APAT
**Agenzia per la protezione
dell'ambiente e per i servizi tecnici**

A new technology for production of broad-leaved forest seedlings to promote sustainable management of European forestry

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PREFACE

The report *A new technology for production of broad-leaved forest seedlings to promote sustainable management of European forestry* is the outcome of a research project carried out by a consortium of a state agency, two research organisations and three privately owned tree nursery enterprises.
The main objective of the project (sort-handed *Broad-Tech*) funded by the European Commission (EC), within the Cooperative Research Action For Technology (CRAFT) of the Fifth Framework Research Programme (FRP), was acquiring an innovative nursery technology for environmental friendly production of high quality and cost efficient broad-leaved tree seedlings.
The participation of the Agency we represent – as well as of the other partners – to *Broad-Tech* was enthusiastic, for many reasons.
Firstly, as data from the Community Innovation Survey suggests, the European Union has a population of around 145,000 innovating SMEs. These technology-based SMEs are the principle creators of future economic growth and employment. They form a dynamic and heterogeneous community, but all face the immense challenges of the Single European Market and, more widely, of globalisation. To survive and grow, these SMEs must innovate constantly – that is, they must either develop new technologies internally or acquire and apply those developed by others. Many also need to internationalise in search of new markets. The problem is that normally these SMEs have little or no in-house research capabilities to take up technical and industrial problems.
The main intention of CRAFT, which opportunely has been done again with the Sixth EC FRT, is to facilitate the creation of trans-national partnerships between small and medium enterprises and among these and third parties, such as universities or research agencies, to address common technological problems and acquire innovation.
That's why we believe that CRAFT offers these firms—which are extremely crucial for the European and, particularly, the Italian economy—the opportunity to achieve these goals, facilitating the creation of trans-national partnerships to third parties, such as universities or research agencies.
Secondly, it is very encouraging to observe the EC funding a research project dealing with innovation in forestry, a sector typically considered conservative and old-fashioned and for that reason neglected.
Lastly, while nature conservation themes are usually dealt with provisional and restrictive approaches, yet *Broad-Tech* has taken purposeful and deliberate actions to protect biological diversity, at genetic and species level, and to provide essentials for regenerating nature ecosystems.
We are confident that this report will be useful both for the industrials involved in forest planting stock production and the scientific community.

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SUMMARY

Forest seedling requirement for re- and afforestation in Europe comprises a substantial volume. Almost 1900 million seedlings, mostly conifers, are today produced at European forest nurseries each year. The aspects of sustainable forestry together with focus on bio-diversity and the discussion of global climatic changes, however, have shifted market interest from conifers to broad-leaved seedlings. Hence, a considerable increase in the requirement for broad-leaved forest seedlings will develop in the future. This change will have a major impact on the production technology of broad-leaved forest seedlings. Today, state of the art is to produce forest broad-leaves as bare-root seedlings sown and grown on open land. If the production should be intensified, to meet the increase in market demand, future broad-leaved production systems have to be based on a cost-efficient container concept.

This publication describes the results and conclusions of a project recently concluded and funded by the European Commission, involving research organisations and enterprises from Denmark, Italy and Sweden: it exposes a new and innovative technology developed for large-scale production of different species of broad-leaved forest seedlings. The technology involved sowing in mini-plug container systems; germination in a closed compact multiple-floor unit not affected by outdoor climate; and automatic transplanting to any optional end-container system. The new technology is both cost-efficient and environmental friendly and will can be expected to be introduced at forest nurseries all over Europe.

RIASSUNTO IN ITALIANO

La domanda di materiale vivaistico forestale per le attività di afforestazione e riforestazione in Europa ha dimensioni ragguardevoli. Ogni anno circa 1,9 miliardi di piante sono prodotte nei vivai forestali in Europa. Lo sviluppo della gestione sostenibile delle foreste, con particolare riferimento alla conservazione della bio-diversità e la funzione di mitigazione dell'effetto serra svolto dalle nuove piantagioni (attraverso la loro capacità di assorbire e fissare anidride carbonica) hanno dato un impulso alla domanda di materiale vivaistico forestale.

Un mercato in evoluzione, oltre che in termini quantitativi, anche qualitativi: latifoglie al posto di conifere, specie e provenienze locali e certificate piuttosto che specie non native e provenienze non locali.

Questa evoluzione avrà necessariamente un impatto sulle tecnologie di produzione, specialmente per le specie latifoglie. E se, attualmente, lo stato dell'arte è la produzione di latifoglie in pieno campo, a radice nuda, in futuro sarà necessario sviluppare nuovi sistemi di produzione, basati su concetti di coltivazione in contenitore, a costi contenuti.

