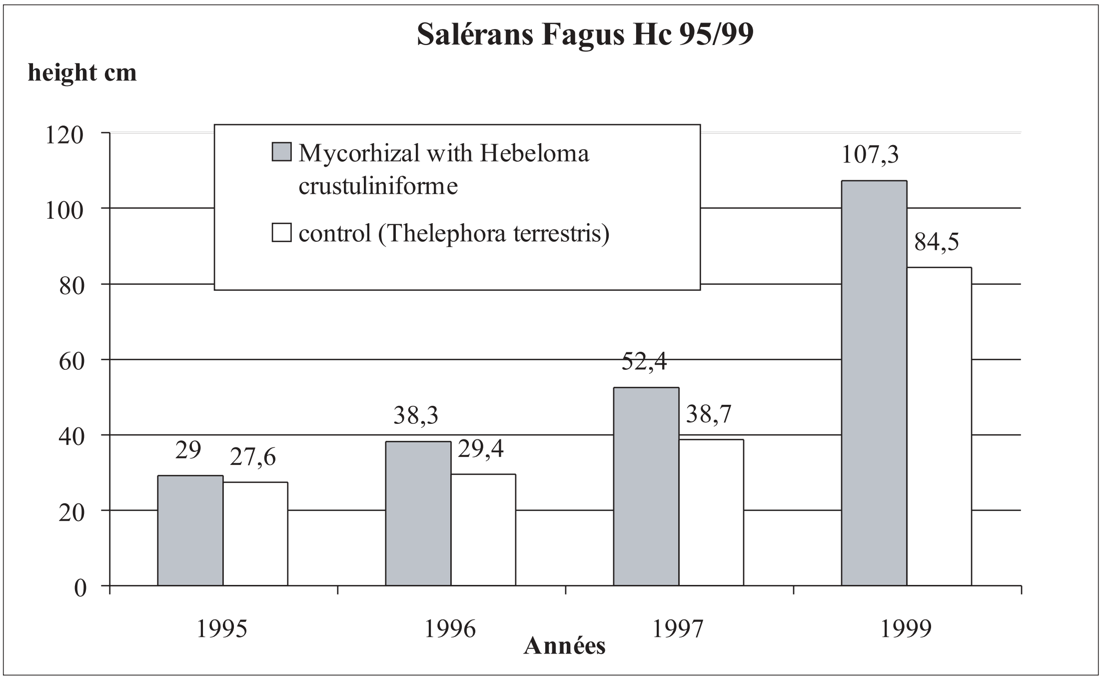
When no selective strains are needed inoculation can be carried out with spores as inoculum . But the viability of spores decreases quickly with time and the inoculation gives unpredictable results except for some species. When spores conservation is well managed Tuber species are successfully inoculated from spores suspension and give rise at the robin nursery to a production of high quality (INRA licensed product) representing 25% of the total truffle plants outplanted every year in France.

The production of an advanced inoculum has been developed at large scale at the laboratory and is now perfectly controlled and allows very efficient inoculation at the nursery for up to 5 millions of plants a year. Each inoculum batch is systematically checked before inoculation in nursery (microbiological purity, viability, mycorrhizal ability) the nursery staff made a lot of experimental studies to optimise for each association all parameters of inoculation, cultural practices, environmental conditions in order to ensure high quality of mycorrhizal seedlings. A strict control of the process is needed to prevent contamination and favour introduced selected strain development. Before delivering to the customers each lot plant is submitted to a statistical control of mycorrhizal rate. The seedlings lot is approved as mycorrhizal lot only if more than 80% of plants display more than 50% of roots mycorrhizal with the introduced strains and no contaminants is accepted.

Nowadays the nursery can supply any customers with a lot of different associations of broadleaves species such oak and beech mycorrhizal with *Laccaria laccata* for acid soils or *Hebeloma crustuliniforme* for neutral or alkaline soils conditions or poplars and wild cherry associated with *Glomus intraradices*. The nursery can also provided customers with pines mycorrhizal with species for the production of edible mushrooms such as *Lactarius deliciosius* and *Suillus luteus*. The nursery can supply custom-tailor saplings under a cultivation agreement established at the beginning of the growing season.

The robin nursery has now 8 years supplying European customers with controlled mycorrhizal plant and has been involved in several European Research and development programmes. A lot of experimental plots and demonstration plantations have been setting up during this time.

If the mycorrhizal association has been chosen according to stand conditions the controlled mycorrhization lead to a positive field response as shown on the Figure.



20. Development of tree nurseries in China and looking ahead 10 years

*L. Wang and X. Yang**

Summary

The tree nurseries in north part of China decreased significantly in last 10 years, around 33% in quantity, due to deduction of timer production, natural forest conservation and the changes of management system. Forest in north part of China is mostly state-owned while forest in south part of China is partly state-owned and partly collective-owned. Each state-owned forest enterprise (named as forest bureau) had its own tree nurseries, whether the the conditions there for tree nurseries were good or not. The management of these tree nurseries during the past strictly followed the planning of forest bureau, and mostly concentrated on the seedling production rather than market, tree species diversity as well as the economical results. For example, the tree species selection was strongly affected by political issues, which resulted in the popularity of larch and poplar, but greatly decreased the forest diversity in those areas. The stage results of research showed it also caused many serious problems, such as deduction of forest soil productivity, forest insects and forest diseases. Of course, the economical results of these tree nurseries were not so good that they needed much investment and funding from governments and forest bureau each year, and some even to quite difficult conditions.

With the development of economic reform in the management system of state-owned forest bureaus, marketing system was introduced into the tree nursery management too. Market, production and management have been synthesized as a whole. Many of these tree nurseries were reorganized. They have produced more seedlings of broadleaf trees, which have higher commercial values, in China market, than those of conifer trees. A lot of new high technologies, such as automatic control green houses, high-intelligent inrrigating system and other genetic techniques, have been introduced and applied in the operations of these new organized nurseries.

The market of tree nurseries will be great in China in next 10 years. Chinese government has decided to invest a large sum of capital to reforestation program around west and north part of China. Management of tree nurseries in Group Business, Join-venture and Stakeholder-share forms will be getting popular in next 10 years too.

Keywords: tree nursery, development, management system, technique, looking ahead.

Development of tree nurseries in China

Seven topics concerning the development of tree nurseries in China, including the management system of tree nursery, nursery amount, plantation area, seedlings, capital investment and employment with nursery operations etc., are discussed in this part.

Management system of tree nursery in China

For most of provinces in China, tree nurseries are run by the forest farms which are superived by local government, such as forestry division of county government. The forest division of a county is supervised by the county director and forestry department of local provincal gov-

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ernment. Almost the same, the forestry department is both supervised by local governer and State Administration Bureau of Forestry. So this type of management system is shown as the left part of Figure1. But there are significant differences of the nursery management system in northeast of China, e.g. in Heilongjiang Province, Jilin Province and Inner-Mongolia Autonomous Region. Besides the forestry department at provincial level, there is another institution sitting at the same level as forestry department of province, which is named as General Administration Bureau of Forestry Industry. It is responsible for the management of state owned forest in these areas. Under the General Administration Bureau, there are over 100 forestry bureaus which are running the state owned forest directly. Around 10 or more forest farms are under the direct supervision of a forestry bureau. This management system is shown as the right part of Figure 1.

There is at least one central tree nursery, managed directly by the forestry bureau, in a forestry bureau. Normally it is the biggest one with the most advanced techniques in this forestry bureau, and several small tree nurseries are distributed in the forest farms. These small nurseries are mostly managed by forest farms, and only a few are run by the central nursery. The differences of management system can be seen in Figure 1 (whole).

Another type of nursery owned by collective came up several years ago due to the marketing system introduced to forest production. This kind of nursery, still in a small amount right now, is technically advised by local governmental instituions, but managed directly by group of individuals.

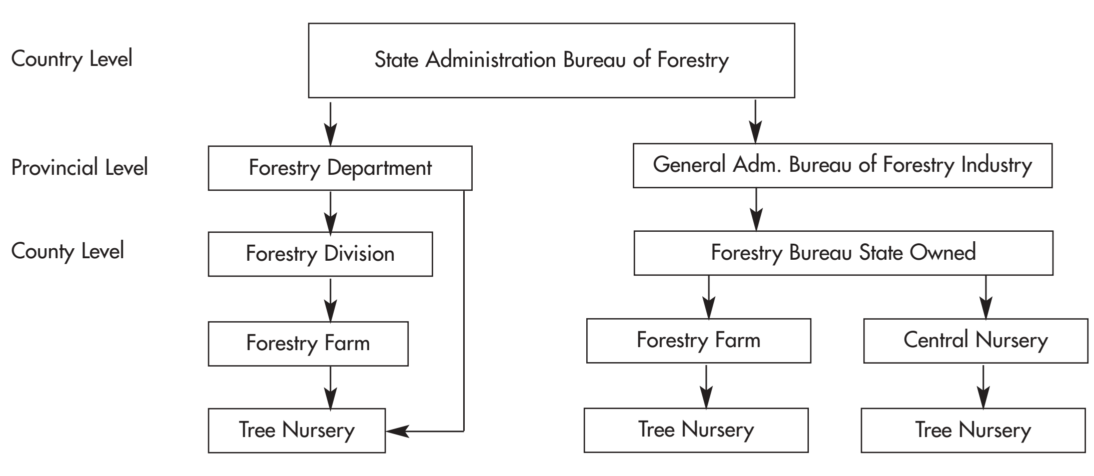

Figure 1: Typical tree nursery management sysytem in China.

Variation of tree nursery amount

The tree nursery amount in 1949 was 104 in whole China, and it was increased significantly since then. The amount of tree nursery reached the highest point in last 50 years, around 2400, in 1984 but it was decreased since late of 1980's and total amount of whole nation accounted for 1750 in 1998. The whole trend of development for last 50 years can be seen in Figure 2.

The reason for tree nursery amount increasing during the period from 1950's to 1980's was due to the high demand of timber for the constructions around whole China in order to meet the needs of economical development. One of the main parts of construction materials was timber rather than other substitute materials, such as poly-synthetic and metal materials. But after 1980, the marketing economic system was started slowly in China, which affected different businesses step by step. In the late of 1980's, the marketing system was introduced to tree nursery management system and it worked so fast that many tree nurseries were merged or stopped due to their business results were not so good to be maintained. Some smaller nurseries were combined into the large ones.

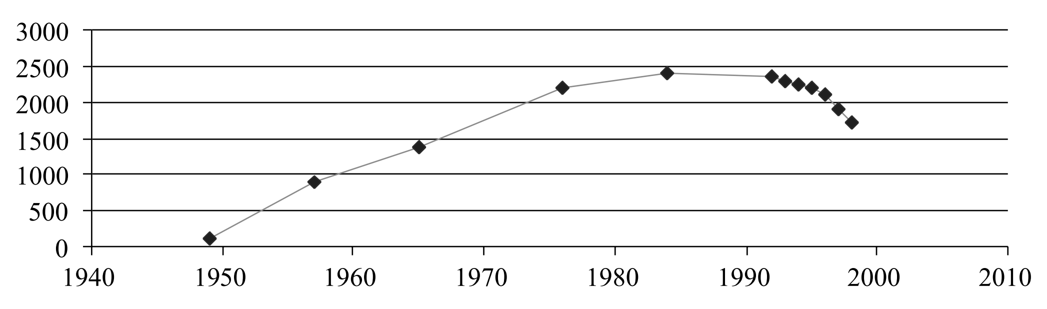

Figure 2: Changing of tree nursery amount (Forestry Ministry of China. 1998 and Forestry Ministry of China. 1998).

Variation of plantations

The plantation area in China was increased smoothly for the last 50 years. There are 2 big peaks (as shown in Figure 3) in its development. The first one occurred in the late of 1950's due to the influence from Economy Jumping Campaign, which was one of the biggest political movements since 1949. The second peak came up at the beginning of 1980's. The Chinese government decided to start a national wide campaign named Greening Land of the Country. Therefore the plantation area was soon shot up but only lasted at a high amount for couple of years. The plantation area during the period of 1990's was got around 5 million hectares yearly.

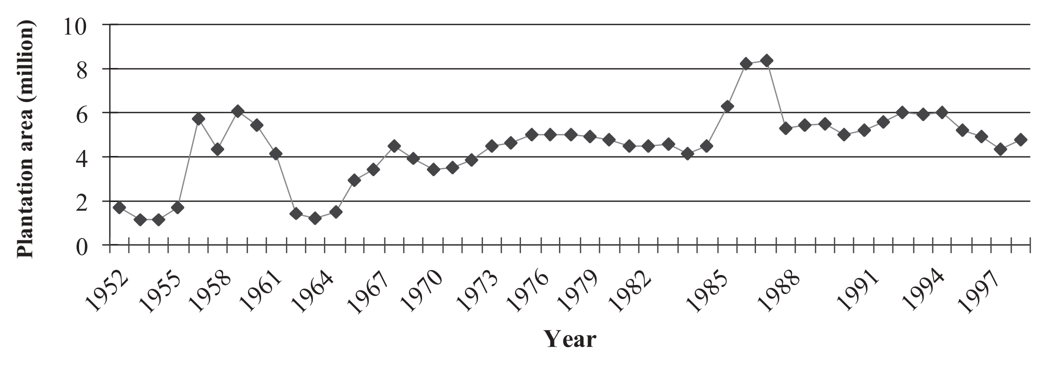

Figure 3: Variation of plantation area (Forestry Ministry of China. 1998 and Forestry Ministry of China. 1998).

Variations of seedlings

Variation of seedling area in China from 1950' to 1990's will be presented in this part. And variations of seedling number and output rate of seedlings for the last decade period, from 1989 to 1998, are also introduced here.

Seedling area
The seedling area in China was kept at rather low level in 1950's, around 30,000 hectares. Then it was increased from 1960's to the middle of 1980's. It reached the highest point, 510,470 hectares in 1984. In 1990's, the seedling area developed steadily around 220,000 hectares.
The highest peak of seedling area (as shown in Figure 4) occurred at the beginning of 1980's, and it was partly caused by the Plantation Campaign around China at that times.

Seedling numbers
It is explicit that the seedling number is mostly proportional to seedling area. From 1970's to 1980's, large number of seedling were highly demanded due to aforestation movements, Greening Land of China and Plantation Campaign around China, which were playing more

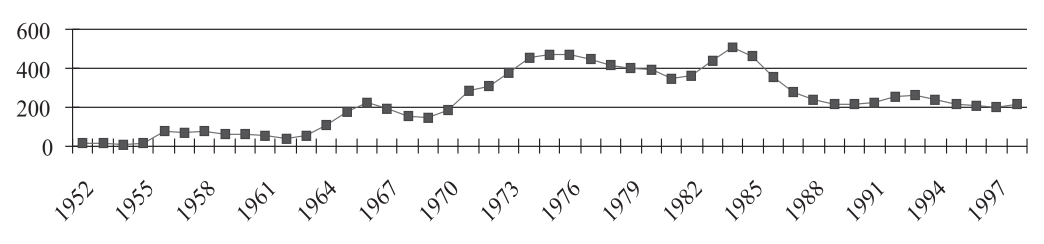

Figure 4: Variation of seedling area (1000 hectare) (Forestry Ministry of China. 1998 and Forestry Ministry of China. 1998).

important role in forestry in 1970's and 1980's respectively. After 1989, the tree seedling number in China has been going around 20 billion each year (as shown in Figure 5), which essentially met the need of plantation around China, at least in amount.

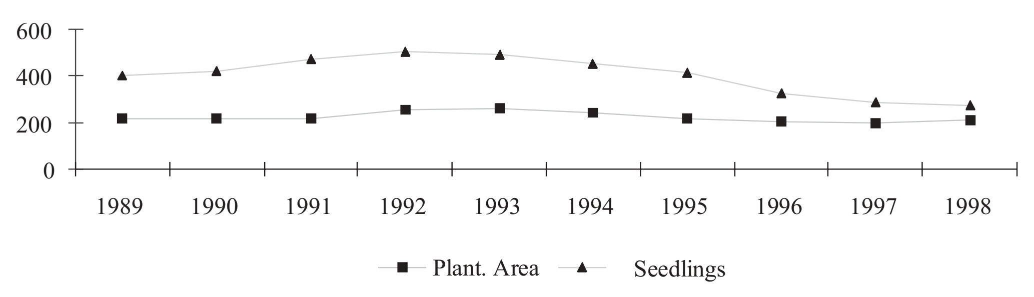

Figure 5: Variation of seedling number (100 million) and plantation area (1000 hectare) (Forestry Ministry of China. 1998 and Forestry Ministry of China. 1998).

<u>Output rate of seedlings</u>
The output rate of seedlings represents the production efficiency of a nursery. From 1960's to 1980's, the output rate of seedlings in China was not so satisfactory due to the conflict between supply and demand in both species and amount. Later on, from 1990's to now, it was improved and increased smoothly from 50% in 1989 to 60% in 1999 (as shown in Figure 6). This significantly improved the economical result of seedling production at nurseries.

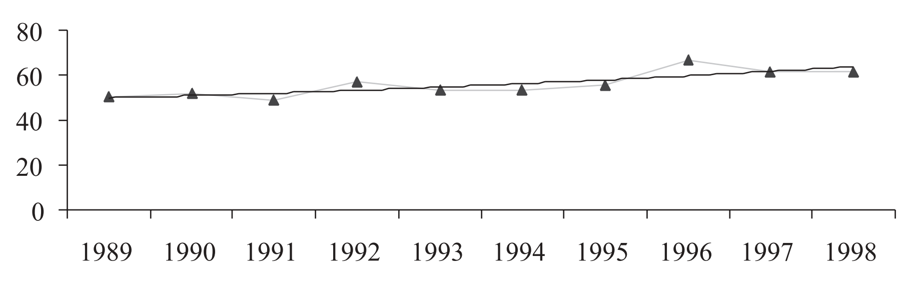

Figure 6: Changes of output rate of seedlings (Forestry Ministry of China. 1998 and Forestry Ministry of China. 1998).

Capital investment and employee involved

The capital investment to nursery production in China was steadily going up in 1950's, and then in 1960's it got down and up significantly due to the impact from the Culture Revolution (a political movement). From 1970's to the middle of 1990's, it was smoothly increased year by year. After 1997, Chinese government has increased the investment very significantly (see Figure 7), particularly after the starting of National Natural Forest Conservation Program and

North-West Exploration Program in 1998 and 2000 respectively. Now the budget for nursery production only from government channel is about 10 times of that in 1994. In addition, there is a large sum of money from privates involved in tree seedling production already.
The people working with nursery production are getting less and less these years due to the reforming of both nursery management system and production system. Parts of the nurseries were merged together and parts stopped the business because of the impact from marketing system. Therefore many employees who were working with nurseries before have to leave the nurseries, particularly for those with no professional skills. So the total trend of the employee involved in nursery production declined significantly for last decade (see Figure 8).

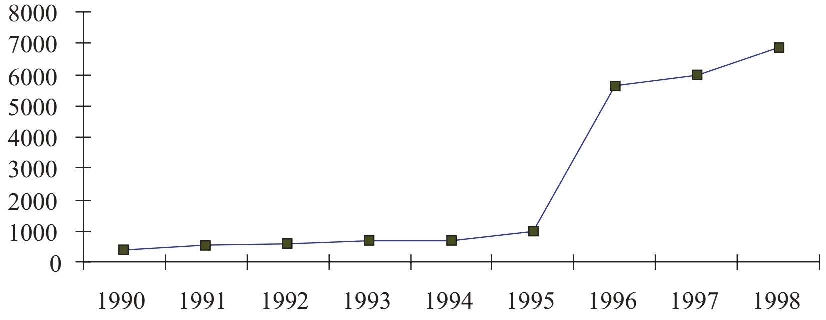

Figure 7: Changes of capital investment to nursery production (Forestry Ministry of China, 1998 and Forestry Ministry of China, 1998).

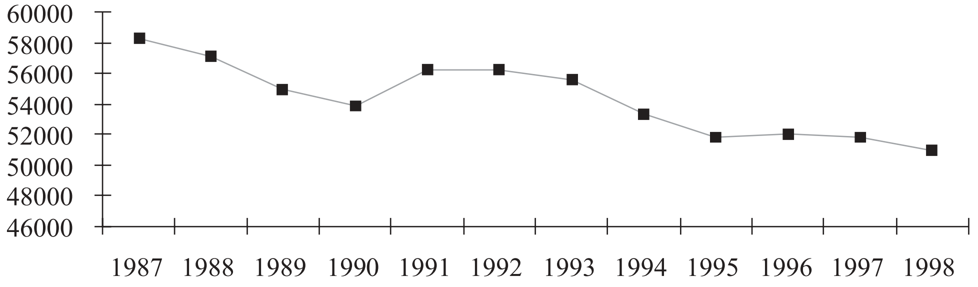

Figure 8: Changes of employee involved in the nursery production (Forestry Ministry of China, 1998 and Forestry Ministry of China, 1998).

Techniques of seedling culture

Culture of bare-rooted seedlings

Many techniques developed in China concerning the bare-rooted seedlings are focus on time of sowing seeds, density of seedlings and fertilizing.

Time of sowing seeds
The time of sowing seeds affects the quality and quantity (output rate) of seedlings. The results of research showed that the best time of sowing seeds for Siberian Larch in Heilongjiang Province is during the period from May 22 to May 28. The seedlings sowed during that period grow fast and have a high capacity against diseases (Z. Peng, 1990).

Density of seedlings
It is well known that diameter of root and total dry weight of seedlings are affected by the seedling density significantly. The results of both research and practical operations showed

that the optimal density of seedlings are as follows for the following species under the ratio of 1/40 ~1/50 for diameter/height (J. Dai, 1992; Y. Lian 1985):
Chines pine: 350 ~ 400 seedlings /m^2*;*
Siberian larch: 300 ~ 400 seedlings/m^2*;*
Cypress: 400 seedlings/m^2.

Fertilizing

Nutrient elements like nitrogen, phosphorus and potassium are quite important to the seedling quality. The amount of fertilizer to different species is different. The results of research showed that, for one year old seedlings of species as followings, the optimal amount of fertilizer should be (Y. Shen and S. Sun, 1992):
Chinese pine: N—125 Kg/hm^2*, P—136* Kg/hm^2*;*
Chinese poplar: N—270 Kg/hm^2*; P—121* Kg/hm^2*;*
Cypress: N—159 Kg/hm^2*; P—100* Kg/hm^2.

Container seedling

Now the containers are applied in seedling production in China for around 50 tree species, such as eucalyptus, China fir, Mongolian Scots pine, Chinese pine, Cypress, larch, Korean pine, spruce, other pines and broadleaf species (T. Song, 1993). Most of the containers are plastic paper bags, paper cups, peat paper cups, hard plastic cups. Normally is diameter of container ranging from 4 cm to 8 cm, and its height ranging from 8 cm to 20 cm. The norms concerning with containers, Techniques of Breeding Seedlings with Containers, issued by Forestry Ministry of China in 1991 represented the breeding techniques of whole seedling production in China by using containers. Many aspects of seedling culture by using containers, such as sizes and types of containers, greenhouses, and transfer medium compositions etc., are listed in it.

Using plastic film to cover the ground

Using plastic film covering the ground is one of the efficient ways and it is popularly used in nursery production in China, especially in north part of China. This simple technique has several advantages (J. Zhang, 1998; Y. Liu, 2000):
(1) Increasing ground temperature 30% and making seedlings available 2 weeks earlier than those in the traditional way;
(2) Increasing the seedling quality. For example, for paulownia tree seedling, the height, the diameter and the output rate of seedlings were increased 16%, 31% and 12% respectively according to the research results of Henan Forestry Research Institute;
(3) Decreasing production cost. The production cost could be decreased 50% by using the plastic film technique in terms of the research mentioned above.
Many research reports also state that it is easy to cause the environmental pollution by the plastic film if using it not properly, and suggestions of improved production ways also be addressed (J. Zhang, 1998).

Applications of biological agents and rare earth

There are many kinds of biological agents used for root fast establishment. ABT fostering root powder is one of the best ones in China, which takes the prevailing role in the applications (J. Xu, 1992). It started to be applied in breeding of tree seedlings in China in 1987 and expanded greatly afterwards due to its effectiveness for improving the root establishment and increasing survival rate of seedlings (normally 10% ~ 15%). In 1992, around 1.6 billion of tree seedlings in China were applied with this agent. The amount of that was increased to 8.9 billion in 1997 (Forestry Ministry of China, 1998).
Besides application of biological agents, in north part of China, the rare earth was also used in the breeding of seedlings. It was reported that the application of rare earth can increase germinating rate of seeds (15% ~ 20%), enhance seedling quality and improve root establishment for seedling cuttage (Y. Liu, 2000).

Looking ahead 10 years

A great deal of positive changes for tree nurseries in China would occur in next decade. The following items just give out a brief view of them.

Capital investment

It was estimated that the capital investment to nursery production would be steadily increasing in the next 10 years, at least 2 ~ 3 times of investment now by the year 2010 due to implementation of Exploiting North-West Program and Natural Forest Conservation Program.

Nursery quantity

Chinese government plans to increase forest coverage of the whole land in the country up to 17% by the year 2010. A great large area of which has to be from plantations. Experts predicted that steadily slow growing for the state owned tree nurseries would be the main trend of the development for next 10 years. The state owned nurseries will be reorganized continuously but the individual nurseries may be fast growth in amount for next 10 years too.

Management system

It is clear that marketing management system position (market, production and sales) will take prevailing in nursery production and the businesses for seedling production, in the forms of Group Business, Join-venture and Stockholder Share, will be also getting popular in the coming years.

Biological techniques

The demand for advanced technologies like genetic improvement, biological agents, environmentally sound fertilizers and herbicides will be increasing definitely in China in the coming years. Sciences and technology concerning with biological techniques will also play more and more important role in nursery production in next decade.

Species

The selection of tree species for seedling production would be emphasis on:

- *High commercial value timber forest (more broadleaf — proportion of broadleaf trees to be increased from 32% in 2000 to 45% by 2010);*
- *Fast growth forest (for energy);*
- *Protection forest (for against wasteland and desert);*
- *Economical forest (fruit forest);*
- *Landscape forest;*
- *Forest diversity.*

And the number of tree species for seedling production could be increased around 50% in the next 10 years.

IT and automation

IT and automation will play more significant role in production control, management information system, seedling production automation and so on. It is estimated by experts that the amount of IT and automation applied in nursery production would be at least double of that right now by the year 2010.

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B. STAND ESTABLISHMENT

1. Forest biodiversity and forest nurseries (BIOFORV) Italian working group

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Summary

The River Po Plain, now transformed into a heavily populated typically agricultural land, shows only faded signs of the ancient natural forests. Still confined as relics in a few sites, the typical potential vegetation is characterised by *Quercus robur* and *Carpinus betulus*. The challenge of strengthening and enlarging native stands depends both on the production of high quality nursery stock and on a suitable forest management. Italian administrative fragmentation does not help to define a nursery policy to fit such a purpose and for this reason the working group BIOFORV was created in 1996. At present, members of BIOFORV are drawn from many regional administrations of North Italy, Universities, Research Institutes and national administrative organizations.

BIOFORV working group is now involved in studies regarding biodiversity and nursery production in Italy

Keywords: River Po Plain, native tree, biodiversity, nursery production, genetic erosion.

Introduction

During the last few years, forest ecosystems have been considerably exploited in Italy. Nowadays, forest trees are important not only for wood production, but also as fundamental elements for sustainable land management. The European Union has indeed stimulated the implementation of wooded areas, from both quantitative and qualitative points of view. In Italy, following Regulations 2080 of 1992, during the period 1994 to 2000 more than 100,000 ha of previously cultivated land has been converted to woodland (mostly using broad-leaved species), while another 112,000 ha have been involved in implementation projects of existing woods. In total, more than one billion Italian liras have been spent.

The River Po Plain landscape is characterized by monotonous extensive agriculture cultivations, which have replaced, in quite recent periods, the former dominant forest. Small remnants of woods are today still alive, but however they are under risk of extinction. Only some of these are fully protected. From these areas nurserymen sometimes get material for vegetative propagation and nursery production.

Usually, the genetic provenance of the material used in afforestation activity has not been taken into due consideration. Seeds and seedlings used have been chosen mainly on the basis of nursery availability more than ecological and genetic suitability to the local conditions and planting sites. This fact has negatively affected the genetic resources of native populations and may have given rise to genetic erosion. It is important to emphasise that many species (including *Fraxinus excelsior*) have been included in Annex A of Law 269/73 (the Law that governs the seed and seedlings trade in Italy) only in 1998. Lastly, it must be pointed out that there

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[7] Ministero delle politiche agricole e forestali.
[8] Agency for the environmental protection and for technical services.

is a lack of genetic knowledge about many forest species in Italy: this hampers a policy of propagative material production which should safeguard forest biodiversity.
A real danger for these fragments of forests is also the fragmentation of the administrative management. This fact has taken north Italian districts, along with others public organizations to constitute in 1996 a working group (Bioforv) with objectives to co-ordinate management of forestry activities (rules, techniques and administrative problems).
In particular in the agreement protocol of Bioforv the following objectives can be found:

- constitution of an over-district network of ecological homogeneous areas for seed stands;
- preparation of criteria for the harmonization of regional regulations (for example certification of nursery material);
- definition of modern technologies for seed quality evaluation and for genetic resources management;
- definition of standards of nursery planting stock quality and suitability;
- definition of conditions for exchanges of nursery stock;
- drafting of research projects, of experimentation, training and divulgation of information within and outside Bioforv members;
- drafting of technical guidelines for nursery production.

In activity programs

Forms to describe on seed stands

The first objective achieved by the group, intended to harmonize the regional regulation, was the adoption of the form for the definition and the classification of seed stands. The form contains:

- the date of the survey and the names of the form surveyors (compilers);
- the map and administrative identification (location: province and town; forest species suitable for seed production; property; accessibility; feasibility; description of boundaries);
- description of the site (height; slope; exposure), with an analysis of the climate and geopedologic situation;
- description of the site and silvicultural characteristics (typology, silvicultural system, structure, crown density, age, height, regeneration type, kind of management) as well as the origin and the composition of the woody species present there. In this section an evaluation is given for every species, which identifies the validity of the process of population with the only aim of seed production and collection.

This kind of form has been adopted by northern Italian regions: Piedmont has used it recently to select over fifty areas as suitable for seed collection and Veneto for nearly a hundred and fifty. Finally Lombardy has classified as suitable about twenty populations.

Research project "Riselvitalia"

Within the multidisciplinary programme "Riselvitalia", funded by Italian Agricultural and Forest Policy Ministry, that has been financed since spring 2001, the working group Bioforv is engaged in a research program, named "Biodiversity and production of nursery stock". This program anticipates what the European Directive CE 105/99 foresees, on a forest nursery basis, to be adopted by the member states.
The aims of the project are the conservation of biodiversity, through the use of correct nursery techniques and management, investigating if the different production steps result in any biodiversity loss and, in this case, identifying the stages in which these losses occur. The evalua-

tion of possible advantages offered by the creation of a network of seed orchards are also aims of the project.

From genetic data already available, regarding species and stands, an inventory of genetic resources will be carried out

The genetic analysis will be based on biochemical and molecular markers. The genetic structures of seed stands, seed orchards, seed trade samples, nursery plantlets and reforstations will be examined. The three species undergoing investigations are: *Prunus avium*, *Juglans regia* and *Pinus sylvestris*.

Important results are expected. They will be useful as general guidelines to preserve genetic diversity in nursery production. This could also create the basis for seed orchards establishment.

Research project on the genetic variability of *Fraxinus excelsior* *and identification of genetically homogeneous areas.*

In the analysis of genetic diversity in forest trees is important to know each stands genetic structure and therefore to plan biodiversity conservation programmes. The link between genetic diversity and species adaptability is well-known: as a consequence only a broad genetic basis can allow forest species survival even under unfavourable and changeable environmental conditions. This is particularly important when ecosystems have to be restored.

Genetic variability analysis is also important for the identification of stands for the production of high quality seed, as provided by Italian law.

In regards to this matter, Bioforv is involved in a broad research project, aimed at defining a working method, by using a model species. This method will be extended to other species, if necessary after modifications.

The object of the research is the analysis of structure, amount and distribution of genetic variability among and within several populations of European ash (*Fraxinus excelsior*) of northern Italy. The species has been chosen due to its ecological role as well as to its importance in reafforestation programmes, mainly in plain areas. In the meantime it will be possible to deeper our knowledge of the distribution of the species, mainly with respect to the similar *Fraxinus oxyphilla*.

Data from genetic analysis will be bound up with existing cartography, mainly concerning ecological and soil characteristics. In this way it will be possible to define areas that are homogeneous from both genetical and ecological points of view (breeding zones).

Analysis of biodiversity will give information useful for its conservation: moreover, the study will help to indentify stands for the production of high quality seed.

About 15-20 populations of European ash will be chosen in such a way that they represent different ecological environments of Northern Italy and Tuscany. Populations will be native and wide enough to prevent inbreeding. Plant material (winter buds) will be collected from at least 30 non-adjacent individuals per population, chosen at random. Genetic analysis will be carried out by studying variability of biochemical (isozymes) and molecular (RAPDs) markers.

Once the genetic variability of European ash in Northern Italy is defined, it will be evaluated if areas which are genetically homogeneous overlay areas which are ecologically homogeneous, as determined by the European Soil Bureau of the Joint Research Centre of Ispra-Varese (Italy). Therefore, the final results of the research will be the individuation of "breeding zones", homogeneous from both genetic and ecological points of view. Within these areas it will be possible to exchange seeds and propagative material.

Conclusion

Reaching goals of "Riselvitalia" project and individualization of ecological and genetic homogeneous areas in north Italy of main forest species, will allow area operators a greater and better safeguard of actual genetic resources.

Particularly with Riselvitalia project it will be individuated, along the nursery production, the moment in which erosion of genetic variability occurs (such variability being compared with that of the *in situ* populations).
With the *Fraxinus excelsior* project a pattern to individuate ecological and genetic homogeneous areas will be developed: the cartograph obtained will give valuable indications to nurserymen about appropriate use of seed provenances.

2. Effect of container-washing at different temperatures on the viability of fungal inoculum

*I. Børja and K. Kohmann**

Summary

In Norway, more than 90% of plants in forest nurseries are produced in containers. Containers are used continuously and may, if not cleaned sufficiently, accumulate potentially harmful fungal propagules. Under conducive conditions, the propagules may germinate and cause root dieback of the seedlings. To prevent infection from containers several cleaning methods were tested.

Containers were washed with high-pressure cold water or immersed in a tub with water temperature 60, 70, 80 and 95°C for 30 seconds, respectively. The viability of the residual fungal flora on the container walls was assessed after the washing treatments using the dilution plate method. The washing at 60°C reduced the viability of fungal propagules significantly. There were, however, no differences in amount of viable fungal propagules among the thermal treatments of 60, 70, 80 and 95 degrees. In our study there were no pathogenic fungi recovered from the container walls. The most frequently recovered fungal genera were *Paecilomyces* spp. and *Penicillium* spp. Electron microscopic images of the container cavity walls confirmed the results that without any washing treatment the walls retained organic debris and fungal spores. Bacteria and yeast did not seem to be affected by the washing and were isolated abundantly, irrespective of the cleaning treatments.

Keywords: containerised seedling, root dieback, washing, thermal treatment.

Introduction

In Norway nowadays more than 90 % of the total forest plant production is containerised. In the transition phase from bare root production to containerized production there appeared several problems. The most serious was a seedling-disease commonly named "root dieback" (Kohmann, 1986). The diseased seedlings had a dying or stunted root system, discoloration or yellowing of foliage and reduced growth (Børja, 1995). At an early stage of the disease the shoots looked healthy and didn't reflect the root deterioration. The symptoms became usually visible in the late spring (June) in a two-year production, or the seedling died after outplanting

Increased container seedling production causes that seedling roots are exposed to container-borne pathogens. Isolation from the diseased roots of Norway spruce seedlings yielded pathogenic oomycetes and fungi such as *Pythium sylvaticum*, *Pythium* sp., *Rhizoctonia* spp., *Fusarium avenaceum*, *Cylindrocarpon destructans*, *Cylindrocarpon magnusianum*, *Trichoderma viride* and *Botrytis cinerea* (Galaaen and Venn, 1979a; Venn, 1983; Venn, 1985; Venn et al., 1986) that were associated with the root dieback. A similar problem of root dieback has been reported also from other Nordic countries (Beyer–Ericson et al., 1991; Lilja et al., 1992; Lilja et al., 1998). It was clear that the disease was due to combination of conducive abiotic conditions (such as temperature, substrate humidity, pH) and presence of sufficient inoculum of pathogenic fungi.

The containers in nurseries are used repeatedly, and most of the production is run through a two-year rotation. Different container cleaning techniques were tested (Sturrock & Dennis,

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1988; Dumroese et al.,1993). Even if the containers are conventionally cleaned with pressure water, the inner walls of cavities may accumulate organic debris, including propagules of fungal pathogens. Many of the soil borne pathogenic fungi associated with root dieback of seedlings have durable spores, chlamydospores or sclerotia that can adhere to the container walls and may survive for many years despite the usual sanitizing procedures. There may occur build up of fungal propagules both within and outside the containers (Juzwik, et al., 1999) from season to season and under favourable abiotic conditions cause a severe root dieback. To avoid contamination the sand layer under containers was replaced by a layer of gravel, or the production was lifted from the ground onto frames. A two step washing machine procedure was established as a standard for all Norwegian nurseries.

In spring and autumn 1998 there appeared symptoms of heavy root dieback in the forest nursery of Telemark. The diseased seedlings were mainly found in containers which were either unwashed or washed in cold water before sowing. Containers cleaned with submersion into warm water carried less diseased seedlings This observation suggested that the containers remained contaminated with potentially pathogenic propagules despite the cleaning procedures with cold water.

The objective of this work was 1/ to find a washing temperature threshold that kills/inactivates the propagules, 2/ to assess the remnants of fungal flora inside the container cavities after washing containers at different temperatures.

Materials and methods

Container cleaning treatment

The containers were of type M95, with 95 cavities, each with volume of 50 cm^3. In the nursery (Forestry Society of Telemark, Norway), before the cleaning the containers were sorted in two groups according to the quality of seedlings that they carried (group H: containers, that carried only the healthy seedlings; group D: containers that carried mostly diseased seedlings). Containers from both groups were emptied and cleaned in a standard washing equipment for Norwegian forest nurseries. The washing was either by pressure cold water wash (spraying nozzles with pressure 7 kg/cm_) or, in addition, a subsequent immersion in a tub with a running water at temperatures 60°, 70°, 80° and 95° C respectively, for 30 seconds. The temperature in the water tub was measured with an electronic thermometer calibrated at 100° C.

Three randomly chosen containers from each cleaning treatment were separately preserved in plastic bags and stored at 5° C until the further treatment. Table 1 gives the codes for the different container treatments.

Table 1: Codes for containers and cleaning treatments

Container code	Treatment
H	Containers previously carrying healthy seedlings
D	Containers previously carrying diseased seedlings
U	Unwashed containers
W	Containers washed only with cold water, 8° – 10°C
60°C, 70°C, 80°C, 95°C	Containers washed with cold water first and later immersed into a tub with water temperature. 60°C, 70°C, 80°C, 95°C respectively, for 30 seconds.

Cavity washing procedure

From each container 3 cavities were randomly chosen for washing. The bottom of each cavity was sealed with Parafilm "M" laboratory film (American National Can) and 5 ml of sterile, distilled water was pipetted into each cavity. Inner wall of each cavity was cleaned thoroughly with a rubber spatula in order to loosen the attached particles. The wash off from all 3 cavities was mixed together into one sample of total 15 ml. This mixed suspension was considered to be representative for the container.

Isolation of fungi

The dilution plate method was used for isolation of fungi. Malt agar medium (25 g/l) and *Phytophthora* selective medium (cornmeal agar 18 g/l, amended with pentachlornitrobenzene 133 mg, ampicillin trihydrate 125 mg, rifampicin 10 mg, pimaricin 10 mg, hymexazol 25 mg) were used as isolation medium.

After the preliminary testing of fungal growth at different dilutions of the suspension (1:10; 1:100; 1:1000) the dilution of 1:10 was chosen for further isolation. Diluted suspension was vortexed for 15 sec. on whirlmixer and 0.5 ml was immediately spread evenly on each plate with isolation medium. Triplicate plates of each isolation medium were inoculated from the same suspension. The plates were incubated at 21° C, in darkness until the first fungal/bacterial colonies begun to appear (7-10 days later). The number of colony forming units (cfu) was calculated by counting the number of fungal/bacterial colonies with Telly-counter. The petri dish was divided into in 15 equal sections and the counting was done only in one, then multiplied with 15.

The fungal colonies were isolated and identified as to genus with aid of microscope.

Electron microscopy

Scanning electron microscopy (SEM) was used to visualise the distribution of organic debris and fungal propagules *in situ*, on the surface of inner cavity walls. From containers of all treatment categories a representative segment of cavity wall (1 cm_) was cut out. Segments were critical point dried using carbon dioxide as the transmission fluid, mounted with colloidal silver on aluminium stubs and coated with platinum/palladium in a sputtercoater before examination in a JEOL 859 microscope at 15 kV.

Statistical analysis

The data were analysed with the GLM procedure (Anon. 1989) and LSMEANS statement with the PDIFF option.

Results

Colony forming units (cfu) of fungi, yeast and bacteria isolated from container cavities after different cleaning treatments

The viability of fungal propagules was significantly reduced after the cold wash (W) treatment (Figure 1A). The fungal propagules germinated significantly more from cold water-treatment (W) than others (Figure 1A). However, viable fungal propagules were recovered also from containers treated with cold wash and immersion at 95° C (W-95° C). Bacteria and yeast seemed to be resistant to the thermal treatment and colonies formed abundantly irrelevant of the treatment (Figure 1B). The amount of formed colonies was higher from "healthy" containers (H) than from "diseased" (D) (Figure 1B).

Identification of isolated fungi

The most frequently recovered fungi on malt extract medium were *Paecilomyces* sp. and *Penicillium* sp., 43 % and 60 %, respectively (Table 2). In 17% of cases were they isolated together. Other fungi, such as *Trichoderma* sp., *Sporothrix* sp., *Cladosporium* sp., and *Rhizopus* sp. were isolated only sporadically. Dark septate, sterile mycelia were isolated in 23 % cases (Table 2). The fungal growth on *Phytophthora* selective medium was rare (Table3). No *Phytophthora* spp. or other oomycetes were found. Other fungal propagules on Phytophthora-selective medium germinated only from cold-water washed containers (W) and were classified as sterile mycelia. There were mostly recovered bacteria (27%) and light sterile nonseptate mycelia (17%).

The cavity walls of new, yet unused containers revealed slight mechanical rifts on the surface, but no remnants of organic debris (Figure 2A). Cold washed containers (W) had many organic particles and fungal spores attached to the cavity walls (Figure 1B). Among other fungal spores there were clearly visible chains of Paecilomyces spp. spores (Figure 1B, white arrow) which proved to be viable in germinated when plated on media (Table 2).

Table 2: Fungi recovered from the surface of cavity walls of nursery containers that previously contained healthy seedlings (H) or diseased seedlings (D) after cleaning treatments with cold water, 60∞C, 70∞C , 80∞C and 95∞C respectively. Presence of the fungi in each dish is marked by "+". Each treatment is based on 9 dishes with malt extract agar and 9 dishes with Phytophthora selective medium

Treatment	Penicillium spp.	Paecilomyces spp.	Trichoderma spp.	Rhizopus spp.	Cladosporium spp.	Sporothrix spp.	Sterile mycelia
H – cold water	+++++++	++	++			+	+++++
H – 60°C	+	++++++					
H – 70°C	++	++++++					+
H – 80°C	+	+++++++					
H – 95°C	++				+		++++
D – cold water	+++++++++						++++++++
D – 60°C		++++++++					
D – 70°C		++++					
D – 80°C		++++++++					+
D – 95°C	++++			++			++++

Table 3: Sterile mycelia and bacteria growing on Phytophthora selective medium. Fungi/bacteria were recovered from the surface of cavity walls of nursery containers that previously contained healthy seedlings (H) or diseased seedlings (D) after cleaning treatments with cold water, 60° C, 70° C , 80° C and 95° C respectively. Presence of fungi and bacteria in each dish is marked by "+". Each treatment is based on 9 dishes with Phytophthora selective medium. Electron microscopy studies of container cavity walls before and after cleaning treatment

Treatment	Sterile mycelia	Bacteria
H – cold water	+++++++	++++++
H – 60° C		++
H – 70° C		+
H – 80° C		++
H – 95° C		++++
D – cold water	++++++++	+++++++++
D – 60° C		++
D – 70°C		+++
D – 80° C		+++
D – 95° C		+++

Discussion

Previous studies revealed that root-dieback was linked to the sandy beds in the greenhouses where the containers initially were placed for germination and first year growth (Venn et al. 1986). Studies showed elevated amounts of fungal propagules were retained in the old nursery sand beds. There was found 50 000 spores of *Pythium* spp. per g sand and 170 000 spores of other Hyphomycetes per g sand, from a 9- year old sandy nursery bed. The corresponding numbers from a 3- year old sandy bed were 20 000 and 10 000 spores, respectively (Olsen, pers. comm.). It was also found that the proportion of Oomycetes in relation to the total number of spores was 0.01 under containers with healthy plants and 0.52 under containers with seedlings with dieback symptoms. However, an examination of one single container showed that after emptying the substrate it may contain up to 10 000 propagules of *Pythium* spp. retained in one single cavity (Kohmann, 1986).

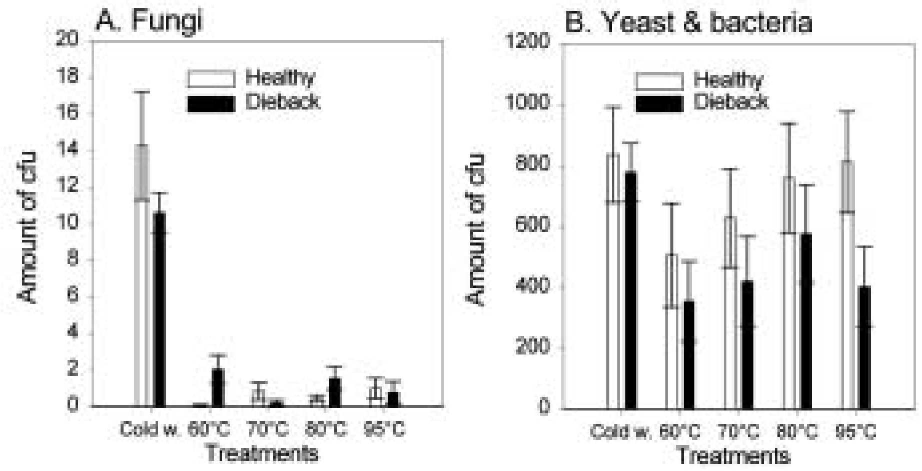

Figure 1: Fungal and yeast/bacterial colony forming units (cfu) on malt agar and Phytophthora-selective media, recovered from the container cavity walls after different washing treatments. Vertical lines represent standard deviation. Amount of cfu is expressed as total number of cfu based on 2 different media and 3 plates per medium.

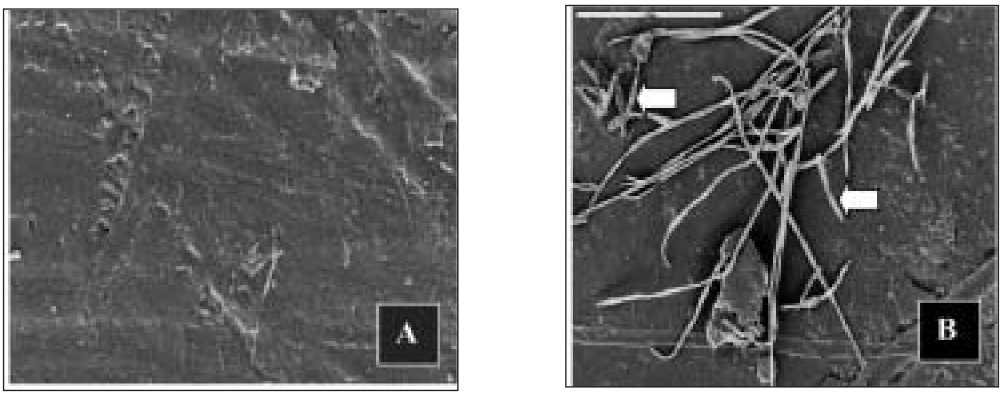

Figure 2: SEM images of container cavity wall of unused and washed containers (the bar in the upper left corner equals 20 µm). A: New, unused container. The walls have mechanical rifts, but no organic debris are visible. B: Container washed with cold water (W). Fungal spores and hyphae are visible (arrows). The spores belong to the most frequently isolated fungus, *Paecilomyces* spp.

The viable fungal propagules were to be found in all treatments. In our case there were no pathogenic fungi isolated from the containers. The absence of germinating propagules of pathogenic fungi may indicate that the diseased seedlings growing in the containers were not diseased due to the presence of root infecting pathogenic fungi. However, the analysis of fungi were not conducted on unwashed containers (U), since these containers are never used in nursery production. The minimum washing treatment for used containers is washing with cold water. It is likely that the unwashed containers contained inoculum of pathogens.

The most frequently isolated fungus was *Paecilomyces* sp. It is a rather common fungus in the air, soil, in compost, self-heated substrates and is frequently recorded as a thermophilous organism (Samson 1974). It is generally considered as a saprophyte, however it may become pathogenic in man and animals, when ingested, causing the so-called paecilomycosis. *Paecilomyces* and *Penicillium* are closely related differing mainly in the absence of green pigment in the colonies of *Paecilomyces*. *Penicilliums* are also saprophytic fungi, found in air, soil, water and different organic substrates. Neither *Paecilomyces*, nor *Penicillium* are pathogenic on seedlings.

The presence of high amounts of bacterial inoculum in containers with healthy seedlings indicates that the bacterial flora has a beneficient influence on the seedlings.

In the nursery production it is of utmost importance to minimise the source of fungal infection. A number of cleaning treatments for the containers was tested in order to make the cleaning routine simple, efficient environmentally unobtrusive and inexpensive. Conventionally the containers are cleaned with combination of high-pressure water wash followed by applying heat. This treatment is often insufficient for styroblock and wood containers. In this case, chemical treatments, such as fumigation of containers or rinsing with different chemical solutions such as methyl bromide, formaldehyde, metabisulphite, iodine, chlorine compounds, are applied. All of these provide a potential environmental threat at spillage. Electromagnetic and electron beam radiation were also used to kill the fungal propagules.
Our results show that already washing at 60°C reduces significantly the amount of viable fungal propagules in containers. Warm water treatment has therefore contributed to an important better production hygiene.

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3. Preliminary analysis of forest plantation development 1980-2000[1]

J.B. Carle[1]

Summary

According to the Global Forest Resources Assessment, FRA 2000, forest plantations cover 187 million hectares, of which Asia accounts for 62%. The largest plantation resources are found in China with 24% and India with 17%. The forest plantation area is a significant increase over the 1995 estimate of 124 million hectares. The new annual planting rate is 4.5 million hectares globally, with Asia and South America accounting for 89%. Broadleaf species account for 40% of global forest plantation resources, conifers, 31% and not specified, 29%. Globally, 48% of the forest plantation estate is for industrial end-use; 26% for non-industrial end-use (fuelwood, soil and water, other); and not specified, 26%. Forest plantation ownership is public, 27%; private, 24%; other, 20% and not specified, 29%.

The geographic (national and regional), economic (developed and developing), eco-floristic (tropical and non-tropical) stratification and bases of the global forest resources assessment of forest plantations and reliability of data have varied markedly between FRA 1980, 1990 and 2000. The unspecified species has reduced from 81% in 1980, 58% in 1990 to 34% in 2000. Broadleaf species increased from 12% in 1980 to 36% in 1990 and 40% in 2000. Conifers increased from 4% in 1980, to 6% in 1990 and 31% in 2000. Although in 2000 there remained 26% unspecified purpose, industrial purpose increased from 39% in 1980, 36% in 1990 to 48% in 2000, with the significant increase in the last decade. There has been a corresponding decrease in non-industrial purpose forest plantations.

The potential for forest plantations to partially meet demand from natural forests for wood and fibre for industrial uses is increasing. Although accounting for only 5% of global forest cover, forest plantations were estimated in the year 2000 to supply about 35% of global roundwood, with anticipated increase to 44% by 2020. In some countries forest plantation production already contributes the majority of industrial wood supply.

Keywords: forest plantation, industrial, non-industrial, wood supply, FAO Forest Resources Assessment.

Introduction

Background

Increasingly wood and non-wood forest products, fuelwood, environmental benefits and carbon sequestration will be from forest plantation resources managed on a sustainable basis. The trends in forest plantation development (1980-2000) give indications on the scale, location and direction for future policy, planning, technical and knowledge change required to respond to priority needs for the sector.

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[1] Quantitative data and figures are based on information available as by 8 May 2001 and may be subject to changes in later versions of the document. For further information and updated versions of the present working paper, please contact the author.

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Global Forest Resource Assessments (FRA) have been carried out in 1980, 1990 and 2000 to detail forest cover areas and change, including forest plantations. The results of FRA 2000 have recently become available.

Objectives for Measuring Forest Plantation Resources

The objectives for including forest plantation data in global forest resource assessments are to:

(a) Measure trends at regional and global level in forest plantation areas, species, purpose and ownership for planning and policy development;
(b) Model potential present and future wood and fibre supply;
(c) Estimate carbon sequestration;
(d) Estimate the extent to which plantations may reduce pressure on natural forest wood supply;
(e) Estimate the area of plantations established for the provision of environmental functions and services;
(f) Estimate the area and species established for the production of fuelwood; and
(g) Contribute to estimates of new economic benefits.

Concept of Forest Plantations

It is not always possible to distinguish forest plantations from natural forests in those countries where long rotation, natural species are grown, often in mixed species plantings in temperate and boreal regions. Between the extremes of afforestation and unaided natural regeneration of natural forests, there is a range of forest conditions where human interventions occur. The distinction between natural forests and forest plantations is more clear-cut if plantings are in single species, uniform-planting densities, even age-classes and shorter rotation.

European forests have long traditions of human interventions in harvesting, nursery management, site preparation, tree establishment, silviculture and protection, but are not always defined as forest plantations. Terms like natural forests under management, or assisted natural regeneration, are generally preferred. Reforestation is generally with indigenous species in more heterogenous management mechanisms than the traditional forest plantation concept (single species, uniform planting densities, even age-classes, fixed rotation and clearfell harvesting).

FRA 2000 - Forest Plantation Component

Definition of Forest Plantation

In FRA 2000 *forest plantations* are defined as those forest stands established by planting or/and seeding in the process of afforestation or reforestation. They are either of introduced or indigenous species which meet all the following criteria – minimum area of 0.5 hectare; tree crown cover of at least 10% of the land cover; and total height of adult trees above 5 meters.

In country responses terms such as "man made forest" or "artificial forest" were considered synonyms for forest plantations as defined in FRA 2000.

The definition excludes stands which were established as plantations but which have been without intensive management for a significant period of time. These are considered semi-natural. Due to their increasing significance as a supply of fibre to the wood industries sector, rubber plantations are included as forest plantation resources.

Forest plantations can be classified as afforestation or reforestation according to definitions:

(a) *Afforestation* is the conversion from other land uses to forest or the increase of the canopy cover to above the 10% threshold;
(b) *Reforestation* is the re-establishment of forests after a temporary condition with less than 10% canopy cover due to human-induced or natural perturbations.

(c) *Replanting* where afforestation or reforestation has failed or where the crop is felled and regenerated is not added to the plantation area.

With population pressures on available land for food security, there is an increasing proportion of tree plantings, by human intervention, which also do not fit within the characteristics of traditional forest plantations. Trees supporting livelihoods of rural populations and agriculture (shelterbelts, shade, home gardens), smallholder, social and community forestry, agroforestry (inter-cropping, grazing, multi-purposes, fruit) and urban and peri-urban (schools, parks, reserves) represent a valuable growing stock of planted trees for wood and non-wood forest products in high population density countries. These are defined as "Trees Outside Forests" if canopy closure falls below 10% and as forest plantations if above.

Methodology for Measuring Forest Plantations

The area of existing forest plantations is ideally derived from statistically designed inventories of forest plantations or statistics for planted areas reported by planting agencies or appearing in national reports. For consistency between countries, FRA 2000 prepared guidelines and questionnaires for the collection of forest plantation statistics in which the objectives, scope, definitions, sources of data and templates for specific data collection were supplied to each country.

Data Collection

Country responses were incomplete, however there was sufficient data from questionnaires and other sources to derive the following information:

(a) Total forest plantation area estimated at the year 2000;
(b) Annual area of new plantations;
(c) Species groups according to broadleaf (including rubber), conifer, non-forest (oil palm, coconut palm, bamboo) and where no data was provided, unspecified species;
(d) Purpose and end-use objective of forest plantations according to industrial (producing wood, or fibre for supply to wood processing industry) and non-industrial (fuelwood, soil and water protection);
(e) Ownership according to public, private, other (e.g. traditional, customary) and unspecified

Other data requested in the guidelines, that proved difficult for each country to provide by species group included age class distribution; end-use by forest product (industrial plantations); growth (mean annual increment); standing volumes; rotation lengths and harvest yields. Despite the absence of this data, FRA 2000 is the most comprehensive, transparent, neutral and responsive forest plantation resource assessment carried out.

Analysis and Interpretation

The quantity and quality of forest plantation data provided is dependent upon the national forest inventory systems to collect and analyse data and to adjust the information to conform with global and regional reporting parameters. In many developing countries there is a lack of institutional capacity and capability to carry out periodic national forest inventories, so data can be incomplete, inconsistent, outdated and of variable reliability. Because of this, it was necessary to derive, and in some instances verify, forest plantation statistics from desk research from available country reports. Additionally regional and national focal persons were appointed to assist in the forest plantation data collection and to ensure that the latest data was available and to maintain co-ordination and communication between FRA 2000, regional offices and each participating country. On completion of data sets a formal verification process was undertaken with each participating country.

Results

Regional Forest Plantation Areas, Species and Annual Plantings

The annual plantation rates and plantation areas by regions and species groups are summarised in Table 1 and demonstrated in the following graphics to assist in interpretation of results.

Table 1: Annual Plantation Rates and Plantation Areas by Regions and Species Groups

Region	Total Area (000 ha)	Annual rate (000 ha/yr)	Acacia	Eucalyptus	Hevea	Tectona	Other broadleaf	Pinus	Other conifer	Unspecified
Africa	8.036	194	345	1.799	573	207	902	1.648	578	1.985
Asia	115.847	3.500	7.964	10.994	9.058	5.409	31.556	15.532	19.968	15.365
Europe	32.015	5	-	-	-	-	15	-	-	32.000
North/Central America	17.533	234	-	198	52	76	383	15.440	88	1.297
Oceania	3.201	50	8	33	20	7	101	73	10	2.948
South America	10.455	509	-	4.836	183	18	599	4.699	98	23
World total	**187.086**	**4.493**	**8317**	**17.860**	**9.885**	**5.716**	**33.556**	**37.391**	**20.743**	**53.618**

Source FRA 2000

According to global forest plantation area distribution, Asia accounts for 62%; of the total, Europe, 17%; North and Central America, 9%; South America, 6%; Africa, 4% and Oceania, less than 2%. Based upon annual planting rate, Asia leads with 79%; South America, 12%; North and Central America, 5%; and Africa, 4%. Major new forest plantation development is in Asia and South America.

The global annual planting rate is estimated at 4.5 million ha/year, with Asia, 78% and Sth America, 11% accounting for 89% of all new plantings in 2000 (Figure 1)

Globally, broadleaves make up 40% with *Eucalyptus* the principal species. Coniferous species make up 31% of which *Pinus* is the principal species (Figure 2).

In Asia broadleaves make up 57% of which *Eucalyptus, Hevea, Acacia, Tectona* are principal species. Conifers make up 30% of primarily *Pinus* species (Figure 3).

In North and Central America, *Pinus* species account for 88% of area planted (Figure 4).

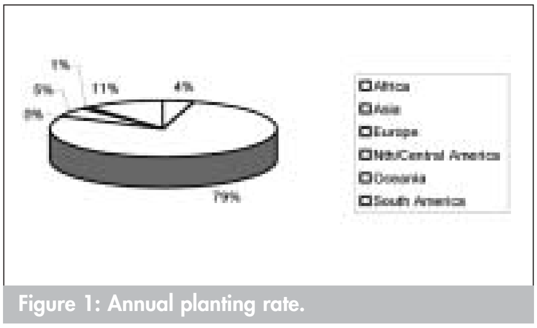

Figure 1: Annual planting rate.

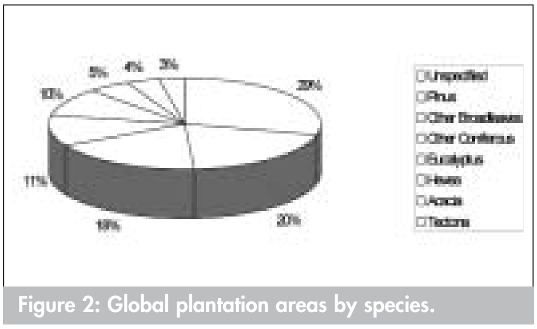

Figure 2: Global plantation areas by species.

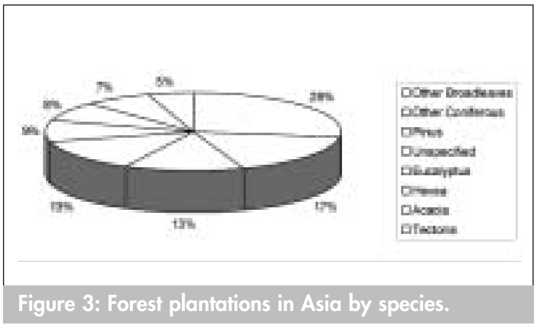

Figure 3: Forest plantations in Asia by species.

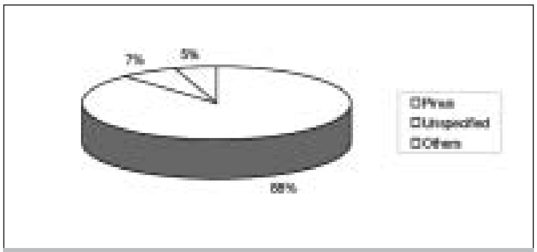

Figure 4: Forest plantations in North and Central America by species by species.

In South America broadleaves make up 52%, of which *Eucalyptus* is the principal species. Conifers make up 45% of which *Pinus* is the principal species group (Figure 5). In Africa broadleaves make up 47%, with primary species groups being *Eucalyptus, Hevea, Acacia*, and *Tectona*. Conifers make up 28%, of which *Pinus* is the primary species Group (Figure 6). In Oceania the species distribution is primarily unspecified.

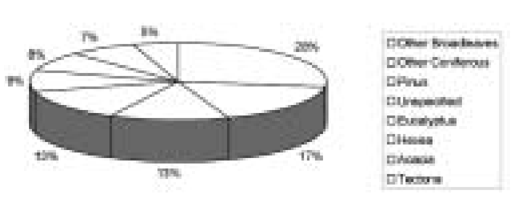

Figure 5: Forest plantations in South America by species.

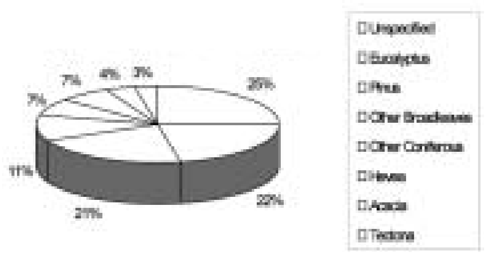

Figure 6: Forest plantations in Africa species.

Purpose and Ownership within the Global Forest Plantation Estate

Purpose and ownership varies markedly between regions, however, comparisons are done between the global data and select regions demonstrating contrasts in purpose and ownership. The purpose and ownership is not available for European countries. Table 2 details regional plantation areas by purpose and ownership for the global forest plantation estate.

Table 2: Regional Plantation Areas by Purpose and Ownership

Region	Total Area (000 ha)	Industrial purpose (000) ha					Non-industrial purpose (000) ha					Purpose unspecified
		Public	Private	Other	Unspecified	Subtotal	Public	Private	Other	Unspecified	Subtotal	
Africa	8.036	1.770	1.161	51	410	3.392	2.035	297	611	330	3.273	1.371
Asia	115.847	25.798	5.973	27.032	-	58.803	17.177	17.268	9.145	72	43.662	13.381
Europe	32.015	-	-	-	569	569	9	6	-	-	15	31.431
North/Central America	17.533	1.446	15.172	118	39	16.775	362	58	16	35	471	287
Oceania	3.201	151	14	-	24	189	2	3	-	19	24	2.987
South America	10.455	1.061	3.557	-	4.827	9.445	251	528	-	225	1.004	6
World total	**187.086**	**30.226**	**25.876**	**27.202**	**5.871**	**89.175**	**19.836**	**18.161**	**9.772**	**680**	**48.449**	**49.463**

Source FRA 2000

Globally, 48% of the forest plantation estate is for industrial end-use; 26% for non-industrial (fuelwood, soil and water, other); and 26% is not specified (Figure 7).

Globally industrial plantations are 34% is publicly owned, 29% privately owned and 37% other or unspecified. Within non-industrial plantations, 41% are publicly owned, 37% are privately owned, 22% are other or unspecified (Figures 8 and 9).

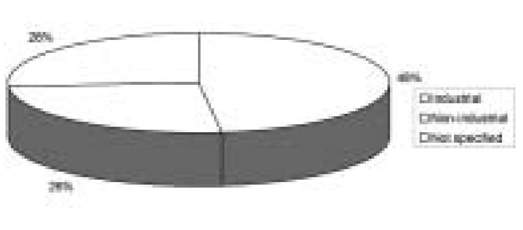

Figure 7: Forest plantation end-use globally.

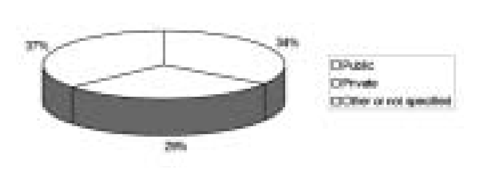

Figure 8: Ownership of industrial forest plantations Globally.

The industrial forest estate in Asia accounts for 51% of forest plantation area, of which 44% is owned publicly; 10%, privately; and 46%, other or unspecified (Figures 10 and 11).
The industrial forest estate in North and Central America accounts for 96% of forest plantation area, of which 90% is owned privately (Figures 12 and 13).

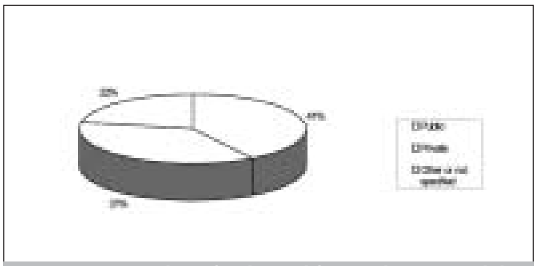

Figure 9: Owership of industrial forest plantatios Globally.

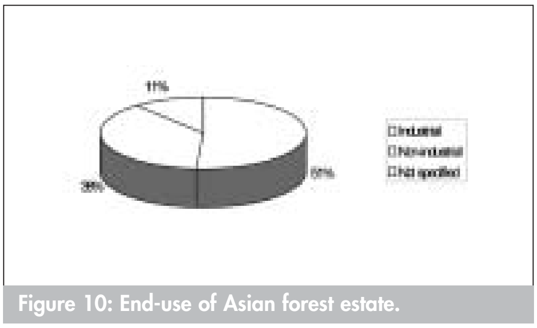

Figure 10: End-use of Asian forest estate.

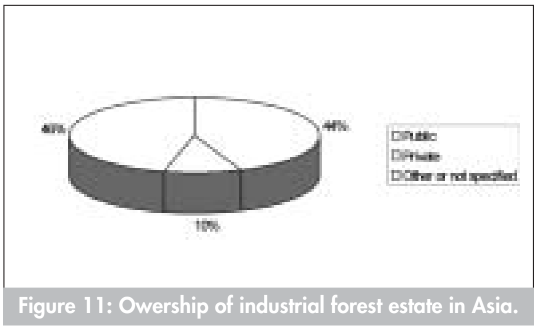

Figure 11: Owership of industrial forest estate in Asia.

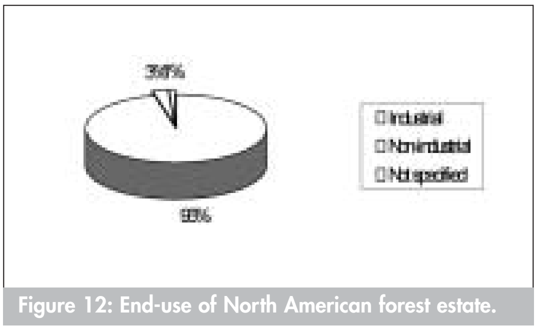

Figure 12: End-use of North American forest estate.

The industrial forest estate in South America accounts for 90% of forest plantation area, of which 11% is owned publicly; 38%, privately; and 51%, other or unspecified (Figure 14 and 15).
The industrial forest estate in Africa accounts for 42% of forest plantation area, of which 52% is owned publicly; 34%, privately; and 14%, other (Figures 16 and 17).
The ten largest forest plantation development countries account for 79% of the global forest plantation development area of which 56% of global forest plantations are in the Asia region.

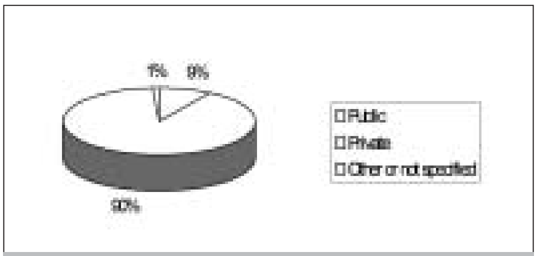

Figure 13: Owership of North and central American industrial forest estate.

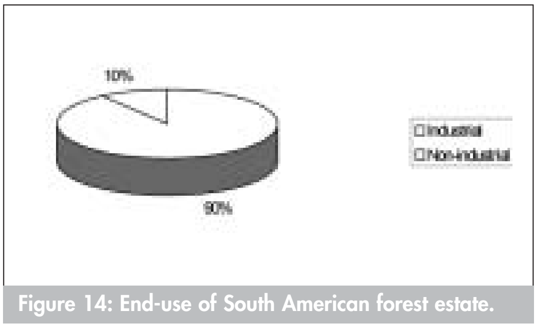

Figure 14: End-use of South American forest estate.

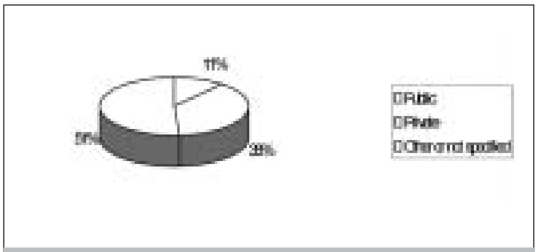

Figure 15: Owernship of South American industrial forest estate.

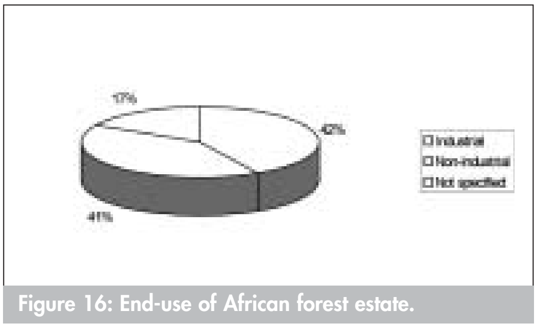

Figure 16: End-use of African forest estate.

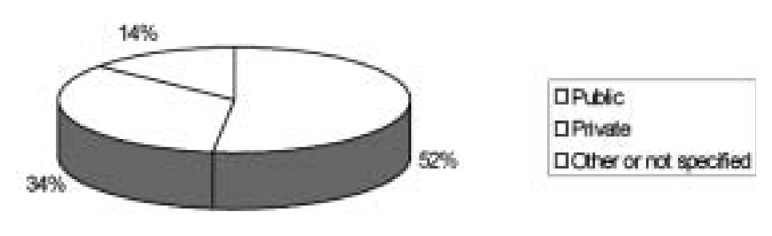

Figure 17: Owernship of African forest estate.

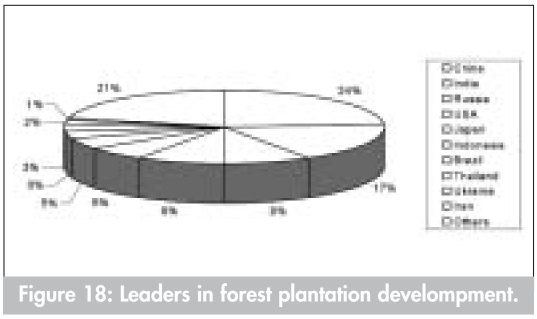

Figure 18: Leaders in forest plantation develompment.

Leaders in Forest Plantation Development (Top Ten Countries by Area)

The top ten countries according to area include: China, 24%; India, 17%; Russia, 9%; USA, 9%; Japan, 6%; Indonesia, 5%; Brazil, 3%; Thailand, 3%; Ukraine, 2% and Iran, 1% (Figure 18). Within the top ten, an estimated 52% of forest plantations are grown for industrial purposes to supply raw material for industry; 26% for non-industrial uses (fuelwood, soil and water protection, biodiversity conservation); and the purpose was not specified in 22%, particularly in Russia, Japan and the Ukraine. The industrial forest estate, where specified in these top ten countries was owned publicly, 33%; privately, 26%; and other or unspecified, 41% (Figures 19 and 20).

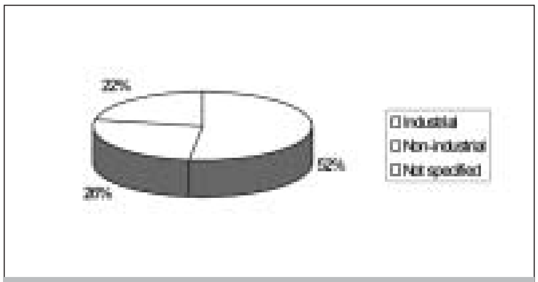

Figure 19: End use of forest plantations in the top 10 countries.

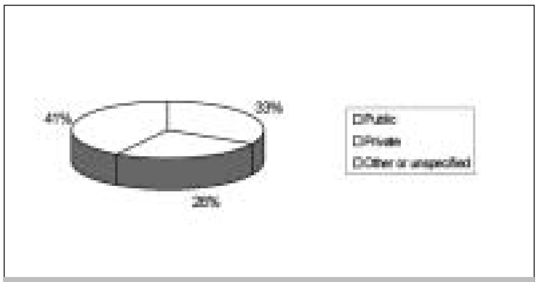

Figure 20: Owernship industrial plantations in top 10 countries.

Select Global Trends, 1980-2000

Comparisons

The geographic (national and regional), economic (developed and developing), eco-floristic (tropical and non-tropical) stratification and bases of the global forest resources assessment of forest plantations have varied markedly between FRA 1980, 1990 and 2000 global syntheses. There are significant forest plantation data additions to FRA 2000 for the first time include:

(a) Developed countries (Europe, CIS, North America, Australia, Japan and New Zealand); and
(b) Expanded forest plantation species list, including Hevea (rubber) and "non-forest" plantation species (oil palm, coconut palm).

However, the FRA results from each decade allow comparisons of trends for planting rates, species groups, areas and purpose (end-use).

Table 3. Plantation Purpose and Ownership by Reported Area for the Ten Largest Plantation Development Countries

Country Top 10	Total Area (000 ha)	Industrial purpose (000) ha					Non-industrial purpose (000) ha					Purpose unspecified
		Public	Private	Other	Unspecified	Sub-tot	Public	Private	Other	Unspecified	Sub-tot	
China	45.083	10.182	-	26.994	-	37.176	102	-	7.805	-	7.907	-
India	32.578	8.258	3.749	-	-	12.007		11.370	8.641	560	-	20.571
Russia	17.340	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	17.340.0
USA	16.238	1.185	15.053	-	-	16.238	-	-	-	-	-	-
Japan	10.682	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	10.682.0
Indonesia	9.871	4.531	1.228	-	-	5.759	358	3.754	-	-	4.112	-
Brazil	4.982	-	-	4.802	-	4.802	-	-	180	-	180	-
Thailand	4.920	850	314	-	-	1.164	1.219	2.537	-	-	3.756	-
Ukraine	4.425	NA	NA	NA	NA		NA	NA	NA	NA	NA	4.425
Iran	2.284	241	-	-	-	241	1.938	105	-	-	2.043	-
Top 10 Tot	**148.403**	**25.247**	**20.344**	**31.796**	**-**	**77.387**	**14.987**	**15.037**	**8.545**	**-**	**38.569**	**32.447.0**
Top 10 (%)	79					87					80	66
World Tot.	**187.086**	**30.226**	**25.876**	**27.202**	**5.871**	**89.175**	**19.836**	**18.161**	**9.772**	**680**	**48.449**	**49.463**

Source: FRA 2000

Global Forest Plantation

The global forest plantation estate has increased markedly from 17.8 million hectares in 1980; 43.6 million hectares in 1990 to 187 million hectares in 2000 (Table 4).

Table 4: Forest Plantation Purpose Trends by Regions, 1980-2000

Region	Total	Plantation Area by Purpose (000 ha)		
		Industrial	Non-industrial	Unspecified
		2000		
Africa	8036	3392	3273	1371
Asia	115847	58803	43662	13381
Oceania	3201	189	24	2987
Europe	32015	569	15	31431
North & Central America	17533	16775	471	287
South America	10455	9446	1004	6
GLOBAL TOTAL	**187087**	**89175**	**48449**	**49463**
		1990		
Africa	2990	1366	1623	
Asia	31775	8991	23119	
Oceania	189	167	22	
Europe				
North & Central America	691	457	234	
South America	7946	4645	3301	
GLOBAL TOTAL	**43590**	**15625**	**28300**	
Africa	1713	939	780	
Asia	11088	3487	7601	
Oceania	88	41	47	

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Region	Total	Plantation Area by Purpose (000 ha)		
		Industrial	Non-industrial	Unspecified
		1980		
Europe				
North & Central America	287	272	15	
South America	4604	2261	2348	
GLOBAL TOTAL	**17779**	**7000**	**10791**	

Source: FRA 1980, 1990; 2000

Although in 2000 there remained 26% unspecified purpose, industrial purpose increased from 39% in 1980, 36% in 1990 to 48% in 2000, with the significant increase in the last decade. There has been a corresponding decrease in non-industrial purpose forest plantations.

Species Trends by Region - a Graphic Illustration

Species trends from FRA 1980, 1990 and 2000 are graphically illustrated below by regions. The **graphics are not to scale** but to illustrate relative growth within the region over the period and to show trends in species used.

Impact of the Forest Plantation Estate

The potential for forest plantations to partially meet demand from natural forests for wood and fibre for industrial uses is increasing. According to FRA 2000, global forest plantation area accounts for only 5% of global forest cover and the industrial forest plantation estate for less than 3%. Forest plantations were estimated in the year 2000 to supply about 35% of global roundwood, with anticipated increase to 44% by 2020 (Jaakko Pöyry, 1999). If targeted at the most appropriate ecological zones and sustainable forest management principles are applied, forest plantations can provide a critical substitute for natural forest raw material supply. In several countries industrial wood production from forest plantations has significantly substituted for wood supply from natural forests resources. Forest plantations in New Zealand met 99% of the needs for industrial roundwood in the country in 1997; the corresponding figure in Chile was 84%, Brazil, 62% and Zambia and Zimbabwe, 50% each. This substitution by forest plantations may help reduce logging pressure on natural forests in areas in which unsustainable harvesting of wood is a major cause of forest degradation and where logging roads facilitate access that may lead to deforestation.

Forest plantations provide additional non-wood forest products, from the tree planted or from other elements of the ecosytem they help to create. They also represent values enhancing environmental, social and economic benefits. Forest plantations are used in combatting desertification, protecting bio-diversity, absorbing carbon to offset carbon emissions, protecting soil and water values, rehabilitating lands exhausted from other land-uses, providing rural employment, and if planned effectively, diversifying the rural landscape. They may also provide amenities, and repositories of cultural values.

Select Forest Plantation Technical Issues

Reliable and consistent data is not available on the forest plantation resource - on areas of natural forest cleared for forest plantation establishment; areas established with mixtures of tree species; total areas of forest plantations by species, purpose, ownership, age class distribution, growth, rotation, harvest yield and forest products outturn. In addition to the lack of quantitative data, the poor quality of the available information is a major impediment to policy-making in this field. There is a need to improve the reliability and timeliness of forest plantation data. FAO will continue to support member countries in institutional strengthening and capacity building to provide increasingly accurate data on forest plantations at regional and global levels, to be used in national policy making, in regional and global outlook studies and in a range of other studies.

Land availability and land tenure is one of the most important social issues related to forest plantation establishment. In developed countries and in some countries with economies in transition, surplus, or marginal agricultural land is becoming increasingly available for forest plantation development; however, such land may not be suitable for the establishment of all kinds of forest plantations, nor may the owner be willing to commit land for the long term investment to maturity. Land-use conflicts can occur where forest plantations are developed on land perceived as "waste-land" but actually used for grazing and provision of non-wood goods and services by landless people. FAO is assisting developing countries to review the role of forest plantations and facilitating factors for investment in this land-use.

Increasingly trees are being planted to support agricultural production systems, community livelihoods, alleviate poverty and to provide food security. Communities and smallholder investors, including individual farmers, grow trees as shelterbelts, home gardens, woodlots and a diverse range of agroforestry systems to provide wood, non-wood forest products, fuelwood, fodder and shelter. Outgrower schemes under various forms of contract with wood processing industries can also provide valuable sources of wood supply. Smallholder investors are producing an increasing proportion of decorative veneer species, especially teak, using such schemes. FAO is presently carrying out a review and an analysis of experiences with outgrower and contract schemes, to develop extension guidelines.

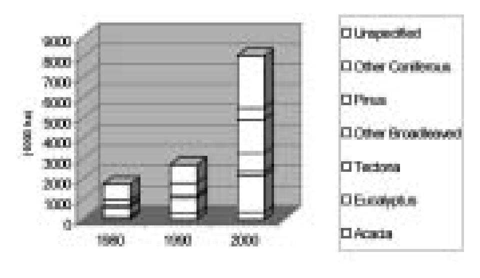


Figure 21: African Plantation Areas by Species Groups.

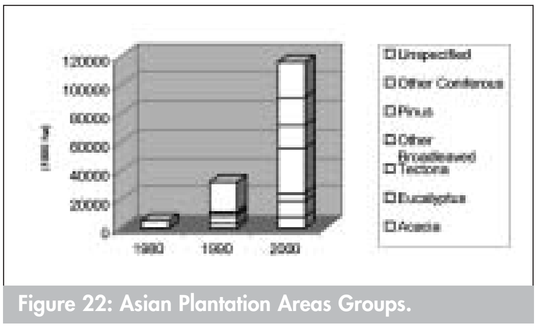


Figure 22: Asian Plantation Areas Groups.

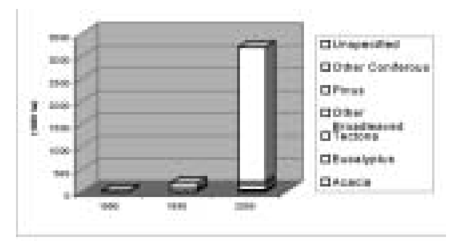


Figure 23: North and central American Plantation Areas by species Groups.

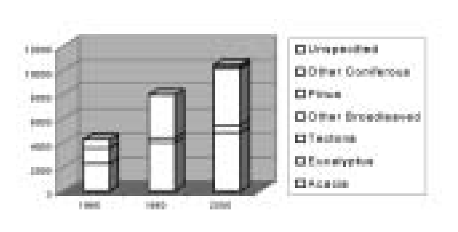


Figure 24: South American Plantation Areas by Species Groups.

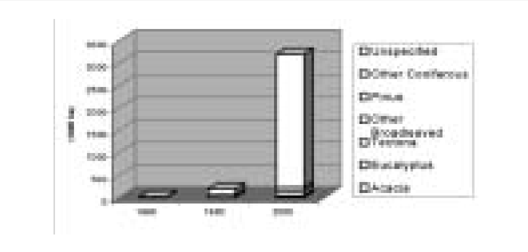


Figure 25: Oceanian Plantation Areas by Species Groups.

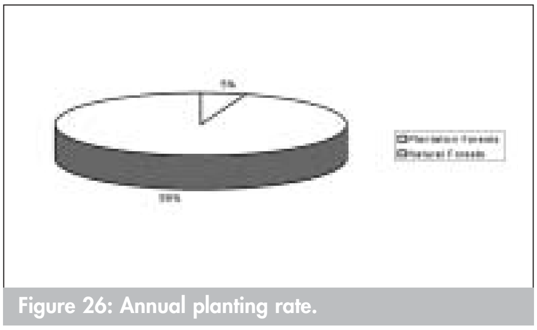
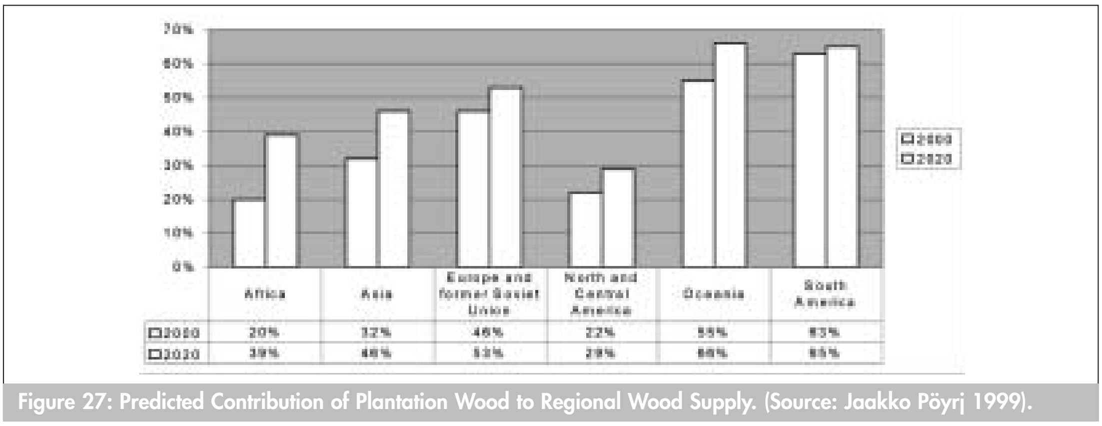


Figure 26: Annual planting rate.



	Africa	Asia	Europe and former Soviet Union	North and Central America	Oceania	South America
2000	20%	32%	46%	22%	55%	63%
2020	39%	46%	53%	29%	66%	65%

Figure 27: Predicted Contribution of Plantation Wood to Regional Wood Supply. (Source: Jaakko Pöyrj 1999).

Environmental considerations related to forest plantations include the maintenance of the productive potential of the site. These can be promoted through the development of silvicultural techniques and forest management practices that reduce soil erosion, conserve water, maintain soil fertility (including maintaining fertility in the second and subsequent plantation rotations). Appropriate forest plantation management techniques can also favour the maintenance of biological diversity. The protection of forest plantations from fire, insects and disease is critical. FAO provides policy, planning, management and monitoring support and guidelines to maintain productivity and maximize environmental benefits.

FAO will continue to monitor experiences with mixed species plantations. Such forest plantations may provide a larger range of products and provide "insurance" against unfavourable market conditions, reduce the effects and economic consequences of insect and disease attacks, contain the spread of wildfires, and provide greater variety and aesthetic value in the landscape.

Particularly in SE Asia, wood supply difficulties, has led to the utilisation of woody or fibrous species which are not traditionally considered "forestry" species such as rubberwood, and stems and leaves of oil and coconut palms. This trend is expected to continue and consequences and implications will be monitored by FAO.

The concept of mitigating global climate change through forestry has gained considerable impetus in recent years. Increasing the amount or rate of carbon accumulation by creating or enhancing carbon sinks (carbon sequestration) could offer an option towards the strategic management of forest carbon. Estimates taking into account land availability for afforestation/reforestation indicate that these activities could reasonably absorb about 0.28 billion tonnes carbon per year, and agroforestry could absorb 0.04 billion tonnes carbon per year. Careful selection of project sites is a critical factor.

Conclusions

For reasons already outlined, it is difficult to compare directly between FRA 1990 and FRA 2000. However, it is apparent that:

(a) New forest plantation areas are increasing globally at the rate of 4.5 million hectares per year;
(b) Asia and South America account for more new plantation development than other regions;
(c) The Asian region has the largest areas in forest plantation development;
(d) Broadleaf species account for 40%; coniferous species, 31% and unspecified species, 29%;
(e) Unspecified species, purpose and ownership remain too high for accurate analysis;
(f) Industrial plantations account for 48%, non-industrial, 26% and unspecified, 26% of the global forest plantation estate;
(g) Industrial plantation resources are dominated by China, India and USA;

(h) Non-industrial plantation resources are dominated by China, India, Thailand and Indonesia;
(i) Forest plantation ownership in both industrial and non-industrial plantations is evenly balanced between public and private;
(j) Forest plantations provide a critical substitute for raw material supply from natural forests;
(k) Forest plantations provide critical environmental, social and economic benefits

Detailed FRA 2000 reporting on forest resources, including forest plantation descriptions and areas by country, region, species, purpose and ownership together with references are available on www.fao.org/forestry/fo/country/navworld.jsp and www.fao.org/forestry/fo/fra/index.jsp .