Proprio con l'obiettivo di sviluppare una nuova tecnologia di produzione di specie latifoglie è stato svolto un progetto di ricerca, che ha coinvolto istituzioni e imprese di tre paesi diversi (Italia, Svezia e Danimarca). Il progetto, durato due anni, è stato finanziato dalla Commissione Europea, attraverso il *Cooperative Research Action For Technology* (CRAFT), il piano del Quinto Programma Quadro di Ricerca indirizzato a migliorare l'impatto sociale ed economico dei progetti di ricerca, soprattutto attraverso il consolidamento dei congegni che consentono di assicurare la migliore utilizzazione dei risultati, e allo stesso tempo la disseminazione e il trasferimento delle tecnologie prodotte dai progetti di ricerca.

Nel caso specifico, il progetto di ricerca, i cui risultati sono presentati in questo rapporto, intendeva sviluppare un nuovo metodo di produrre semenzali (piantine ottenute da seme, e come tali preferibili per la conservazione della variabilità genetica) di latifoglie, in grado di ottimizzazione dell'uso delle risorse, dal suolo ai substrati artificiali, dai fertilizzanti ai pesticidi, dall'acqua ai combustibili.

La tecnologia sviluppata consiste nella semina in contenitori di piccolo volume, la germinazione e lo sviluppo dei semenzali in un dispositivo a più livelli (per ottimizzare l'uso degli spazi protetti di crescita), il loro trapianto automatico in un contenitore o in pieno campo.

SVENSKA SAMMANFATTNING

Behovet av skogsplantor för återbeskogning i Europa omfattar en avsevärd volym. Nästan 1900 miljoner plantor, huvudsakligen barrträd, produceras idag årligen vid europeiska skogsplantskolor. Diskussioner kring ett uthålligt skogsbruk, biologisk mångfald och globala klimatförändringar har dock inneburit ett allt större intresse för lövträd. Mot denna bakgrund kommer behovet av lövplantor att öka i framtiden. Denna förändring kommer att få ett stort inflytande på produktionstekniken. Idag produceras lövträd för skogsplantering som barrotsplantor på friland. Om produktionen skall intensifieras för att möta en kraftig ökning i marknadens efterfrågan måste framtidens produktionssystem baseras på kostnadseffektiva täckrotskoncept.

Denna publikation beskriver resultat och slutsatser från ett tvåårigt projekt som avslutades under 2003 och som finansierats av EU kommissionens 6:e ramprogram. Projektet innefattade forskningsorganisationer och företag från Danmark, Italien och Sverige. I publikationen beskrivs en ny och innovativ teknik för storskalig produktion av olika lövträdsarter för skogsplantering. Tekniken innefattar sådd och förodling av små täckrotsplantor i en sluten kompakt odlingsenhet med odling i flera plan. Enheten är inte påverkad av utomhusklimatet. Efter förodling sker en automatisk omskolning till valfritt täckrotssystem för vidare odling på friland. Den nya teknologin är både kostnadseffektiv och miljövänlig och kan förväntas att under de närmaste åren introduceras vid skogsplantskolor över hela Europa.

DANSK SAMMENDRAG

Behovet for skovplanter til ny- og genplantninger er stort i Europa. I europæiske planteskoler produceres der omkring 1900 mill. småplanter per år, hvor størsteparten er nåletræer. Markedet vil imidlertid ændre sig fra nåletræer til løvtræer i lyset af diskussionen om bæredygtigt skovbrug med fokus på biodiversitet og i relation til klimaændringer. Derfor kan der også forventes en stigende interesse for løvtræer i fremtiden. Denne ændring i markedet vil have en stor indflydelse på dyrkningsmetoden for løvtræer. I dag produceres løvtræer primært som barrodsplanter med såning og dyrkning på friland. Når produktionen skal intensiveres pga. stigende efterspørgsel, skal fremtidig løvtræsproduktion baseres på en rentabel produktion af dækrodsplanter.

Denne rapport beskriver resultater og konklusioner fra et 2-årigt projekt, som blev afsluttet i 2003, og som var støttet af den Europæiske Kommission. Projektet omfattede firmaer og forskningsinstitutioner i Danmark, Italien og Sverige. Rapporten fremlægger en ny og innovativ teknologi udviklet til stor-produktion af forskellige arter af løvtræer til skovbrug. Teknologien omfatter såning i mini-plug systemer med stor udnyttelse af pladsen, fremspiring i et fler-etagers lukket dyrkningsrum uden indflydelse af udendørsklimaet og automatisk omplantning i et større containersystem til slutdyrkning. Den nye teknologi er både rentabel og miljømæssig forsvarlig og er allerede introduceret til skovbruget og planteskolerne.

CONTENTS

1. INTRODUCTION

Forest seedling requirement for afforestation and reforestation in Europe comprises a substantial volume. Almost 1700 million seedlings, mostly conifers, are today produced in European forest nurseries each year.