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4. Cork-oak seedling production: Container capacity and substrate effect on seedling field performance

F. Costa[1], E. Silva[1], S. Moura[1], M.H. Almeida[1], M.R. Chambel[2] and C. Pereira[2]

Summary

Cork oak is the second forest species in Portugal covering an area of about 721000 ha. In the context of the Common Agriculture Policy (CAP), large areas (ca. 10% of total area) were reforested between 1994-98 with low survival rates due to inappropriate nursery and establishment techniques, as well as the use of unsuitable genetic material. The main purpose of this study was to evaluate the effect of container capacity and substrate in field performance of cork oak seedling with 1 year of age during the first 3 years after plantation. Therefore 3 container capacities were tested (210, 300 and 400 cm^3) in combination with 4 types of substrate: composted pine bark, composted pine bark with vermiculite 3:1(v/v), composted pine bark with peat 1:1 (v/v) and peat with vermiculite 3:1 (v/v). With the 300 cm^3 container capacity 3 other substrates were also tested: F+H organic layers, F+H organic layers with composted pine bark 1:1 (v/v) and F+H organic layers with peat 1:1 (v/v). A field trial was established in the South of Portugal in April 1998. Just before plantation seedlings morphological characteristics (root and shoot biomass, leaf area, height, stem diameter, root length and root development patterns) were measured and correlated with survival and growth evaluated one, two and three years after plantation. The results showed that after three years in the field only the type of substrate had a highly significant influence in survival and early growth. Container capacity (210, 300 and 400 cm_) did not have an influence on height growth during the first 3 years, just as there was no clear influence on survival rate. Peat with vermiculite (3:1) substrate led to 30% higher survivals than other substrates. Substrate with peat favoured secondary root development (length), which seems to be an advantage in field performance.

Keywords: cork-oak seedling, field performance, substrate, container capacity.

Introduction

Cork oak is the second forest species in Portugal covering an area of about 721000 ha. In the context of the Common Agriculture Policy (CAP), large areas (ca. 10% of total area) were reforested between 1994-98 with low survival rates (Louro, 1999) due to inappropriate nursery and installation techniques and the use of unsuitable genetic material. Traditionally natural regeneration and sowing was used for cork oak forestation. However, incompatibility with agro-forestry practices (e.g. frequent soil mobilisations and grazing), irregularity of seed production and improvement of nursery techniques, led to a decrease in the use of these techniques in favour of plantation of nursery stock.

Cork oak afforestation takes place in the South of Portugal where summer water stress and degraded soils are survival constraints. Survival and initial growth, after transplanting shock, results from the plant root growth capacity to supply sufficient water to compensate for water lost in transpiration and thereby attaining a new internal water balance (Gil & Pardos, 1997; McKay, 1997). The physical and chemical properties of substrate (e.g. porosity, water reten-

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tion) have an important influence in seedling root development during nursery phase. This influence is likely maintained during the early period after plantation.
This study intends to assess the effect of container capacity and substrate on seedling field performance.

Material and methods

Seedlings were produced at *Emporsil* nursery in Abrantes, from acorns harvested in Machouqueira do Grou, Coruche. Sowing took place in April 1997, black propylene container with rips in the inner surface and 3 capacities were used: 210, 300 and 400 cm^3 (CETAP 28 high, 28 extra and 40 extra, respectively) (Table 1). Four types of substrate were chosen for these 3 container capacities: composted pine bark, composted pine bark with vermiculite 3:1(v/v), composted pine bark with peat 1:1 (v/v) and peat with vermiculite 3:1 (v/v). Being the 300 cm^3 container the most commonly used in Portuguese nurseries for cork oak, 3 other substrates were also tested: F+H organic layers, F+H organic layers with composted pine bark 1:1 (v/v) and F+H organic layers with peat 1:1 (v/v) (Table 1).

Table1: Type of substrate and container capacity of each treatment and container characteristics

Type of substrate	Container capacity		
	210 cm^3	300 cm^3	400 cm^3
Pine bark	A2	A3	A4
Pine bark with vermiculite (3:1)	B2	B3	B4
Pine bark with peat (1:1)	C2	C3	C4
Peat with vermiculite (3:1)	D2	D3	D4
F+H organic layers		T	
F+H organic layers with peat (1:1)		TT	
F+H organic layers with pine bark (1:1)		TC	
Container characteristics			
Density (seedling/m^2)	372	372	266
Height (cm)	12	15	19.5
Diameter (mm)	49	49	60

In April 1998 the cork oak seedlings were established in a field trial at Alcácer do Sal (8°38′ W longitude and 38°31′ N latitude); this site has an average annual temperature of 16.3°C, annual rainfall of 574.5mm and the dry season occurs from May to September. Heavy disc harrowing followed by ripping with fertilisation (500 Kg/ha of P-K (20:17) improved with calcium, magnesium and boron $P_2O_5 - K_2O - B$) was used in soil preparation. A randomised complete block with repetitions was the experimental design adopted in the field trial (5 blocks, 15 plots and 20 seedlings per plot).
Height, diameter, shoot and root dry weight, secondary root length and leaf area were measured just before plantation in a sample (7-10 seedlings) of each treatment. Immediately after plantation and again on the first, second and third year, height and survival rate were assessed in all plants. Diameter was measured at plantation and in the third year.
Seedlings root system were washed under running water and separated by tap root and secondary roots. Stem branches and leaves were also separated. Dry weight of all components was measured after 48h in an 80°C oven. Leaves and secondary roots were scanned and leaf area and root length was calculated through *Delta t scan* software (DELTA-T Devices LTD). Characterisation of tap root conformation was done, using a qualitative scale.

Growth Indexes

Allometric relations of plant components were evaluated through relative growth indexes: tap root/ secondary root biomass, root/shoot ratio, leaf area ratio (LAR, $cm^2 . g^{-1}$), specific leaf area (SLA, $cm^2. g^{-1}$) and Dickson Index described by Dickson *et al*, *cit in* Johnson & Cline (1991). Field data at plantation was used for determination of sturdiness (height/diameter, $cm.mm^{-1}$) and growth increment after three years.

Statistical analysis

Two-way ANOVA (substrate x container capacity) and one-way ANOVA (substrate) models were used for biomass components, leaf area and growth indexes. For field data analysis the model considered was randomised complete block. Whenever means difference was significant Student-Newman-Keuls test (Zar, 1984) was used. Significance level was α= 0.05.
Pearson correlation coefficients between growth indexes and survival rate after the first and third year were calculated.

Results

Survival rate

Only 3 years after plantation survival rate showed significant differences ($P<0.05$) between container capacities (Figure 1). Seedlings produced in 210 cm^3 container capacity had a higher survival rate (60.3%) while the 300 cm^3 showed the lowest (49.8%).
Differences in survival rate, after 3 years, in the 7 types of substrate were highly significant ($P<0.001$). Peat with vermiculite presented a significantly higher survival rate (73%), being 24% higher than the second best. All 3 substrates containing peat had higher survival rates (Figure 2).
Evolution of survival rates throughout the 3 years and for all treatments denotes a higher mortality occurring after the first summer (1st year). Survival remains fairly constant in subsequent 2nd and 3rd year (Figure 3). Some treatments showed an increase in survival rate from 2nd to 3rd year, which is due to resprouting ability of cork oak seedlings.

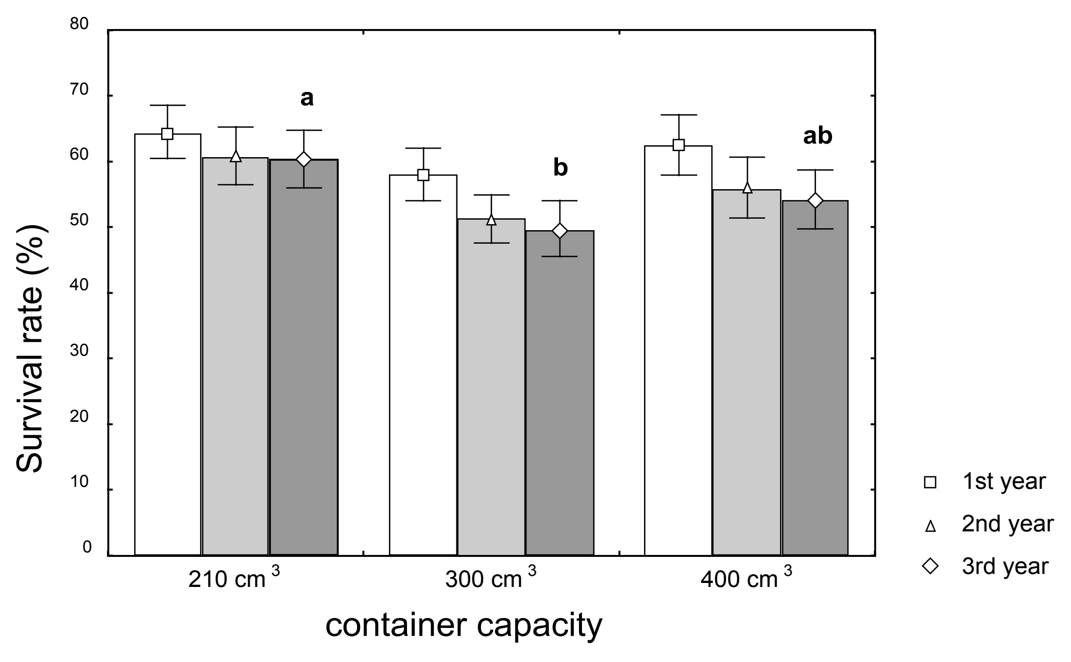

Figure 1: Mean survival rate and standard errors of container capacities, 1, 2 and 3 years after plantation. Columns with no letters in common differ significantly at P=0.05.

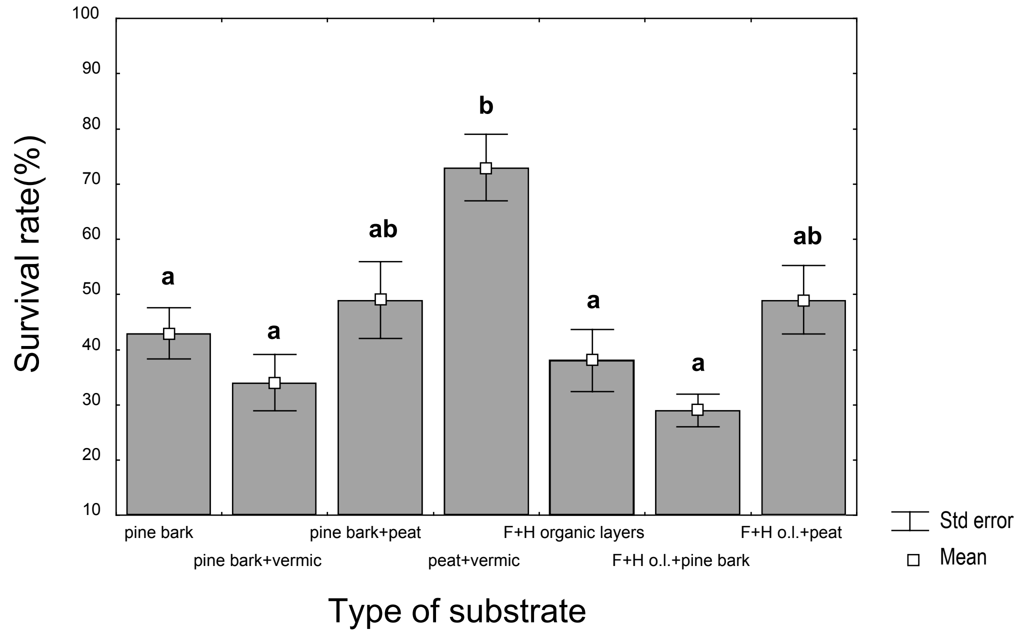

Figure 2: Mean survival rate and standard error of the seven types of substrate, 3 years after plantation. Columns with no letters in common differ significantly at p = 0.05.

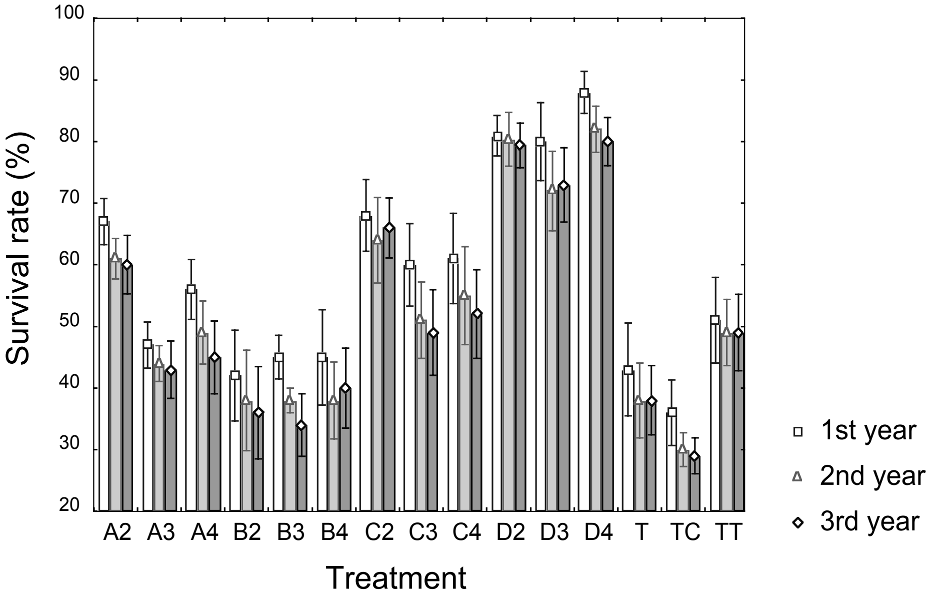

Figure 3: Mean survival rate and standard error of the seven types of substrate, 3 years after plantation. Columns with no letters in common differ significantly at p = 0.05.

Height and diameter growth

ANOVA showed that seedlings with 12 months in the nursery have significant differences in height (P=0.019) and diameter (P<0.037) between container capacities. Differences between heights for substrate treatments were highly significant (P<0.001). After three years in the field, differences between heights were no longer significant for the different container capacities, but highly significant differences (P<0.001) between the substrates were however maintained.

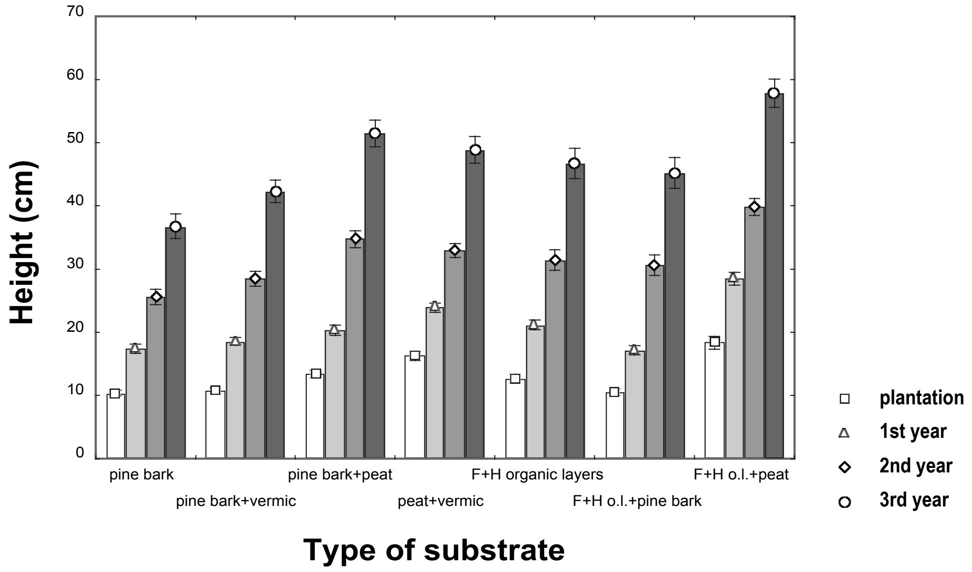

Figure 4: Mean height and standard errors of seedlings grown in the 7 types of substrate at plantation, 1, 2 and 3 years after out-planting.

Considering the 7 types of substrate tested it was observed that, during the 3 years, substrates containing pine bark produced smaller seedlings in contrast with substrates containing peat. Substrate of F + H organic layers presented intermediate values.

There were no significant differences between height increment for substrate types for neither of the container capacities tested. Nevertheless the diameter increment showed significant differences only for substrate ($P<0.05$), pine bark with vermiculite showing the lowest value and peat with vermiculite the highest (1.4 mm *vs* 2.5 mm respectively).

Growth Indexes

Pearson correlation coefficient between survival rate and shoot biomass was negative (*r*= -0.66), in contrast with root biomass (*r*= 0.66). Likewise LAR was negatively correlated (*r*= -0.80) and root/shoot ratio and leaf area were positively correlated (*r*= 0.65, *r*= 0.65 respectively). The correlation between survival rate and secondary root length was positive (*r*= 0.74). Tap root biomass, secondary root biomass, SLA, tap root/secondary root ratio biomass and Dickson index have no significant correlation with survival rate (Table 2).

Morphological parameters (height, diameter and sturdiness measured at plantation) showed significant but low correlations with survival rate (*r*= 0.57, *r*= 0.27, *r*= 0.57 respectively). A slight decrease occurred in the correlation coefficient from the 1st to 3rd year. Also no significant correlations were obtained between growth indexes and height increment (3 years after plantation).

Tap root conformation analysis did not show patterns associated with container capacities (Figure 5).

Discussion

During the first three years in the field 210 cm^3 container capacity did not show low survival rates as referred by Domínguez (1997). Also in our study no patterns of tap root curling were found associated with container capacities. However a too long nursery period (more than 1 year) may cause malformation in the root system of seedlings grown in small containers.

All substrates containing peat showed a higher height growth whereas the seedlings grown with pine bark were smaller. The same peat influence in height growth was found by Suárez *et*

Table 2: Pearson correlation coefficients between growth indexes and survival rate after the first and third year

Growth Index	Survival rate (1st year)		Survival rate (1st year)	
	Correl.	*p*	Correl.	*p*
Total plant biomass[1]	0.73	.002	0.67	.006
Shoot biomass[1]	- 0.66	.007	- 0.60	.018
Root biomass[1]	0.66	.007	0.60	.017
Tap root biomass[1]	n.s.	n.s.		
Secondary root biomass[1]	n.s.	n.s.		
Secondary root length[1]	0.74	.002	0.72	.002
Leaf area[1]	0.65	.009	0.62	.014
Leaf area ratio (LAR)[1]	- 0.80	.000	- 0.72	.002
Specific leaf area (SLA)[1]	n.s.	n.s.		
Root/shoot ratio[1]	0.65	.009	0.60	.017
Tap root/secondary root ratio[1]	n.s.	n.s.		
Dickson Index[1]	n.s.	n.s.		
Height[2]	0.51	.000	0.57	.000
Diameter[2]	0.29	.011	0.27	.019
Height/Diameter[2]	0.49	.000	0.57	.000

([1] n=15 lab analysis data [2] n=75 field trial data)

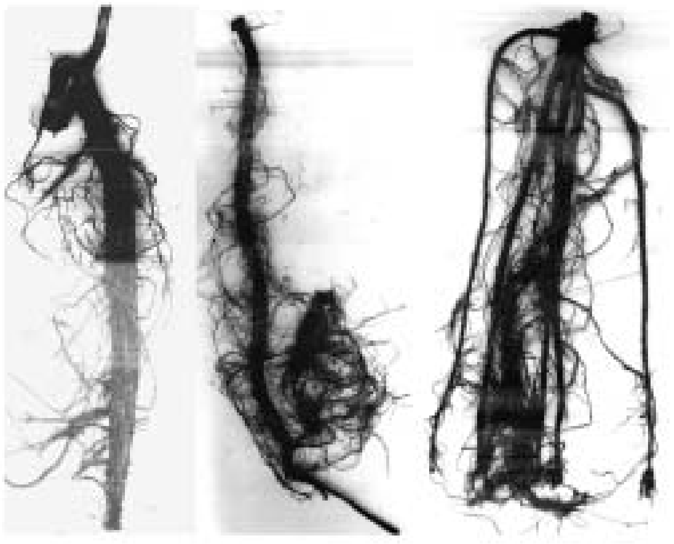

Figure 5: Example of different root development patterns.

al (1997) in cork oak and by Dominguez *et al* (1997) with holm oak during nursery period. Higher growing density (container spacing) and volume did not lead to a clear effect in seedling height growth in nursery as expected and described by Landis *et al.* (1990), possibly due to an interaction of the two factors. Anyway, after the first year in the field, differences in height growth between container capacities disappeared. Also the absence of differences in height increment between the substrates after 3 years of plantation can be regarded as the overcome of transplanting stress, the seedlings being then dependent of site conditions for growth. The correlation found between height and diameter and survival rate confirms the results that these parameters cannot be considered good predictors of field performance (Mattsson, 1997 and Pardos & Montero, 2000)

A large plant investment in root system development is an advantage for field survival as demonstrated by the correlations found, in opposition to an investment in the photosynthetic apparatus (LAR). This can be explained by a decrease in the transpiration surface, which leads to an advantage in the maintenance of water balance, therefore seedlings are more adjusted to water stress conditions. This can also be supported by the positive correlation found between seedling survival rate and root/shoot ratio; these seedlings are favoured with a higher relation between uptake surface (water and nutrients) and transpiration surface. This confirms Gil & Pardos (1997) results using this ratio as a predictor of field survival in draught-prone sites. A high leaf area favours seedling survival as long as accompanied by a well-developed root system, which will support higher water loss.

Substrate has a major role on cork oak seedling field performance. Inclusion of peat in substrate induces higher survival and height growth. Physical characteristics of substrates can possibly explain this result, once peat has better properties (e.g. water retention and availability) in accordance with seedling functional requirements (Landis, 1990, and Ocaña, 2000). This can be strengthened by the positive correlation of secondary root length with survival rate, since peat induces the development of secondary roots (length), allowing for better exploitation of water and nutrients. The use of pine bark in substrate leads to poor performances, as can be explained by the fact that composted pine bark is hydrophobic when dry, being difficult to rewet (Donald *et al.*, 1994), which can be a disadvantage specially in a Mediterranean climate.

The F+H organic layers proved to be the worst substrate, having both low heights and survival. One crucial reason that may be appointed is that a firm root plug formation could not be obtained and seedlings were planted with diminished substrate. Anyhow this type of substrate decreases its importance in nursery production, being replaced by others less expensive with lower environmental impact.

In a nursery, substrate selection is mainly based on economical criteria, once minimising production costs is a priority (Pardos & Montero, 2000). Besides, several types of substrate are commercially available with significant price differences. Thus the use of an expensive substrate (e.g. peat with vermiculite) represents an increment in the production costs. Nevertheless, for the consumer, the increase in seedling price is acceptable, once establishment cost (e.g. site preparation and plantation) and eventual replanting cost have the major influence in the budget. Therefore, choosing an expensive but higher quality substrate compensates through higher field performances. The selection of a substrate with peat has the inconvenience of being a non-renewal resource; consequently, in the future, an alternative growing media will have to be developed with similar characteristics.

Conclusions

As an output of this study we can emphasise that, for cork oak nursery production, the type of substrate, rather than container capacity, influenced field performance, mainly survival rate. Peat with vermiculite (3:1) was the most suitable substrate among the seven studied, proving to be a significant advantage for seedling survival.

Container capacity of 210 did not show any disadvantages both in nursery height growth and field performance, although a long nursery period in this container might be detrimental for the root system. Furthermore the use of higher container capacities did not bring any improvement in field performance. This can be relevant for nursery management since production cost may be reduced (e.g. less substrate and space used in the nursery).

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5. The effects of coppicing on the growth characteristics of juvenile oak trees

*M. Cowell**

Summary

The establishment of high quality broad-leaved crops is normally achieved by planting in high densities. High planting densities, such as 1.0m x 1.0m spacing, promote apical dominance and restrict branch development. Planting at high densities is often avoided because of excessive costs. The investigations described here represent a novel approach to the establishment of broad-leaves that could reduce overall establishment costs and improve stem quality. Young oak trees, if damaged or cut, will reproduce vegetatively from dormant buds. The oak trees used in these studies were cut to ground level (coppiced) one year after planting. Their subsequent development was monitored for changes in vigour and stem quality. The effect of initial planting density on growth was also monitored. Trees were planted at spacings of 1.0m x 1.0m, 1.2m x 1.2m and 1.8m x 1.8m. The mean height increment of the coppiced trees was 32cm while that of the controls was 12cm, ($P < 0.0001$). The mean length of straight stem in the coppiced trees was 30cm while that of the controls was 22cm, ($P < 0.0001$). The mean percentage straightness of the twice-coppiced trees after two growing seasons was 93% whereas it was 69%, ($P < 0.0001$), in the controls. Coppicing had no effect on the total height of the trees. Coppicing increased apical dominance by inhibiting branch production, irrespective of planting density. The mean length of the longest branch on each uncoppiced tree was 17cm and the length on each of the trees coppiced once was 14cm. The mean length of branches of the trees coppiced twice was 5.0cm, ($P < 0.0007$).

Keywords: oak, coppicing, growth, density.

Introduction

The expansion of broad-leaved planting in Great Britain during the 1980s and 1990s has been achieved at the expense of the recommended planting densities for veneer quality timber for each species. Research has shown that high stocking densities during the early years of establishment are required to produce veneer quality hardwood timber (Savill & Spilsbury, 1991; Kerr & Evans, 1993). High stocking densities prevent epicormic branch development and induce apical dominance. The potential for the production of veneer butts is increased due to fewer and smaller knots. Savill & Spilsbury (1991) recommend planting densities for oak of 5000 to 6250 stems ha^{-1}. This is very close to continental European practice but also reflects a compromise between high densities and financial constraints. Kerr & Evans (1993) recommend that oak should have an initial density of 3086 stems ha^{-1} for high quality timber production. The British Woodland Grant Scheme (Forestry Commission, 1988) accepts initial densities for many broad-leaves of 1100 stems ha^{-1}. This minimum density has become the norm in British forestry (Miller *et al.*, 1988a and b). Attempts to reduce costs have lead to the lower planting densities and reduced competition, and thus, stands have a poorer potential for the production of high quality timber (Kerr & Evans, 1993). Novel methods of tree establishment, which have very low net costs, are essential if investment in veneer quality timber is to be achieved.

Most broad-leaved trees, if damaged or cut back, will react by producing new shoots. This reaction is thought to be an ecological response to fire, insect damage, browsing by deer, drought

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and other sources of natural disturbance (Morris & Perring, 1974). This characteristic has been used for centuries in silvicultural systems known as coppice and coppice with standards. Coppiced stems are cut close to the ground so that the resulting new shoots will develop new root systems (Troup, 1928). This system produces small diameter produce during short rotations in both temperate and tropical conditions. The characteristics of vegetative reproduction as a result of coppice treatments are well known. Regrowth can be both rapid and of good form. A single stem of good form and vigour is selected from a coppice stool and allowed to develop into a mature tree. Leffelman & Hawley (1925) noted that butt rot was insignificant on stumps of less than 50 cm diameter because stumps of this size usually callus over before they become infected. In recent times the ability of broad-leaved trees to regenerate by coppicing has been exploited in the development of energy crops. Juvenile trees are cut to ground level resulting in a profusion of new shoots (multiple stems). Much of this work has been concentrated on high yielding eucalyptus, willow and poplar species and clones (Ceulemans *et al.*, 1996). Crockford & Savill (1991) produced yield tables for mature oak coppice but there have been no attempts to evaluate coppice shoots produced from juvenile trees. This study investigates the growth response of juvenile oak following successive coppice treatments.

Materials and methods

Experimental areas

Data was collected from *Quercus robur* L., in a rabbit-proof enclosure, at the Riseholme Estate in Lincolnshire, Long 0°31_W , Lat 53° 16_N. The oak plots were established in November 1997, using two-year old containerised plants produced from locally collected acorns. The experiment was designed as nine main plots, each containing 81 trees. The nine plots formed a 3 x 3 Latin Square. Three plots were laid out at 1.0m x 1.0m spacing, three at 1.2m x 1.2m and three at 1.8m x 1.8m. These spacings reflect the range of recommended planting densities, from 10000 stems per ha^{-1} down to 3086 stems per ha^{-1} (Savill & Spilsbury, 1991: Kerr & Evans, 1993). The main plot treatments were designed to test the effects of crop density on tree growth characteristics. Each of the main plots was made up of nine sub-plots, each also in a 3 x 3 Latin Square design. Sub-plot treatments were trees coppiced once, trees coppiced twice and a control of uncoppiced trees.

Mortality

Less than 1% of trees died after the first growing season. This figure rose to 4% after the second growing season. There was no evidence to suggest that the losses were caused by coppicing. They may have been due to voles.

Coppicing method

Coppicing was by cutting at ground level using secateurs. This was carried out five months after planting, in March 1998. Half of the coppiced trees were coppiced again in March 1999.

Measurement techniques

The total height of each tree was measured from the base of the tree (or root collar) to the tip of the leading shoot or leading branch, whichever was the higher, following established procedures (Hamilton, 1975). The measurements were rounded down to the nearest centimetre. The length of the longest branch on each tree was measured and rounded down to the nearest centimetre. Stem straightness was expressed as the percentage of the total length of the stem that was straight when measured from the base, up to the first kink or where the stem became indistinguishable from the crown. Deviations from absolute straightness were considered acceptable as long as they were in the form of slight, gradual bowing, not exceeding 1cm for every 1m length and this in one plane and one direction only (Forestry Commission, 1990).

Analysis

The Latin Square design enabled a rigorous examination of possible interrow and intercolumn effects, unrelated to the treatments, as well as variations due to fertility gradients and soil moisture. Statistical analysis was carried out with SAS software using the Generalised Linear Models Procedure.

Results

A summary of results can be seen in Table 1.

Table 1: Effects of coppicing on growth characteristics of juvenile oak trees

	Uncoppiced	Coppiced once	Coppiced twice	Units
Total height of oak after one year	37***	31***	-	cm
Height increment after one year	12***	31***	-	cm
Total height of oak after two years	41a	41a	33***	cm
Length of straight stem	22**	30**	-	cm
Mean stem straightness	69**	87**	93**	%
Totally straight stems	22***	62***	82***	%
Straightness of poorest stems	34***	45***	56***	%
Branch length	17**	14**	5**	cm
Stems per stool	1.13[b]	1.75[b]	1.65[b]	mean
Effects of spacing on straightness 1.0m x 1.0m	58[c]	98[c]	-	%
1.2m x 1.2m	62[d]	99[d]	-	%
1.8m x 1.8m	57[e]	98[e]	-	%

, **, * Significant at $P<0.05$, $P<0.01$, $P<0.001$, respectively.*

[a] Differences in total height between uncoppiced and trees coppiced once were not significant.

[b] Differences in stem numbers between the uncoppiced and coppiced trees were not significant.

[c,d,e] Differences in stem straightness between uncoppiced and coppiced trees, as a result of spacing, were not significant.

Total height

The mean total height of the uncoppiced trees after one growing season, in autumn 1998, was 37cm compared with 32cm in the coppiced trees. After two growing seasons there was no difference between the coppiced and uncoppiced trees. Height increment in the first growing season was rapid in the coppiced trees. They achieved 32cm compared with only 12cm in the uncoppiced trees. Half of the coppiced trees were coppiced again before the second growing season. These twice-coppiced trees grew of 33cm by the end of the second growing season.

Stem straightness

A typical example of an uncoppiced tree is shown in Figure 1a. The main stem is characteristically twisted and the leading shoot at the crown has relatively weak apical dominance. An example of a coppiced tree is shown in Figure 1b. The stem remains straight, without kinks or deformations and the leading shoot has strong apical dominance. Successive coppicing improved the straightness percentage from 69% for the uncoppiced trees compared with 81% for the trees coppiced once and 93% for trees coppiced twice. Only 22% of the uncoppiced trees were totally straight compared with 62% of the trees coppiced once and 82% of the trees coppiced twice. The poorest example of an uncoppiced tree was only 34% straight compared with 45% for trees coppiced once and 56% for trees coppiced twice. Successive coppicing narrowed the distribution of values towards the higher straightness percentages.

Figure 1a: Photograph showing a typical uncoppiced oak tree. The stem is characterised by deviations in stem straightness, potential forking in the crown and large branches.

Figure 1b: Photograph showing a typical coppiced tree. Stem characteristics include a well defined straight stem, apical dominance and light branching habit.

Branch length

The mean length of the longest branches of the uncoppiced trees was 17cm compared with 14cm for the trees coppiced once and 5cm for the trees coppiced twice. Successive coppicing reduced branch length.

Multiple stems

The production of multiple stems was uncommon but did occur occasionally in both the coppiced and uncoppiced trees. There was no significant difference in the occurrence of multiple stems between the coppiced and uncoppiced trees. Most trees with multiple stems had only two or three stems. The main stem was usually dominant, with the minor stems providing little competition. Multiple stems did not have any effect on the straightness characteristics of the main stem on each stool.

Effects of spacing on growth characteristics

Spacing had no effect on the growth characteristics of the trees examined at this stage in the study.

Discussion

At the outset of this study it was assumed that coppicing would encourage the production of multiple stems. Each coppice stool would provide a microenvironment of competing stems, the most vigorous of which could be selected at a later date for the purpose of growing on until maturity. Close initial spacing would no longer be required to produce competition for light. Surprisingly, this did not happen. Coppicing did not encourage the production of multiple stems. Where they did occur, they had no effect on the straightness of the main stem.

Initial plant spacing had no effect on the growth characteristics of the trees during the period of this study. This may have been because the trees were very young. Even at very close spacings such as 1.0m x 1.0m, the branches of newly planted trees were able to grow unrestrained until the onset of canopy closure. Trees grown at wider spacings take longer to close canopy and therefore longer to take advantage of the benefits of mutual competition. Coppicing had a very powerful effect on both stem straightness and length of branches irrespective of initial plant spacing. The natural habit of unrestrained branch development in the uncoppiced trees was absent in the coppiced trees. The overwhelming priority of the coppiced trees is to send shoots rapidly upwards at the expense of branch development. Successive coppicing accentuated this characteristic. It could be argued that the improvements in stem straightness as a result of coppicing may eventually be reduced as annual height increment slows to the rate of the uncoppiced trees. Apical dominance may be reduced if the coppiced trees revert to their original growth habit. There was no evidence of this happening after two growing seasons. The question arises, will the coppiced trees eventually revert to poor growth characteristics? As time goes on the opportunity for the trees to revert will be reduced because of the onset of canopy closure and mutual competition. In other words, the benefits of improved straightness characteristics, as a result of coppicing, are only required until canopy closure. Furthermore, the large percentage of trees that had totally straight stems as a result of the coppicing may permit an improved selection of potential final crop trees compared with those of the controls.

Conclusions

Coppicing improves the straightness characteristics of the stems of juvenile oak trees without the need for expensive, high initial planting densities and the benefits of early mutual competition. Coppicing two years in succession greatly improved the proportion of trees that had totally straight stems. Successive coppicing also drastically reduced branch length. The full significance of shorter branch length is not known but does merit further investigation. These benefits were achieved without any reduction in total height and without risk of mortality.

The coppicing of the oak trees, one year after planting, had a dramatic and positive effect on growth and vigour. Coppicing improved apical dominance and the trees grew much faster and straighter than the uncoppiced trees. Improvements in apical dominance and form were achieved in the coppiced trees without the use of high planting densities. The coppicing of juvenile broad-leaved trees could contribute to improvements in the quality of tree planting programmes without loss of overall yield, while planting at low densities and conbsequently without increasing costs.

Acknowledgements

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6. Growth and production of stemwood in 16 provenances of pedunculate oak (*Quercus robur* L.) in Croatia

*J. Gracan and S. Peric**

Abstract

Provenance experiments of the pedunculate oak were established in the autumn of 1988 and in the spring of 1989 in the areas of central and eastern Croatia. The Gajno Locality is located in central Croatia in the Pokupsko valley, Forest Administration Karlovac, and the Slavir locality (Forest Administration Vinkovci) in the eastern part of Croatia in the renowned forest complex Spacva where the best quality oak orginates. The experiments were made in a randomised block design with 4 repetitions. A total of 400 plants 2+0 years old where planted per provenance. The height, diameter breast height and volume of wood were monitored on both localities during a number of years. This research pertains to the analysis of stemwood production of 16 provenances of the Pedunculate Oak in Croatia in relation to different site and climatic conditions.

Keywords: Pedunculate oak, provenance, height, diameter breast height, volume of wood.

Introduction

The share of pedunculate oak species (*Quercus robur* L.) amounts to one tenth of Croatian forests and is distributed over 35% of its area. The specific natural conditions in Croatia enabled the optimal growth of pedunculate oak forests. Natural sites of these forests are in the valleys of the Sava, Drava, Kupa, Cesma, Danube rivers and their tributaries, and particularly large forest basins, e.g. Spacva, Pokupsko Cesma and Lipovljani basins. During 1988-89 two provenance trials with 16 pedunculate oak provenances were established in the Spacva and Pokupsko basins. Although pedunculate oak is one of the most important and most valuable forest tree species in Croatia, investigation of the growth of different provenances in nurseries and experimental plots commenced relatively late (Gracan 1986; Komlenovic et al 1988; Gracan et al., 1991; Gracan 1993; Gracan and Peric, 1993; Gracan et al., 1995; Peric et al., 2000). The first provenance tests for Pedunculate Oak in some European countries (Germany, Austria, Denmark) were established at the end of the 19th century and beginning of the 20th (Kientz 1779; Hauch 1909; Burger 1921; Cieslar 1923).
The present investigation is related to the analysis of diameter breast height, height and volume of wood production in 16 pedunculate oak provenances in Croatia with reference to various sites and climatic conditions.

Materials and methods

During 1988-89 two provenence trials with 16 pedunculate oak provenances were established in the Spacva and Pokupsko basins. The Gajno locality is in the Pokupsko basin in the area of the Jastrebarsko Forest Office, Forest Administration of Karlovac, while the Slavir locality is in the Spacva basin in the area of the Otok Forest Office, Forest Administration of Vinkovci. A detailed description of the gathering of acorn samples, sowing, laying out of experimental plots and initial measurings have already been presented in published papers and

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referred to in the Introduction, and therefore they are not presented here. Basic data on the pedunculate oak provenances and experimental plots are given in Table 1 and Figure 1. Measuring of diameter and height was carried out on both localities during the Autumn of 1999 and 2000. An analysis of the volume of wood was peformed for 1997, 1998, 1999 and 2000, while the production of wood volume was analysed for the last three years.

Table 1: The general data about oak provenances

Number	Provenances	Altitude	Longitude	Elevation
1	Motovun	45°20′	13°50′	90
2	Skakavac	45°29′	15°42′	112
3	Orlovac	45°33′	15°44′	112
4	Velika Gorica	45°40′	16°10′	98
5	Novska	45°02′	16°55′	143
6	Lipovljani	45°26′	16°49′	143
7	Okucani	45°11′	17°10′	95
8	Durdenovac	45°34′	18°08′	97
9	Gusevac	45°13′	18°29′	96
10	Spacva	44°56′	18°50′	85
11	Gunja	44°57′	18°49′	86
12	Morovic	45°02′	19°11′	82-85
13	Dubica	45°17′	16°44′	98
14	Zdenacki gaj	45°37′	17°04′	160
15	Kljucevi	45°11′	17°21′	95
16	Vrbanja	45°01′	18°59′	85

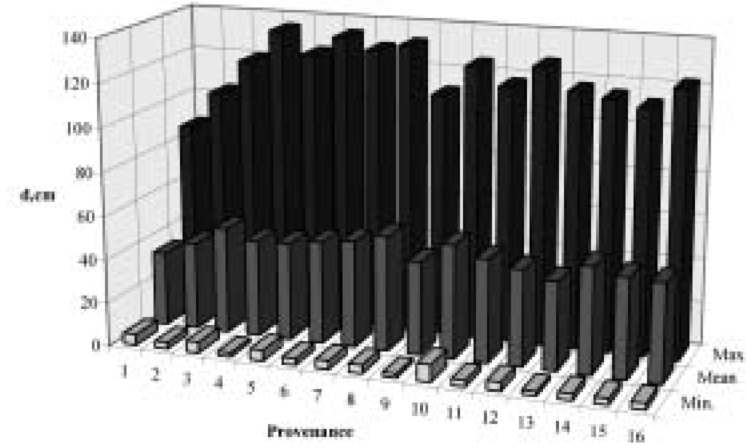

Figure 1. Diameter breast height of Pedunculate Oak provenances at Gajno locality (2000).

Results and discussion

Results of the measuring of diameters and heights on the Gajno and Slavir localities in the Autumn of 1999 and 2000 are shown in Table 2 and Graphs 1 and 2.

According to these data the highest average breast-height diameter was recorded on the Gajno locality in 1999 in the provenances of Durdenovac (47.91 mm), Spacva (47.32 mm), Orlovac (45. 57 mm) and Okucani (44.78 mm). An almost identical order of the provenances can be seen in the data for 2000. The lowest average breast diameters in 1999 and 2000 were recorded in the provenances of Motovun (1999. - 31.72 mm and in 2000. - 34.14 mm) and Skakavac (1999. - 37.28 mm and in 2000. - 40.28 mm). The highest average height on the Gajno local-

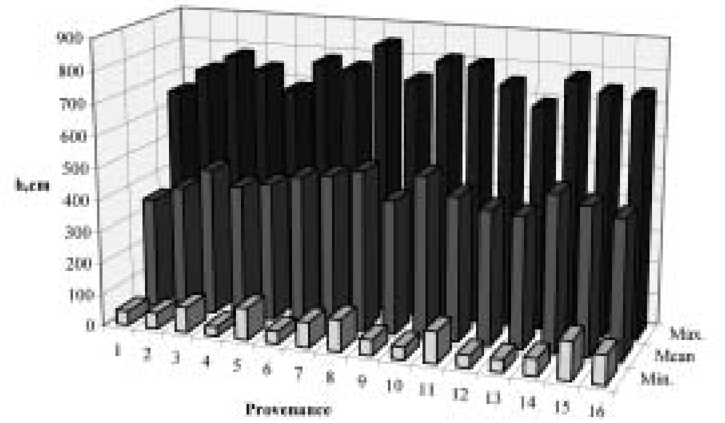

Figure 2: Height of Pedunculate Oak provenances at Gajno locality (2000).

Distribution of 16 pedunculate oak provenainces in experiment and location of field trials

ity in 1999 was recorded for provenances Durdenovac (481.50 cm), Spacva (480.63 cm) and Okucani (466.68 cm), and in 2000 Spacva (507.45 cm), Durdenovac (503.12 cm) and Zdenacki gaj (489.49 cm). The lowest average heights in 1999 and 2000 were recorded for the provenances Motovun (1999 - 321.45 cm and 2000 - 368.56 cm) and Skakavac (1999 - 348.00 and in 2000 -395.25 cm).

The highest average diameter breast height on the Slavir locality in 1999 was recorded for the provenances Gusevac (13.90 mm), Novska (12.92 mm) and Zdenacki gaj (12.45 mm), and in 2000 the provenances Novska (18.44 mm) Gusevac (18.41 mm) and Durdenovac (18.41 mm). In 1999 the smallest diameters were recorded in the provenances Orlovac (9.78 m) and Skakavac (10.80 mm), and in 2000 provenance Motovun (14.47 mm). The greatest average height on the Slavir locality in 1999 was recorded in the provenances of Novska (179.57 cm), Spacva (176.26 cm) and Durdenovac (175.14 cm), and in 2000 the provenances of Novska (190.91 cm), Morovic (190.50 cm) and Durdenovac (190.40 cm). The lowest average heights in 1999 and 2000 were recorded in the provenances of Motovun, Skakavac and Orlovac.

In general, it can be concluded that the height and diameter growth of plants for all provenances is higher on the Gajno locality than on the Slavir locality. In 2000 the average height of all plants on the Gajno locality was 444.30 cm, and on the Slavir locality 180.24 cm, i.e. 264.06 cm less. These results were the consequence of a very severe rodent attack (mice, voles) during 1990, 1991 and 1992. During that period no care or protective measures were possible due to the war.

The climatic conditions are one of the factors that influence growth of pedunculate oak provenances. In Table 3 are data of monthly and annual amount and in Table 4 data of mean, maximum and minimum monthly and annual air temperatures at Meteorological Station Jastrebarsko and Vinkovci.

Data on the volume of wood and wood volume production on the Gajno and Slavir localities are shown in Tables 5 and 6 and Graph 3.

These data show that the volume of wood on the Slavir locality was uniform according to provenences, while on the Gajno locality it ranged from 4.81 m^3/ha (Motovun) up to 14.37 m^3/ha (Durdenovac).

Data on the volume of wood taken on the Gajno locality (1998-2000) show that provenances

Table 3: Monthly and annual amount (mm)

Year	Meteorological Station	Month												
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Yearly
1997	Vinkovci	65,7	38,5	31,3	49,2	28,9	65,4	92,4	39,6	35,6	117,5	48,2	102,7	715,0
	Jastrebarsko	67,4	37,7	24,8	85,9	52,3	133,6	101,5	76,1	45,1	62,9	101,6	97,9	886,8
1998	Vinkovci	101	0,4	30,2	56,9	47,3	88	66	83,5	103	96,7	78,6	39,2	791
	Jastrebarsko	21,9	8,2	36,2	60,2	75	53,3	145	37,7	202	157	81,2	63,7	941
1999	Vinkovci	53,1	54,4	29,9	96,7	59,8	82,4	102	50,9	72,5	39,6	131	124	896
	Jastrebarsko	42,5	85,9	30,4	63,9	143	51,1	154	55,9	64,1	91,4	68,6	106	957
2000	Vinkovci	21,8	17,7	44,5	39,5	30,9	68,4	56,5	4,4	26,4	18,4	23,3	30,6	382
	Jastrebarsko	12,1	24,2	65,4	35	38,5	52,2	78,1	8,1	65,8	182	123	134	819

(Meteorological Station Vinkovci and Jastrebarsko)

Table 4: Mean, maximum and minimum monthly and annual air temperatures

Year	Meteorological Station	Temp. in C	Month												
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Yearly
1997	Vinkovci	Mean	-1,0	4,0	6,5	8,0	18,0	21,1	20,8	20,9	16,5	9,1	6,5	3,2	11,1
		Max.	0,3	9,5	12,0	13,5	23,9	26,7	26,1	27,4	24,0	14,9	9,9	5,9	16,2
		Min.	-2,6	-0,7	1,3	3,1	12,0	14,5	15,3	15,3	9,9	4,4	3,2	0,8	6,4
	Jastrebarsko	Mean	-1,2	3,2	5,9	7,2	16,1	19,3	19,7	19,5	15,2	8,6	4,9	2,3	10,1
		Max.	5,0	18,5	21,5	20,5	30,0	31,0	31,5	30,0	30,0	26,2	22,5	12,6	31,5
		Min.	-10,6	-10,5	-3,5	-4,5	2,1	4,0	9,2	9,0	2,0	-3,0	-7,5	-6,5	-10,6
1998	Vinkovci	Mean	3,3	5,7	5,2	13,0	16,0	21,1	21,6	21,4	15,9	12,4	4,4	-3,0	11,4
		Max.	7,6	12,0	10,8	18,9	21,4	27,4	28,1	28,1	21,7	18,1	8,5	0,5	16,9
		Min.	-0,3	0,3	-0,1	7,7	10,7	15,0	15,5	15,4	11,1	7,6		-6,0	
	Jastrebarsko	Mean	2,6	4,3	4,7	11,9	15,2	19,9	20,7	21,6	15,2	10,8	3,2	-3,9	10,5
		Max.	15,5	23,0	20,5	25,6	29,1	34,2	32,5	34,0	29,0	22,0	19,0	5,4	34,2
		Min.	-8,7	-9,5	-6,0	-1,5	3,2	5,5	7,3	5,0	3,5	-0,4	-8,5	-16,5	-16,5
1999	Vinkovci	Mean	0,3	1,5	8,1	12,6	17,0	19,9	21,4	21,4	18,9	11,8	4,1	0,8	11,5
		Max.	3,6	6,4	13,9	18,1	22,7	25,9	27,4	27,5	25,7	17,8	7,2	4,8	16,8
		Min.	-2,7	-3,0	3,0	7,3	10,8	13,7	16,2	14,8	13,2	7,0	1,7	-3,1	6,6
	Jastrebarsko	Mean	1,7	0,8	7,6	11,1	16,1	19,2	20,8	20,3	17,8	11,3	3,1	0,5	10,9
		Max.	13,0	19,1	20,5	25,0	31,0	30,0	34,5	33,0	29,5	25,5	21,0	13,0	34,5
		Min.	-6,0	-14,5	-2,0	-0,6	6,2	7,6	12,5	10,0	8,8	1,0	-11,2	-14,0	-14,5
2000	Vinkovci	Mean	-1,9	3,9	6,9	14,8	17,8	21,7	21,6	23,9	17,0	14,2	10,2	3,1	12,8
		Max.	1,8	9,9	13,1	21,1	25,0	28,6	28,1	31,2	23,0	20,9	16,8	7,9	18,9
		Min.	-4,9	-1,0	0,8	8,3	10,3	12,7	14,5	15,3	10,7	7,9	5,4	-0,4	6,6
	Jastrebarsko	Mean	-2,2	3,8	6,7	13,4	16,3	20,7	19,8	22,1	16,0	12,4	8,8	4,4	11,8
		Max.	15,5	18,6	20,1	29,0	30,5	36,0	35,0	38,0	29,5	25,7	23,5	18,2	38,0
		Min.	-20,5	-7,5	-5,5	-1,5	1,5	7,0	6,5	9,5	5,2	-0,6	-2,0	-9,5	-20,5

(Meteorological Station Vinkovci and Jastrebarsko)

Table 5.: Volume of wood at Gajno and Slavir locality (2000)

No.	Provenance	Volume of wood, m³/ha	
		Slavir	Gajno
1	Motovun	6,28030	4,80736
2	Skakavac	6,27635	7,18283
3	Orlovac	6,28598	12,40809
4	Velika Gorica	6,27955	9,18361
5	Novska	6,29966	9,54573
6	Lipovljani	6,27886	12,05566
7	Okucani	6,28682	12,31677
8	Durdenovac	6,31167	14,37286
9	Gusevac	6,28174	8,95909
10	Spacva	6,30192	13,74915
11	Gunja	6,31325	11,51916
12	Mitrovica	6,30464	9,86934
13	Dubica	6,29290	7,71440
14	Zdenacki gaj	6,31025	12,27480
15	Kljucevi	6,28568	9,34954
16	Vrbanja	6,28614	9,80570
	Mean	6,29223	10,31963

Durdenovac, Spacva, Orlovac and Zdenacki gaj have the largest volume of wood. Wood volume production varies each year and it ranges from 2.08 m³/ha (2000) to 2.76 m³/ha (1999). The best results were recorded in the Durdenovac provenance during the period of monitoring the production of wood volume (1998 - 3.41 m³/ha, 1999 - 4.16 m³/ha, 2000 - 2.91 m³/ha.

In Croatia the research of production of wood volume hasn't been done jet. Due to the fact that the observation of growth still continues in 2001, the processing and testing of the obtained results will be carried out upon finishing observation.

Conclusions

Based on the results so far of an investigation on the growth of pedunculate oak provenances on the Gajno and Slavir localities, related to 15 year old plants, the following can be concluded:

- Greater average heights and diameters were recorded for the Pedunculate Oak provenances on the Gajno locality. In 1999 the best average heights on the Gajno locality were rercorded for provenanceas of Durdenovac (481.50 cm), and in 2000 provenances of Spacva (507.45 cm). The provenances of Motovun and Skakavac had the lowest average heights on both localities.
- The greatest average diameters on the Gajno locality during the period of monitoring were recorded for the the provenances Durdenovac and Spacva, while the smallest were recorded in the provenances of Motovun and Skakavac.
- Volume of wood on the Slavir locality is uniform according to provenances , while on the Gajno locality it ranged from 4.81 m³/ha (Motovun) to 14.37 m³/ha (Durdenovac). Production of volume of wood varies each year, ranging from 2.08 m³/ha (2000) to 2.76 m³/ha (1999). The Durdenovac provenance achieved the greatest increase in the volume of wood during the years (1998 - 3.14 m³/ha, 1999 - 4.16 m³/ha, 2000 - 2.91 m³/ha).

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7. Clonal technology - Nursery and plantation Advancementsin ITC Bhadrachalam, India.

*H. D. Kulkarni**

Abstract

At ITC Bhadrachalam, a modern clonal nursery with an annual production capacity of 3.3 million eucalyptus plants is established with indigenous technological know how at mill premises. The vegetative propagation protocols through mist propagation are standardized. From 1989 till this year, 613 plus trees are selected from provenance trials and farm forestry plantations and are cloned. The propagation facility includes 19 mist chambers covering 1944 m^2 area. Nearly 950 m^2 space is provided for shade house and 16,600 m^2 for open clonal nursery. The gene bank for 613 clones is established in 23 ha area. There are 123 clonal testing trials covering 29 ha area at various sites from where the 86 promising clones in respect of growth, disease resistance, wood properties and tolerant to adverse sites and wind are short listed for commercial production. For normal soils, 59 clones are selected and for alkaline soils 37 clones are selected. The productivity of Eucalyptus "Bhadrachalam" clones range from 22 to 58 m^3/ha/yr compared to 6 to10 m^3/ha/yr from seedling origin plantations. Another significant achievement is that the rotation period is reduced by half.

This paper discusses the development of clones through vegetative propagation and root trainer technology, evaluation through clonal testing and required package of practices for plantations for achieving high productivity.

Keywords: clonal propagation, package of practices, performance, productivity, rotation and hybridization.

Introduction

Development of both hard wood and soft wood fast growing and high yielding tree cultivars has been in progress world over for more than 30 years (Arnold, 2000). The result is significant. The Genera most widely exploited have been various species of Eucalyptus, Pines, Acacias, Casuarina, Lucaenea, Paulownia etc. In case of Acacias the hybrid clones developed have given average yield of 30 m^3/ha/yr in Indonesia and Vietnam. The best six clones gave an MAI of 44 m3/ha/yr while the worst clone gave MAI of 17.5 m3/ha/yr (Nguyen, 2000). Nearly, 20 superior clones have been selected for Paulownia in China. (Zhang, 2000).

The country with largest plantation resources now is Brazil where hard wood plantations cover 2.5 million hectares and soft wood plantation 1.5 million hectares raised with high yielding tree cultivars. This development of short rotation woody crops for commercial purpose has given three main advantages to the pulp and paper industry *viz.* Low cost, reliability and sustainability of wood supply and uniformity of biological material i.e. pulp wood.

Materials and methods

The experimental site and clonal research station of ITC Bhadrachalam Paperboards Ltd., is located at 17°40′ N latitude and 81° E longitude. The altitude is 100 m and the climate is

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sub-tropical with annual rainfall of 1033 mm mostly from southwest monsoon. The maximum temperature is 49° C and minimum 10°C. The soil types are red sandy and black cotton and are either normal or alkaline and saline.

Plus trees of Eucalyptus mainly *E. tereticornis* and *E. camaldulensis* are selected in Government forest plantations and were propagated vegetatively in mist chambers. Successful ramets were planted in clonal testing areas (CTA) and in Gene banks / Clonal multiplication areas (CMA). The spacing adopted mainly is 3 x 2 m with RBD for CTA`s while 1 x 1 m for CMA`s. Short listing of promising clones for growth and disease resistance was attempted. Clonal demonstration plots (CDP) were raised under extension scheme to convince the growers about growth and performance of the clones. Clonal seed orchards (CSO) were raised for obtaining improved seed. Inter and Intra specific hybridization is carried out between selected best clones and other species like *E.grandis, E.urophylla, E. alba, E.torreliana*. Half-sib and Full-sib progeny trials were laid out and hybrids selected for cloning. Genotype X Site interaction studies of various clones and hybrids were carried out on normal and refractory sites for choosing the best adopted clones.

Results and discussions

Clonal technology research and development

With a mission to achieve substantial improvements in productivity and profitability of plantations and secure future raw material supplies on cost effective basis, the company implemented a major research and development project since 1989 focussed on genetic improvement of planting stock and improvement of package of practices. Major gains in productivity of eucalyptus plantations have been achieved in short time span of 11 years through applications of cloning techniques for gainful exploitation of existing useful variation.

Candidate Plus Tree Selection

For development and commercial scale deployment of clones, the programme aimed at selecting the most desirable tree with factors of great importance such as straightness of the tree stem, annual growth rate, disease, insect and wind resistance, apparent adaptability to refractory sites, crown structure, wood density, fiber morphology, cellulose/lignin balance, bark to solid wood under bark relationships etc.

Starting with cloning of 64 number of CPTs during 1989, more than 613 CPTs have been cloned by now.

Vegetative Multiplication

Leafy stem internodal cuttings from 50 to 60 days old juvenile coppice shoots treated with 6000 PPM of Indole Butyric Acid were used for rooting under controlled environment in the green houses with relative humidity of 70 % and temperature range of 35 to 40°C.

Clonal Testing and Promising Clones

Clones were evaluated from CTAs for comparative genetic superiority and short listing of promising clones was made. Nearly, 123 trial plots in 29 ha area were established since 1989 in various soil types (G x E interaction). The promising clones 86 in number were short listed consisting of specific groups of genetically superior clones most adaptable to problematic sites such as alkaline and calcareous black cotton soils apart from clone suitable for normal soils (plastic clones). The most important 37 commercial clones are 3, 6, 7, 10, 27, 71, 72, 99, 105, 115, 122, 128, 130, 223, 265, 266, 271, 272, 273, 274, 275, 277, 284, 285, 286, 288, 290, 292, 316, 319, 405, 411,412,413,417, 439 and 470.

The most adaptable clones for alkaline black soils are 1, 10, 27, 71, 99, 105, 115, 116, 122, 128, 130, 158, 223, 266, 271, 272, 273, 274, 277, 290, 316, 318, 328, 410, 411, 412, 413, 417. The plastic clones are 10, 27, 71, 83, 99,105, 116, 128, 130, 147, 271, 285.

Productivity of clones

The productivity range of "Bhadrachalam clones" of Eucalyptus (trade / brand name) is from 10 to 58 m3/ha/yr compared to 6 to10 m3/ha /yr of normal seedling origin plantations (Tables 1 - 3, Figures 1 and 2). Another significant achievement is that the rotation period is reduced by half. Because of high growth, farmers fell plantations at 4 to 5 year's age. The survival percentage of clonal plantations was more than 95 per cent (Kulkarni and Lal, 1995).

Table 1: Productivity of promising clones

				Species and serial numbers of shortlisted clones					
CTA n°	pH	EC (millimhos /cm)	Shortlisted clones number	Eucaliptus tereticornis	Eucaliptus camaldulensis	Control pollinated hybrid	Mysore gum	Productivity range MAI vol. (m^3/ha/yr)	Age (years)
1	7,4	0,118	8	1, 3, 4, 5, 6, 7, 8, 10	-	-	-	19-43	10
2	6,75	0,068	2	-	-	-	27, 52	30-33	5
5	7,35	0,078	5	71	-	-	99, 128, 130, 142	12-21	6
7	7,35	0,078	1	-	-	-	105	21	6
8	4,35	0,078	1	-	-	-	147	12-24	6
10	6,22	0,077	5	-	-	-	113, 115, 119, 124, 128	13-21	6
11	6,22	0,077	3	158,159	-	-	84	17-22	6
12	6,7	0,093	1	-	-	-	165	16	7
19	8,6	0,7	1	-	-	236	-	24	6
20	7,9	0,209	2	222	-	-	116	18-21	4
21	-	-	11	288, 289, 284, 285, 274, 275, 277, 271, 269, 276, 268	-	-	-	21-34	5
22	-	-	6	72, 272, 292, 290, 291	-	-	226	24-28	6
23	-	-	6	266, 273, 265, 289, 267, 287	-	-	-	26-58	6
32	-	-	6	316, 315, 314	-	-	323,353,354	14-33	5
33	7,2	0,144	2	223	-	-	356	24	4
34	7,2	0,144	5	318, 319, 317	-	-	326,355	13-24	4
35	7,2	0,144	9	404, 405	409, 410, 411, 412, 413, 417	-	399	12-23	4
37	7,2	0,144	4	-	458, 459	-	438, 439	12-17	4
38	7,87	0,39	1	-	-	-	83	11	3
39	7,87	0,39	1	-	-	-	351	17	3
40	7,87	0,39	3	-	407	-	433, 359	15-19	3
44	7,87	0,39	2	-	-	-	470, 469	10-16	3
Total			**85**	**43**	**9**	**1**	**32**	**11-58**	**3-10**

Note: CTA nos 1, 2, 20, 21, 22, 23, 32, 34, 35 and 37 planted at Bhadrachalam; 5,7 and 8 at Maripalem; 10 and 11 at Cherupally; 12 at Narasingapeta; 19 at Medikondoru; 39,39 and 40 at Santhravuru

Table 2: Year wise growth data for CAI and MAI (clonal testing area 1, location – Bhadrachalam; date of planting – 24.9.89; age – 10 years)

Sl no	clone no	CAI (UB-Vol/Ha) Year									MAI (UB-Vol/Ha) Year									GB cm	HT m	10 th Year data		Survival %
		1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9			CAI	MAI	
1	6	12	27	47	29	29	75	58	75	35	12	20	29	29	29	36	39	44	43	58	27	46	43	100
2	10	10	18	38	32	23	69	45	65	28	10	14	22	25	24	32	34	38	37	56	26	40	37	96
3	3	12	18	48	24	26	62	34	55	22	12	15	26	26	26	32	32	35	34	55	25	33	33	96
4	5	6	10	20	17	17	49	45	41	38	6	8	12	13	14	20	23	26	27	50	23	39	28	100
5	7	10	15	32	11	22	55	35	43	21	10	13	19	17	18	24	26	28	27	50	25	25	27	89
6	4	7	13	26	12	21	50	32	41	22	7	10	15	14	16	22	23	25	25	47	25	22	25	96
7	1	9	13	28	17	16	45	30	31	17	9	11	16	17	16	21	22	24	23	49	24	20	22	81
8	8	9	22	44	21	12	52		21	6	9	16	25	24	22	27	22	22	20	48	25	7	19	74
9	9	9	12	19	10	9	30	14	27	20	9	11	13	12	12	15	15	16	17	43	20	15	16	89
10	2	6	5	9	11	7	23	11	18	5	6	6	7	8	8	10	10	11	11	35	18	9	10	100
11	22	5	4	10	7	8	18	8	16	3	5	4	6	6	7	9	8	9	9	36	15	8	9	93
12	15	6	6	10	5	5	12		7		6	6	7	7	6	7	6	6	5	28	14	1	5	89
13	23	5	2	8	3	3	10	2	9	6	5	3	5	4	4	5	5	5	5	27	13	2	5	100
14	19	5	3	6	6	2	7	3	5	2	5	4	5	5	4	5	5	5	4	26	13	1	4	85
15	21		6	5	10	2	2	8	2	4		6	5	7	6	5	6	5	5	4	25	13	3	81
16	24	5	2	6	2	2	7	4	5		5	4	4	4	3	4	4	4	3	24	13		3	81
17	49	6	5	7	2	4	9		6		6	5	6	5	5	5	5	5	3	25	13		3	81
18	47		7	8	12	3	6				7	7	9	7	7									
19	20	10	15	8	4	5					10	13	11	9	8									
MEAN	8	11	20	11	12	34	23	28	17	8	9	13	13	12	16	17	18	17	40	19	19	17	90	
S.D. +/-	2	7	15	9	9	24	19	23	12	2	5	8	8	8	11	12	13	13	13	6	16	13	8	
C.V.	31	68	73	83	78	70	82	82	71	31	52	61	65	66	67	71	72	75	31	29	81	77	9	

Abbreviations: CAI = Current annual increment / ha in cubic meters under bark; MAI = Mean annual increment / ha in cubic meters under bark; GBH = Girth at Breast Height in centimeters; Ht = Height in meters; Vol/ha = Volume per hectare in cubic meters under bark; UB = Under Bark.

Notes:

a. Volume in cubic meters (without bark) calculated based on Regression Equation V = 0.00258 + 0.0281 GxGxH
b. Data arranged in descending order of MAI as per last assessment
c. Spacing 3 x 2 m
d. Number of saplings planted per treatment is 9 with 3 replications.
e. Species: Eucalyptus tereticornis clone numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10; Mysore gum clones numbers 15, 19, 20, 21, 22, 23, 24, 47, 49.
f. Clones number 47 and 20 were highly diseased and were uprooted during the 6th year.
g. Shortlisted promising `Bhadrachalam clones number 1, 3, 4, 5, 6, 7, 8, 10.
h. Blank spaces in 7,8,9 and 10 years CAI column are because of no increment during previous years

Table 3: Year wise growth data for CAI and MAI (clonal testing area 21, location - Bhadrachalam, date of planting –1.12.93, age – 6 years).

Sl no	clone no	CAI (UB-Vol/Ha) Year					MAI (UB-Vol/Ha) Year					6 th Year data				
		1	2	3	4	5	1	2	3	4	5	GB cm	HT m	CAI	MAI	Survival %
1	6	14	44	33	47	51	14	29	30	34	38	53	18	38,1	37,8	93
2	286	11	35	31	44	49	11	23	26	30	34	50	18	45,1	35,9	100
3	288	11	30	32	50	49	11	20	24	31	34	50	18	40,8	35,3	100
4	284	11	35	28	48	45	11	23	25	31	33	48	18	33,2	33,4	100
5	285	13	35	28	38	44	13	24	26	29	32	48	17	29,7	31,3	100
6	3	20	46	26	35	29	20	33	31	32	31	45	18	16,8	28,8	100
7	277	10	32	28	34	39	10	21	23	26	29	47	15	26,7	28,3	100
8	275	10	29	28	38	36	10	20	23	26	28	45	17	26,4	28,1	100
9	274	13	34	27	32	35	13	23	25	27	28	44	17	18,1	26,5	100
10	271	13	34	25	32	26	13	23	24	26	26	43	17	17,3	24,5	96
11	269	11	32	23	25	29	11	21	22	23	24	43	16	22,1	23,8	100
12	276	9	30	18	30	30	9	19	19	22	23	43	16	23,9	23,5	96
13	268	11	29	23	22	22	11	20	21	21	21	40	16	14,8	20,3	96
14	283	10	27	16	18	24	10	19	18	18	19	38	15	11,7	17,9	100
15	270	10	24	18	22	21	10	17	17	18	19	37	15	10,8	17,5	100
16	S C	7	15	9	12	7	7	11	10	11	10	31	13	3,2	8,9	85
MEAN			32	25	33	34	12	22	23	25	27	44	16	24	26	98
S.D +/-		3	7	6	11	12	3	5	5	6	7	5	2	12	8	4
C.V		23	23	26	34	36	23	22	22	25	27	12	9	49	29	4

Abbreviations: CAI = Current annual increment/ha in cubic meters under bark; MAI = Mean annual increment/ha in cubic meters under bark; GBH = Girth at Breast Height in centimeters; Ht = Height in meters; Vol/ha = Volume per hectare in cubic meters under bark; UB = Under Bark.

Notes:

a. Volume in cubic meters (without bark) calculated based on Regression Equation V = 0.00258 + 0.0281 GxGxH

b. Data arranged in descending order of MAI as per last assessment

c. Spacing 3 x 2 m

d. Number of saplings planted per treatment is 9 with 3 replications.

e. Species: Eucalyptus tereticornis clone numbers 3,6,269,270,271,274,268,275,276,277,283,284,285,286,288.

f. Shortlisted promising `Bhadrachalam clones number 288,286,284,285,277,275,274,271,269,276,268.

g. Soil type is red soil

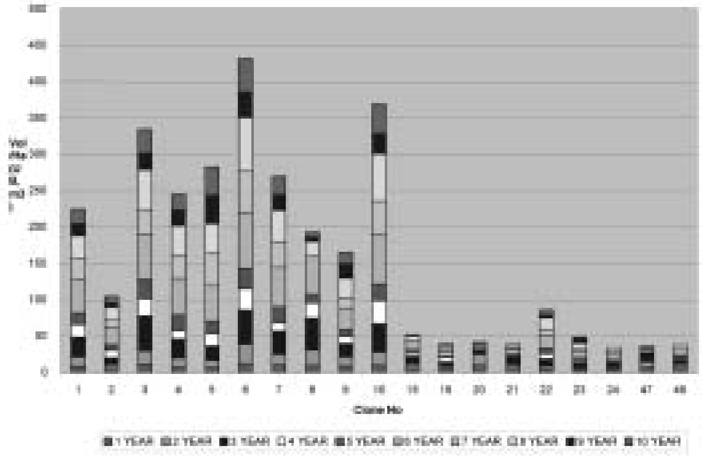

Figure 1: Current Annual Increment: CTA 1, Age: 10 Years Location - Bhadrachalam.

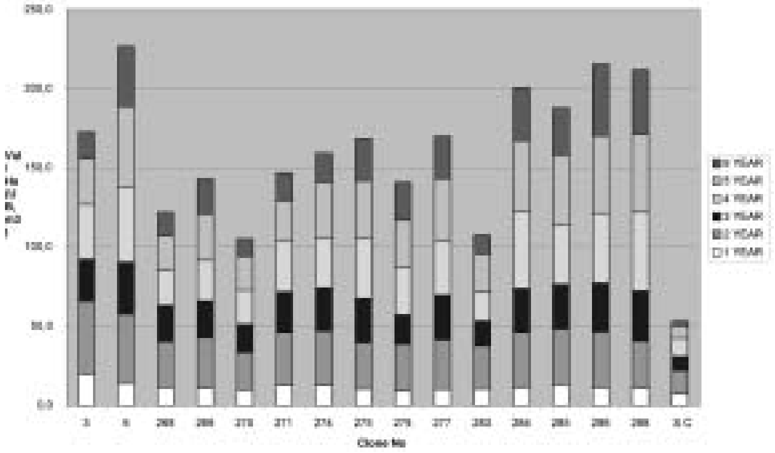

Figure 2: Current Annual Increment: CTA 21, Age: 6 Years Location - Bhadrachalam.

Clonal Multiplication Areas (Gene bank)

Gene banks were established on 23 ha area consisting of 2 lac ramets since 1989. Clones were planted in blocks and coppiced at 2 years age for obtaining the propagules for regular multiplication. The gene banks were irrigated and fertilized to maximize the production of coppice shoots.

Clonal Demonstration Plots

Clonal demonstration plantations raised by the company resulted in large-scale adoption of genetically superior "Bhadrachalam clones" of eucalyptus by the farmers and State Forest Departments / Forest Development Corporations. Since 1989, 24 ha of clonal demonstration plots were established.

Clonal Seed Orchards

Two plots of clonal seed orchards covering 0.71 ha have been planted with best "Bhadrachalam clones" of Eucalyptus for production of genetically improved seed. The design adopted was permutated neighbor hood with single and double ring isolation for the CSO. Yearly, 5 to 10 kgs of improved seed is being collected and distributed to growers. CPT selection is being made from plantations raised from CSO seed for obtaining next generation clones.

Hybridization

Several intra-specific hybrids have been developed through controlled pollination between selected best clones of *E. tereticornis* Smith. Development of inter-specific hybrids such as *E. tereticornis* Smith. x *E. urophyla* Blake.; *E.tereticornis* Smith. x *E.grandis* Muell.; *E. tereticornis* Smith. x *E. camaldulensis* Dehnh.; and *E. tereticornis* Smith. x *E.alba* Reinw.

Controlled breeding is undertaken to achieve required goals in order to eliminate defects and to add disease resistance characters. Clones, which have well defined traits and are included in breeding programme such as

Clones with clear bole: 1,4,6,7,27,122,223,265,266,274,275,284,286,288.

Clones with high productivity 3,6,7,10,105,130,265,266,272,274,284, 286,288, 292, 316,319.

Clones adaptable to refractory site 1,10,71,105,115,116,128,130,223,266,271,272, 274,285,290,316,405,411,413.

Clones for disease resistance 1,3,6,7,288,316.

Nearly, 100 seedlings for each successful crosses were planted and 3 to 4 best progeny per family are selected for cloning.

Some of the control-pollinated hybrids have shown good heterosis at 1 to 2 years age (Table 4) and such plants have been cloned for field trials to select superior hybrid clones for commercial scale multiplication for raising future plantations. Nearly, 212 hybrid clones are presently under field evaluation.

Table 4: Performance of Hybrid clones

Sl. number	Clone number	Age years	MAI Vol/ ha
1	2023	1.5	16.19
2	2001	1.5	16.01
3	2014	1.5	13.71
4	2045	1.5	12.71
5	2004	1.5	12.70
6	2005	1.5	12.54
7	2011	1.5	12.17
8	2018	1.5	12.11
9	2012	1.5	12.07
10	2003	1.5	11.56
11	2013	1.5	10.98
12	2040	1.5	10.76
13	2028	1.5	10.58
14	2036	1.5	10.48
15	2046	1.5	10.45
16	2015	1.5	10.34
17	2041	1.5	10.30
18	130	1.5	9.85
19	6	1.5	8.88

Abbreviations: MAI = Mean annual increment; Vol/ha = Volume per hectare in cubic meters under bark.

Nursery infrastructure

Presently, there are 19 mist chambers having a production capacity of 3 million plants per annum. The total area of nursery is 3 ha (1944 m^2 mist chamber area, 950 m^2 hardening chamber area, 10600 m^2 open nursery area and 16600 m^2 buildings and other facility).

Clonal planting stock of Eucalyptus is raised in this nursery using vermiculite as the growing medium. Moulded plastic trays (Root trainers) with 20 to 40 built in cavities are used as containers for growing clonal nursery plants. There are vertical ribs in each of the container cavities for prevention of coiling of the roots. These containers are supported on suitable benches in the nurseries for facilitating self-pruning of roots, good aeration, easy handling and sprinkler irrigation. These containers also facilitate multi-tier-loading arrangements in trucks for transport of clonal planting stock for cost-effective deliveries at the farmers' fields. Nearly, 20 thousand plants per truck are transported easily.

Fungal Diseases encountered in the nursery and plantations are caused by the following fungi. *Cylindrocladium spp.; Alternaria spp.; Chaetomella spp.; Curvularia spp.;Pesalotiopsis spp.; Glomerella cingulata. ; Dreschlera spp.; Heliminthosporium spp.; Macrophomina spp. ; Fusarium spp.; Sclerotium spp.; Rhizoctonia spp.; Phomopsis spp.; Gynoderma lucidum; Helicobasidium spp.*

Following insects were recorded damaging the young (1 to 2 years old) eucalyptus plantations. *Batocera rufomaculata; Apriona germarii; Inderabella quadrinotota; Xyloborous spp.; Mites,* Aphids and Psyllids .

Mycorrhiza

Useful Mycorrhizal associationin eucalyptus plantation was found with *Physolithus tinctorius* (Ectomycorrhiza).

The Company developed improved package of practices for raising and maintenance of clonal eucalyptus plantations and demonstrated benefits of the same to the farmers. Study of soil profiles and analysis of soil samples is carried out to match adaptable clones to the planting sites.

I. Handling of clonal planting stock

1. Minimum age of the clonal planting stock should not be less than 3 months.
2. 0.2% Bavistin or Captan spray should be carried out on all clonal saplings shortly before they are transferred to containers for despatch.
3. Clonal plants should be issued only after getting confirmation that the site and the planting pits are absolutely ready.
4. Light irrigation of the plants should be arranged on arrival of the clonal planting stock at the planting sites and kept under partial sun light. Avoid congestion of plants and provide good aeration.

II. Site selection and preparation

5. It is absolutely mandatory to study soil profiles, pH and electric conductivity of soils before deciding to raise clonal plantations. Areas with shallow soils less than 1 m in depth or those with strong calcareous or lateritic pans must be avoided. Likewise, areas with high alkalinity or salinity must not be planted. Generally the pH should be less than 8.5 and electric conductivity less than 2 millimhos/cm. Highly eroded sites or lands subjected to heavy water logging must also be avoided.
6. Planting sites must be extremely well prepared by deep ploughing in either direction followed by harrowing.
7. The recommended spacing for clonal plantations is 3 x 2 m. In case of slope or undulating terrain, the 3 m rows should be along with contour. In case of level plane areas, the 3 m wide spacing should be in the east and west direction and 2 m spacing in the north to south direction. This will ensure better exposure to sunlight through 3 m wide inter spacing. Ploughing in between the lines in such cases will be in the north-south direction. However, in the coastal districts subject to winds, the 3 m wide spacing should be parallel to the prevalent wind direction. This will ensure exposure of minimum number of trees to the onslaught of direct strong winds. Clones susceptible to wind breaks should not be planted in the coastal areas.
8. Each farmer must be encouraged to plant minimum 3 or preferably more "Bhadrachalam clones" in separate blocks of each year's planting area.

III. Planting operations and maintenance

9. Planting pits must not be less than 30^3 cms. There should be no weeds in the soil around the planting pit. The dug out soil, which will be used for refilling at the time of planting, must be treated with 3ml of Chloropyriphos (CPP) in 1 litre of water to prevent damage to the young clonal saplings by termites. Repeated application of CPP is given to avoid termite damage.
10. Refill the planting pit with treated soil upto 5 cms level. Hold the clonal sapling in an upright position in the center of the planting pit in such a way that lowest roots or the mass of vermiculite is 2 cms above the level of soil in the planting pit. Holding the sapling in this position, the treated soil should be refilled into the pit and gently compacted. After compaction, about 7.5 cms of the pit should remain unfilled for irrigation and holding rainwater. In case of black cotton soils, aforesaid procedure should be modified. Irrigation water is added to the planting pit after refilling the pit upto 5 cms level. No compaction should be carried out after completing the transplanting operations. Only 5 cms upper part of the pits should be left unfilled to retain irrigation / rain water.
11. Irrigation or pot watering at 7 – 10 days interval will be required till establishment of the transplanted clonal saplings in case of inadequacy of natural rains.
12. As most of the soils are deficient in phosphorous and nitrogen, 100 gms of single superphosphate and 25 gms of urea should be mixed thoroughly with the entire dug out soil, which can then be used for refilling the pit at the time of transplanting the clonal saplings. Alternatively, 50 gms diammonium phosphate (DAP) can be used per plant in the same manner. After the establishment of plants, first dose of nitrogenous fertilizer can be given as top dressing, after weeding, @ 25 gms urea per plant. Any chemical fertilizer placed close to the stem may dehydrate and kill the plant.
13. Farmers should be encouraged to apply farmyard manure to the entire field or raise green manure crops for ploughing back into the fields. Application of Farm Yard Manure and 25 kg/ha zinc sulphate will be helpful to minimise incidence of chlorosis in marginally saline soils.
14. Young plants are very sensitive to competition from weeds. At least three weedings, in 50 cms radius around the plants will be required every year during the first 3 years.
15. Ploughing in between the 3 m wide rows of plants will help improve soil aeration, moisture conservation and control the weeds. During first year, plough the 3 m wide strips after harvest of intercrops and arrange second ploughing at the end of monsoon rains. During subsequent years, one ploughing after the first monsoon showers and sowing of green crops like sunhemp is recommended. Green manure crop should be incorporated into the soil by ploughing just before flowering.

IV. Protection of plantations

16. The farmers must be explained that rigid protection of plants against damage by cattle is absolutely necessary. No grazing should be permitted. Likewise, prevention of damage to the plants during the ploughing operations should also be ensured. Normal ploughing should be only in one direction in the 3 m wide strips.
17. All "Bhadrachalam clones" are self-pruning. No pruning of the branches should be carried out.

V. Best time for transplanting

18. Beginning of the monsoon rains is the best time for transplanting. However, if assured irrigation facilities are available, transplanting can be carried out any time during the year. No transplanting is advised during the extremely hot summer period between April to June.

Clonal Plantation growth

Eucalyptus clonal plantations promoted by the Company between 1992-2000 benefited 2500 farmers who planted 7.6 million saplings covering 4300 ha. In addition, 1.85 million saplings of "Bhadrachalam clones" have been supplied to State Forest Departments / Forest Development Corporations during 1992-2000 which now form the basis of clonal Eucalyptus plantations in those states. From 1992 to 2000, nearly 9.5 million clonal plants were supplied and 5869 ha planted in India. Nearly 8000 ha degraded forest areas have been planted with "Bhadrachalam clones" of Eucalyptus by A.P. Forest Development Corporation. The total figure for clonal plantation of Eucalyptus in India is around 20,000 ha.

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8. Polyphenols determination in leaves of different populations of *Milicia excelsa* (Welw.) C.C. Berg

M. Innocenti[1], M. Michelozzi[2], N. Mulinacci[1], A. Ragazzi[3], E. Silvestrini[2] and F. F. Vincieri[1]

Summary

Milicia excelsa (Welw.) C.C. Berg is an important species for timber production and reforestation purposes in west Africa.
Polyphenols, as secondary compounds, are found in both conifers and broadleaves and the concentrations of these substances vary among populations, families and clones. Phenolics are involved in the defence chemistry of the plants and these compounds can affect the suceptibility of the tree to the attack of insects and fungi.
The purpose of this preliminary phytochemical investigation on fresh leaves, was to determine the geographic variability of different populations of *M. excelsa*.
Leaves were collected from seedlings that represent three characteristic natural areas in Ghana, Sierra Leone and Cote d'Ivoire. A preliminary screening was carried out by High Performance Thin-Layer Chromatography (HP-TLC) analysis. This methodology allowed to easily compare the polyphenolic content of total raw extract of the leaves.
The chemical structure of the main compounds was detected by means of High Performance Liquid Chromatography/Diode Array Detector (HPLC/DAD) and High Performance Liquid Chromatography/Mass Spectrometry (HPLC/MS).
Our preliminary results show that the phenolic composition varied between the provenances and that phenolic markers could be an useful tool for selection of ecophysiologically adapted indigenous genotypes for sustainable timber production.

Keywords: *Milicia excelsa*, timber production, biochemical marker, polyphenol.

Introduction

Milicia excelsa (Welw.) C.C. Berg (*Chlorophora excelsa* (Welw.) Benth, & J.D. Hook) is an important species for timber production and reforestation purposes in West Africa.
The wood, commercially known as Iroko, is largely used for local and foreign markets (Irvine, 1961).
Polyphenols, as secondary metabolites, are widely diffused both in conifers and broadleaves and the quali-quantitative content of these substances vary among populations, families and clones. However, major emphasis has been placed on the flavonoids that have been largely used as markers in biochemical systematics (Santos and Salatino 2000, Harborne, 1988).
Phenolics and particularly specific flavonoids are also involved in the defence chemistry of the plants since these compounds can affect the susceptibility of the tree to the attack of insects and fungi (Croteau *et al.*, 2000). Therefore, phenols may offer opportunities to select less susceptible chemotypes to pest and diseases.
The purpose of this study was to determine utility of phenols as biochemical markers in defining the geographic variability of different populations of *M. excelsa* since to our knowledge no information are reported on literature on the phytochemical aspects of this plant.
This work reports preliminary findings relating to the quali-quantitative contents of polyphenols in the fresh leaves of *Milicia.*

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Materials and methods

The experiment was conducted on seedlings that represent three characteristic natural areas in Africa. Leaves were collected from 28 seedlings from Ghana, 4 from Sierra Leone and 7 from Cote d'Ivoire.

All the samples of *M. excelsa* leaves were extracted with 5 ml for gram of EtOH/H_2O (pH=2 by HCOOH) 7:3 v/v. The hydroalcoholic extracts were analysed by HP-TLC, HPLC/DAD and MS techniques.

HP-TLC Analysis

The screening by mono-dimensional HP-TLC analysis was performed using a vertical separating chamber. The plate was 5x5 cm Silica gel 60 F_{254} (Merck, Darmstadt, Germany). The runs were developed using the following eluent: EtOAc/CH_3COOH/HCOOH/H_2O 100:11:11:26 v/v.

The spots were detected after spraying with a 1% methanolic diphenilboric acid complex with ethanolamine followed by 5% ethanolic polyethylene glycol (PEG 4000) and observing the fluorescence at 365 nm (Wagner, 1996).

HPLC-DAD Analysis

The analyses were carried out on three samples representative of the three geographic areas by using a hp 1090L liquid chromatograph equipped with a DAD detector (Hewlett & Packard, Palo Alto, ca, Usa). Column was Luna’ C18 (5mm) (Phenomenex, Germany) equipped with a 4x3.0 mm id C18 precolumn. The oven column was maintained at 26°C. The eluents were H_2O (ph 3.2 by H_3PO_4) and CH_3CN. A multistep linear solvent gradient was used starting from 100% H_2O (adjusted to pH 3.2 by H_3PO_4) up to 100% CH_3CN, during a 45-min period. The flow rate was 0.6 mL min^{-1}. UV-Vis spectra were recorded in the range 190-450 nm, and the chromatograms were acquired at 254, 280, 330 and 350 nm.

HPLC-MS Analysis

MS spectra were performed using a HP 1100 MSD API-electrospray coupled with a HP 1100L liquid chromatography equipped with a DAD detector (Hewlett & Packard).

Negative and positive ionisation modes were used with a gas temperature of 350° C, nitrogen flow rate of 10.0 L/min, nebulizer pressure 30 psi, quadrupole temperature 30° C, capillary voltage 3500 V. The applied fragmentors were in the range 80-150 V.

The orthogonal position of the nebulizer with respect to the capillary inlet allowed the use of the same conditions of HPLC/DAD analysis with H_2O adjusted to pH 3.2 by HCOOH.

Quantitative determination

Quantitation of the main compounds was directly performed by HPLC-DAD using a three-point regression curve ($r^2 \geq 0.999$). Calibration of quinic and kaempferol derivatives was performed at 330 nm and 350 nm using chlorogenic acid and kaempferol-rutinoside as reference compounds, respectively. The content of the identified quinic esters and kaempferol glicosides were calculated applying corrections for molecular weight with respect to the standards.

Results and discussion

HP-TLC pointed out remarkable quali-quantitative difference in between all the samples from the three geographic areas. After this screening the more representative samples for each areas, were analysed by HPLC/DAD technique and HPLC/MS techniques in order to obtain more information on their chemical structures.

Figure 1a shows a zoom of the chromatographic profile at 350 nm of one sample from Sierra Leone and the total ion current is reported in Figure 1b, in negative ionization mode, of the same sample.

By means UV-Vis and MS spectra shown in Figure 2, the main compounds were identified and belong to two chemical classes: quinic esters and kaempferol glycosides. As result by MS spectra shown in Figure 3, the most abundant compound is an isomer of chlorogenic acid or a monocaffeoil quinic esters (Rt= 18.89) while another isomer is the product with Rt= 20.79 (Figure 1). The majority of compounds are kaempferoil derivatives both di-and three-glycosides: in particular, peak with Rt= 33.7 represents a gluco-rhamno derivative probably with the glycosides linked in two different positions because the mass spectra (Figure 4) evidences only the loss of a single sugar residues. Other two di-glycosides are also individuated: a rhamno-penthoside (Rt=34.9) and gluco-rhamnoside (Rt=30.8). By the evaluation of their MS spectra it was evidenced the presence of a disaccharide moiety presumably linked in position 3 or 7 of kaempherol. All the other signed peaks indicated by K in Figure 1 correspond to kaempheroil three glycosides. The polyphenols quali-quantitative determination of the three areas was carried out by the comparison of their HPLC/DAD profiles. Quantitative data, as total sum of the two main chemical classes, are reported in Table 1.

Table 1: Comparison among the quantitative content of phenols in three representative samples of Milicia. The determination were performed by HPLC/DAD (*GH= Ghana, CI= Cotè d'Ivoire, SL= Sierra Leone*)

Quantitative results (mg/g fresh leaves)				
Compounds	λ_{max}	GH	CI	SL
Quinic esters	330 nm	0.79	traces	0.32
Kaempherol glycosides	350 nm	0.18	traces	0.46

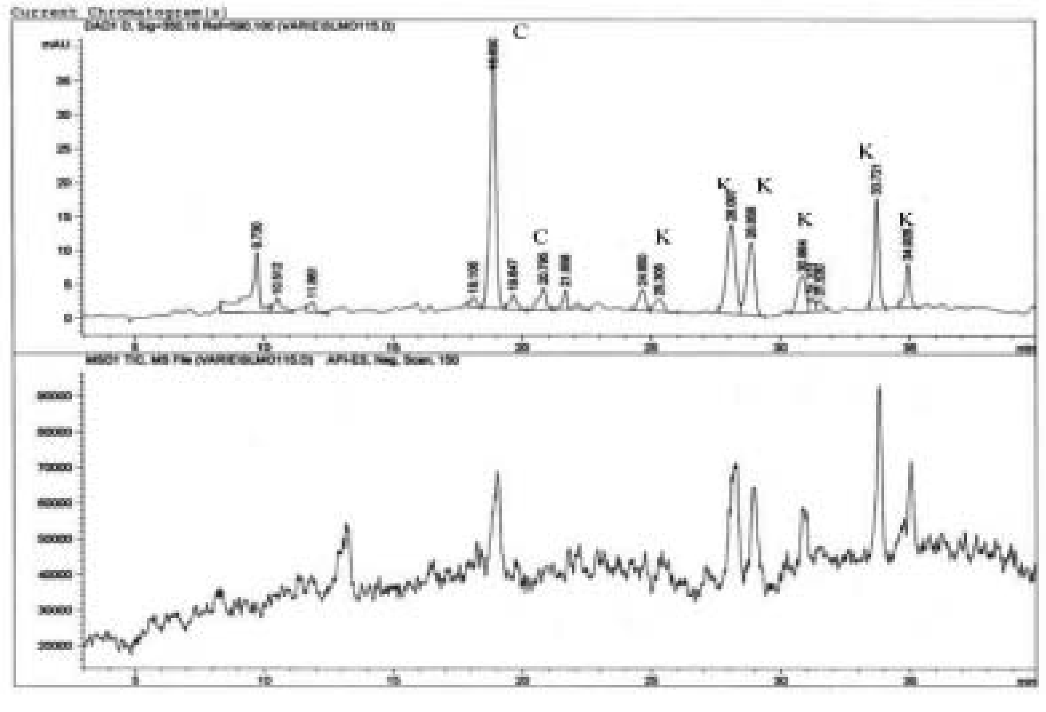

Figure 1: a) HPLC/DAD profiles at 350 nm of the Sierra Leone sample (hydroalchoolic extract); b) Total ion current (TIC) of the same sample with fragmentor 150 and negative ionization mode.