Worldwide, the aspects of sustainable forestry together with focus on biological diversity and the recent provisions on the use of new forest stand establishment to implement the Kyoto Protocol have shifted market interest from conifers to broad-leaved seedlings. Hence, a considerable increase in the requirement for broad-leaved forest seedlings will develop in the future (Arbez, 2001; Dumroese *et al*., 2001; Wilkinson, 2001; Burnett, 2002). This change will have a major impact on the production technology of broad-leaved forest seedlings (Colombo, 2005). At European level, the implementation of member states' forest policies, aimed at supporting and further developing the principles of sustainable forest management, and re-vegetating and expanding the forest area for wood production, and for environmental and socio-cultural purposes (EC, 2003) will turn out an increase of the demand for a much broader range of species, e.g. broadleaved and wildlife-crop species, diverse species and local provenances more practical information is needed in many aspects of forest nursery production.

Today, state of the art is to produce forest broad-leaves as bare-root seedlings sown and grown on open land. If the production should be intensified to meet the increase in market demand, future broad-leaved production systems have to be based on a cost-efficient container concept. Today, the technology for large-scale production of containerised conifer seedlings is, contradictory to what would be possible for broad-leaves, based on seed lots with high germination capacity and subsequent seedling growth in the nursery at high densities during the whole growing season (Odlum *et al*., 2001). Hence, conifers can be grown in the same container during all stages of nursery production.

This concept would not be possible for broad-leaves since it will leave many empty cavities due to (general) poor germination of species, making production very expensive. Consequently, to make broad-leaved containerised production cost-efficient, a transplanting concept has to be introduced, making it possible to move seedlings germinated in small containers (mini-plugs) to a larger container or transplanting to open field. When using mini-plugs, a special compact multiple-floor facility with high capacity could also be implemented in the production process as a cost-efficient and environmental friendly alternative to germination in large greenhouses.

The development of this technology for large-scale production of broad-leaved forest seedlings will be highly beneficial to the small and medium enterprises (SMEs) in this project as a way to increase their competitiveness when producing high-quality cost-efficient broad-leaved seedlings for a growing market.

The following figure presents the project according to the production process, the technical components that will be developed and the expected results.

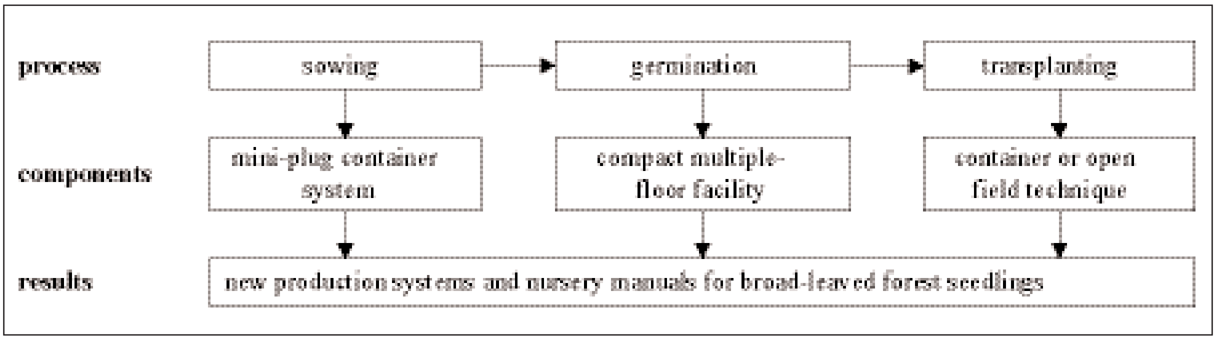

Figure 1.1. Production process, technical components to be developed and expected results of the BROAD_TEACH project,

The main objective for the project is to develop an innovative nursery technology for environmental friendly production of high quality and cost efficient broad-leaved forest seedlings. To obtain this a new compact germination facility, new mini-plug container systems and transplanting procedures will be developed together with new growing manuals and protocols for various growth factors and cultural practices.

Considering the growing demand for broad-leaved seedlings, in order to promote the sustainable management of European forestry, the results from this project will facilitate the establishment of broad-leaved forest all over Europe.

2. MATERIALS AND METHODS

2.1. Species

According to the initial programme, APAT (the Italian RDT partner) had to focus on two species: *Fraxinus excelsior* L. (ash), specific for Italy, and *Fagus sylvatica* L. (beech), common to all participants to the project. However, the poor germination of the ash seedlot, acquired for the first year trials, would have not allowed to have enough seedlings to carry out the program. Being necessary to have a country-specific species, it was decided to change to *Ulmus campestris* L. (common elm). Nevertheless, considered the importance of ash in Italy and in Europe, it has been added to the other two species (beech and elm) in the second year of the project. The Danish partner used pre-treated beech seeds of Danish source (Bregentved DK 659) in 2001 and of French provenance in 2002.
Finally, birch (*Betula pendula*) and beech (*Fagus silvatica*) of Swedish origin were sown by Swedish partners.