From these results it was evidenced that the sample from Cote d'Ivoire was the less rich in polyphenols (Figure 5b) while the sample from Ghana shows remarkable quantity of the isomers of chlorogenic acid and same kaempheroil derivatives (Figure 5a). Moreover some more lipophylic compounds (Rt range 45-50 min) with a particular UV-VIS spectra (Figure 6) are detected in all the samples. Other studies are in progress for a more complete characterisation of these products.

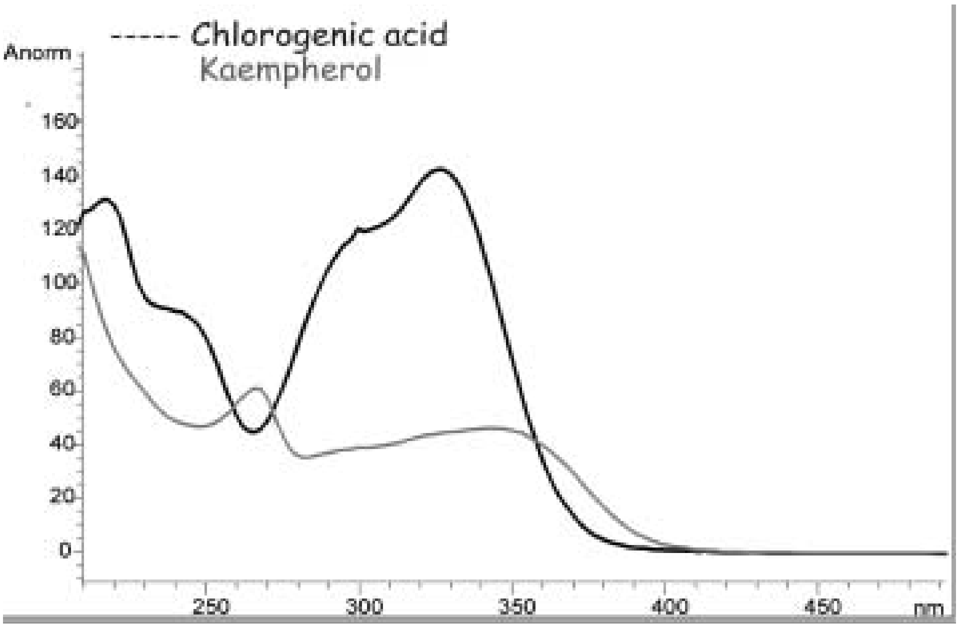

Figure 2: UV spectrum of chlorogenic isomers (λ_{max} 330 nm) and kaempherol glycosides (λ_{max} 350 nm).

These data show preliminary results and need further studies in order to define the utility of phenolic compounds as biochemical markers for characterization of ecophysiologically adapted indigenous genotypes of *M. excelsa* for sustainable timber production.

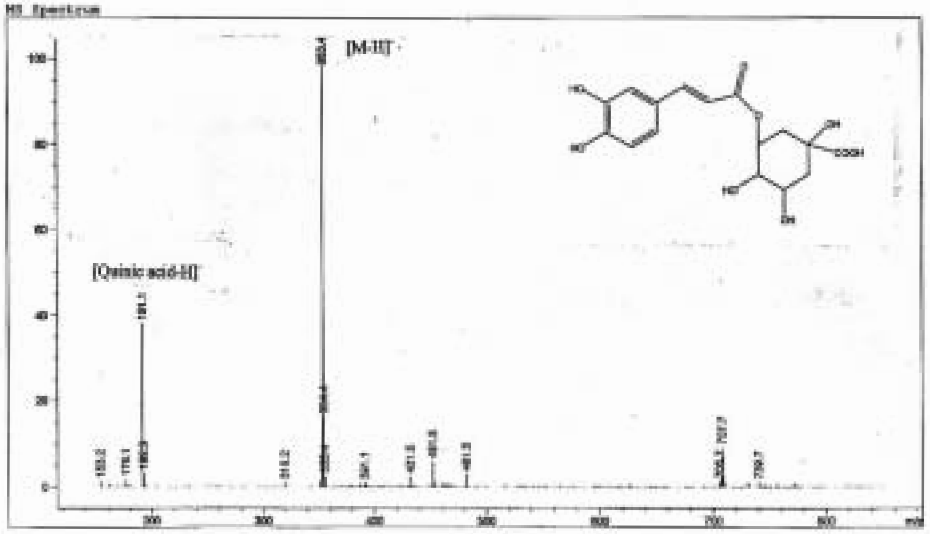

Figure 3: MS spectrum of chlorogenic acid.

Acknowledgment

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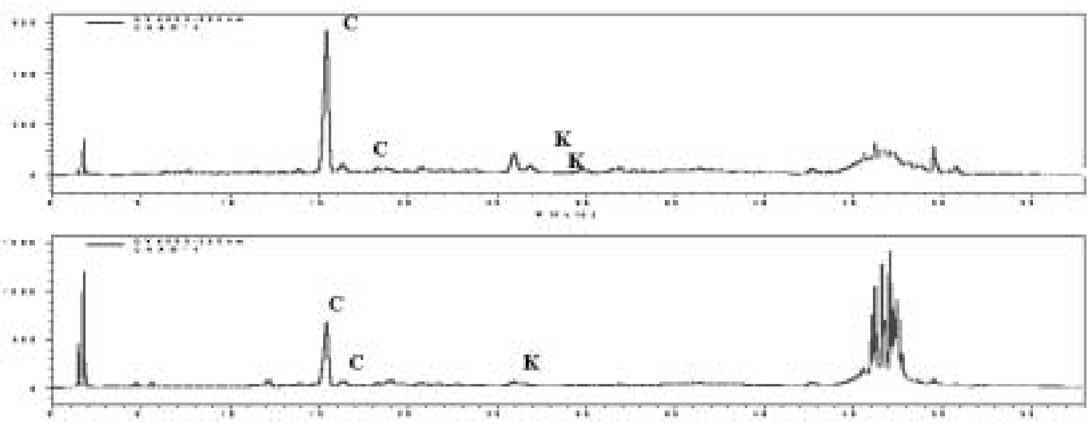

Figure 5 a): UV-DAD profile of the Ghana sample (5a) and Cote d'Ivoire sample (5b) at 280 and 350 nm.

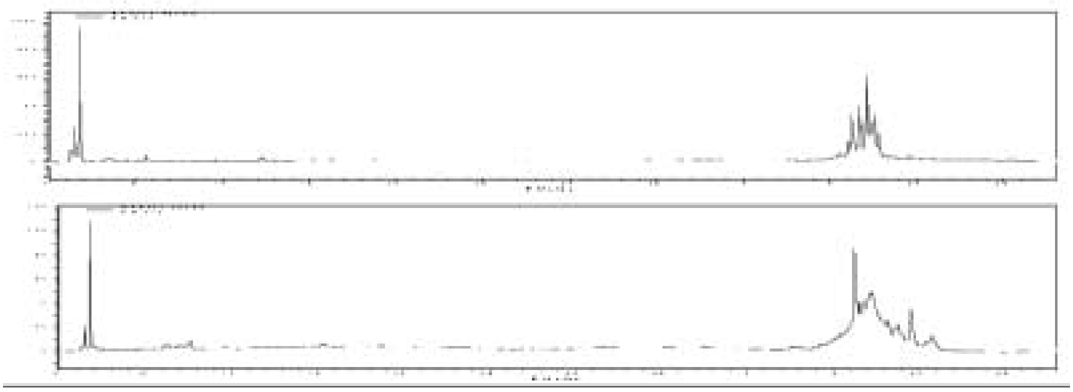

Figure 5 b): UV-DAD profile of the Ghana sample (5a) and Cote d'Ivoire sample (5b) at 280 and 350 nm.

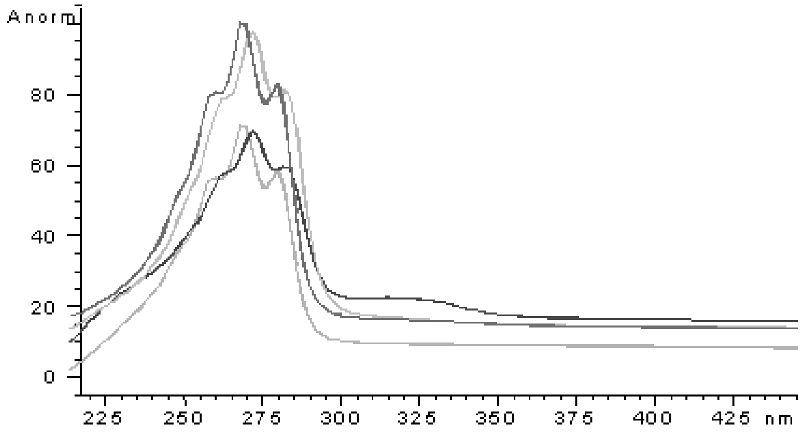

Figure 6: UV-VIS spectra of compounds with RT range 45-50 min in Figure 5.

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9. Summer planting of hot-lifted silver birch container seedlings

J. Luoranen[1], R. Rikala[1] and H. Smolander[1]

Summary

In Finland, silver birch (*Betula pendula* Roth) seedlings are traditionally planted at the dormant stage in May and to a lesser extent after cessation of height growth in September. During the 1990's, we studied possibilities to extend the planting window to summer by planting small, actively-growing container-grown seedlings during their first growing season. In this project, carried out in central Finland, we investigated seedling production, transport, field storage, and timing of the planting of actively-growing seedlings.

When actively-growing container seedlings of birch were planted between mid-June and mid-August, their growth during the following seasons improved and survival was the same as that of seedlings planted in spring or autumn. Root egress of birch seedlings was rapid in July and in the early part of the August, but slow in September and the next May. Because soil temperature in Finland is at its seasonal maximum from late June to August, seedlings become well-established after planting.

Height growth and survival in the years after planting were observed to decrease if seedlings were exposed to stresses during transportation, storage and planting. It was also shown that high water content in the peat plug before planting promoted survival and root egress. However, if seedlings were handled carefully and watered regularly while stored in the field a few days before planting, their survival was good and their growth was the same as that of well-watered seedlings planted without storage and transportation.

In reforestation, summer planting differs from spring planting in many ways. Summer-planted seedlings are younger (8-12 weeks) and shorter (25-40 cm) than spring-planted seedlings (1 year-old, 60-80 cm long). Consequently, birch seedlings can be grown in small-volume cells, which reduce the cost of seedling production and makes it easier to handle and plant the seedlings. Seedling height, cell volume and growing density must be in balance, which means that timing of growth and planting is important. Tall seedlings grown too closely spaced are more vulnerable to pathogens, and tall seedlings with a large leaf area are not as tolerant to drought as 'balanced' seedlings are.

The encouraging results of studies looking into the survival and growth of summer-planted birch seedlings led to the application of this method in practical-scale reforestation some years ago.

Keywords: drought, field performance, height growth, pre-planting watering, root egress, rough handling.

Introduction

Some 145-150 million tree seedlings are annually planted in Finland, with 12-15 million of this amount being broadleaves, mainly silver birch (*Betula pendula* Roth) container seedlings (Västilä & Herrala-Ylinen 2000). Seedlings are traditionally planted while still dormant in May and to a lesser extent after the cessation of height growth in September. Professional or even casual labour interested in silvicultural work has been difficult to engage. For example, the

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number of workers employed in silvicultural work in 1999 was 1,600 persons, while in 1991 it was 5,500 persons (Ylitalo 2000). Thus, there is need to enlarge the planting window in order that enough time can be allocated for all forestation and other silvicultural works.

Silver birch container seedlings planted in the spring are 50-100 cm tall. Production of birch seedlings starts by sowing in late April or May. The seedlings are grown in containers 300-400 cm^3 in volume in greenhouses until they are moved outside in mid- or late June. After leaf abscission, the seedlings are lifted and stored either outside or in freezer storage. Tall birch seedlings are expensive and difficult to handle during lifting, transportation and planting, which means high costs of birch forestation.

May and early June are times of the year when the water content of the soil is generally high because of the spring thaw. However, the soil temperature is still low, whereas the air temperature is relatively high (Figure 1). On the other hand, the roots of birch seedlings cannot grow before the leaves are able to produce fresh carbohydrates (Abod et al. 1991). Thus, birch seedlings planted while still dormant are at great risk of suffering from post-planting water stress, which then impairs the field performance potential of the seedlings. Some studies conducted in Finland have shown the field performance of birch container seedlings planted in May to be poor (Parviainen et al. 1989, Ferm et al. 1993, Hytönen 1995, 1998).

In some silver birch plantations in central Finland, promising results were achieved in the late 1980s, when short, leaf-bearing container-grown seedlings were planted during their first growing season (Figure 2). These plantations were small-scale trials without replications. An argument for spring planting is that dormant seedlings are more tolerant against stresses during lifting, transport and planting than actively-growing seedlings are. The effects of rough handling on summer-planted seedlings have been but relatively little studied and when studied the seedlings had already flushed (Kerr 1994) or set buds (Stjernberg 1997). No studies, as far as we know, have been conducted involving young, actively-growing, leaf-bearing broad-leaved seedlings.

To ascertain the results of small-scale trails and to study the factors affecting both seedling production for summer planting and post-planting seedling establishment, we carried out a large project in central Finland during the 1990s. The main results of the project are presented in this article.

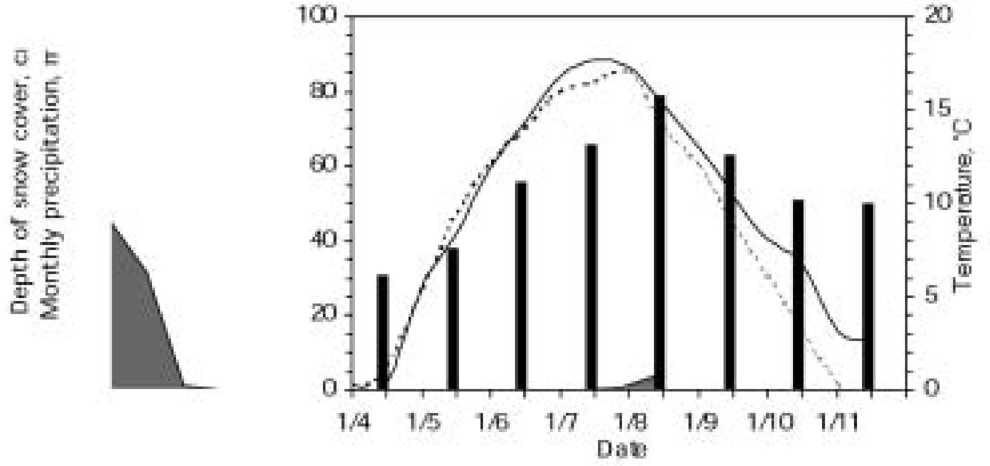

Figure 1: The depth of snow cover in spring and autumn (gray area), daily mean air temperature (at a height of 2 m; broken line) and daily soil temperatures (at a depth of 15 cm, solid line) recorded at Suonenjoki Research Station and monthly precipitation (mm, bars) recorded at Kuopio airport.

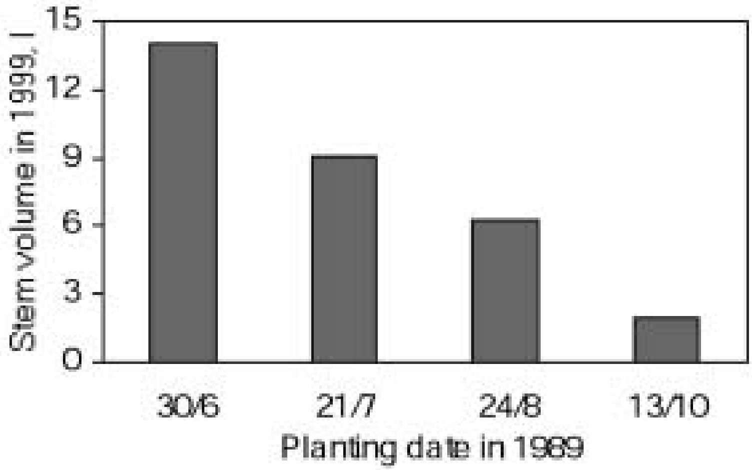

Figure 2: Stem volume (liters) of the average tree measured in a 10-year-old silver birch stand, which was established by planting seedlings on four days in the summer and autumn of 1989. These seedlings were grown in Plantek 25 trays and were two to five months old when planted on former agricultural land in Kerimäki, eastern-central Finland.

Material and methods

Root egress

The ability of seedlings to root egress at different times of the growing season was evaluated by using a modified root growth capacity test (root-egress test). Seeds of silver birch were sown on May 2, 1996, and germinants were transplanted into Plantek 25 trays (25 cells per tray, 380 cm^3 per cell, 156 cells per m^2, Lännen Plant Systems, Finland) filled with fertilized sphagnum peat (Vapo, XL, Finland) on May 23, 1996.

The seedlings were grown in accordance with normal nursery practice until they were transplanted into plastic pots (2.2 liters in volume) filled with sand. Randomly selected twenty seedlings were planted weekly into ten blocks between July 1 and September 30, 1996. After planting, the seedlings were kept in an unheated greenhouse and subjected to a natural photoperiod and light conditions with the daily mean temperature during the summer being about 21°C (the biggest difference between minimum and maximum temperature was 12°C in the middle of August, otherwise the difference was within the range of 1-5°C) and the mean relative humidity was 58% (range 48-65%). The pots were watered at least twice a week with tap water. After three weeks, the seedlings were harvested and roots growing out from the peat plug into the sand were cut, washed and dried in an oven for 24 hours at 105°C and weighed applying an accuracy of 1 mg.

Field trials with summer planting

To determine the best planting window for summer planting, conventionally grown silver birch container seedlings were planted in five nurseries in Kerimäki, Lapinlahti, Suonenjoki, Tohmajärvi and Tuusniemi. The seeds were sown in early May and grown in peat-filled Plantek 25 trays in a greenhouse until mid- or late June. Then they were moved to an outdoor growing area at each nursery. Randomly selected seedlings were planted out weekly from mid-July to end of September 1995 and 1996, and during the following May in 1996 and 1997 in harrowed and tilled fields near each nursery. In 1996, seedlings were planted also in a clear-cut and scarified reforestation site in Suonenjoki.

A total of eleven field trials were established. Each trial consisted of six randomized blocks with eleven planting dates (treatments). In each trial, 72 seedlings were planted weekly, twelve seedlings in each block (0.75 m intervals between seedlings in the rows, and 1.0 m intervals between the rows (planting dates). The height of each seedling was measured to the nearest

0.5 cm at planting and at the end of September every year during four years after planting. Survival was also evaluated in September of each year.

Drought tolerance of leaf-bearing two- to-three-month-old seedlings

Drought tolerance of growing, leaf-bearing birch seedlings was studied in two experiments conducted at the Suonenjoki Research Station. Seeds of silver birch were sown on April 24 and May 2, 1997. Three weeks later, the germinants were transplanted into Blockplant 64 trays (64 cells per tray, 154 cm^3 per cell, 426 cells per m^2, Panth, Sweden) or Plantek 25 trays (see above) filled with fertilized sphagnum peat (Vapo, XL, Finland). The seedlings were kept in a greenhouse until the middle of June, when they moved to an outside growing area.

In the beginning of July and August 1997, randomly-selected Blockplant 64 (July) or Plantek 25 trays (August) were watered to the container capacity and then the peat plugs were left to dry to different water contents. On both planting dates, on July 7 and August 15, the water content of the peat plugs varied between 5% and 85%. Seedlings were planted in sandy soil under a plastic shelter in a split-plot design. The design consisted of five blocks divided into dry and wet sub-blocks. Three seedlings from each pre-drying treatment were planted randomly to dry and wet blocks in a grid measuring 25 cm x 25 cm. The blocks were separated by 50 cm strips. The mean height of the seedlings at planting was 35 cm in July and 75 cm in August. Watering was applied to keep the soil moisture at approximately 7% in the wet soil and at 5% and 3% in the dry soil in July and August, respectively. The daily mean air temperature during the four-week experiment varied from 12°C to 24°C in July and from 7°C to 22°C in August.

After the four-week growing period, the seedlings were dug up from the soil, the mortality of seedlings was evaluated, and all roots grown out from the peat plug were cut, washed and dried in an oven for 24 hours at 105°C and then weighed applying an accuracy of 1 mg.

Rough handling between lifting and planting

In July 1998, several small-scale experiments were done at Suonenjoki Research Station for evaluating the effects of rough handling and the duration of field storage on field performance of summer-planted, hot-lifted silver birch seedlings.

In order to evaluate the effect of duration of field storage, fifty randomly-selected leaf-bearing birch seedlings (mean height 23 cm) grown in peat-filled Ecopot PS608 trays (608 cells per tray, 152 cm^3 per cell, 433 cells per m^2, Lännen Plant Systems, Finland) were lifted and packed into plastic bags on July 2, 1998. The unclosed bags were stored under a semi-shading rain shelter (11% shading) 0, 4, 8, 12 and 16 days. The seedlings were not watered during storage and the water content of the peat plugs declined from 45% by volume to 5% by volume during the 6-day-storage. The seedlings were planted out into five blocks, ten seedlings from each treatment to each block.

The effects of transportation stress were investigated in an experiment in which seedlings (mean height 32 cm) grown in Blockplant 64 trays were transported 0, 10, 30, 60 and 120 km without cover on an open-bed trailer at a speed of 80 km per hour on July 7. After the transportation treatment, the seedlings were stored without watering in semi-shade conditions (11% shading) until planting out the next day. Randomly selected thirty-two seedlings from each treatment (transportation distance) were planted into four blocks (eight seedlings in each treatment and block) set out on a sandy field.

Resistance to mechanical stress of actively-growing birch seedlings was also studied. Seedlings (mean height 26 cm) grown in peat-filled Ecopot PS608 trays were packed into five plastic bags (fifty seedlings in each) and dropped 1, 3, 9, 27 and 81 times from a height of 1 m onto a concrete floor on July 9. The seedlings were then planted out in five blocks, ten seedlings from each treatment to each block.

In all the experiments involving the studying of the effects of rough handling, seedling heights were measured at the time of planting and again after one and two years. Concurrently with these measurements, seedling survival and injuries were also evaluated.

Scheduling of seedling production for summer planting

In 1996, seeds of silver birch were sown into one Plantek 64 and one Plantek 25 tray (see above) weekly from May 13 to July 8. After germination, the cells were thinned. The seedlings were then grown in an unheated greenhouse until the mean height of seedlings in the particular a tray was 10 cm. Then the tray was transferred outside to a growing area. Seedling heights were measured weekly from thinning to the beginning of September.

Results and discussion

Root egress and field performance

When applying the conventional planting time in May, root egress in silver birch container seedlings was slow (Figure 3). When leaf-bearing, short seedlings a few months old were planted in July and early August, the roots grew rapidly from the peat plug into the surrounding soil. Seedlings planted at the same time in the field trials grew more during the following seasons after planting than seedlings planted after mid-August or in following May (Figure 4). Similar results have earlier been presented by Nyström (1993) in Sweden and by Rikala (1996) in Finland. There were no differences in either root egress or height growth after planting out between autumn- and spring-planted seedlings (Figures 3 and 4).

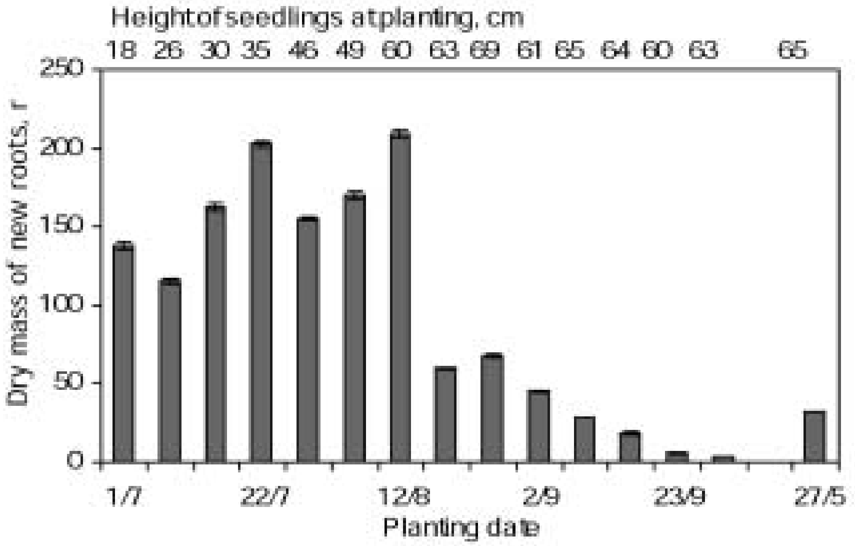

Figure 3: The dry mass of roots grown out from the peat plug (mg) during the three-week test period in the summer of 1996 and spring of 1997. The numbers above the bars indicate mean height of the seedlings (cm) at planting in root-egress test. The seeds were sown on May 2, 1996, and the germinants were subsequently transplanted into Planted 25 trays.

The performance of seedlings after planting out depends strongly on their capacity to grow roots into the surrounding soil and thus ensure water and nutrient uptake (Kozlowski & Davis 1975). Both the growth rhythm of roots and environmental conditions affect the ability of seedlings to become rapidly established after planting out. Seedlings planted while still dormant have to burst buds and grow leaves to their full size before root growth is possible (Abod et al. 1991). Old, suberized roots are poor into taking up water and nutrients (Bowen, 1970, Örlander & Due 1986, Häussling et al. 1988, Karlsson & Nordell 1996, Ryyppö et al. 1994). In addition, the low temperature in the root zone slows up root metabolism (Ryyppö et al. 1998) and increases the viscosity of water (Kaufmann 1975). Because of slow root growth before leaf growth, winds can cause shoots to sway so that the anchorage of seedlings and contact with the soil is impaired. Consequently, the height growth of spring-planted seedlings during the first summer after planting was poor (Figure 4). When actively-growing seedlings are planted in warm soil in summer (Figure 1), they readily establish themselves. With conifer seedlings, it has been observed that established seedlings are more acclimated to low temperatures than spring-planted seedlings are (Söderström 1974). If this is also true of birch seedlings, summer-planted seedlings are able to take up water and nutrients at lower soil temperatures in the spring. This could be the reason for the increased growth of summer-planted seedlings during the seasons after planting (Figure 4).

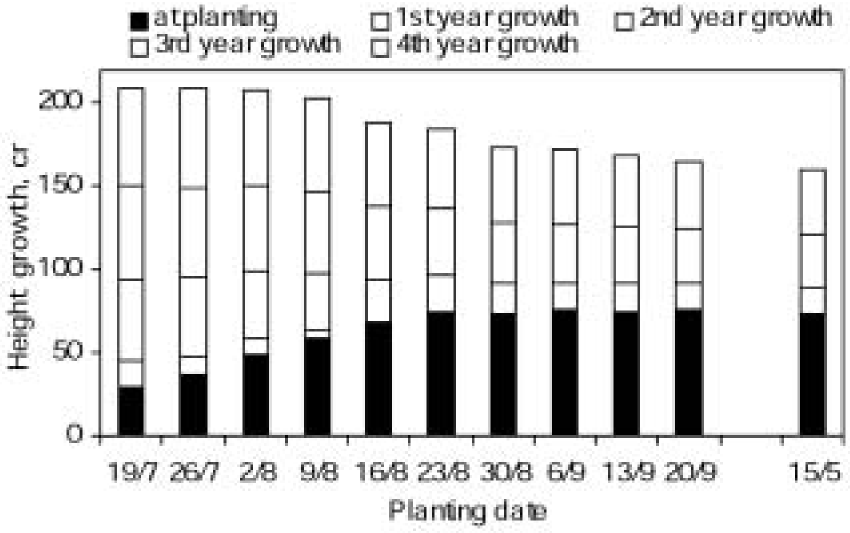

Figure 4. The height growth of silver birch container seedlings planted weekly from mid July to end of September in 1995 and 1996, and in May 1996 and 1997. The lowest sections in the bars indicate height at planting and the other sections height growth in first (planting summer), second, third and fourth year after planting in the six experiments with six blocks with twenty seedlings in each.

The average seedling survival in all trials did not differ between the planting dates during the four years after planting (Figure 5). There was, however, large variation in survival between trials. In some trials, there was severe mammalian damage during the first winter, but both hares (*Lepus timidus* L.) and voles (*Microtus* ssp.) ate equally seedlings planted all dates in summer and autumn. In the trial established into the easily-drying coarse sandy soil in Suonenjoki, seedling mortality increased from 10% to 50-60%, when the period of drought in the soil was in effect a few weeks before planting. The survival of seedlings a few years after planting has varied greatly in different studies in Finland. In the study by Leikola (1976) using silver birch bareroot seedlings, for example, survival after 3-4 years after planting was 15-75%. On the other hand, survival of silver birch seedlings planted on former agricultural land was approximately 84% three years after planting (Ferm et al. 1993), and after five years in the same trials it had decreased to 63% (Hytönen 1995). Compared to those results, the survival of summer-planted seedlings observed in this study was quite high (78-100% for planting dates from the middle of July to the middle of August). The lowest survival three years after planting was observed on the reforestation site in Suonenjoki, with the seedlings having planted in mid-August.

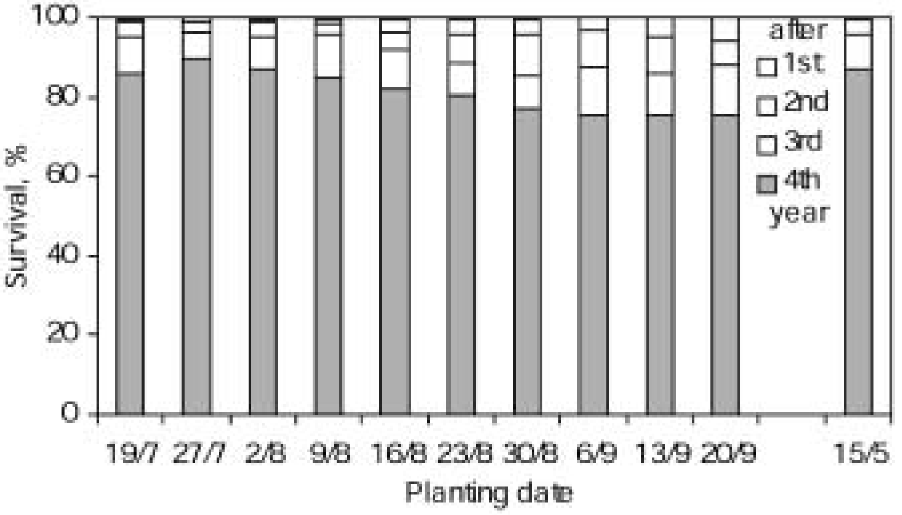

Figure 5. The survival of silver birch seedlings at the end of first (planting summer) and until the fourth season after planting with seedlings having been planted weekly from mid July to end of September in 1995 and 1996, and in May 1996 and 1997. Each section in the bars indicates the proportion of living seedlings scored as being undamaged, alive but weakened, or alive but the top of the seedling damaged, or dead. Each bar represents the mean of ten experiments with six blocks with twenty seedlings in each.

The field trials to investigate the effects of planting date on field performance were established on nursery fields and seedlings were not transported or field-stored before planting. In addition, the seedlings were handled well during lifting and planting. The effects of rough handling on young, leaf-bearing seedlings were studied in separate experiments.

Effect of rough handling on the field performance of hot-lifted birch seedlings

The results of our experiments, in which we studied the effects of rough handling, showed that the pre-planting moisture of peat plugs was the most important factor affecting the field performance of leaf-bearing birch container seedlings. Transportation and dropping of packed seedlings impaired their growth, but did not have as great an effect on post-planting survival. Pre-planting watering markedly decreased mortality even when the seedlings were planted in dry soil (Figure 6). Differences between the water contents of peat plugs (from 5% to 85%) decreased immediately after planting. In July, these differences disappeared after four days in dry soil and after eight days in wet soil. After the four-week growing period, seedling mortality increased with increasing pre-planting dryness of the peat plugs and post-planting dryness of the soil. In July, seedlings planted in wet soil died as a consequence of the pre-planting water content of peat plugs below 15% (Figure 6a). In dry soil, seedling mortality increased linearly when the pre-planting water content decreased from 65% to 5%. In August (Figure 6b), seedling mortality was higher than in the experiment in July (Figure 6a). This could be explained by the seedling being taller and the soil a little drier in August than in July.

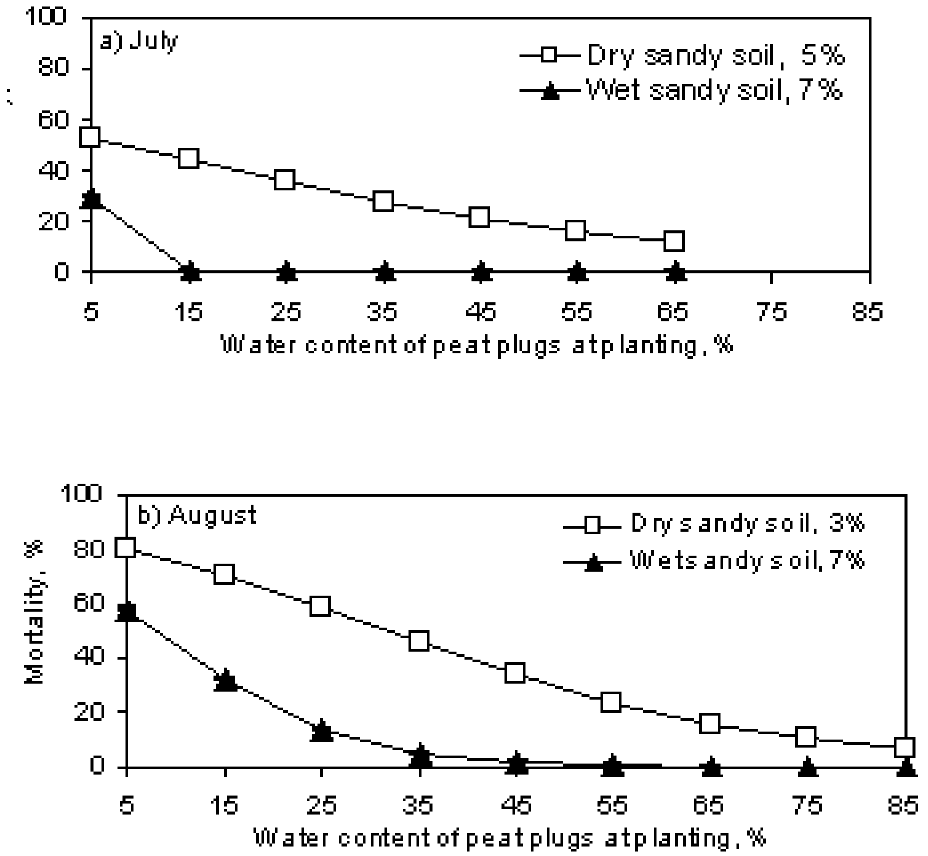

Figure 6. The effects of pre-planting water content of peat plugs (%) and post-planting soil moisture on the mortality of silver birch container seedlings. a) 2-months-old, leaf-bearing seedlings grown in cells 154 cm3 in volume, planted on July 7 and b) 3-months-old, leaf-bearing seedlings grown in cells 380 cm3 in volume, planted on August 15. Mortality was scored after a four-week growing period.

The importance of pre-planting watering was also observed when seedlings were stored without watering. Seedlings planted after storage periods of 0-, 4- and 8- days survived, but after 12 days of storage seedling mortality was 44% and after 16 days it was 84% two years after planting. The height growth of seedlings, however, declined already when seedlings were stored for more than four days: after two growing seasons, the mean heights of seedlings stored 12, 8, 4 and 0 days were 60 cm, 70 cm, 80 cm and 80 cm, respectively.

To conclude, the field performance of leaf-bearing seedlings planted in summer was good as long as the water content of the peat plugs at the time of planting was over 30%. Most of the water in peat plugs moves into the surrounding soil within a few hours after planting (Day & Skoupy 1971, Heiskanen & Rikala 2000). If dry peat plugs are planted in wet soil, they remain drier for several days compared to wet-planted plugs, even though they may absorb water from the surrounding soil (Heiskanen & Rikala 2000). During this period, especially during warm weather, seedlings may suffer drought stress, which, even if it does not kill the seedling, reduces seedling growth. Hence, seedlings in dropping-wet peat plug can be planted in summer.

The effects of transportation without packing on an open-bed trailer on seedling survival were unexpectedly minor. Only two seedlings transported 120 km before planting died during the first two years after planting. The increase in transportation distance, however, decreased the growth of seedlings after the planting (Figure 7). Differences between the effects of transportation distances more than 10 km were statistically significant (P<0.001).

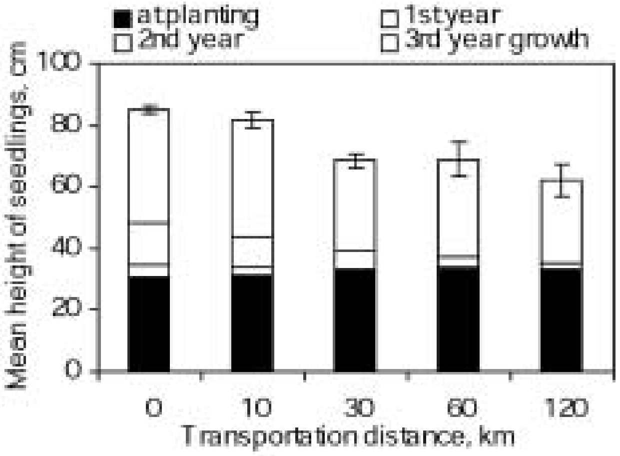

Figure 7: The height growth of silver birch container seedlings transported 0–120 km on an open-bed trailer. Each bar indicates the mean of four blocks (8 seedlings in each) per treatment.

Similarly, the mechanical stress caused by dropping of seedling bags before planting had little effect on field performance. For example McKay et al. (1993), have earlier observed that only extreme dropping treatments increased the mortality of Sitka spruce seedlings, but height growth was also decreased by mild treatments. In our experiment, three years after the planting, 10% of the seedlings that had been dropped 81 times, and 4% of the seedlings dropped 27 times, were dead. However, the dropping treatments did not affect the height growth of seedlings. Seedlings were well-watered and planted immediately after the dropping treatment into moist soil, which possibly improved their field performance. Peat plugs were crushed by dropping and thus the seedlings could not be planted using a planting tube. In this experiment, the effect of dropping seedling bags was evaluated; e.g. how seedlings tolerate continuous shaking when transporting seedlings along rough forest roads is another issue. Conifer seedlings, however, have been observed to tolerate quite well mechanical shocks caused by transportation along gravel roads (Stjernberg 1997).

Stress combinations have cumulative effects (Kauppi 1984, Stjernberg 1997). Thus, our results may overestimate the performance of young, leaf-bearing birch container seedlings. However, normal handling, regular irrigation during storage of at most 2-3 days in the field, and watering seedlings until the plugs are dropping wet immediately before planting, should guarantee a well-established birch plantation.

Production of seedlings for summer planting

Traditionally birch seedlings are grown in large-volume cells (300-400 cm^3) and the resultant seedlings are 50-80 cm tall at the time of planting. For summer planting, short, 2-3- month-old seedlings can be grown in smaller cells. Seedling height, cell volume and growing density must be in balance. Seedlings can be planted when the root system of the seedlings is dense enough to keep the peat plug in one piece between being lifted and planted out. Based on our experience, seedlings have to be 15-25 cm in height at this stage when seedlings are grown in cells 110 – 380 cm^3 in volume. On the other hand, tall seedlings grown too dense become thin and succulent and are vulnerable to pathogens. After planting out, seedlings with a large leaf area and small root volume are also more susceptible to drying than balanced seedlings. In our experiment, in which we monitored the height development of birch container seedlings sown at different times in the spring and summer, the period from sowing to the moment point in time when the seedlings were tall enough for planting out was 7-8 weeks (Figure 8). After achieving the minimum target height (15-20 cm), for example, at a density of 431 seedlings per m^2, the seedlings stay at a suitable size for planting out for about two weeks. If seedlings are grown at lower densities (156 seedlings per m^2), the optimal period for planting out (median height of seedling stock 25-50 cm) in the summer was 3-4 weeks depending on growing conditions. All this means that the grower and customer have to carefully schedule the growing and planting times.

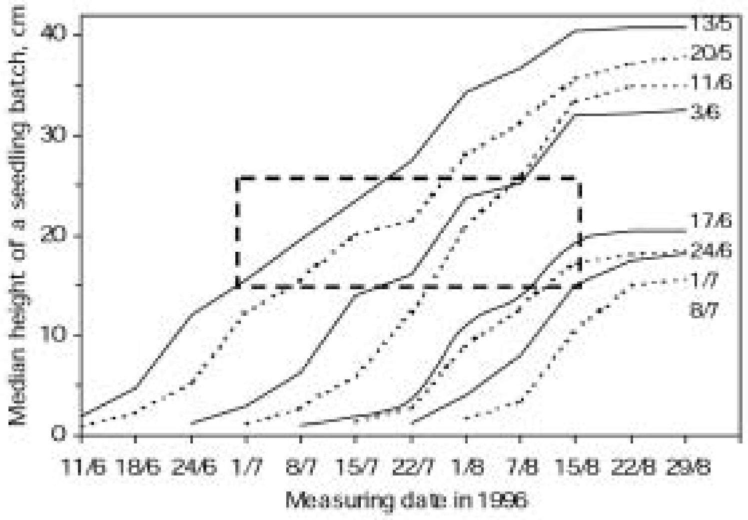

Figure 8: The height growth of silver birch seedlings sown into Plantek 64F trays (64 cells per tray, 110 cm3 per cell, 431 cells per m2) weekly from mid May to mid July. The sowing dates are shown on the right. The broken-lined rectangle indicates the period when the median height of a particular seedling batch is suitable for planting out as leaf-bearing seedlings in summer.

Conclusions

Our experimental-scale results showed that the post-planting performance of well-watered and carefully-handled leaf-bearing silver birch container seedlings, 20-30 cm in height, planted in July and early August was as good or better than that of dormant seedlings planted in spring. The first experiences of practical-scale forestation with silver birch container seedlings planted in July and early part of August are also promising. Monitoring of the results of large-scale forestation over several years will, however, yield more realistic figures on the risks involved in summer planting of freshly lifted birch container seedlings.

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10. Management of British Columbia broadleaves

*J.P. McClarnon and C.F. McClarnon**

Summary

Broadleaves in British Columbia (BC) have historically been utilised marginally and regarded as weed species to be controlled or replaced. Interest in broadleaf management has, however, increased markedly in the past decade after growing recognition of their many valuable attributes, including their importance in: managing for wildlife habitat; riparian area and biodiversity objectives; high value sawlog production; producing fibre for oriented strand board and pulp; enhancement of forest productivity; and, maintaining forest health.

Broad-leaved and mixed-wood forests comprise approximately 11% and 24%, respectively, of British Columbia's productive forest land base. The current annual harvest level of broadleaves is around 2.5 million m^3. The broad-leaved species most actively managed at this time are trembling aspen (*Populus tremuloides*), red alder (*Alnus rubra*), black cottonwood (*Populus balsamifera* spp. *trichocarpa*) and hybrid poplars (*Populus* spp.).

A large inventory of mature aspen is the basis for an oriented strand board/veneer industry. Low intensity management regimes utilise the inherent ability of aspen to reproduce vegetatively in situ and rapidly self thin. Projected rotations are 60–90 years. Management issues include protecting the inventory of understory conifers, ensuring the replacement of intimate mixtures of aspen and spruce at the landscape level, and developing guidelines that address the management of superior clones.

Red alder grows throughout coastal BC. Management is for production of high value 30-cm sawlogs in 30–40 year rotations. Large one-year old container or container-transplant seedlings are planted promptly after harvest, at densities of 1100–1400 stems per hectare (sph). The moderately high initial density promotes good form, small branches, and self-thinning. Thinning to 800 sph at age 12 is anticipated to optimise log quality.

Black cottonwood and hybrid poplars are managed in coastal BC. Timber production objectives are primarily for short rotation, high yield pulp. Two management regimes are currently practised based on different investment criteria. Short rotation intensive culture may include site preparation, planting 45-cm hybrid poplar cuttings at 800–1200 sph, annual vegetation control until crown closure, and fertilisation. Low intensive management includes planting 1–2 metre whips at 800–900 sph, without site preparation, brushing or fertilisation.

Keywords: Brititsh Columbia, broadleaved forest, vegetative reproduction, plantations, short rotation.

Introduction

Broadleaves in British Columbia (BC) have historically been utilised marginally and regarded as weed species to be controlled or replaced. Interest in broadleaf management has, however, increased markedly in the past decade after growing recognition of their many valuable attributes, including their potential for use in: producing short rotation high-yield crops; high-value sawlog production; producing fibre for oriented strand board and pulp production; riparian forest management; maintenance of forest health; sewage effluent treatment; ecologi-

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cal restoration; visual landscape management and tourism; wildlife habitat and biodiversity objectives; and, enhancement of forest productivity.

Broad-leaved and mixed-wood forests comprise approximately 11% and 24%, respectively, of BC's 46 million ha productive forest land-base (Comeau 1996). Current annual harvest of broadleaf species is estimated at 2.5 million m^3, which is approximately 4% of the total committed broadleaf and coniferous harvest volume (BC Ministry of Forests 2001). The potential 20-year annual broadleaf harvest[1] is 7 million m^3/year (Massie 1996).