The trials included the following species:
a) elm - *Ulmus campestris* L. - (provenance San Lazzaro, Bologna, Italy, collected spring 2001), used by the Italian partner
b) beech - *Fagus sylvatica* L. - (Swedish provenance, collected Spring 2000), used by the Swedish and Italian partners
b) beech - *Fagus sylvatica* L. - (Danish provenance, collected Spring 2000), used by the Danish partner
d) birch - *Betula pendula* Roth – (Swedish provenance, collected Spring 2000), used by the Swedish partner.
While, the 2002 trial considered:
a) ash – *Fraxinus excelsior* L. – (Danish provenance, collected in Autumn 2001), used by the Italian partner
b) elm - *Ulmus campestris* L. - (provenance San Lazzaro, Bologna, Italy, collected in Spring 2002), used by the Italian partner
c) beech - *Fagus sylvatica* L. - (France's Office National des Forêts, provenance 04-NORDEST-calcaire, collected in Autumn 2001), used by the Danish, Italian and Swedish partners.

2.2. Pre-treatment of seeds

Elm seeds are not dormant, thus no pre-treatment has been performed.
Beech seeds, collected in Sweden and provided by the Swedish RTD partner, were pre-treated. The treatment consisted in 2 weeks of cold stratification.
Pre-treatment of beech seeds collected in Denmark consisted in cold stratification.
During the second year trials, all RDT performers employed non-dormant beech seeds. Seeds were purchased from the French *Office National des Forêts*. Even if percentage of germination was supposed to be rather high (71%), it showed a poor germinability in all cases. Ash seeds, collected in Denmark, and provided by the Danish RTD partner, were pre-treated. The treatment consisted in a 16-week period of warm stratification followed by a period of 16-week of cold stratification.

2.3. Containers

In 2001, with the aim to produce seedlings with marked variability in morphological and physiological characters, a consistent range of containers were used.
In particular, the containers utilized by the Italian partner were SP (Synprodo Plantpack) of different types (SP285, SP330, SP360, SP504) filled with IHT rooting plugs and Jiffy-7 Forestry system, containing Jiffy-7 pellets, 18 mm in diameter (Table 2.3.1).

Table 2.3.1. System and cell density utilised to produce seedlings of the different species in greenhouse or other holding area by the Italian partner

Year	Species	System	Cell density/m^2
2001	Elm	Jiffy 7 Forestry	2400
		Jiffy 7 Forestry (*)	1200
		SP/IHT 504	2100
		SP/IHT 285	1200
	Beech	SP/IHT 330	1400
		SP/IHT 360 (*)	750
2002	Elm	SP/IHT 360	1500
		SP/IHT 504	2100
		IHT/IHT 540	2250
	Ash	SP/IHT 360	1500
		IHT/IHT 540	2250
	Beech	IHT/IHT 209	870
		SP/IHT 360	1500

(*) Density obtained filling one out of two cells.

In Denmark four different plug systems with 2 densities were used for germination and early growth of European beech (*Fagus sylvatica* L.) and compared with that of a Danish soil pot (Table 2.3.1)
Furthermore a closed system HIKO 265 & 150 was used for sowing and growing of beech without transplanting and for fertilisation and hardening aspects.
SP and Beaver plugtrays are made of Expanded Polystyrene. The code number characterising the SP plugtrays (285, 330, etc.) stands for the number of cells present in a tray. With only one exception, tray size is 40 x 60 cm (2400 cm^2).

In the case of Jiffy-7, each plastic tray (25 x 51 cm) is made of extremely bendable plastic sheet. It contains 300 pellets, corresponding to a density of 2400 per m^2. To reach a density of 1200 cells per m^2, every other cell was left empty while the other was filled with a pellet (Plate 1).
The Italian partners used seedlings previously grown for five or seven weeks in IHT rooting plugs and Jiffy pellets were transplanted in the Jiffy 8 x 8 pots, with lateral fissures. Jiffy pots were kept in 32 x 55 cm plastic trays, having 20 cells each. The pots are made of a light sphagnum peat (at least 50%), wood fibres and lime to stabilise pH.
On the base of the results reached in 2001, 2002 trials employed IHT rooting plugs only. Plugs were set in SP and IHT trays at the highest densities (Table 2.3.1).