Broadleaf species most actively managed are trembling aspen (*Populus tremuloides* [Michx.]), red alder (*Alnus rubra* [Bong.]), black cottonwood (*Populus balsamifera* spp. *trichocarpa* [T.&G.] Brayshaw) and hybrid poplars (*Populus* L. *x spp.).* Existing paper birch (*Betula papyrifera* [Marsh.]) inventories are moderately utilised; and while the species has significant potential, management is currently limited to trials. Bigleaf maple (*Acer macrophyllum* [Pursh]), a lowland coastal species, is utilised on a small scale. Opportunities exist for a small specialised niche market. Propagation and planting of non-commercial minor broadleaf species such as western flowering dogwood (*Cornus nutalli* [Aud. *ex* T.&G.]), Garry Oak (*Quercus garryana* [Doug. *ex* Hook.]), Sitka alder (*Alnus crispa* [Pursh]) and willow species (*Salix spp*) has increased in recent years, reflecting an increase in ecological restoration projects (Province of British Columbia 1998). Broadleaves are also utilised in streamside–slope stabilisation techniques such as live staking or contour wattling (Chatwin et al. 1994).

In 2001, 327,800 seedlings were sowed for broadleaf production. This is 0.15% of the provincial sowing of 220.6 million seedlings. Not included are cottonwood cuttings. In considering this statistic it must be remembered that 75% of BC's broadleaf harvest[2] is comprised of aspen which is regenerated entirely through natural regeneration.

Developing Expertise in Management of Broadleaves

In recognition of the increased interest in broadleaves, a Broadleaf Technical Advisory Committee was formed in 1990 to co-ordinate research related to broadleaves and mixedwoods. Priorities identified by the committee were broadleaf silviculture, ecology (site selection, stand dynamics and site productivity), integrated resource management, and forest health (Peterson and Peterson 1995).

Managers' handbooks have been published for aspen (Peterson and Peterson 1995), red alder (Peterson et al. 1996), black cottonwood and balsam poplar (Peterson et al. 1996a), paper birch (Peterson et al. 1997), and bigleaf maple (Peterson et al. 1999). They summarise current knowledge on silvics, recommended management regimes for pure and mixed stands, growth and yield, and damaging agents. Symposiums on the *Ecology and management of B.C. hardwoods* and the *Silviculture of temperate and boreal broadleaf-conifer mixtures* were held, respectively, in 1993 (Comeau et al. 1996) and 1995 (Comeau and Thomas 1996).

The *Provincial seedling stock type selection and ordering guidelines* (Province of British Columbia 1998) now include stock type recommendations for several broadleaf species. The provincial free-growing[3] stocking standards (BC MOF 2000 2000a 2000b 2000c 2000d 2000e) provide practitioners with broadleaf species recommendations within the ecological framework of BC's biogeoclimatic ecosystem classification system (Pojar et al. 1987). Increased thresholds for presence of aspen, birch, and "upland" cottonwood were implemented in the 2000 field season. This will ensure a good distribution and occurrence of broadleaves in conifer plantations for biodiversity objectives as well as incidental broadleaf volume for future harvest. Damage criteria (forest health impact tolerances) for acceptable free growing broadleaf stems are under development.

Issues pertaining to broadleaf management in the boreal forest are currently a high priority.

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[1] Based on the assumption of 50% availability of the existing mature and near mature inventory.

[2] Based on data in BC Ministry of Forests 2001.

[3] A "free growing stand" is defined by the Forest Practices Code of British Columbia Act as "a stand of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs or other trees."

Mixedwood draft guidelines for the boreal forest and an operational definition of "mixedwood" are expected to be implemented this year. The rest of this paper summarises the current management status of aspen, red alder, black cottonwood and hybrid poplars in BC.

Aspen Management

Utilization

Prior to 1986 aspen was utilised minimally in northern BC. The large inventory of mature aspen in BC's northeastern boreal forest now forms the basis for an oriented strand board/veneer industry as well as a source of pulp fibre. The estimated gross volume of broadleaf leading species in northeastern BC is 299 million m^3, occupying 2.25 million hectares (Baber 1996). Most of the aspen volume in BC is classified as mature (81–120 years) or over-mature (121 years) (Massie 1996). The current annual harvest of 2 million m^3 accounts for approximately 75% of the provincial broadleaf harvest (BC Ministry of Forests 2001). The potential 20-year provincial annual aspen harvest[4] has been estimated at 5,616,000 m^3 (Massie 1996).

Regeneration

Aspen, a shade intolerant species, has very early rapid height growth and self thins rapidly, with the best growth occurring on fresh to moist sites with calcium rich soil (Peterson and Peterson 1996). Regeneration occurs to some extent by seed but primarily through aspen's remarkable capacity for root suckering. Following disturbance and the release of apical dominance, aspen can regenerate through suckering at high densities (e.g., in excess of 200,000 ramets/ha) (Peterson and Peterson 1995, 1996). In northeastern BC, stem densities at one year following disturbance are commonly in the range of 40,000 stems per hectare (sph) (Kabzems 1998). However aspen stands typically self-thin to yield stem densities of less than 10,000 sph by year ten (Peterson and Peterson 1995).

Stand Management

1. Pure Aspen Stands

Aspen is regenerated by clear-cutting and managed in even-aged stands. Low intensity management regimes (i.e., no site preparation, brushing or fertilisation) utilise the inherent ability of aspen to reproduce vegetatively in situ. At this time aspen is not planted. Trials have been established to assess the potential benefits of fertilisation and thinning but these treatments are not practised operationally.

The key to successful aspen management is with protecting the clonal root systems to ensure vigorous suckering (Peterson and Peterson 1996). For example, fine textured soils are common throughout northern BC. If these soils are compacted by summer logging then the density and productivity of aspen regeneration is significantly impacted (Kabzems 1996). Several other factors may also limit the suckering capacity of aspen, including: low soil temperatures that may be exacerbated by dense *Calamagrostis* grass or a thick duff layer; a rise in the water table close to the soil surface after harvest; post disturbance invasion of alder and willow; reduced light levels; and repeated grazing (Peterson and Peterson 1995, 1996; Navratil 1996).

2. Mixedwoods

The boreal forest landscape is comprised of a patchwork of intimate horizontal and vertical mixtures of conifers and broadleaves. Ecologically sustainable forestry must ensure the maintenance of this diversity at the landscape level (Kabzens 1998). While aspen is relatively eas-

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[4] Based on the assumption of 50% availability of near mature and mature aspen inventory.

ily regenerated as pure stands there is growing recognition of the need for replacement of mixed-wood stands comprised of aspen and its conifer associate white spruce (Picea glauca [Moench] Voss) (Man and Lieffers 1999).

Where aspen is the leading species pre-harvest, the stand often includes a shade tolerant white spruce understory. This stand structure develops due to the slower growth of white spruce relative to aspen in the establishment phase. Growing slowly in the reduced light conditions below the aspen canopy, the longer-lived spruce eventually emerges into a dominant canopy position as the aspen declines. Three issues therefore confront managers in the boreal forest (Bedford[5] pers comm, Greenway 2001):

1. Developing an operational definition of mixed-wood and then setting goals for amounts of mixedwoods, conifers, and broadleaves to be managed at the landscape level;
2. Developing silviculture regimes for the regeneration of mixed-wood forests; and,
3. Determining when understory spruce in broad-leaved stands should be retained to contribute to future volume.

Where acceptable understory white spruce in an aspen stand exceeds 600 sph and is projected to produce a harvest volume of greater than 125 m^3/ha then the spruce may require protection during harvest[6] (BC Ministry of Forests 2001a). The retained spruce release, and having an initial height advantage, are projected to maintain a dominant crown position. The windthrow hazard (Stathers et al. 1994) associated with the released spruce must be carefully assessed (Navaratil 1996). The recommended silvicultural system is a modified strip shelterwood[7], incorporating regularly spaced buffers of unlogged aspen to protect the retained spruce from windthrow (Greenway 2001). Aspen suckers fill the gaps, given sufficient light and soil warming, resulting in development of a mixed-wood stand. At the second harvest both the aspen and spruce would be harvested together.

Red Alder Management

Utilization

Red alder is estimated to be the leading species on 18,425 ha in coastal BC (Sigurdson et al. 1997). Approximately 10% of this area is comprised of stands that are between 0-40 years; 60% is 40-70 years of age; and 30% is 70+ years (Massie 1996). In 1995 an estimated 416,000 m^3 were harvested (Sigurdson et al. 1997). The majority is milled to produce 1-inch thick furniture stock, while the residual product, approximately 20%, is utilised as pulp chips (Sigurdson et al. 1997).

The outer portions of the logs yield the highest value "shop" grades while the inner portions produce lower value furniture frame grades (Sigurdson et al. 1998). Red alder wood competes in the market with several North American eastern broadleaves including birch, yellow poplar, soft maple, and cherry. The best wood is a honey brown colour achieved through careful kiln drying (Sigurdson et al. 1998). Incorrect colour set significantly reduces the end product value (Sigurdson et al. 1998). Red alder wood contains the chemical oregonin which, when oxidised, creates a red stain that significantly reduces the value of the wood (Allen 1996). Harvesting in the winter, minimising storage time, and careful log handling to prevent bark scarring can minimise the risk of staining (Allen 1996).

Its value has been long recognised in riparian forest management, as a fallow crop in areas with root diseases, and for enhancing site productivity through nitrogen fixation (Peterson et

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[5] Bedford, Forest Establishment Officer, Forest Practices Branch, BC Ministry of Forests, Victoria.

[6] However, where an aspen stand is assessed as a superior clone, the spruce retention requirement would be waived and the stand would be regenerated to pure aspen.

[7] Strip shelterwood systems are described in Province of British Columbia 1995.

al. 1996). With nitrogen fixation rates in the range of 23-340 kg/ha (Miller et al. 1999) the potential for growing red alder in mixtures with conifers to enhance site productivity is a subject of interest. However, one study reporting 17-year results of red alder/Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) mixtures found growth reductions in the Douglas-fir due to the competitive effects of the overtopping red alder (Miller et al. 1999).

Regeneration

Red alder grows at lower elevations throughout coastal BC. It is a fast growing, shade intolerant species that rapidly colonises disturbed areas. Choice of appropriate site is critical. Red alder grows best on moist to very moist sites with a good but not excessive growing season moisture supply (Peterson et al. 1996; Sigurdson 1997). Soils low in phosphorus can greatly limit establishment and growth of red alder, as can sites prone to severe frost, high winds, heavy cover of competing vegetation, or heavy animal browsing (Ahrens et al. 1992). Red alder is established by planting even-aged, single species stands following clear-cutting. Seed is collected from wild stands from trees as young as seven years. Younger seed sources appear to yield larger seed with higher germination (Sigurdson et al. 1998). There is currently no program for genetic improvement. However there is substantial variability within existing populations indicating good opportunities for genetic selection and identification of superior provenances (Dang et al. 1996; Harrington 1990). In 2001, a total of 280,700 seedlings were sowed for one-year old container/bare root transplant stock (predominantly), or large container stock.

Large one-year old container or container-transplant seedlings are planted promptly the first spring after harvest, at densities of 1400–1700 sph. Successful early establishment must address frost, drought, and vegetative competition. The moderately high initial density promotes good form, small branches, and self-thinning. Below 1000 sph the quality of stem form is anticipated to be unreliable for sawlog production (Hughes[8], pers. comm.). Trials are underway with inter-planting slower growing western redcedar, which is anticipated to promote self-pruning of alder (Hughes, pers. comm.).

Stand Management

To support an allowable annual cut of 150,000 m^3 it has been estimated that it is necessary to regenerate 400 ha annually to red alder (Sigurdson 1997). Plantation establishment is currently limited to 100 ha annually, with further expansion pending detailed review of red alder inventories.

It is anticipated that thinning to 800–1000 sph at age 12, combined with dead branch pruning, will be required to optimise log quality (Sigurdson et al. 1998). Ideally thinning would occur before live crown recession below 40–50% to avoid risks associated with sunscald and epicormic branching. The target objective is a high quality 30-cm sawlog on a 30–35 year rotation.

Since BC currently has no mature managed red alder stands, current growth and yield projections are based on a Hibbs and DeBell (1994) stand density management diagram (cited by Courtin et al. 1995). A financial analysis suggests that a managed red alder stand with a 20% yield gain and log size increase compares favourably with western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), and a 30% yield gain for Douglas fir (Sigurdson 1997). However for red alder to be financially competitive with conifer species on productive sites, it must be thinned to 600 sph at a stand height of 12–16 m (Sigurdson 1997) to increase diameter growth which markedly affects final log value.

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[8] Neil Hughes, Weyerhauser Ltd. Vancouver, British Columbia.

Black Cottonwood and Hybrid Poplar Management

Utilization

Two thirds of the existing coastal cottonwood volume are in the near mature age class (41–80 years) with excellent opportunities for utilisation (Massie 1996). Timber production objectives are primarily for short rotation, high yield pulp. Scott Paper utilises black cottonwood and hybrid poplar for production of tissue paper products. Its tree farm license (TFL) occurs over a total area of 10,106 ha[9], supporting an annual allowable cut of 40,000 m^3. Black cottonwood is also important in managing non-timber resources; for example, enhancing wildlife habitat and biodiversity; riparian zone management; and restoration of ecosystems (Peterson et al. 1996a).

Regeneration

Black cottonwood, a shade and drought intolerant species, is the largest hardwood in BC (Peterson et al. 1996a). It dominates nitrogen rich alluvial flood plains throughout coastal and central BC, with the best growth occurring on nutrient rich, fresh to very moist sites, and is replaced in the northeast by balsam poplar (*Populus balsamifera* ssp. *balsamifera* L.), a taxonomically similar species (Peterson et al. 1996a). Site index[10] is between 7–28 metres at 15 years (McLennan 1990). It sprouts from stumps, broken stems, partially buried branch fragments, and cuttings (Peterson et al. 1996a). Hybrid poplars have similar growing requirements and are propagated from unrooted stem or branch cuttings (45 cm long), or unrooted whips (1–2 m long) (Thomas et al. 2000).

Stand Management

Yield from cottonwood and particularly hybrid poplar plantations are much higher than yields from natural stands (Peterson et al. 1996a; Stettler 1999). Two management regimes currently implemented in BC are short rotation intensive culture (SRIC) and low-intensity management.
SRIC includes site preparation to fully clear and destump the site and remove competing vegetation, planting 45-cm hybrid poplar cuttings at 1100–1200 sph, annual vegetation control (by disking 2–4 times per season) until crown closure (i.e., for 3–4 years), and fertilisation (Thomas et al. 2000). Target piece size is an average diameter at breast height of 35 cm. A 15- year rotation yields 300-400 m^3/ha (Thomas et al. 2000). Scott Paper implements SRIC practices on approximately 25% of their TFL, and is shifting to establishment densities of 800 sph (using euroamericana and/or interamericana hybrids) as a result of high survival rates and to promote larger diameters in shorter time frames (Minhas[11], pers. comm.). Herbicides have never been used on the Scott Paper TFL (Minhas, pers. comm.).
The SRIC regime, which can be categorised as an agricultural model (Stettler 1999), is strongly tempered by conservation measures. The large area net down from the timber harvesting land base protects environmentally sensitive areas and contributes to biodiversity. Management practices protect riparian ecosystems. Scott Paper also conducts two aerial surveys each year to identify bald eagle nesting and roost sites. Plans are then prepared to ensure these sites are not disturbed (Minhas, pers. comm.).
Low-intensity management includes planting 1–2 m black cottonwood whips at 800–900 sph, without site preparation, brushing or fertilisation. A 25–30 year rotation yields 250–450 m^3/ha (Thomas et al. 2000). This is practised in areas where operational costs do not justify the higher investment costs associated with SRIC.

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[9] After netdowns for environmentally sensitive and inoperable areas, the net timber harvesting landbase is 3326 ha.

[10] Defined as "the potential height growth on a site for a given tree species over a fixed time period." (Province of British Columbia 1997).

[11] David Minhas, Administrative forester, Scott Paper Ltd, New Westminster, British Columbia.

Conclusions

Recent interest in broadleaf management in BC is expected to expand into the foreseeable future given the importance of broadleaves not only for their commercial value, but also for a diverse spectrum of non-timber applications. Research, extension products, revised policy, and the experiences of pioneering forest companies have played key roles in developing management practices and standards as BC emerges from a previously softwood-dominated era to incorporate a broader range of species (including hardwoods) and non-commercial forest values into forest management practices. As a province which prides itself in having the most biologically diverse ecosystems in the country, this new era presents exciting challenges to forestry professionals who are presented with developing innovative forestry practices to accommodate broadleaves into forest management.

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11. First results after ten years of broadleaves plantations in southern Italy

*R. Mercurio and G. Modica**

Summary

Results of the different tree species used in plantations, 10 years old, in the Serre (Calabrian Apennine), are analysed. In the most part of the Serre, between 700 and 1000 m a.s.l., Cherry and Sycamore seem the most promising species but also Service Tree appears as an interesting and appreciable species. While Walnut and Ash found frequently unfavourable site conditions.

Keywords: *Acer pseudoplatanus* L., *Juglans regia* L., *Prunus avium* L., *Fraxinus excelsior* L., *Sorbus domestica* L., plantations.

Introduction

Research programs, aimed at increasing high quality wood production with broadleaves plantations in southern Italy, started only beginning from the '90s. Here, in this first contribution, stem quality, diameter and total height growth, pests and diseases susceptibility of the different tree species used in plantations in the Calabrian Apennine, are analysed.

Site description

The study site is located in the highlands of the Serre (Lat.38°32′ N Long. 3°48′ W) in the Calabrian Apennine (Southern Italy). The climate characteristics are reported in Table 1 and Figure 1.

Table 1: Climate characteristics of meteorological station of Mongiana (VV) 921 m a.s.l. (1990-1999)

Mean annual temperature (°C)	10.8
Mean temperature warmest month (°C)	19.4
Mean temperature coldest month (°C)	3
Annual range (°C)	15.7
Number of months with t>10°C	6
Mean annual precipitation (mm)	1498.3
Wettest month (January) (mm)	260.4
Driest month (July) (mm)	24.6
Rain days	80
Phytoclimatic zones (after Pavari)	**Fagetum Warm subzone**

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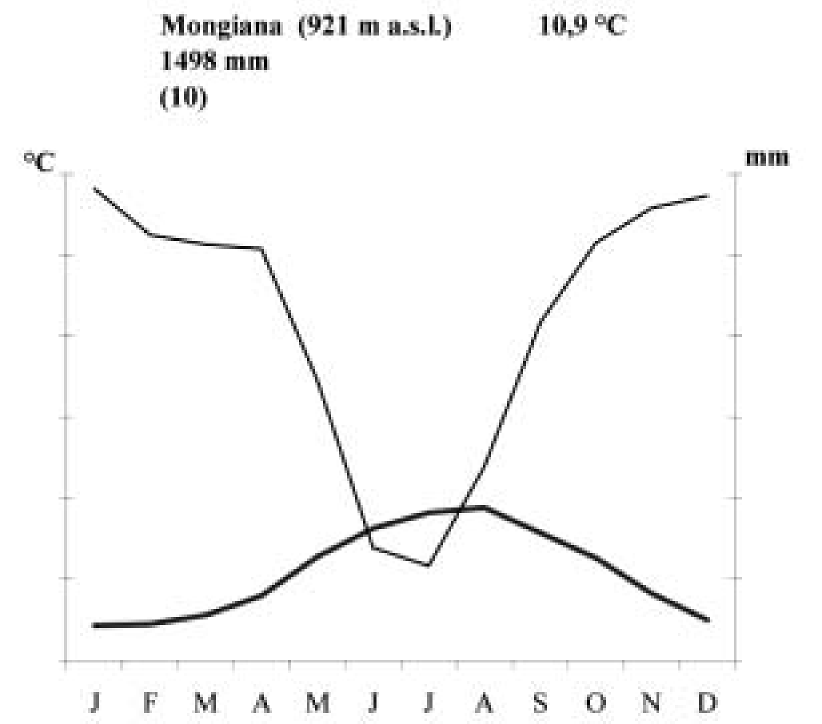

Figure 1: Diagram of Bagnouls & Gaussen of Mongiana (VV).

Materials and methods

The characteristics of each study area are summarized in Table 2.
Surveys were carried out at the end of each growing season in 1998,1999 and 2000. Thebiometrical parameters measured were: diameter at 10 cm, diameter at 1.30 m, diameter at first branches, total height, height at first branches, crown diameter in cross N-S and E-W. Fully randomised design was used in order to reduce the bias (Andrew,1984). The 15% of each species in different areas was tested. Data were statistically analysed by one-way ANOVA. Post hoc comparison among means was performed using HSD Tukey test. In the case of La Villa area the two theses have been compared by t-test for dependent samples (STATISTICA, StatSoft® Inc.).

Results and discussion

The main results of the inventories are given in Figures 2a, 2b,2c; 3a, 3b, 3c.
In the experimental area of Tre Arie, ANOVA and HSD Tukey test showed significant differences ($p<0.05$) in diameter and height among all tree species. No significant differences in diameter were recorded between Walnut and Ash. As regards species performances, Sycamore and Cherry showed the best results in diameter and height growth while Walnut and Ash lower increments. Sycamore displayed a mean annual height increment of 0.56 m and a mean annual diameter increment of 0.74 cm. These results confirm the statements of Evans (1984) that Sycamore grows best on acid brown earths. Even if there is no clear relationship between growth rate and soil pH, Cherry appears well acclimated (mean annual height increment of 0.45 m and mean annual diameter increment of 0.48 cm) to acid sandy loam soils as reported by Prior (1988) and Boulet-Gercourt (1997). These differences between the two species support the conclusions of Mercurio & Minotta (2000) that Sycamore has, in the early years, a faster growth than Wild Cherry. Conversely, in the present study, the diameter and height growth of Walnut was lower than those recorded in plantations, of the same age, in central Italy (Minotta *et al.*,1993; Bordin *et al.*,1994-1995; Bagnaresi *et al.*,2000).

Table 2: Characteristics of the experimental areas

Experiment areas	Elevation (m) a.s.l.	Slope aspect	Slope inclination (%)	Stand Age (years)	Spacing (m)	Species	Surface area (ha)	Bedrock	$CaCO_3$	pH	Texture	Effective depth (cm)	Type of soils
Tre Arie	1110	SW	15	10	4.5 x 4.5	Cherry Ash Sycamore Walnut	22	Granite	—	5.02	Sandy Loam	>80	Acid Brown Earths (Humic Dystrudepts)
Speranza	825	W	5	9	4.5 x 4.5	Cherry Walnut Service Tree	7	Granite	—	6.08	Sandy Loam	>80	Acid Brown Earths (Humic Dystrudepts)
La Villa	820	W	5	10	4.5 x 4.5	Walnut Sycamore	1	Granite	—	6.08	Sandy Clay Loam	>80	Acid Brown Earths (Humic Dystrudepts)

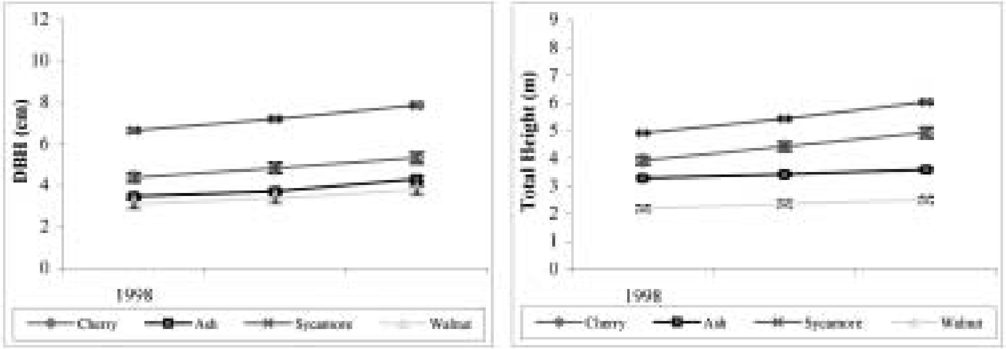

Figure 2a: Tre Arie. Comparison between diameter and total height of Cherry, Ash, Sycamore and Walnut. Bars not visible indicate S.E. smaller than the symbol.

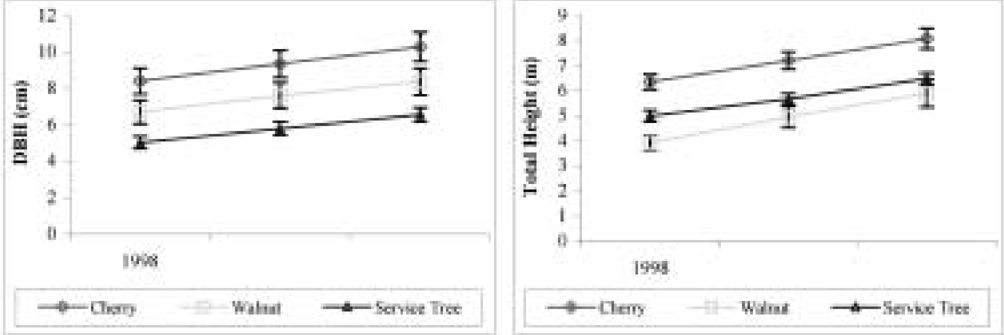

Figure 2b: Speranza. Comparison between diameter and total height of Cherry, Walnut, and Service Tree. Bars not visible indicate S.E. smaller than the symbol.

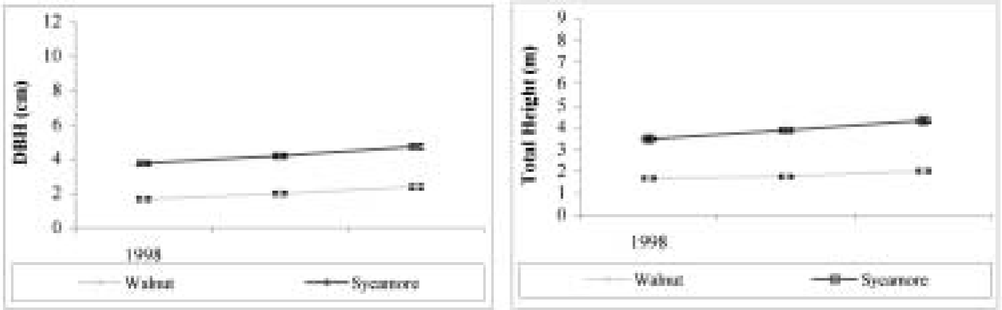

Figure 2c: La Villa. Comparison between diameter and total height of Walnut and Sycamore. Bars not visible indicate S.E. smaller than the symbol.

This could be probably ascribed to not favourable site conditions (Giannini & Mercurio, 1997; Bequey,1997) and namely to low spring temperatures, windy exposures, low value of pH and low soil nutrient levels. Likewise it is important to point out that low increments of Ash could be due to several constraints such as: attacks of *Lytta vesicatoria* L., that frequently provoked the complete defoliation, the lack of good soil conditions ($pH<5.5$) (Thill,1978; Evans,1984 and Duflot,1995) and the inadequate soil moisture availability (Aussenac & Levy,1992). In particular stem diameter and total height were the half (4.3 cm and 3.6 m) of those (9.0 cm and 7.9 m) observed in plantations, 7 years old, in central Italy by Bagnaresi *et al.* (2000).

In the experimental area of Speranza, ANOVA displayed significant differences among all tree species ($p<0.05$). HSD Tukey test indicated the following means significantly different: Service Tree a, Walnut a, Cherry b (species with different letters are significantly different). Cherry showed at 9 years a mean annual height increment (0.81 m) quite similar to mixed plantations with Walnuts 8 years old (0.87 m) established in central Italy, while the mean annual diameter increment were lower: 1.03 as to 1.63 cm (Buresti *et al.*,1994-1995). The stems were straight and of high quality with a good H/D ratio. In these first data, Service Tree showed, at 10 years, an intermediate mean annual height increment (0.65 m) between Cherry (0.81 m) and Walnut (0.59 m) but larger than those (0.40-0.50 m) reported by Mariano (1998) in the first 5 years. All the stems were of high quality and no pests and diseases were observed. In this study, Walnut showed the best results of all the experimental areas even if lower than those in central Italy. In the experimental area of La Villa, t-test showed significant differences between the two tree species ($p<0.05$). Sycamore displayed a diameter and height growth twice larger than Walnut. In both cases the whole growth was lower than in other areas. This could be due to frost injuries in the late spring and to inadequate cultivation practices: nursery material (caused the high mortality in the early years), post-establishment treatments.

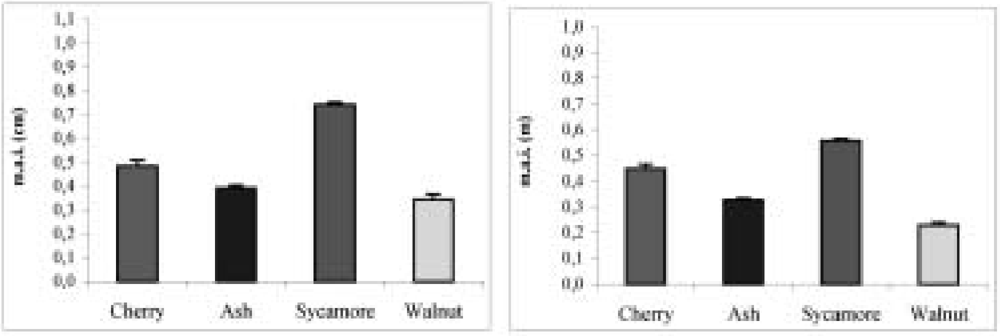

Figure 3a: Tre Arie. Comparison between diameter and height mean annual increment of Cherry, Ash, Sycamore and Walnut. Vertical bars represent S.E.

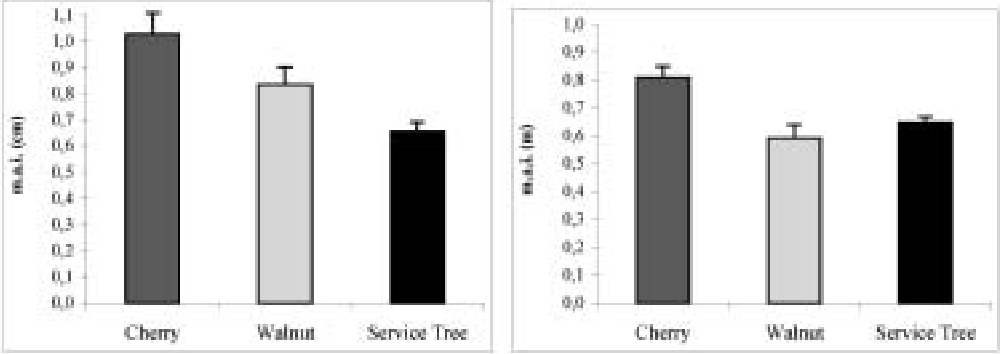

Figure 3b:. Speranza. Comparison between diameter and height mean annual increment of Cherry, Walnut and Service Tree. Vertical bars represent S.E.

Conclusions

In the most part of the Serre, namely between 700 and 1000 m a.s.l, environmental conditions are favourable to the spreading of new broadleaved plantations with the exceptions of

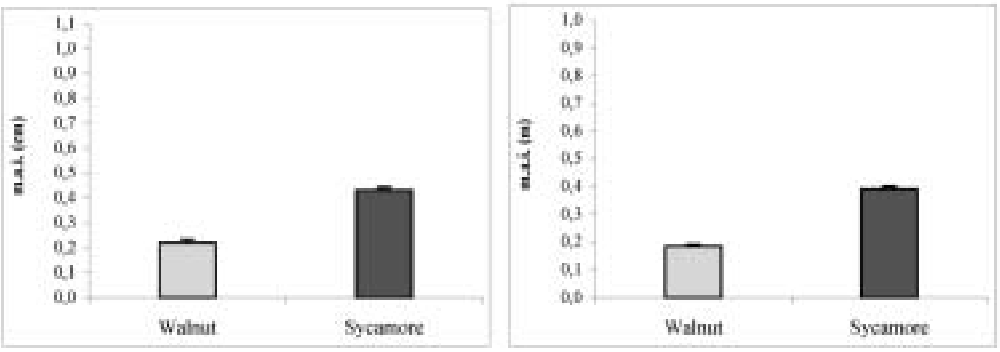

Figure 3c:. La Villa. Comparison between diameter and height mean annual increment of Walnut and Sycamore. Vertical bars represent S.E.

windy areas. According to these first results, Cherry and Sycamore seem the most promising species. In addition, Service Tree appears to be an interesting and appreciable species. More attention should be devoted, in new plantations, to the choice of the provenance and planting stock. In order to obtain good stem quality and to take full advantage from these plantations it is suggested that cultivation models, with regard to site preparation, spacing, pruning, tending and thinning, should be also pointed out.

Acknowledgements

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12. Effects of individual tree protections on the early growth of sessile oak and wild cherry

R. Mercurio[1] *and L. Nocentini*[2]

Summary

The experiment here described was set up to investigate the effects of two of the most widespread individual tree protections in Italy on the survival and early growth of Sessile Oak (*Quercus petraea* Matt. (Liebl.)) and Wild Cherry (*Prunus avium* L.). After three years, survival rate was noticeable in Wild Cherry and less in Sessile Oak. The use of treeshelters improves the height growth as regards wire mesh but the plants of Wild Cherry were less stable.

Keywords: *Quercus petraea* Matt. (Liebl.), *Prunus avium* L., treeshelter, wire mesh

Introduction

Recently a lot of papers were devoted to investigate the effects of different individual tree protections on tree form and development. Results were often inconsistent, especially in the Mediterranean area, as a consequence of bias of different factors such as: site conditions, tree species, plant quality, type and size of protection (Mercurio & Minotta, 2000). The experiment here described was set up to investigate the effects of two of the most widespread individual tree protections in Italy on the survival and early growth of Sessile Oak (*Quercus petraea* Matt. (Liebl.)) and Wild Cherry (*Prunus avium* L.).

Site description

The study site is located in S.Martino in Poggio (AR) (Lat. 43° 26′ N, Long. 0° 17′ W), 14 Km NW Arezzo (Tuscany, Central Italy). The site, at 450 m asl, SE aspect, was an agricultural land.
The climatic and soil data are reported in Table 1 and Figure 1.

Materials and methods

Seedlings of sessile Oak in plastic containers (1+1) and Wild Cherry bare root seedlings (2+0) from commercial nursery were used. Seedlings were characterised by a good form and balanced root system and clear apical dominance; height ranged from 30 to 50 cm. They were planted (February 1998) at a square spacing of 5x5 m. Both species underwent two types of protection: treeshelter 120 cm tall and wire mesh 120 cm tall for a total of four theses under comparison:
Sessile Oak with treeshelter (TSO)
Sessile Oak with wire mesh (WMO)
Wild Cherry with treeshelter (TSC)
Wild Cherry with wire mesh (WMC).

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Table 1: Climate characteristcs of meterorological station of Arezzo (277 m asl.)

Mean annual temperature (°C)	14
Mean temperature warmest month (°C)	23.1
Mean temperature coldest month (°C)	5.3
Annual range (°C)	17.8
N of months with t>10°C	8
Mean annual precipitation (mm)	865
Wettest month (november) (mm)	110
Dryest month (july) (mm)	38
Thornthwaite classification	C_2 B_2 s b'_4
Humid-subhumid second mesothermic	
with moderate summer deficit	
Soil Characteristics	
Bedrock	shales (galestri)
Texture	clay loam to clay
CaCo$_3$	7
pH	7.7
Effective depth (cm)	70

Treeshelter was square-section, 15 cm side, green translucent; wire mesh was round-section, 25 cm diameter. The site was kept weed free using periodical inter-row ground cultivations. No fertilisation or irrigation were carried out. Each thesis was replicated four times. Each replication consisted of 10 trees in a line for a total of 160 trees. The following parameters were measured: tree survival, stem diameter in mm at 5 cm above soil level and total tree height in cm. Surveys were carried out at the end of each growing season in 1998, 1999 and 2000. Data were analysed statistically using t-test for dependent samples (STATISTICA, Statsoft® Inc.).

Results and discussion

Results are summarized in Figures 2 and 3.
After three years, survival rate was noticeable in Wild Cherry (95%) and less in Sessile Oak (85%). No type of association was observed between survival rate and type of protection.
Results after three growing seasons showed a general larger development in stem diameter and height of Wild Cherry with regard to Sessile Oak.

	J	F	M	A	M	J	J	A	S	O	N	D	Year
T	5.3	6.2	8.8	12.5	16.3	20.1	23.1	23.1	19.9	15.5	10.4	6.5	14.0
P	72	73	69	71	75	58	38	48	81	83	110	87	865
PE	10	13	28	50	85	116	142	131	94	60	28	13	770
AE	10	13	28	50	85	104	84	69	83	60	28	13	627
D	0	0	0	0	0	12	58	62	11	0	0	0	143
S	62	60	41	21	0	0	0	0	0	0	0	54	238
DP	48	31	24	52	39	33	14	8	31	25	66	45	736

S = Surplus R = Soil Moisture Recharge D = Deficit U = Soil Moisture Utilization

Climate Type: C_2 B'_2 s b'_4 *Deficit Index = 18.57*
Umidity Index = 30.91 *Moisture Index = 12.34*
Dry Period: 104 Days *Moisture Available Index: 736/770 =0.95*
(from Bigi and Rustici, 1984)

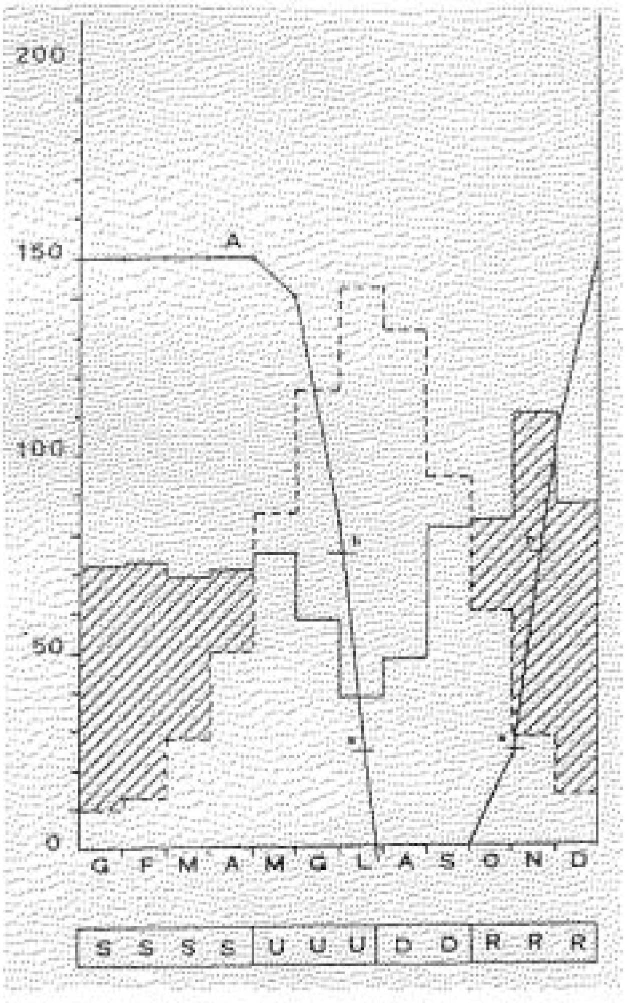

Figure 1: Water balance diagram of the Arezzo (277 m.) according to Thornthwaite and Mather.

As regards protection effects, significant differences were recorded between TSO and WMO in height ($p<0.05$). The same was observed between TSC and WMC in height ($p<0.05$). The use of treeshelters 120 cm tall confirms the enhancement of the height growth, in the first 3 years, as observed in Oaks (Tuley,1985; Potter,1988,1991; Buresti & Sestini,1991; Nixon,1994; Mayhead & Bootman,1997; Mayhead & Price,1998) and in Wild Cherry (Nixon,1994; Andiloro *et al.*,2000).

With respect to radial development significant differences were recorded between TSO and WMO in stem diameter ($p<0.05$). On the other hand, at the end of the third growing season, no significant differences in stem diameter between TSC and WMC were observed. In both cases sheltered trees showed greater dimensions than unsheltered trees as noticed by Andiloro *et al.* (2000) in Wild Cherry comparative plantations in Calabria and in Sessile Oak by Tuley (1985) but not by Mayhead & Bootman (1997) and Dupraz (1997).

Almost all the sheltered trees were branch free but in Oaks lateral branches were often distorted.

Some Wild Cherries bent over when they flushed because their slender stems could not support the spreading crown which had developed above the treeshelters. All the sheltered plants were less stable (high H/D ratio) than those in wire mesh due to height increments not proportioned to those in diameter.

No pests and diseases were noted in different theses except in sheltered trees where honeycombs were frequent.

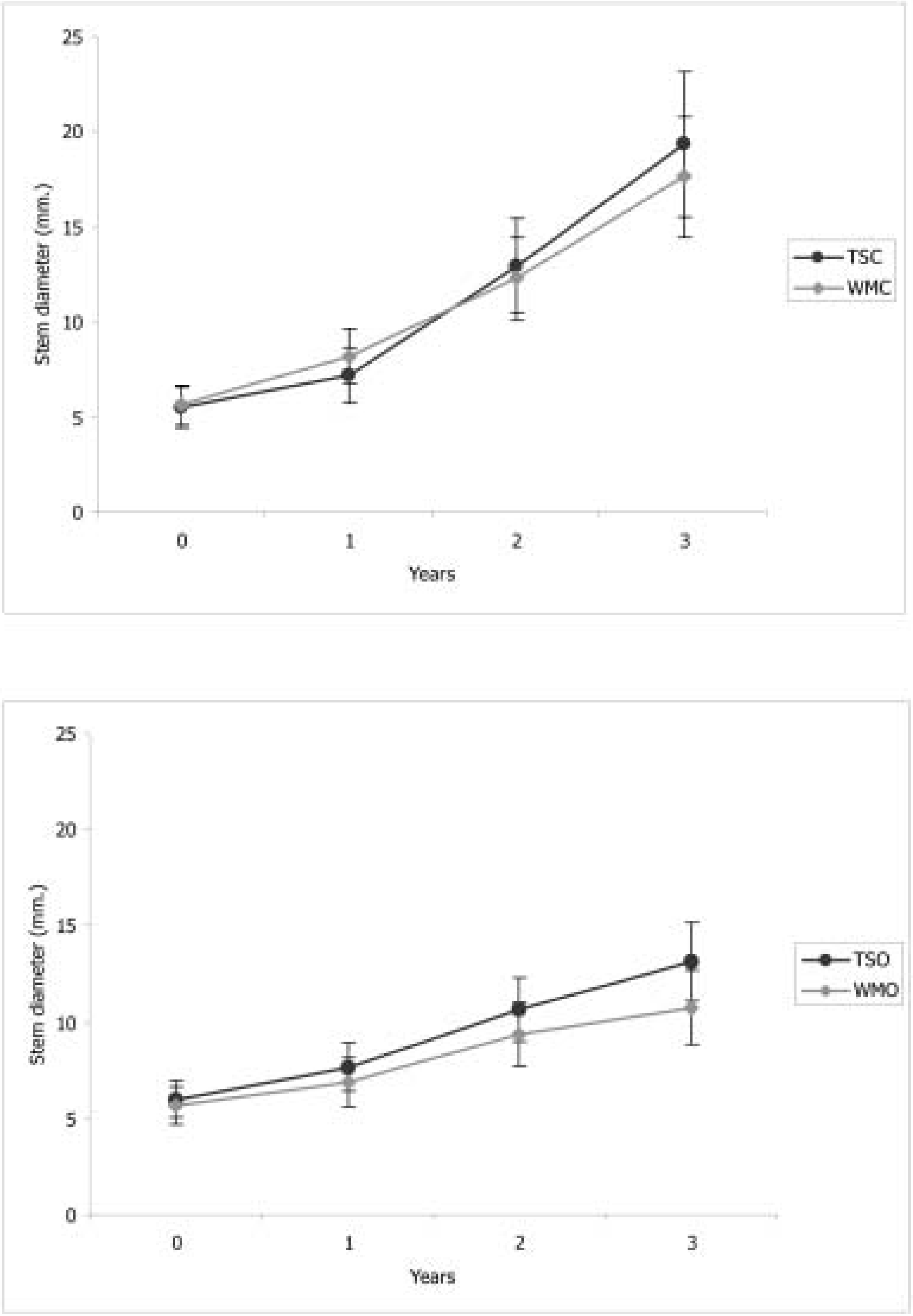

Figure 2: Variations of Stem Diameter of Sessile Oak and Wild Cherry - Vertical bars represent +/- SE.