2.4. Substrate

In 2001, two types of substrates have been used by all the project partners: the International Horticultural Technology (IHT) plugs and the Jiffy pellets. Each system represented a different principle for a stabile plug system that could be transplanted operationally shortly after germination without damages to the root system (see more information about the systems in Annex 3).
The IHT rooting plugs are made of a blend of natural inorganic and organic ingredients, obtained with the Agriphillic Composting Process™. The idea is to synergistically combine ingredients in order to create beneficial condition for nutrient release.
Jiffy pellets are made of compressed peat of light sphagnum peat, contained in a biodegradable and light net. Dolomitic lime is added to adjust pH to about 4.5, but no fertiliser is used. The pellets are produced with a seedling hole in the centre and can be sown both dry or after watering. The second option has been selected in this trial. The watering of the pellets produces a rapid expansion. Jiffy 7 expands to a size of about 19 mm in diameter and 42/45 mm in height, corresponding to a volume of about 25 cc.
The growing media used to fill the larger Jiffy 8 x 8 pots (the containers to 'receive' the small mini-plugs) is the one normally used by the Torsanlorenzo nursery. It is a mix of light peat (the major component), perlite, pumice and sand (in a very low percentage). Jiffy 8 x 8 pots filled with this growing media were used for elm transplants in outdoor nursery. They were kept up by plastic trays, 32 cm by 55 cm in size, able to set up to 20 containers each.
Soil pots used by the Danish SME were made from dark peat and organic fertilizer and formed as compact cubes 4 x 4 x 4 (cm).

Table 2.4.1. Treatments and systems used for germination of beech by Danish partner.

	Treatments	**Plant m^{-2}**
1	Jiffy-7 22	860
2	Jiffy-7 30	360
3	Jiffy-7 30	865
4	IHT Beaver 209/40	500
5	IHT Beaver 209/40	1000
6	Soil pots	275

In 2001, the Swedish partner sowed birch and beech in Jiffy and IHT mini-plug container systems.
In 2002, after the results stemmed out from the experimental phase, only IHT plugs were used by all the partners, in combination with SP and IHT holding trays.

2.5. Sowing

Each species was grown at different densities to investigate the biological limits in order to optimise the economic output of the production.
Elm and beech seeds were sown by Italian partner in plugs and pellets of small size, at a high density (Table 2.3.1.). (Plates 6-11). Elm and beech seeds were sown in the last week of May and first week of June 2001. In detail: both species were sown in IHT plugtrays and rooting plugs the 29th and 30th of May, while elm was sown in the Jiffy pellets the 4th and 5th of June. Birch and beech were

sown by the Swedish partner in May 2001. For Jiffy plugs birch were grown at 1100 and 2200 plugs/m^2 respectively and for beech at 360 and 865 plugs/m^2. For IHT these figures corresponded to 1050 and 2100 plugs/m^2 for birch and 750 and 1500 plugs/m^2 for beech (Table 2.3.1.). In 2002, in Italy sowing of all three species took place the 3rd and 4th of April. In Denmark, the seeds were sown directly in the trays (Table 2.4.1). The seeds were covered with limefree sand (? cm).

2.6. Germination and transplantation

In 2001, after sowing, the seeds were kept under optimal conditions for either 5 or 7 weeks in a greenhouse of the Torsanlorenzo nursery (Plate 8-9 and 12-13). After this initial growing period, in two different dates, the 4th and 18th of July 2001, half of the miniplugs produced were transplanted into larger containers in an outdoor area (Plate 16), while the other half were transplanted in open nursery beds (Plate 14 and 15) to complete growing.
Elm seedlings were either transplanted into Jiffy pots 8 x 8, and immediately moved to an outdoor holding area close to the nursery beds (Plates 14-16), or transplanted directly into open nursery beds for bare-root growing (Table 2.7.1). The density of seedlings, transplanted both to container and open nursery beds, was 1200 per m^2.
Beech seedlings were transplanted only into open nursery beds (bare root) at the same occasions applied for elm (Plate 17). Due to the unsuccessful germination of this species, only two beech treatments (n° 3 and 4, Table 2.7.1) could be used for the following trials (Plate 9). In Plate 25 elm seedlings at the end of the growing season are shown.
Miniplug seedlings transplanted in Jiffy pots 8x8 cm were kept 15 cm above the ground level for air root pruning, moreover a plastic sheet was laid on the soil surface to avoid roots penetration, the soil, as well as to perform weed control. All the treatments were uniformly irrigated whenever necessary.
Factors affecting growing techniques, such as transplanting date and shading, were compared.
In Denmark pre-treated seeds were covered with lime-free sand. After sowing the systems were placed in a greenhouse with an air temperature app. 10 °C during the night and 20-25 °C during the day. The air temperature could not be controlled during the day because of periods with sun. The systems were covered with polystyrene boards to protect the seeds from high temperatures. After 12 days the germination started, but very poorly.
After germination the seedlings were irrigated with nozzles spraying 1.5 mm once or more a day. Liquid fertilizer was added once a week.
In a small trial use of controlled release fertilizer (Osmocote Plus‘ 5-6 month) added to a limed peat at the time of sowing was studied in comparison to addition of conventional fertilizer in containerised systems. Furthermore addition of clay powder (Bara, Sweden) was studied.
In June (14) all seedlings were moved to the container area under white shade net (25% reduction in photosynthetic light) and after a few days transplanted to the open field.
Transplanting to the open field was done by hand in a soil bed. The experimental area was a sandy loam. The distance between the seedlings was 10-15 cm and between the rows 45 cm. The seedlings were placed in 3 replicates with 15 seedlings per replicate (because of the low germination no more seedlings could be used for transplanting).
In 2002 (beginning of April), elm, beech and ash nursery stock grown in IHT plugs was transplanted in open nursery beds (Plates 19-22).