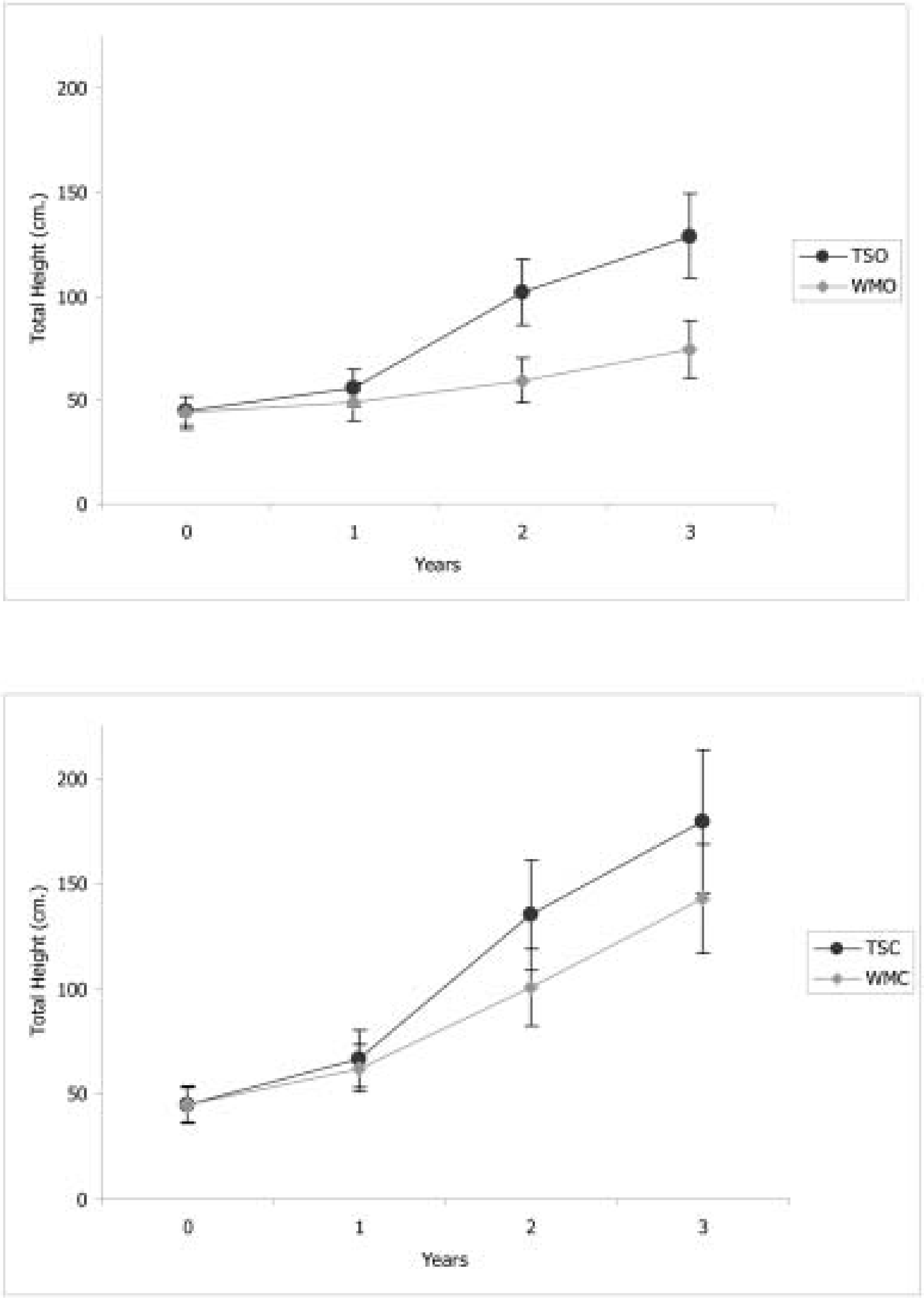

Figure 3: Variations of Total Height of Wild Cherry and Sessile Oak - Vertical bars represent +/- SE.

Conclusions

The use of treeshelters offers certainly some benefits: it improves the height growth and protects trees from animals and ground cultivation damages in the first years. On the other hand, there is no sufficient evidence that this is a very promising technique for individual tree protection if we consider that the plants (Wild Cherry in particular) are unstable and that the treeshelters should not be used in exposed areas and with high tourist use because of aesthetic disadvantages. In addition, it is necessary to consider that later on, once trees have grown out of the treeshelter, the differences between sheltered and unsheltered plants should decrease as reported in literature for many tree species (Buresti & Sestini,1991; Mayhead & Bootman,1997; Dupraz,1997; Mayhead & Price,1998). As a consequence, even if the performances of treeshelter were better than those of wire mesh, the use of the former technique should be carefully evaluated, namely in areas characterised by a high landscape value.

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13. The effect of planting date on field performance of *Castanea sativa* and *Quercus frainetto* seedlings

*K. Radoglou, Y. Raftoyannis and G. Halivopoulos**

Summary

Nursery stock of two-year old, container grown *Castanea sativa* and *Quercus frainetto* seedlings were used in this study. Seedlings were planted at a field site on December, January, February and March. Root electrolyte leakage and root growth potential of seedlings were measured before planting while carbon assimilation, stomatal conductance and leaf water potential during the first year of field establishment and seedling survival was monitored for the first two years after outplanting. No significant difference in root electrolyte leakage values among seedlings planted on January, February and March was found although all were significantly higher from the December planted seedlings. Root growth potential was not affected from planting date. Midday leaf water potential of chestnut seedlings was higher than oak. Both species sustained high carbon assimilation rates and stomatal conductance throughout the first growing season and showed a depression in mid summer. Mean survival of seedlings decreased and corresponding variances increased from the initial assessment to the final one. December and January lifted plants showed the highest survival rates. Oak seedlings planted in January showed the best survival rates for both species and treatments. All other seedling survival was reduced after two years to less than 50%.

Keywords: *Castanea sativa, Quercus frainetto*, planting date, field performance.

Introduction

Reforestation techniques have been improved over the past years in areas such as watering, site cultivation, weed control etc. However, reports of failed reforestation attempts still exist, especially in stressful environments such as the degraded lands of Mediterranean areas. The successful establishment of seedlings depends mainly on selection of proper planting stock and the environmental conditions of the planting site. Phenological and physiological characteristics of seedlings determine their ability to overcome the transplanting stress.

Various morphological, physiological and molecular methods have been developed to test the seedlings' condition before planting (Mattsson, 1997). Root electrolyte leakage (REL) and root growth potential (RGP) are two seedling quality assessment methods that have been investigated widely and applied to forest and nursery practice. REL has been proved a valuable method of predicting field performance (McKay, 1992; McKay & White, 1997). RGP is a useful method for measuring seedling quality before outplanting, particularly when forestation is taking place in dry lands (Ritchie, 1984).

The majority of planting in Greece is carried out in winter and early spring. The ability of seedlings to tolerate desiccation and rough handling in winter is higher than in autumn or spring. The growth habit of perennial plants indigenous to temperate zones is generally characterized by a relatively short period of active shoot elongation followed by a lengthy dormancy period. Although dormancy is an adaptation to permit plant survival during periods of stress, i.e., drought, frost, etc., a plant is not equally resistant to factors of the environment during the entire dormant period, nor are the stages of dormancy normally defined in relation to stress resistance.

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The Reforestation Service of Greece encourages chestnut plantings in this area for their multiple use as wood, chestnut production and wildlife food. However, failures are continuously reported. These failures might have been the result of poor root growth. It is well established that survival and growth of outplanted seedlings depend upon the rapid establishment of a vigorous root system (Margolis and Brant, 1990). Damage to root systems may occur by many external factors during the pre-planting period. Extreme temperatures, water imbalance and rough handling can cause severe damage to root systems.

The objectives of this study were to investigate the influence of planting date on seedling quality and post planting survival, to assess REL and RGP as plant quality indicators, to compare the two species and study the physiological response of plants to environmental conditions.

Materials and methods

Nursery stock of *Castanea sativa* Mill., (origin: Petrokerasa, Lagadas, Greece) and *Quercus frainetto* Ten.(origin: Vertiskos, Lagadas, Greece) was used in this study. Seeds were collected from mature and healthy trees and sown in plastic containers filled with peat:perlite=3:1, with cavities ca 4 cm in diameter and 15 cm deep, in November 1994, in the forest nursery of Lagadas, near Thessaloniki (23°01′ E, 40°38′ N, altitude 100 m, mean annual rainfall is 480 mm). Plant growing conditions at nursery were identical to those used by the local reforestation service (Takos, and Merou, 1995).

In order to investigate the effect of planting date, seedlings were outplanted at four different dates, on 22 December 1996, 28 January 1997, 25 February 1997 and 20 March 1997. Plants were selected for uniformity and carefully transported either to the Forest Research Institute, in Thessaloniki (22°58′ E, 40°35′ N, altitude 10 m) or to the field planting area (transportation time about _ hour, for both locations). Morphological papameters were measured before planting from a sample of 15 seedlings and the mean values were: height=23 cm, stem diameter=9 mm, dry weights of shoot=3.2 gr and root=4.9 gr, root / shoot ratio = 1.72.

The planting area was located at Krioneri (23°18′ E, 40°50′ N) on the Mountain Vertiscos, 70 km north of Thessaloniki. The natural vegetation of the area belongs to the *Quercetalia frainetto* zone, composed mainly by mixed oak woods (*Quercus frainetto, Q.pubescens*) and dispersed beech trees (*Fagus sylvatica*). The soil is a neutral sandy loam (clay 7%, silt 30%, sand 64%) organic matter 1,3%, neutral (pH 7.0). The experimental plot was south facing with a mean elevation of 880 m. The plot had been prepared mechanically by removal of plant cover with powered machinery and fenced. The experimental design was completely randomised with three replications, for each treatment. In each replication, 60 seedlings were shovel planted in a 2x2m planting pattern. No weeding, irrigation or fertilisation was applied, following the common practice of reforestation in Greece.

The climate of the site is transitory between Mediterranean and temperate, Csb according to Köppen classification system, with a mean annual temperature of 12°C and mean annual rainfall of 810 mm. The site environmental conditions were monitored with an automated weather station located inside the experimental site. Air temperature, air humidity and precipitation were recorded every 30 min, while soil temperature and soil moisture were recorded at 30 cm depth with appropriate sensors connected to a data-logging device (DL2 Delta-T Logger, Delta-T Devices Ltd). Environmental conditions during the growing seasons of 1997 and 1998 are shown in Figures 1a and 1b. The mean daily air temperature fluctuated widely during the studied period while soil temperature at 30 cm varied less and reached a maximum of 25°C, in August 1998. Rainfall fell quite often during the summer of 1997, but a long dry period was recorded for the summer of 1998. The temperature fluctuated during the experimental period while the RH and VPD were more or less constant. Rainfall occurred quite often, except for the period from the middle of June to the middle of July when almost no rain felled. The soil moisture followed the rainfall pattern. Air temperature, vapour pressure deficit and photosynthetic active radiation at the leaf level, reflect the microclimate conditions at the canopy and as a result there is much fluctuation during the study period. PAR was always higher than 700 _mol m^{-2} s^{-1}, which is a reasonable threshold for light saturated conditions.

Root electrolyte leakage (REL) was used to measure the physiological status of fine roots before

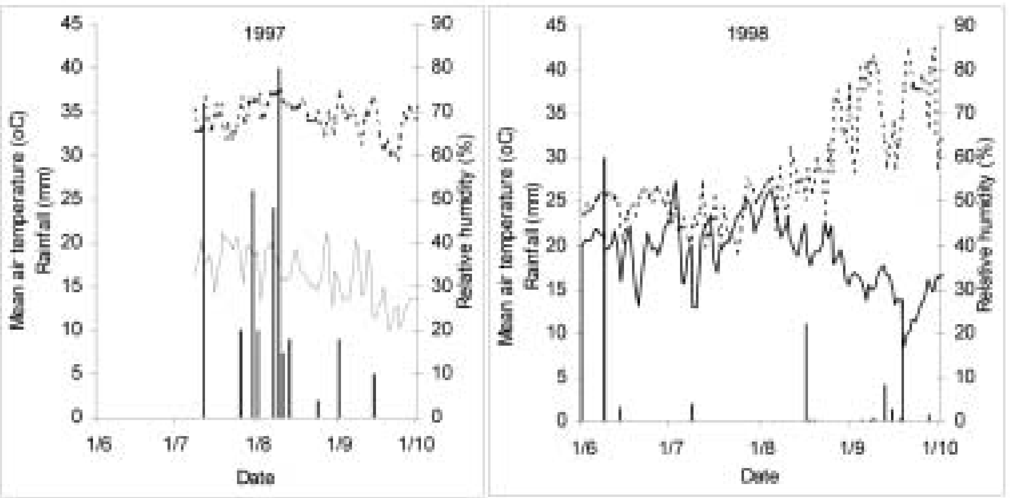

Figure 1: Seasonal courses of mean daily air temperature (full line), relative humidity (dotted line) and rainfall (bars) in 1997 and 1998.

and after treatments, following the method described by McKay (1992). The leakage rate of undamaged control plants was measured to give baseline values. Fifteen seedlings for each treatment were used. Small amounts (100 – 300 mg, fresh weight) of fine roots (<2 mm diameter) were sampled from the midpoint of each root system. Roots were washed in tap water to remove soil and rinsed in de-ionized water to remove surface ions. The samples were placed in 28 ml universal vials containing 15 ml distilled water of known conductivity (C_{in}), shaken and then left at 20°C for 24 h. After 24 h, the bottles were shaken again and the conductivity of the bathing solution (C_{24}) was re-measured. Following this measurement, samples were autoclaved at 110°C for 10 minutes and then allowed to cool (5 h); conductivities (C_{au}) were measured at this time. Root electrolyte leakage was expressed as: $REL = [(C_{24}-C_{in})/(C_{au}-C_{in})] \times 100$.

For the measurement of root growth potential (RGP) a set of 15 plants for each planting date and species was planted in observation boxes (containers of 3x10x70 cm, with a transparent side allowing root observation) and transferred to a greenhouse with controlled environmental conditions for 40 days. The containers were filled with moist horticultural mix (peat:perlite=3:1) and the root system was pressed down against the peat and held in position by a length of transparent plastic sheet secured with adhesive tape. The Perspex face of each box was protected from light, covering them with black polyethylene sheets. The boxes were stacked in an approximately vertical position with the shoot projecting from the top. Environmental conditions in the greenhouse were: air temperature 17 ± 1°C (day) and 10 ± 1°C (night); relative air humidity, 60% (day) and 90% (night); photosynthetic photon flux density, 200 ± 20 _mol m-2 s-1; ambient CO_2 concentration 440 _mol mol-1. Seedlings were watered regularly with tap water. Root regeneration was quantified 40 days after transplanting, by counting the number of new roots.

Total leaf area per plant was estimated on four randomly selected seedlings per treatment. The leaves of each seedling were subdivided into three size categories and the leaves of each category were counted. The area of a representative leaf per category was measured with a LI-3000 portable leaf area meter (Li-Cor, Inc., Lincoln, NE). Total leaf area per plant was estimated as the sum of the leaf areas of the three categories.

Percent survival was determined at the beginning, middle and end of each growing season for 1997 and 1998, when plants had still leaves. Plants with no leaves or alive buds were considered as dead.

Leaf water potential (Ψm) was measured using a pressure chamber (Wescor, Inc., USA), according to the method described by Slavik (1974). Enclosing leaves in polythene bags prevented leaf desiccation.

Leaf gas exchange measurements were made using a portable photosynthesis system (LI-6400, Li-Cor Inc., Lincoln, NE, USA). Leaves were enclosed in the cuvette until the values of assimilation rate (A), transpiration rate (E), intercellular CO_2 concentration (Ci) and stomatal conductance (g_s) had stabilised (usually 30-60 sec). Environmental parameters such as air and leaf temperature (Tair), vapour pressure deficit (VPD), relative humidity (RH), photosynthetic active radiation (PAR) were also recorded at the leaf surface. Humidity was kept constant by setting the flow rate through a desiccant (Drierite™, Hammond Drierite Co., Ohio, USA) at the same rate as transpiration.
Observations were taken between 10.00 and 14.00 h, when PAR values were above 800 mmol $m^{-2}s^{-1}$, at seven different dates during the growing season (June-September). All measurements were made on 3 plants per treatment and 3 leaves per plant. Fully expanded leaves with the same orientation and at the same layer in the crown (middle-top) were selected for measurement.
Differences among treatments for REL and RGP values were assessed using ANOVA procedures and means were compared with Tukey's multiple comparisons test. Survival data did not satisfy ANOVA assumptions even after transformations were applied and they are presented as means followed by their standard deviation. All tests for significance were conducted at $p<0.05$ unless otherwise indicated.

Results

No significant differences in REL or RGP values, among planting dates were found for *C. sativa* (Figure 2a). Similarly, no significant differences in REL values among planting dates were found for *Q. frainetto* (Figure 2b). Seedlings of *Q. frainetto* planted in December and February showed a significantly lower RGP compared to seedlings planted in March while seedlings planted in January did not differ significantly from other seedlings. Mean REL values ranged between 13 and 21% for *C. sativa* and 18 to 21% for *Q. frainetto*. Mean RGP values ranged between 13 and 16 new roots for *C. sativa* and between 8 and 23 for *Q. frainetto.*

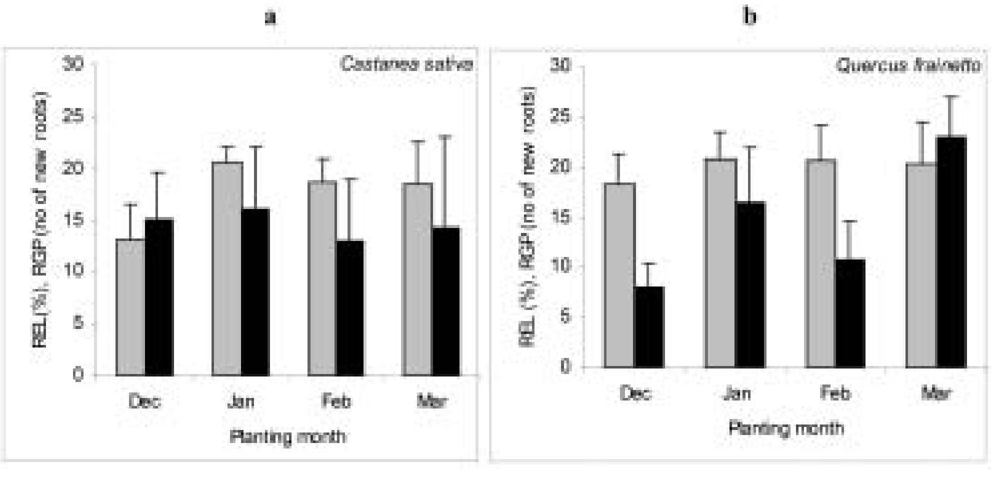

Figure 2: Root electrolyte leakage (REL) (grey collumns) and root growth potential (RGP) (black collumns) of Castanea sativa (a) and Quercus frainetto (b) seedlings planted in December (Dec), January (Jan), February (Feb) and March (Mar). Each column represents the mean +1 SD.

Mean survival of seedlings decreased and corresponding variances increased, from the initial assessment to the final one, for all treatments (Figures 3a and 3b). Survival of *Q. frainetto* seedlings was higher than *C. sativa* for all treatments by the end of 1997 growing season. Further reductions in seedling survival were observed during the second season. The final assessment of seedling survival in 1998, showed higher survival rates for December and January planted seedlings (41 and 45%) of *C. sativa* compared to February and March (24 and 28%). *Q. frainetto* seedlings planted in January showed the highest survival rates at the end of 1998 (73%) while seedlings planted at other months showed a mean survival between 33 and 44%. Total plant leaf area of *C. sativa* seedlings increased sharply until mid-July up to 400 and then stabilized until the end of September (Figure 4a and 4b). The total leaf area of *Q. frainetto* seedlings stabilized at 170 cm^2 at mid-June. No significant differences among seedlings planted at different dates were observed for *C. sativa* whereas clear differences were observed for *Q. frainetto.* January planted seedlings of *Q. frainetto* showed the higher leaf area followed by December, February and March planted seedlings. Figure 5 shows the seasonal pattern of midday leaf water potential (_) of all treatments. Seedlings of *C. sativa* planted in different dates showed a similar seasonal pattern of _ with relatively high values at the beginning of June followed by a reduction during July, a sharp increase at the beginning of August and a subsequent reduction until mid September. Seedlings of *Q. frainetto* showed lower _ at the be-

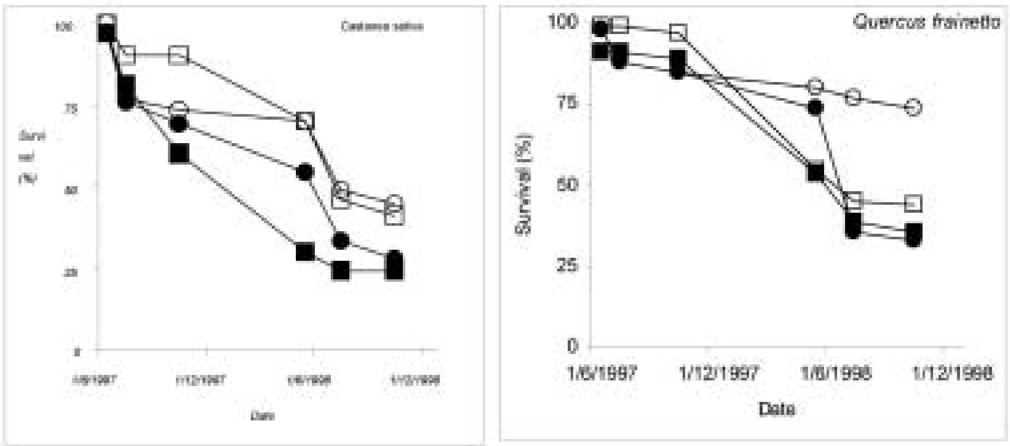

Figure 3: Seedling survival for 1997 and 1998 of Castanea sativa (a) and Quercus frainetto (b) seedlings planted in December (⦿), January (ɷ), February (_) and March (_). Symbols represent means ±1 SD (n = 30).

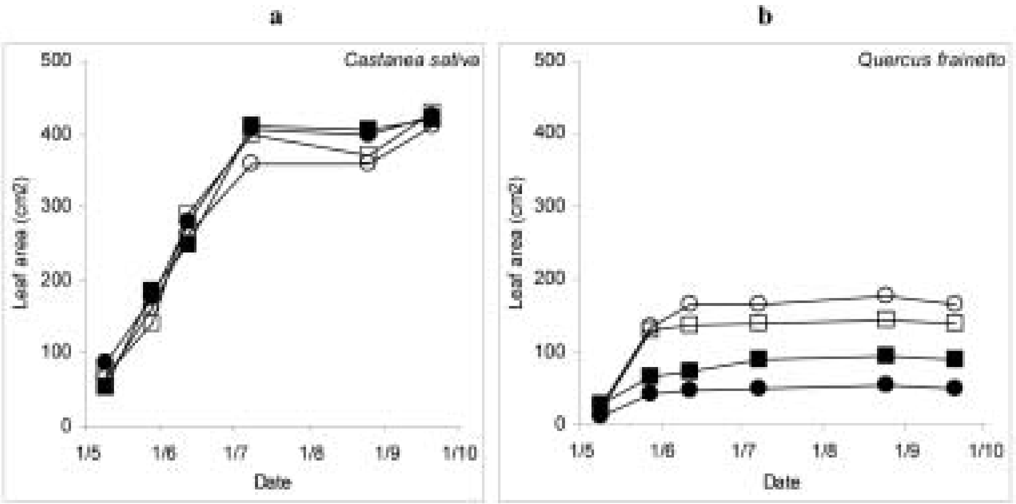

Figure 4. Total leaf area of Castanea sativa (a) and Quercus frainetto (b) seedlings planted in December (⦿), January (ɷ), February (_) and March (_). Symbols represent means ±1 SD.

ginning of the season and their values did not fluctuated largely during the season. Seedlings of *C. sativa* planted in March showed the lowest values of _ of all treatments (-2.8 MPa at 31/7/97), followed by February planted seedlings while January planted seedlings showed the highest values of _ (-1.0 MPa at 7/8/97) until early August but then dropped below the December plantation values.

Carbon assimilation of *C. sativa* seedlings showed stable rates until the beginning of August (between 10 and 15 _mol m^{-2} s^{-1}) then increased to mean values around 20 _mol m^{-2} s^{-1} and then decreased again at the last observation day, in mid September (Figure 6). There was no significant difference in A among seedlings planted at different dates. *Q.f rainetto* seedlings showed higher A values than *C. sativa*. At the beginning of June mean values of A were near 16 _mol m^{-2} s^{-1} , then after a slight increase were reduced down to 10 _mol m^{-2} s^{-1} at the beginning of August, followed by a sharp increase until the end of August were mean A values reached 26 _mol m^{-2} s^{-1} and a final small reduction was recorded at the last measurement at mid-September.

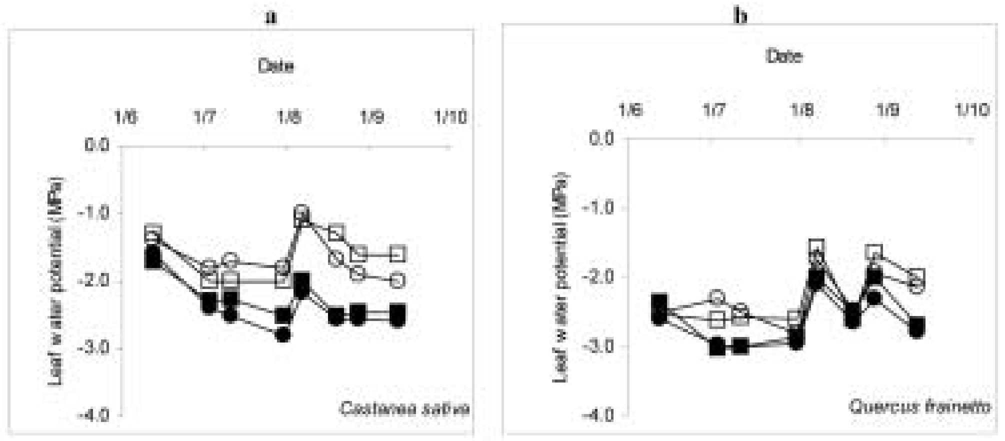

Figure 5: Seasonal courses of midday leaf water potential (Ψ) of Castanea sativa (a) and Quercus frainetto (b) seedlings planted in December (⊙), January (ꝏ), February (_) and March (_). Symbols represent means ±1 SD (n = 4-6).

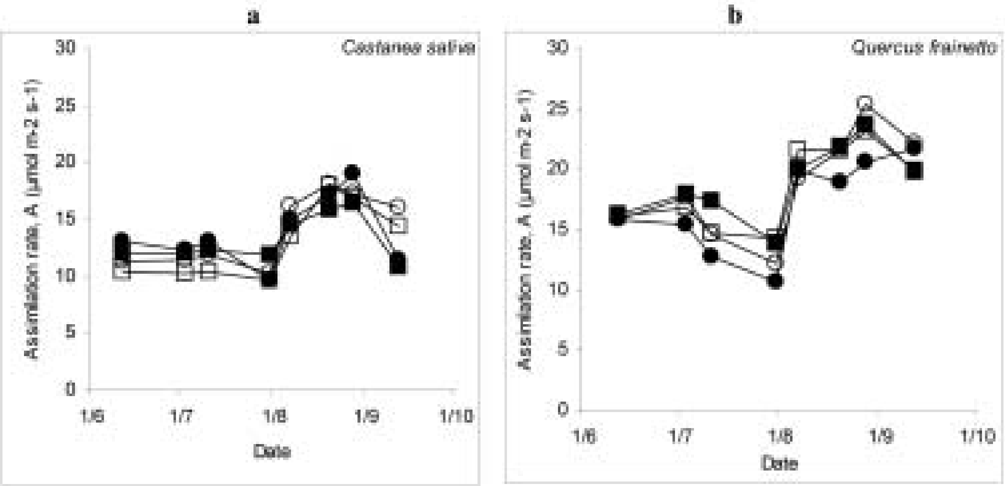

Figure 6: Seasonal courses of CO2 assimilation rate (A) of Castanea sativa (a) and Quercus frainetto (b) seedlings planted in December (⊙), January (ꝏ), February (_) and March (_). Symbols represent means ±1 SD (n = 4-6).

Discussion

Our experiments showed no significant effect of planting date on REL and RGP values of seedlings. Similar results were obtained by McKay (1993) who reported low values and no significant differences in REL among seedlings lifted from December to March for *Picea sitchensis*, *Pseudotsuga menziesii* and *Larix leptolepis*. Also, McCreary & Tecklin (1994) found no significant differences among lifting dates for the number of new roots and concluded that RGP data was inconsistent and difficult to interpret. However, other workers have reported differences in RGP among planting dates. Garriou et al. (2000) found that seedlings of Q. robur, Q. rubra and Pinus nigra ssp laricio var Corsicana lifted in November exhibited lower survival and RGP (except in pine) than those lifted in January and March. Ritchie (1982) reported that the RGP of *Pseudotsuga menziesii* seedlings, varied appreciably with respect to date of lifting, increased until late January and then decreased. Also, Ritchie et al. (1985) observed an increase in RGP from December to February and then a reduction in March lifted seedlings of *Pinus contorta*.

We also found no significant relationship between RGP or REL and survival. McKay (1998) found that survival and RGP were not linearly related in Sitka spruce and Scots pine suggesting that for these species absolute RGP values are poor indicators of survival. On the other hand McKay (1992) found that REL of *Picea sitchensis, Pseudotsuga menziesii* were highly correlated to survival and height growth after 2 growing seasons; she also found that REL was more closely correlated with survival and growth than was RGP. Mattsson (1997) suggested that correlations between quality tests and subsequent field performance have to be established for different species and for different site and climate conditions. Most relevant studies have concentrated in few commercial conifers of temperate climates while very few studies have included deciduous species and carried out in dry climates. To our knowledge it is the first time that *C. sativa* and *Q. frainetto* are used in such studies and as a result no direct comparisons can be made with other reports. As McKay & White (1997) concluded the effect of the stock's condition on its subsequent growth and performance was greatly modified by the planting site and proposed that vitality tests prior to planting may give information to managers of sites likely to experience dry springs while their use in sites with high spring rainfall may be marginal.

In our study, December and January planted seedlings had better chances to survive than February and March ones. Similarly, McCreary & Tecklin (1994) found significant differences in survival of *Quercus douglasii* seedlings between lifting dates, which ranged between approximately 97% and 63%, with the latest lifted seedlings having the lowest survival. Jiang et al. (1995) found that spring-lifted (May) seedlings of *Picea glauca* were better able to withstand water stress than fall-lifted (October) seedlings and McKay and Mason (1991) found that survival of *Picea sitchensis* and *Pseudotsuga menziesii* seedlings increased as lifting date was delayed. In our study we observed a severe reduction of seedling survival at the second year assessment. In contrast, McCreary & Tecklin (1994) found a close similarity between first-, second- and third-year survival of *Quercus douglasii* and suggested that once seedlings survive their first year, there is a high likelihood they will remain alive. Most other studies have reported no-significant differences in plant survival between first and second year of establishment. The survival reduction in our case indicates the adverse conditions of the planting site.

The results of our experiments showed that water potential could be useful in assessing damage to roots of deciduous species where water loss occurs mainly through the fine roots. Girard *et al.* (1997) concluded that for bareroot *Pinus nigra* ssp. *Laricio* var. *Corsicana* seedlings, needle predawn water potential at the time of transplanting was a reliable predictor of the ability to regenerate new roots and of seedling mortality after planting. Webb & von Althen (1980) concluded that shoot xylem water potential may offer a useful and rapid measure of seedling physiological quality. Kaushal & Aussenac (1989) suggested that maintaining a high Ψ after transplanting is a key factor for the subsequent survival of forest seedlings; if it falls below a certain limit the chances of the seedlings' survival are reduced considerably and on reaching a certain level they are unable to recover. Under drought stress, no new roots develop which leads to a further reduction of Ψ and eventually seedlings die. Guehl *et al.* (1993) found that both development and survival of *Pinus nigra* ssp. *Laricio* var. *Corsicana* seedlings were related to their water status assessed at the beginning of the growing season and proposed that the carbon assimilation capacity of the transplanted seedlings was probably reduced as a result of the drought stress. The relatively high survival of seedlings at the beginning of the growing season was possibly the outcome of stored carbohydrates. When these reserves run out, seedlings exhibited reduced photosynthetic capacity due to the drought stress, and subsequently root regeneration and elongation was limited, resulting in reduced survival by the end of the growing period.

The leaf production of *C. sativa* seedlings was higher than *Q. frainetto*, indicating that *C. sativa* has higher demands on carbohydrates, nutrients and water. However, the carbon assimilation rate of *Q. frainetto* was higher than *C.sativa* and as a result *Q.frainetto* is better adapted to grow and survive at this site. Drought induced a strong but not complete reduction of A, indicating that C. sativa can sustain significant CO_2 fixation during adverse water stress conditions. A high percentage of leaves turned yellow during the water stress period, indicating irreversible cell damage. Lauteri et al. (1997) reported that the mean assimilation rates, of different populations of *C. sativa* seedlings, ranged between 6.6 and 9.5 mmol $m^{-2}s^{-1}$ in irrigated and 2.7 and 7.1 mmol $m^{-2}s^{-1}$ under drought conditions.

Drought will have a large ecological impact in the context of climate change and many regions could experience an increased frequency of drought if the current models for climate change proved true. One such region is the East Mediterranean Basin. The occurrence of drought is a major factor determining tree growth, species distribution and forest composition (Hinckley et al. 1981). Resistance to drought depends upon a whole range of factors affecting the balance of evaporative demand and supply such as stomatal conductance and leaf area as well as the ability of stem and root systems to transport water.

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14. Sustainable forestry in western Himalaya

C. M. Seth[1]

Summary

In earlier times, Himalaya were worshipped as abode of gods, but man's onslaught over a period of time, rendered them among the most fragile ecosystems on the earth.

These mountain ranges support some of the world's best conifer and broadleaved forests capped by high altitude alpine pasturelands. Himalaya are not only rich in biodiversity but are also the main source of river valley systems (Ganga, Indus, Brahmputra) in the sub-continent. Tampering with these forests of Himalaya or unscientific management shall result into devastating effects on the people inhabiting in its river valley systems and catchment areas. It is estimated that 50 million people in mountains and another 300 million people in plains are dependant directly or indirectly on Himalaya.

Himalaya are oriented in East-West direction from Nanga Parbhat in West to Namcha Barwa in the east in the form of a great arc, over a length of about 2500 km and average width of 240 km between 27°-36° N and 73°-97° E. The Himalaya can easily be subdivided into three regions viz. Eastern, Central and North Western. The Western Himalaya extends from Kashmir to Kumaon. In the paper, an attempt has been made to discuss various issues related to the sustainable management of forests in northwestern Hiamlaya, only with special reference to the management of broad-leaved forests.

Keywords: Western Himalaya, forest types, wasteland, plantation, joint forest management, sustainable forest management, biodiversity.

Ecology of Western Himalaya

Western Himalaya represent a quarter of India's forest reserves, comprising of three hill states of Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh, covering an area of 572319 sq. kms. Out of this, 107252 sq. kms is recorded as forest, including high altitude pastures. As per satellite data actual forest cover is only 6.74 million ha. Table 1 gives area under forests as per Govt. records, actual forest cover and population of both human and livestock in the area.

These three states being mountainous have varied effects on vegetation due to topographical and climatic conditions. In Western Himalaya there is considerable diversity in geology, geography, soil and climate giving rise to many macro and micro habitats. The Himalaya biota are under five different biogeographic influences, these are Paleoarctic, Mediterranean, Sino-Japanese, Indo-Malayan and Peninsular India. Three major factors viz; longitude, latitude and altitude also greatly influence the species diversity in the area which is reflected in the forest types of the area. According to survey, India has about 17000 flowering plants, out of which 8000 species grow in Himalaya. All these factors have contributed to the endemism of species in Western Himalaya. It appears that endemics in Himalaya are mainly due to the recent origin of species which did not find time to extend their range because of several factors discussed above. It is reported that number of endemics in Himalaya are 3165 out of total of 6850 in India. More than 50% endemics are in Himalaya (Khoshoo, 1993).

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Table 1: Area under forests and population in three west Himalayan States

State	Geographical Area	Recorded Forest Area	Forest Area based on satellite data	Human Population			Livestock Population
	million ha	million ha	million ha	Total million ha	Rural %	Urban %	
H.P.	5.57	3.59	1.3	5.17	91.33	8.67	5.11
J. and K.	22.22	2.02	2.04	7.72	76.17	28.83	8.72
U.P.	29.44	5.17	3.40	139.11	80.16	19.84	64.80
Total	57.30	10.73	6.74	152	-	-	78.63
India	328.72	76.52	63.34	955	-	-	-

Source: MoEF, G.O.I., State of Forest Report, 1999.

The elevation varies from 300 mts to 5000 mts, with very hot summers and severe winters. Monsoons are characteristic of the region with mean annual rainfall varying from 83 mm to 1467 mm. Climate of the area is xerothermic-submediterranean (Kachroo, 1993). It varies from subtropical to arid. There is great variation in temperature in the region which ranges from - 40°C in Ladakh to 45°C in areas adjoining Punjab plains. The main vegetation types, which are represented in the area, are: (Champion and Seth, 1968).

- Tropical Moist Deciduous
- Tropical Dry Deciduous Forest
- Tropical thorn Forest
- Subtropical Dry Evergreen Forest
- Subtropical Pine Forest
- Himalayan Dry Temperate Forests
- Himalayan Moist Temperate Forests
- Subalpine/Alpine Forests.

Out of above, Uttar Pradesh Himalaya are represented by seven forest types and Jammu & Kashmir and Himachal Pradesh Himalaya by five forest types, each. India is one of the 12 megabiodiversity countries of the world (Rao, 1994). As per the botanical explorations completed so for, India accounts for 7-8% of the recorded species of the world. The floral biodiversity of Western Himalaya is fascinating because of species richness & diverse community structure.
Dominant tree species representing above forest types are *Cedrus deodara, Pinus roxburghii,Pinus gerardiana, Betulla utilis, Pinus wallichiana, Abies pindrow,Picea smithiana, Shorea robusta, Quercus incana, Quercus dilatata, Quercus semicarpifolia, Aesculus indica, Alnus nitida, Ulmus wallichiana, Albizzia lebbek, Albizzia procera, Olea cuspidata, Punica granatum, Toona ciliata, Cupressus torulosa, Dalbergia sissoo, Grewia elastica, Pistacia intergerrima, Rhododendron sps, Bombax ceiba, Terminalia chebula, Terminalia bellericia, Embellica offieinale, Acacia modesta, Acacia catechu, Dendrocalamous strictus, Juglans regia, Fraxinus excelsior, Populus ciliata, Salix sps., Hippophae sps.*, etc. Area is also represented by 1400 species of medicinal importance and highly nutritious herbal flora of alpine pastures.

Management of broad-leaved forests

Dr. Brandis, the first Inspector General of Forests, in order to bring the forests of India under scientific management classified forests into reserved, protected and unclassed forests (Champion & Osmaston, 1962). In the state of J&K, these are classified as Demarcated and undemarcated forests. Historically, these forests were brought under scientific management in the year 1894 to meet the requirement of industrial timber. However, very little attention was paid for the management of Broadleaved forests in Western Himalaya, except *Shorea robusta. (Sal).* Other broadleaved species like Khair, Oaks, Walnut, Alnus, Ulmus etc., did not receive much attention and were left as such to meet the requirement of villagers for fodder, fruit and timber. As population increased, so their demands also and the result was deforestation of forest lands around the villages.

In order to manage the national forests, G.O.I issued National Forest Policies in the year 1894, 1952 & 1988. In National Policy of 1952 Govt. of India, in order to preserve the green cover of the country, proposed to cover 33% land mass of the country under forest or tree cover against existing forest cover of 23.28% only but the emphasis was still on production forestry. It was only in the National Forest Policy of 1988 that G.O.I realized the importance of people participation in the plantation programmes.

In next 20 years, it is proposed that 109 million ha shall be brought under forests in India. It is estimated that area which are partially degraded but with sufficient root stocks are 15.5 million ha. Areas which are without root stock are 9.5 million ha and areas totally degraded are estimated as 6.00 million ha. Thus the total areas which need to be rehabilitated by way of mainly broadleaved plantations are 31.00 million ha. In a survey conducted by the Society for promotion of Wastelands Development, estimated that the extent of Waste lands is well over 131 million ha out of which 25 million ha comprises of degraded forest lands only. The latest landsat data has confirmed that India is losing 1.3 million ha of total forests per year.

In J&K State Himalaya, Kawosa (2001) has reported that more than 20 million cft of green forests were allowed officially to be cut in last 50 years resulting into degradation of 0.5 million ha of forest land.

In Himachal Pradesh, Himalaya it is reported that about 2,00,00 trees were felled annually to meet the requirement of packing cases in addition to the commercial fellings for industrial purposes. Famous environmentalists Sunder Lal Bahuguna said that important broadleaved species disappeared from Himalaya long ago till he launched the CHIPKO movement to save oak trees from river Ganga catchments *(Chadha, 1987)*.

In the past, policies of respective Govts., of all the three Himalayan states failed in their duty to protect the forests and rich biodiversity of these States. Ultimately, hon'ble Supreme Court of India had to intervene and passed a historical order in 1997 on the Public Interest petition for ban on green felling of trees in all the States.

Table 2 gives extent of area under wastelands in three West Himalayan States, outside the forest reserves.

Forestry and agriculture are two important land uses in the country. It is unlikely that the agriculture land shall be available for expansion of forest cover. It is only culturable and fallow land other than current fallows which seem potential areas for afforestation of broadleaved species in addition to the areas already degraded with in the forest reserves.

Table 2: Area under Waste land and Agriculture in thousand ha

State	Geographical Area	Agricultural Area. Net area sown	Cultivable wastelands	Fallow land other than current fallows	Total area under waste lands	%
	thousand ha					
H.P.	5567	558	123	26	149	2.67
J. and K.	22224	733	141	8	149	0.67
U.P.	29441	17475	945	832	1777	7.05
Total	**57232**	**18766**	**1209**	**866**	**2075**	**3.62**
India (million ha)	328.73	142.82	13.94	9.89	23.83	7.25

Source: MoEF, G.O.I., 1999.

Rural economy and the broad-leaves

Total population of the area is 27,736,646, out of which 70% of population of the region is mainly in villages whose sustenance depends on forests. There are practically no Industries for generating employment in the region. Traditionally, people live in these forests in harmony and derive benefits out of the surrounding environment. The broadleaved trees, whether they are growing on farmlands or in surrounding villages or high altitude alpine pastures cater to the needs of local fodder, grass and small timber. Several types of medicinal plants also grow in these areas, which are extracted by people to meet their requirements. Western Himalaya are also rich in extensive alpine pasture lands covering an area of 1,57,677 sq. kms. and sustaining a livestock population of 78.13 million migratory and sedentary animals. Since majority of the population in rural areas in these States is pastoral, their complete economy is dependent on these pasture lands and broadleaved forests for sustenance. Infact the meat, wool and milk industry of all these hilly states is dependent on these forest resources (Seth, 1998). So dependence of locals on the forests is tremendous and the resources if used judiciously can sustain their economy. FAO estimates that there will be an acute shortage of firewood in northern India &Indo Gangetic plains. By 2000, a shortfall of 182 million cum of firewood has been estimated for India. At present, the production of Industrial timber is 14 million cum against the demand of 24 million cum, in India.

Afforestation programme

India to meet the challenge of greening of degraded areas formulated National Forest Action Programme by launching several plantation programmes like Samnavit Gram Vanikaran Yojana Samridhi, Integrated Watershed Development Programme, National afforestation and Eco development board, Social forestry and other international aided plantation programmes. Planned afforestation for soil conservation and production of industrial raw material is very old but fuel wood and fodder plantations started in the late 1950's. Industrial plantations were mainly restricted within the forest areas after clear felling the economically less important forests till fifth Five year Plan (1974-79). Species preferred during the period were Teak (*Tectona grandis*), Sal (*Shorea robusta*), Deodar (*Cedrus deodara*), Chir (*Pinus roxburghii*), *Eucalyptus, Acacias,* etc.

To give further boost to sustainable forestry in India the National forest Policy in the year 1988 laid emphasis on creating massive people's movement through involvement of village communities living close to the forest in protection and development of forests. Pursuant to this policy, the Government of India issued a notification in June 1990 requesting the State Governments to involve local communities in the management of forests. In the policy it was envisaged that the communities, in lieu of the participation in protection and development of forest areas, will be entitled to sharing of usufructs in a manner specified by the concerned State Forest Departments. This led to the development of Joint forest Management (JFM) programme in the country.

So far, 22 State Governments have issued resolutions in this regard. Since forest management being the state subject most of the State Governments evolved their own mechanisms of involving local communities in conformity with the proclaimed policy. The local institutions engaged in the task are known by different names in different states like Forest Protection Committee (FPC), Village Forest Committee (VFC), Van Samrakshan Samiti (VSS), etc.

All these Committees work on truly democratic system. All Committees are registered with authorized government agencies under Societies Regulation Act with proper constitution. In each committee there is General body and Executive body. These Committees are responsible for formulation and implementation of projects in their areas as per the local needs under technical guidance of forest departments.