Either open nursery beds or outdoor holding area used for the transplanting into containers were, both years ,entirely bordered with a metallic net, to avoid animals damages (Plate 22).
In spring 2002, elm seedlings produced in the same year at the density of 2100/m^2 (IHT/IHT504 system) and 2250/m^2 (IHT/IHT540 system) were transplanted in open nursery beds by employing a transplanting machine.

2.7. Cultural practices after transplanting

To identify suitable cultural practices that could be expressed in protocols for each species different cultural practices was introduced after transplanting.
For birdh seedlings in Sweden these included different photoperiods using a system for day-length control (long-night treatment) in order to affect seedling morphology and frost hardening (Luoranen and Rikala, 1997). Birch has a very rapid growth and for an effective handling during storage, distribution and planting out a seedling with a balanced root-shoot ratio is to prefer.
For beech actively growing seedlings are quite susceptible to changes in light intensity especially after transplanting to open field after germination and early growth in a greenhouse environment. Therefore different cultural practices regarding variations in light intensity after transplanting were introduced for beech.
Italy. the seedlings, after having placed the containers in the outdoor holding area or having transplanted directly in open nursery beds, were shaded (using shading cloth) or not (Plates 23 and 24) (Table 2.7.1). Other growing conditions and cultural practices were the same for each treatment.
Denmark. the seedlings were covered with yellow net to protect against wind during the transplanting phase and birds. The seedlings were irrigated once a week in June and July if precipitation was lower than evapotranspiration. Fertilisation was done four times with app. 70 kg N ha^{-1} in a total, which is the maximum amount of nitrogen allowed in DK. A spraying against beech aphids was done in July.

Table 2.7.1. Tested cultural practices in Italy

Experimental treatments	Container type	Density (cell/m²)	Growing weeks after germination [1]	Transplanting technique [2] [3]	Field growth technique
Elm 1	S-P/IHT 504	2100	5	c + c	no shade
Elm 2	S-P/IHT 504	2100	5	c + c	shade
Elm 3	S-P/IHT 504	2100	5	c + onb	no shade
Elm 4	S-P/IHT 504	2100	5	c + onb	shade
Elm 5	S-P/IHT 504	2100	7	c + c	no shade
Elm 6	S-P/IHT 504	2100	7	c + c	shade
Elm 7	S-P/IHT 504	2100	7	c + onb	no shade
Elm 8	S-P/IHT 504	2100	7	c + onb	shade
Elm 9	S-P/IHT 285	1200	5	c + c	no shade
Elm 10	S-P/IHT 285	1200	5	c + c	shade
Elm 11	S-P/IHT 285	1200	5	c + onb	no shade
Elm 12	S-P/IHT 285	1200	5	c + onb	shade
Elm 13	S-P/IHT 285	1200	7	c + c	no shade
Elm 14	S-P/IHT 285	1200	7	c + c	shade
Elm 15	S-P/IHT 285	1200	7	c + onb	no shade
Elm 16	S-P/IHT 285	1200	7	c + onb	shade
Elm 17	Jiffy-7 FS (18 mm)	2400	5	c + c	no shade
Elm 18	Jiffy-7 FS (18 mm)	2400	5	c + c	shade
Elm 19	Jiffy-7 FS (18 mm)	2400	5	c + onb	no shade
Elm 20	Jiffy-7 FS (18 mm)	2400	5	c + onb	shade
Elm 21	Jiffy-7 FS (18 mm)	2400	7	c + c	no shade
Elm 22	Jiffy-7 FS (18 mm)	2400	7	c + c	shade
Elm 23	Jiffy-7 FS (18 mm)	2400	7	c + onb	no shade
Elm 24	Jiffy-7 FS (18 mm)	2400	7	c + onb	shade
Elm 25	Jiffy-7 FS (18 mm)	1200	5	c + c	no shade
Elm 26	Jiffy-7 FS (18 mm)	1200	5	c + c	shade
Elm 27	Jiffy-7 FS (18 mm)	1200	5	c + onb	no shade
Elm 28	Jiffy-7 FS (18 mm)	1200	5	c + onb	shade
Elm 29	Jiffy-7 FS (18 mm)	1200	7	c + c	no shade
Elm 30	Jiffy-7 FS (18 mm)	1200	7	c + c	shade
Elm 31	Jiffy-7 FS (18 mm)	1200	7	c + onb	no shade
Elm 32	Jiffy-7 FS (18 mm)	1200	7	c + onb	shade
Beech 1	S-P/IHT 330	1400	5	c + onb	no shade
Beech 2	S-P/IHT 330	1400	5	c + onb	shade
Beech 3	S-P/IHT 330	1400	7	c + onb	no shade
Beech 4	S-P/IHT 330	1400	7	c + onb	shade
Beech 5	S-P/IHT 360	750	5	c + onb	no shade
Beech 6	S-P/IHT 360	750	5	c + onb	shade
Beech 7	S-P/IHT 360	750	7	c + onb	no shade
Beech 8	S-P/IHT 360	750	7	c + onb	shade

(1) Growing weeks after germination = growing period length before transplanting in number of weeks after the sowing date.
(2) c + c = seedling grown in a small container, afterward transplanted to a bigger container and simultaneously transferred in open nursery beds.
(3) c + onb = seedling grown in a small container and afterward transplanted directly to open nursery beds.

2.8. Trials for hardening of beech seedlings in Denmark

Hardening of beech seedlings prior to transfer from greenhouse to open air in Spring. Practical experience shows that actively growing beech seedlings are quite susceptible to changes in the environment, which can lead to state of quiescence for the rest of the growing season. The objectives with these experiments were to study the sensitivity of beech to environmental changes (transfer from greenhouse to open air conditions) and to investigate the effects of drought and temperature in the greenhouse on the sensitivity to changes (hardening).

On 5th May 2001 beech seedlings grown in HIKO 265 trays were allocated to 6 separate greenhouse cells. The seedlings were subjected to 3 temperature regimes and 2 irrigations treatment in a split-plot experimental design (2 cells per temperature regime; 2 irrigation treatments per cell). The cells were ventilated when the air temperature exceeded 10°C, 15°C and 20°C respectively. Half of the seedlings were given optimal irrigation (control treatment) depending on evapotranspiration, while the other half were only irrigated every second time (drought treatment). The seedlings were transferred to a container growing area outside on 7th June.

Hardening of beech seedlings prior to transfer to cold storage in Autumn. Premature autumn cold storage of tree seedlings is known to cause poor growth and survival when the seedlings are replanted after the storage period. Several studies have shown that shoot tip frost hardiness (i.e. physiological maturity) can be used as an indicator of storability in conifers. It still remains, however, to study which criteria for storability that applies for broad-leaves. The objective of this experiment is to determine storability criteria for containerised beech seedlings.

A sample of beech seedlings were planted in November (2001) immediately after the cultivation period. In week no. 44, 46, 48 and 50 (2001) samples of beech seedlings were collected and cold stored at 4°C (from December at –1°C), packed in wax-coated paper bags. In addition, a control sample was stored outside during winter protected by cloth coverage. The control and the stored seedlings were planted in April 2002 for assessment of field performance. These seedlings were lifted in winter 2003.

2.9. Other laboratory tests

Italy. In coincidence with the two transplanting dates (4th and 18th of July 2001), a sample of 30 seedlings per treatment was taken for morphological measurements and for physiological performance tests. Among morphological features, shoot height (top of upper leaf), stem diameter, dry weight and moisture content of root, stem and leaves were measured. Performance tests on root (RGP) and shoot growth potential (SGP) as described by Mattsson (1997), root (REL) and shoot electrolyte leakage (SEL) (McKay, 1992) and root architecture using root study boxes (Lindström, 1981), were conducted as well.

In three occasions (week 41, 45 and 50) samples of 30 elm seedlings of the experimental treatments n° 17, 18, 21 and 22 (Table 2.7.1) was drawn to conduct REL and SEL measurements, with the aim to estimate the influence of the different cultural practices on the hardening process of elm seedlings and for studying root architecture using root study boxes.

At the end of the first year, after out-planting to a field experimental area selected for plantation trials (Figure 1), samples from each treatment were drawn again for morphological and physiological measurements, as well as for performance tests.

Denmark. Within the transplanting trials, 10 seedlings from each treatment were lifted in October and morphological charactheristics as root collar diameter, height, dry weight of root and shoot were determined. Concerning the trials on beech seedlings hardening prior to transfer from greenhouse to open air, the physiological state of the seedlings (water status) and stem height were measured before the transfer. Water status was assessed as stem water potential using a Scholander pressure bomb and the stomata conductance using a porometer. Stomata conductance measurements were repeated four days after the transfer to open air conditions (11^{th} June). After the first growing season (December 2001) stem height was measured again and height increment was calculated. Final biomass yield was determined as stem dry weight and diameter.

Concerning the trials on beech seedlings hardening prior to transfer to cold storage in autumn, at each storage occasion the physiological maturity (frost hardiness) was assessed in a controlled freezing test. Shoot tips of 15 seedlings were frozen to –25°C while another 15 shoot tips were kept at +4°C as control. Frost hardiness was evaluated using the conductivity method and expressed as the difference in shoot electrolyte leakage (SELdiff-25) of frozen and unfrozen samples (Lindström and Håkansson 1996, Brønnum 1999).