The nature of usufruct sharing also varies from state to state. In constitution of committees, representation to women is also ensured. About 36,130 Forest Protection Committees are managing a total of 10.25 million ha of forest area. The details of number of committees and area under their management in Western Himalayan States are given in Table 3.

Recently G.O.I., has further improved the system by constituting Forest Development Agencies. In the year 1979, after the establishment of the Forest Development Corporations in the states and launching of Social Forestry Projects with the assistance of external donors, massive afforestation of broad leaved species were started. While the forest Corporations continued planting industrially important species after clear felling of the commercially less valued forests, most of the plantations under social forestry were done outside forest reserves, along rail, road and canal sides, other Government wastelands and in private farmlands with short rotation species. The annual planting rate increased to about 1.0 million ha during 1980-85. Plantation forestry received further impetus when a national wasteland Development Board (NWDB) was created in 1985. The annual rate of planting increased to 1.78 million ha during 1985-90. The area planted in the Sixth, the Seventh and the Eight plans were 4.65 million ha, 8.86 million ha and 7.95 million ha, respectively. The cumulative area of forest plantations from 1951 until 1999 is 31.20 million ha.

Table 3: Number and area under JFM Committees

State	Date of notification	No. of JFM Committees	Area under JFM thousand ha
H.P.	10.05.93	203	62.00
J. &K.	19.03.92	1599	79.27
U.P.	30.08.97	197	34.59

Source: Ministry of Environment & Forests, G.O.I., 1999.

Area under plantations by all agencies in Western Himalayan states is 5.28 million ha against 31.20 million ha of the country. Thus, the contribution of plantations in Western Himalaya in last 40 years is only 16.94%.

Table 5 gives plan period wise area planted by forest department from 1951 to 1999 in three Himalayan States.

Species wise plantations by Forest Deptt. only in Western Himayalan states upto the year 1998–99 is given in Table 4.

Table 4. Total area under Plantations from 1951 to 1999

State	Government plantations	Private plantation	Total plantation area
		thousand ha	
H.P.	665.84	53.60	719.44
J. and K.	323.04	59.39	382.43
U.P.	1844.36	2341.41	4185.77
Total (Western Himalaya)	**2833.24**	**2454.40**	**5287.64**
India	20944.86	10264.31	31209.17
Percentage	13.53	23.91	16.94

Source: MoEF, G.O.I, 1999.

Species choice

Due to varied agro-climatic conditions, a large number of species are being planted under different plantation programmes of the country. But it has been observed that although the focus of different schemes is to meet different requirements, but, since plantations are handled by the Forest Departments, the choice ultimately rests on success of species in the nursery and plantation areas. Some species which are difficult to be raised in nursery and survival percentage is poor in field, are simply ignored by the foresters, even if, these species are in great demand in villages, ecologically suitable to the areas or these plantations are needed for biodiversity conservation. Thus in most of the areas in countryside, particularly in Agroforestry sector monoculture of some selected species is quite visible. Table 6 also gives an indication of concentration of some of the selected species. However a try is always made to maintain the species mixture for biodiversity conservation of indigenous plant species in government managed forest reserves.

From above it is clear that *Eucalyptus spp., Tectona grandis* and *Accacia spp.*, are the main species having larger area under plantations as compared to other species. Among *Eucalyptus, E.globules, E.grandis, E.teriticornis* are most common. Among *Acacia*, A. *auriculiformis, A. catechu, A.mearnsii, A. nilotica and A. tortalis* are common. Other broadleaved species

Table 5: Forest Plantation by all agencies in thousand ha

Period	H.P.	J. and K.	U.P.	Total
1951-80	147.82	23.24	482.56	653.62
1980-85	103.22	46.29	562.01	711.52
1985-90	164.76	113.31	1189.69	1467.76
1990-91	32.15	21.40	217.23	270.78
1991-92	39.42	18.92	249.19	307.53
1992-97	169.30	113.28	1123.95	1406.53
1997.98	29.52	25.13	186.94	241.59
1998-99	33.25	20.88	174.20	228.33
Total	**719.44**	**382.43**	**4185.77**	**5287.66**

Source: MoEF G.O.I, 1999.

Table 6: Species wise area under plantations in Western Himalaya in thousand ha

Species	H.P.	J. and K.	U.P.
Pinus roxburghii	250.92	-	107.92
Acaccia catechu	139.61	-	-
Cedrus deodara	92.83	-	-
Robinia spp.	36.61	-	-
Eucalyptus	31.11	-	129.37
Picea smithiana and Abies pindrow	15.64	-	-
Poplus Sps.	11.32	16.40	-
Pinus wallichiana	10.58	-	-
Dalbergia sissoo	10.38	4.13	58.57
Fruit Trees	-	44.25	-
Juglans regia	-	17.38	
Acacia arabica	-	17.15	
Salix Sps.	-	14.03	
Bamboo	-	-	82.80
Tectona grandis		-	80.71
Others	169.53	3.49	1334.30
Total	**768.53**	**382.43**	**1793.17**

Source: Ministry of Environment and Forests, G.O.I., 1999.

are Albizia spp., Azadirachta indica, Dalbergia sisoo, Gmelina arborea, Populus spp., Prosopis spp. and Terminalia spp. Among conifers, Cedrus deodara, Pinus roxburghii and Pinus kesiya occupy major area. Pinus patula and *P. carribaea* have been planted in a limited area.

Other category includes a large number of species, excluding teak, sal, chir, deodar and wattle. It may be noted that the area shown in category 'others' is more than 58%.

Nursery practices

Nursery practices in western Himalaya are adopted suited to local site conditions, lead from metalled road, remoteness of area and damage in transport. Infact, nursery practices are combination of both traditional and new technologies. Most of the species are generally raised in central and in-situ nurseries, Seeds are collected manually, cleaned and stored. For sowing, generally fresh seeds with good viability are preferred. Sowings of small seeds are carried out in raised beds and in case of bigger seeds direct sowings in polythene bags is carried out. Popular and Willows are raised through 9" cuttings. The polythene bags are filled with loamy soil and farm yard manure. Irrigation is carried out either through flooding or by sprinklers. Continuous weeding every month is prescribed for good height. With the onset of

Table 7: Species planted in India up to 1997

Species	Area in thousand ha	Percentage
Eucalyptus spp.	1360.91	8.87
Tectona grandis	1330.09	8.67
Acacia nilotica	801.61	5.23
Acacia auriculiformis	564.67	3.68
Bamboo	408.09	2.66
Acacia catechu	259.54	1.69
Pinus roxburghii	318.54	2.08
Dalbergia sisoo	266.58	1.74
Shorea robusta	250.28	1.63
Gmelina arborea	148.01	0.97
Anacardium occidentele	141.54	0.92
Casuarina equisetifolia	133.99	0.87
Pinus kesia	127.12	0.83
Cedrus deodara	124.93	0.81
Populus spp.	47.48	0.31
Bombax ceiba	37.97	0.25
Acacia mearnsi	37.56	0.24
Picea smithian and Abies pindrow	16.74	0.11
Hevea brasiliensis	12.30	0.08
Santalam album	10.58	0.07
Others	8938.10	58.28
Total	**15,336.60**	**100.00**

Source: Ministry of Environment & Forests, G.O.I., 1999.

monsoon rains in July the polythene bags are shifted to plantation areas. In case of temperate species, plants remain in seed beds from one to three year depending on nature of species. Recently, root trainer nurseries have also been established to produce quality seedlings in Green Houses. Generally three types of root trainers are being used viz: Individual cells, Book type and Block type. The potting medium prescribed is a mixture of soil, sand and compost in the ratio of 1:2:2 or 1:1:3 depending upon wheather soil is black cotton or sandy loam. Deoild Neem cake @ 10 Kg/m^3 , Indofil M-45 fungicide @ 0.25 Kg/m^3 , Phorate 10G @ 0.25Kg/m^3 of potting medium is used (Gera, 1999).

Stand establishment

In western Himalaya, there are two planting seasons. First, during monsoon rains from July to August and second during winters from February to March. In India, generally the polythene bagged plats are planted in a pit of the size 45x45x45 cms or trenches 1 mtx45 cm depending on site. The size can be different, if conditions are more harsh and degraded for better moisture conservation. Polythene bags are removed and plants with ball of earth are placed in pit. Pit is filled with soft soil and one teaspoon full of insecticide, to prevent termite attack, is used and then the soil is rammed. After monsoon rain of three months, plants generally strike roots and survival percentage varies from 70 to 80% depending on site and climatic conditions. In temperate zones, the plantation is carried out in winter months of Ulmus, Walnut, Robinia, Poplar, Willows and Horsechestnut. All these species are planted with naked roots. Size of nursery stocks is not more than 2 feet for good success of plantation. Poplar and Willow timber is used for packing cases and sport industry. While as other species are used for construction, fuel wood and fodder. Eucalyptus is mainly used for plywood and pulp industry.

Conclusions

From the forgoing scenario, it is evident that India in general and western Himalaya in particular with increasing population and high rate of degradation of mountain slopes is facing a great challenge to bring back these areas under green cover by launching extensive tree plantation programmes of preferably indigenous species by involving local communities who are the major stake holders in conservation of ecology around these villages. Sustainable Forest management is, therefore, a normative concept whereby societies define broadly which aspects of forests, their components, process or functions they intend to preserve over the long term and which to utilize. SFM therefore is a dynamic concept, the result of ongoing political process driven by various actors, their respective values, interest, knowledge and their relative negotiation power (Sharma 2000). Besides, financial and infrastructural capital, the sustainability of any programme will largely depend upon capital base consisting of human capital, natural resources and social capital. As a corollary to this, the sustainability will be governed by the capacities of the institutions, relationship among them and their relative power. Stated briefly, the concept of Sustainability rests on three pillars viz. Ecological Sustainability, Economic Sustainability and Social Sustainability

Thus for sustainable forest management it is important that participation of villagers and other stake holders in the plantation programmes is made *sine-qua-non,* both for management of broadleaved forests as well as sharing of usufructs.

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15. The use of spontaneous poplars (*Populus nigra* and *Populus alba*) in environmental restoration

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Summary

Populus nigra and *Populus alba* are two species that need particular attention as they suffered considerably from urbanization and competition with human productive activities. Moreover *P. nigra* is considered to be on the verge of extinction in Europe so that many measures were undertaken to protect its germplasm (EUFORGEN, EUROPOP, EFP). However, if properly maintained, Black and White poplars could be effectively used in establishing plantations in fluvial ecosystems and, generally, in damp areas, as they are typical pioneer species and favour the natural evolution of forests.

During the past ten years the 'Istituto di Sperimentazione per la Pioppicoltura', together with local State-run organizations, conducted trials to restore environments from conventional cropping to natural landscapes and to recover areas previously damaged. A germplasm bank and a nursery stock is guaranteed annually by the I.S.P. which can be used in restoration activities.

Three significant trials for environmental restoration are reported. These trials were performed by environment friendly methods and selected poplar genotypes at:

Sala Bolognese (BO) – 20 hectares of farmland, characterized by extremely variable pedologic conditions and particular water systems, were afforested with poplars and autochthonous broadleaves;

Roaschia (CN) - 3 hectares were afforested with Black poplars in a mountainous area dedicated to limestone mining activities;

Isola Santa Maria (VC) – 10 hectares were afforested with poplars, willow, shrubs and broadleaves in a typical floodplain presenting natural forests and farmland included in the 'Parco Fluviale del Po e dell'Orba'.

The results obtained in the above-mentioned trials can be used in other similar situations.

Keywords: *Populus;* biodiversity; genetic resources, environmental restoration.

Introduction

The genus *Populus* has significant importance in a field that is different from traditional intensive poplar culture, owing to the growing importance of the rehabilitation of degraded zones, the need to establish and manage plantations for wood in fluvial areas using low-impact cultural techniques and the public incentives to reconvert farmlands into natural forest areas.

The poplar species spontaneous in Italy are *Populus nigra* L. (European Black poplar), *Populus alba* L. (White poplar), *Populus tremula* L. (Aspen or Trembling poplar) and *Populus canescens* Smith (Grey poplar, the natural hybrid between *P. alba* and *P. tremula*).

Natural populations of *P. alba* and *P. nigra* need particular attention as they suffered considerably from urbanization and competition with human productive activities. The Black poplar is rarely found in Italy as also in a large part of Western Europe, and can be considered on

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the verge of extinction (Arbez, 1993; White, 1993). Its gene pool is threatened by a large-scale presence of cultivated hybrids and of the fastigiate cultivar 'Lombardy poplar' both of which spontaneously hybridize with *P. nigra* (Cagelli & Lefévre, 1995). Even if the white poplar does not risk genetic pollution, it suffered a significant area reduction due to the above-mentioned human activities. Many measures have been undertaken at the European level to protect the germplasm of these two species. The results of these programmes should indicate conservation strategies of this species and riparian eco-system management. Two international research programmes were launched in the 90's: EUFORGEN (European Forest Genetic Resources Programme – IBPGR/FAO 1993) and by EUROPOP (Genetic Diversity in river Population of European Poplar for the Evaluation of Biodiversity, Conservation Strategies, Nature Development and Genetic Improvement), giving particular attention to the conservation of genetic resources of the Black poplar, the study of genetic diversity and the dynamics of naturally formed populations. The results of these programmes will directly affect conservation strategies of this species and riparian ecosystem management. Recently, the WWF established the European Freshwater Programme (EFP) with the overall goal to promote the sustainable use of floodplain forests, to stimulate restoration of important damaged sites and to promote, above-all, the European-wide protection of the current Black Poplar sites by rising the awareness on the functions and the biodiversity of floodplain forests.

P. nigra and *P. alba* are the species used in establishing plantations, especially in fluvial environments and, normally, in damp areas. As these species are typical pioneer species, they can grow in poor soil in floodplain areas and create favourable conditions for more valuable species such as *Quercus robur, Acer campestre, Fraxinus angustifolia, Carpinus betulus* (Bisoffi *et al.,* 1999 a). Moreover, owing to their capacity of rapid growth and tolerance to diseases, White and Black poplars can be established in plantations using environment friendly methods, for the production of logs for commercial use too.

During the past ten years the 'Istituto di Sperimentazione per la Pioppicoltura' (I.S.P.), together with the local State-run organizations, conducted trials to restore environments from conventional cropping to natural landscapes and to recover areas previously damaged, using new selvicultural management techniques. Nursery stock is guaranteed annually by the I.S.P., due to the fact that for many years the I.S.P. established a germplasm bank which maintains a collection of hundreds of White and Black poplar cultivars collected from every part of Italy (Bisoffi *et al*, 1999 b). White poplar individuals (mostly males) as well as about 50 genotypes of the Black poplar were propagated to establish new plantations for environmental restoration. The former was selected partly from natural populations and partly from the progeny of the cultivar 'Villafranca', whilst the latter was selected taking into consideration the genetic evaluation of natural populations which resulted in fairly rapid growth, well formed boles and resistance to the diseases.

Three significant trials for environmental restoration are reported.

Sala Bolognese (Bologna)

Site description

Environmental restoration carried out at Sala Bolognese - 'Cassa di espansione dello Scolo Dosolo' - consisted in converting farmlands into natural forests.

This operation goes back to 1992 in an area of about 55 hectares of alluvial plains (Figure1) having extremely variable pedologic conditions and peculiar water systems.

Before the trials were conducted, the forest-type vegetation was practically non-existent due to the fact that this area was cultivated using the intensive-traditional cultivation techniques. Using methods causing low environmental impact, plantations were established in 20 hectares to increase the value of production of the areas concerned together with afforestation having many naturalistic, landscape, recreative and, possibly, productive functions (Zampighi & Gasparini, 1999).

Different types of soil are found at the 'Cassa di espansione dello Scolo Dosolo'. In fact there are three different types of soil - 'Galisano', 'Risaia del Duca' and 'Ascensione' - (A.A.V.V.,

2000) having different contents of clay and soil formation. These are characterized by a moderately alkaline reaction and fine texture made up of clay and lime, poor in sand (less than 10%) and in organic substances. In spite of the high water holding capacity, the quantity of water available during the summer is somewhat limited. Owing to the high clay contents frequent fissures to varying depth can be found. The climatic conditions are temperate sub-humid. The average annual temperature for the period 1996-2000 was 13,6°C and the average annual rainfall 581 mm, whereas during the Summer months (June to August) it was 159 mm.

As this area is a retention/sedimentation basin, it is subject to recurring floods. During the past ten years this area was almost completely flooded five times and for a period of two to seven days.

Planting methods and cultivation techniques

The original structure of the fields was maintained to facilitate the different types of operations. The plots were ploughed before planting. Subsequently cultivation sperations were carried out for a couple of years in order to facilitate rooting and growth of plants. These plantations were established with autochthonous species of the Po Valley (*Q. robur, A. campestris, F. angustifolia, C. betulus, Salix* spp., *P. nigra, P. alba*) and valuable naturalized species such as *Fraxinus excelsior, Prunus avium.*

In order to facilitate maintenance operations in all the plantations the plants were set following a geometric pattern of 6x6 m spacing for poplar stands and 3x3 m spacing for mixed forest. In the case of shrubs which were set to close in or protect the plantations the spacing varied from 0,3 to 1,5 m.

The areas allotted to grassland and glades were chopped only at the end of Summer so that no disturbance was caused to the avifauna.

Figure 1: Sala Bolognese (BO) – Aerial photo of “Cassa di espansione dello Scolo Dosolo”.

Operations carried out (Figure 2)

1992: Establishment of poplar stands for demonstrative and experimental purposes. Clonal comparisons for wood production were carried out between some traditional poplar clones ('Boccalari', 'Lux', 'San Martino') and the white poplars (12,1 hectares). As regards *P.alba,* one-year old nursery plants of the clones 'Villafranca', 'Casole 56B', 'DI-1' and 'DI-102' were used. A mixed forest was established with broad-leaved plants (4 hectares) and another one with oak trees only (1 hectare);
1993: aquatic environments were created (3,5 hectares);
1994: an experimental Black poplar stand was established (0,8 hectares) and another mixed forest was established with Ash, Alder, Maple and Cherry plants. Regarding *P. nigra*, 2-year old nursery plants of 42 genotypes used as parents in the *P. nigra* breeding programme of I.S.P. were utilized;
1997 open spaces, shrubs and hedges were created as a refuge (5 hectares); belts with cultivation for wild animal feed (2,4 hectares) and a willow-grove (1,4 hectares) were established.

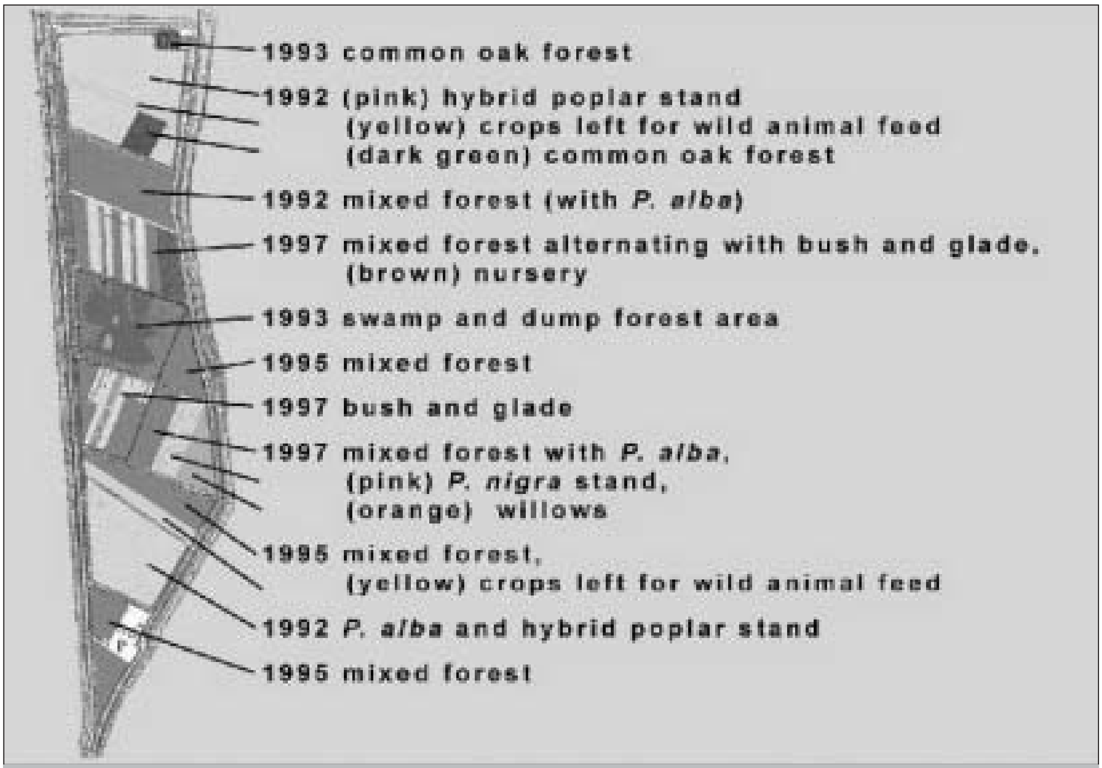

Figure 2: Sala Bolognese (BO) – Map of the operations carried out.

Results

This trial demonstrated that *P. nigra* and *P. alba* increase the value of the area both from the naturalistic and economical point of view. The material used survived well (92% of the White poplars and 78% of Black poplars). The 'DI-1' and 'DI-102' clones stood out for their growth and for the shape of the boles; this *P.alba* stand (Figures 3 a, 3 b) will be maintained as an experimental field until 2007. Even the growth rate of the Black poplar can be considered good (Figures 3 d, 3 e). Floral branches and seeds will be collected from this plantation to produce 'qualified' material. Plantations established and managed with low environmental impact techniques make some land plots attractive even from the production point of view.
Today, the 'Dosolo' area represents an area for ecologic stabilization. It is like an open-air laboratory where new and different ways of managing a territory are experimented (Figure 3 c), taking into consideration economical and environmental conservation. This trial for en-

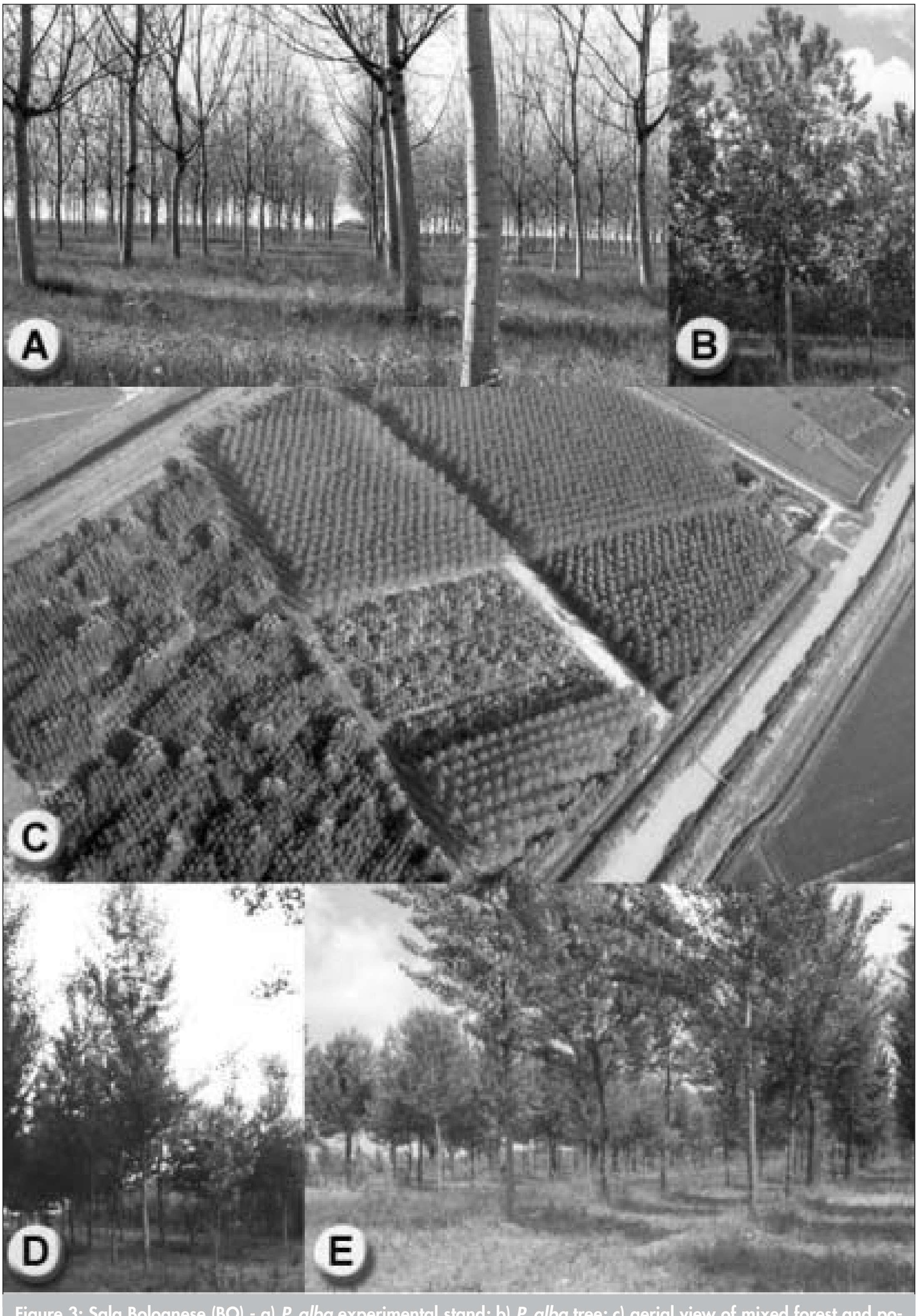

Figure 3: Sala Bolognese (BO) - a) *P. alba* experimental stand; b) *P. alba* tree; c) aerial view of mixed forest and poplar stands; d) P. nigra tree e) *P. nigra* experimental stand.

vironmental restoration demonstrates the possibility of increasing the natural process of evolution of the arboreal vegetation and accomplishing highly interesting environments in a relatively short time, by introducing forest species which are suitable for this type of land rehabilitation.

Roaschia (Cuneo)

Site description

Environmental restoration operations were conducted in mountainous areas dedicated to limestone-mining activities (Figure 4); only Black poplars were utilized to establish plantations. This experiment was carried out to study the adaptibility of a few Black poplar genetic reserves in particular pedoclimatic conditions and to verify important characteristics such as resistance to diseases, branching habit, shape of bole. This area (3 hectares) is situated about 800 m a.s.l. at the bottom of the valley of a tributary of the Gesso river. The land is completely artificial. The mine which was worked to a depth of 200 m, was filled up at the end of mining operations with the remains of the excavation of the surrounding mines (limestone and silica). The topmost layer was made up using soil from surface excavation.
The climatic conditions are perhumid subalpine and are referred to the period 1951-1986, with an average annual temperature of 8,0°C and an average rainfall of 1280 mm, whereas it was 254 mm during the Summer months (Regione Piemonte *et al.*, 1998).
The vegetation in this area is typical of the South Alpine Valleys. Frequent formations of *Alnus* and *Fraxinus* can be found around the water courses, whilst coppices of *Castanea sativa* and *Fagus sylvatica* can be found among groves of *Pinus sylvestris*.

Figure 4: Roaschia (CN) – Aerial photo of the mining area.

Planting methods and cultivation techniques

The only operation carried out before establishment was levelling of the soil. In April, the planting holes were dug after thawing by means of a back-hoe excavator. One-year old poplars were uprooted from the nursery in March, before budding and conserved in water for more than a month at the plantation site. No other forest species were used.
To reafforest this area 54 *P. nigra* italian genotypes from the I.S.P. genetic sources (40 males and 14 females) were used in two different operations. The experiment was carried out following an arrangement of plots (10 plants of each clone) without replications, with rectangular layouts and 6x4 m spacing.

During the first two years after planting disc harrowing was carried out to help rooting and initial development of the plants. Subsequently no other operations were carried out, allowing an uncontrolled evolution of spontaneous vegetation.

Operations carried out (Figure 5)

1980: First trial with *P. nigra* 'Nero di Brisighella' (Figures 6 d, 6 e); 0,5 hectares afforested;
1997: second trial with *P. nigra* I.S.P. Genetic Resources (border filling with *P. nigra* 'Jean Pourtet'); 2,5 hectares afforested (Figures 6 a, 6 b, 6 c).

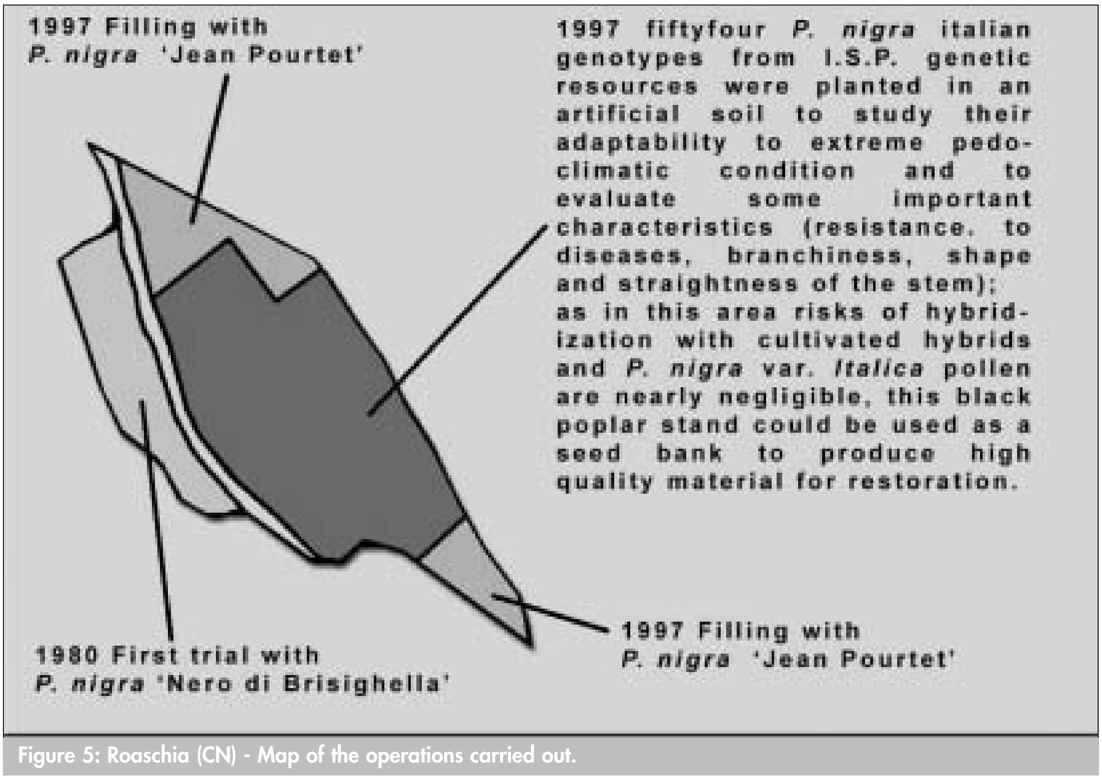

Figure 5: Roaschia (CN) - Map of the operations carried out.

Results

The Black poplar proved to be a very adaptive species even in difficult pedoclimatic conditions. Rooting and plant survival can be considered fairly satisfactory (over 70%) considering soil type and climate. On the contrary the growth of the plants proved to be very limited, especially when compared to the growth of plants in other poplar sites in the valley.
As in this area risks of hybridization with cultivated hybrids and *P. nigra var.* 'Italica' pollen are negligible, this Black poplar stand could be used as a seed bank to produce high quality material for restoration activities.

Isola Santa Maria – Crescentino (Vercelli)

Site description

A project was set up to restablish plantations which will transform agricultural land into floodplain forests using *Salicaceae*, shrubs and other broadleaves.
The entire area (10 hectares) is found within the 'A belt' according to the 'Watershed Authority' in the 'Piano Stralcio delle fasce Fluviali', and is included within the 'Parco Fluviale del Po e dell'Orba' which was set up by the 'Regione Piemonte' in 1990.
It is a typical floodplain area of the River Po presenting natural forests and farmlands (Figure

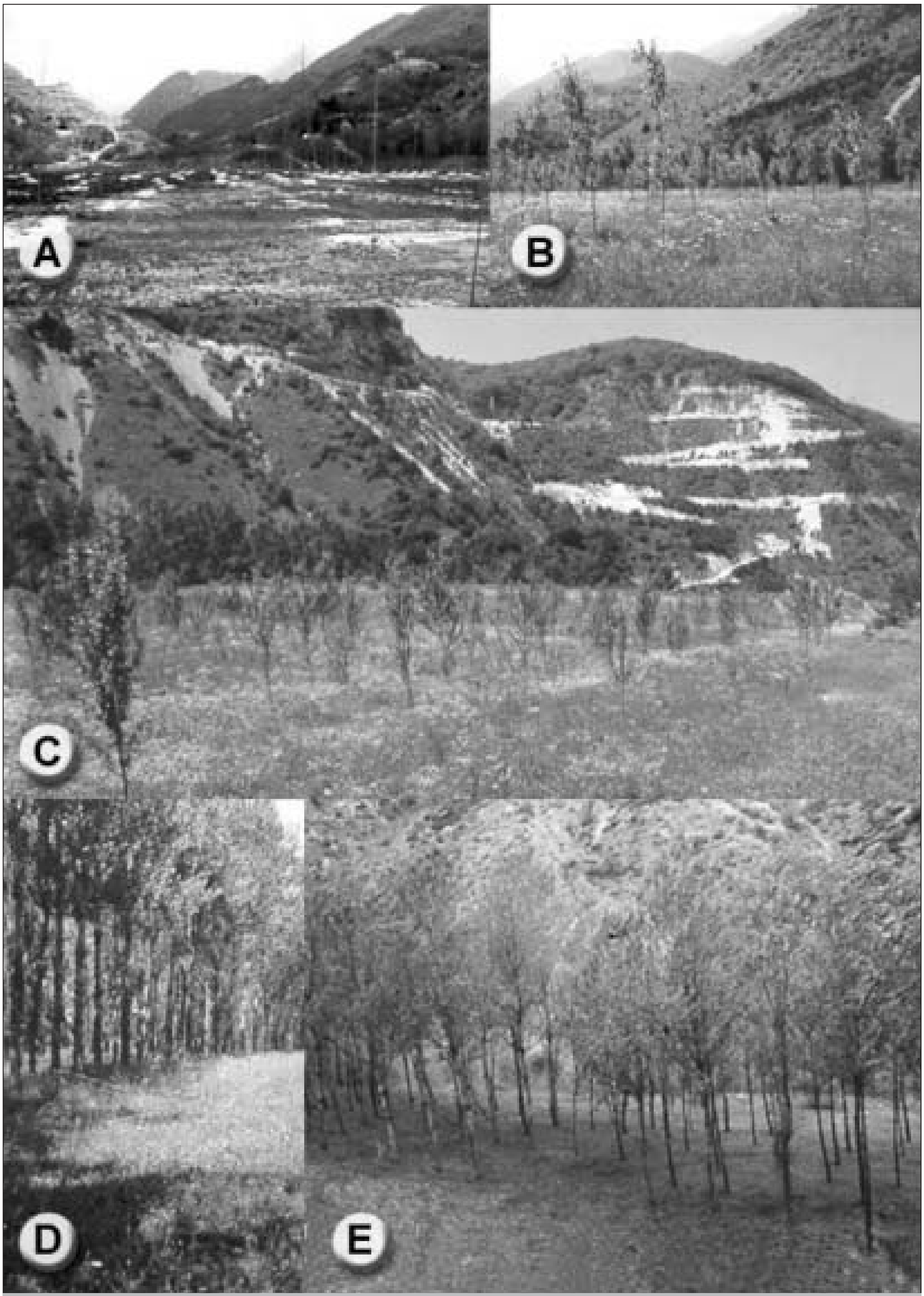

Figure 6: Roaschia (CN) – a) *P. nigra* experimental stand after planting b/c) the same stand three years later; d/e) *P. nigra* 'Nero di Brisighella' twenty years after planting.Different types of intercropping between arboreal and shrub species and different types of spacing was tested, taking into consideration that enough space was available for cultivation operations. Wire net shelters ensured protection from rodents.

7). The surrounding areas suffer from an intense agricultural pressure as there are a number of poplar stands established with hybrid poplar clones together with rice-fields.

The soil is alluvial and is circumscribed by the River Po and by the 'palaeo-riverbed' of the River Dora which collects water coming from water drainage ditches of the rice-fields and spring water. For a few days during Spring and Autumn this area regularly suffers from partial or total submersion. In November 1994 and in October 2000 this area was completely flooded.

The climatic conditions are temperate and sub-humid and are referred to the period 1951-1986, with an average annual temperature of 12,7° C and average annual rainfall of 827 mm, whereas it was only 195,2 mm in the Summer from June to August (Regione Piemonte *et al.*, 1998).

The potential vegetation is represented by oak and elm *Quercus-Ulmetum*. The arboreal species found in natural formations in this area are *Q. robur, Ulmus minor*, *F. excelsior, Alnus glutinosa* and, among shrubs *Cornus sanguinea, Crategus monogyna*, *Euonymus europaeus*.

Planting methods and cultivation techniques

The preparation of the soil was limited to only one surface operation carried out with a disc harrow.

One-year old sets, without roots and hydrated for a week before planting were used as planting material for *Salicaceae*. One-year old seedlings grown in containers were used for other forest species.

As pioneer species *Salix alba, P. nigra* (spontaneous genotypes collected from different parts of Northern Italy) and *P. alba* (cultivar 'Villafranca' and its relative open-pollinated progenies) were used. Among the fixed arboreal species *Quercus cerris, Q. robur, A. camprestre, F. excelsior, P. avium, Malus silvestris, Carpinus betulus* and, among the main shrub species *C. monogina, Rhamnus catarthica, Corylus avellana and Cornus sanguinea* were chosen.

Figure 7: Isola S. Maria, Crescentino (VC) - Aerial photo of the flood plain area of the Po river.

Operations carried out (Figure 8)

1996: 20% of pioneer species, 60% of broadleaves, 20% of shrubs with 3x1,8 m spacing. Grass-cutting was carried out twice along the rows;

1999: 50% pioneer species, 50% broadleaves, with 3x2 m spacing. At that time a belt of willows to protect the plantation from potential floods was established. An annual grass-cutting operation was scheduled along the rows and mowing with land-clearing machine near the rows;

2000: 50% pioneer species, 25% broadleaves, 25% shrub species, fixed spacing of 3x2 m (6x6 in black poplar stands and 6x4 in White poplar stands). The plantations were established very late in the season and during a particularly long dry period. The material was arranged following a curvilineal course in order to create an environment which seemed natural (Figures 9 a, 9 b). At that time in order to facilitate waterholding capacity a hygroscopic additive mixed together with the soil was used to fill the holes. Emergency irrigation was carried out together with chemical weed control using mixtures of pre-emergent herbicide (pendimethalin) and post-emergent herbicide (ammonium gluphosinate). Subsequently, grass-cutting was carried out twice along the rows together with mowing with a land-clearing machine near the rows;

2001: about 2/3 of poplar material was felled owing to damages caused by floods in October 2000 (Figure 9 c);

2002: 70% pioneer species, 20% broadleaves, 10% shrub species, fixed spacing of 3x2 (6x6 m in black poplar stands and 6x4 m in White poplar stands). A seed stand of *P. nigra* will be established and the same planting methods used in 2000 will be adopted.

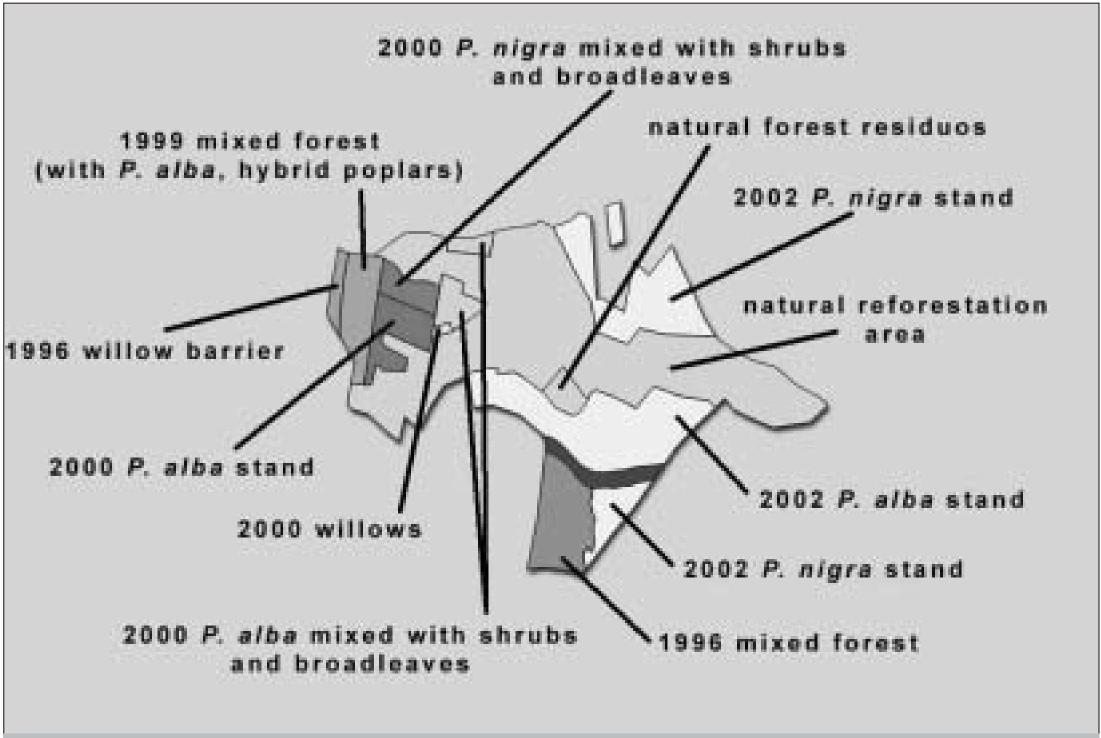

Figure 8: Isola S. Maria, Crescentino (VC) - Map of the operations carried out.

Results

It has been confirmed that poplars and willows are trees that ensure, in a short time, a fairly good plant coverage even when pedoclimatic conditions are difficult and the spacings are wide among the trees. However, to guarantee good results when establishing plantations it is of fundamental importance to use well-developed, woody, well-hydrated nursery material of

reliable origin. Moreover, it is necessary to ensure, at least during the first and second year after plantation, cultivation operations aimed at weed control and possibly emergecy irrigation. As these precautions were not taken into consideration during the first operation conducted in 1996, the results were quite disastrous. In fact after a period of five years, the survival of the planting material was poor (only 30% of the plants survived). Furthermore a high genetic pollution rate was found in *P. nigr*a (Lombardy poplars and poplar hybrids). Satisfactory results were obtained in more recent establishments. Despite the characteristics of the soil (significant presence of gravel and sand), the late period of establishment (in April) and the lack of water during the Summer season, rooting and survival of planting material were good (more than 95%). This was also due to the emergency irrigations and the good results obtained by filling the holes with hygroscopic material. The willow barrier proved to be a good protection in slowing down water flow and preventing accumulation of debris (Figure 9 d). Moreover, the absence of soil surface operations and land planting limited the phenomenon of surface erosion (Figure 9 e).
The curvilineal arrangement of plants in rows facilitated cultivation operations (establishment and maintenance) and guaranteed a natural-looking environment.

Conclusions

The results obtained in the above-mentioned trials can be used in other similar situations.
The trials conducted confirm that Black and White poplars are the ideal species to rapidly increase the natural process of forestry evolution in floodplain areas, creating a beneficial forest environment in a relatively brief period, irrespective of the environmental conditions.
In addition to the work of environmental restoration, taking advantage of the good formation of the bole, the resistance to the main diseases and the productive capacity of these species and of some of their genotypes, it is possible to accomplish, with reduced environmental impact, wood plantations so as to increase the value of a few areas from the productive point of view.
In order not to jeopardize the success of the stands and the purpose of the restoration activities, it is important to use, instead of single clones, a mix of autocthonous genotypes genetically selected and, above all, excellent quality nursery stock coming from a reliable source.
In order to establish mixed plantations it is convenient to wait until the end of the second year before intercropping with shrub species. It is useful to harrow and till in order to favour rooting of the young poplars, especial during the first two years and when plantations have been established in areas characterised by difficult pedologic conditions.
Biodiversity preservation is of fundamental importance for environmental restoration and for sustainable forest management. Therefore, in the future, in addition to setting programmes for protection and conservation *in situ,* it is absolutely necessary to complete the collection of the already existing germplasm, continue the activity of selecting genotypes and study genetic variability among populations. Restoration, conservation and utilisation of local ecotypes of Black and White poplars, selected by means of genetic evaluation could help to establish collections *ex situ* (seed arboretum) distributed all over the territory based on the origin of different genotypes. In this way natural sexual reproduction could be favoured and the evolution of gene set in reply to environmental changes, creating the opportunity of collecting seeds produced by free pollination and certify qualified material to be used in reafforestation.

Figure 9. Isola S. Maria, Crescentino (VC) - a/b) establishment of a mixed forest; c) view of the area during the floods in october 2000; d) willow barrier after flooding; e) poplar stand after flooding.

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