In April 2002 the root growth potential (RGP) of control and cold stored seedlings was assessed using the method of Tabbush (1988). The RGP showed no significant difference between the storage occasions, as the variation between the seedlings within each treatment was large.

Sweden. Different measurements have been conducted during the first vegetation period in order to evaluate the results of the different growing regimes described above. At the time of transplanting the following measurements were conducted: Dry weight of leaf, stem and root, shoot height, stem diameter and root (RGP) and shoot (SGP) growth potential (Mattsson, 1986; 1991). Also shoot and root growth development for the evaluation of appropriate systems regarding density and mini-plug design for the respective species was studied using root study boxes (Lindström, 1981).

During the fall the hardening process for seedlings grown under different cultural practices were analysed using root (REL) and shoot (SEL) electrolyte leakage (McKay, 1992). Finally, after the vegetation period seedlings were again tested for the following attributes; dry weight of leaf, stem and root together with shoot height and stem diameter.

Birch seedlings from the respective treatments were cold stores during the winter of 2001-2002. In the spring of 2002 all treatment were then outplanted in a field trial using a randomised block design. At the time of outplanting height and stem diameter were recorded for each seedling.

In October 2002, after one vegetation period in the field, the height and stem diameter was again recorded for each treatment for analyses of the growth potential during the first year after outplanting. In connection to this inventory also damages and survival for the respective treatments were recorded.

2.10. Field experimental plantation established in Italy

In order to study the field performance and simulate plantation conditions, the last week of February 2002 elm and beech nursery stock produced in 2001[1] was out-planted in a site close to the nursery area

[1] No fiield trials were carried out for seedlings grown in 2002.

(Plates 26 and 27). Elm seedlings belonged to every experimental treatment considered (32 treatments), while beech seedlings, due to poor results registered during the growing period, belonged to two treatments only (Table 2.7.1).
The out-planting site is located 40 km south of Rome, 4 km from the Tirrenian sea. The climate is characterised by annual average temperature of 15°C, while the average temperature in the hottest year's month is 23°C and the average temperature in the coldest year's month is 7°C. Rainfall is around 781 mm per year, of which only 55 mm over summer. The site was used in the past for growing ornamentals. Early November 2001 the soil was ploughed at the depth of about 40 cm and, in spring 2002, tilled. The soil is well drained and has a modest presence of stones; the percentage of sand in the soil is almost 50%, while the complement to 100% is represented by loam and clay, both in similar proportion. Soil's pH fluctuates between 7.0 and 7.2 and depth is between 80 and 100 cm.
The field plantation was established with a randomised block design (Figure 1, Annex I). The following factors were focused (Table 2.7.1):
- growing media (IHT rooting plug and Jiffy-7 pellet),
- growing system during the initial period (two densities and two transplanting dates);
- growing system after the initial period which ended with the first transplant (bare-root versus containers and shading versus no shading).

The 32 treatments were replicated 4 times. Seedlings were out-planted at the density of 50 cm by 50 cm. Field performance of seedlings, obtained under the different growing systems, was evaluated and compared. Percentage of survival, shoot height and diameter, both soon after out-planting and one year later, were measured for all seedlings in each treatment. Shoot height was measured from collar to top of terminal bud and stem diameter 2 cm above ground.

2.11. Growing media and transplanting time: second year experimental trials held in Denmark

The plant quality of beech when transplanting from container to open field was evaluated by the SME and compared to the plant quality of bare-rooted seedlings. The quality of the transplanted seedlings from container to the open field was not optimal compared to the bare-rooted seedlings. The reason for this is probably related to climatic conditions in the open field as air and soil temperature is lower in the open field than on the container area and in the containers (2-3 °C lower, and 1∞ less means 10% less growth according to Grace (1971).
Hence, it was decided that transplanting from container to the open field was not optimal under normal growing conditions in Denmark.
Instead transplanting from container to container on the container area was tried.
In 2002 growing media and transplanting time from container to container was evaluated in an experimental trial. Growing media is important if transplanting with robots is to be used and air- and water content to be maintained at the same time.
After one growing season the morphological quality of the seedlings was compared with that of bare-rooted seedlings.

2.11.1. Growing media

Three growing media were used in the first container, shown in Table 2.10.1.

Table 2.10.1. Growing media used in the first container

Growing media	Type
IHT	Peat with glue
Floragard	Dark peat with compost added
Kasper	Blond Finnish peat

The growing media were used in Biomatic trays 360 plugs m^{-2}.
The trays were placed on net on the container area and covered with acryl (17 gram m^{-2}) during the first week.
Liquid fertiliser was used at each irrigation, and a boom with spraying nozzles made irrigation. The gardener controlled irrigation.

2.11.2. Transplanting

Transplanting was done to a container of 200 cm^3, 15 cm high with a plant density of 350 seedlings m^{-2} (Quick, Herkuplast). The growing media was Pindstrup (blond peat 0-20 mm).
At each time seedlings were transplanted from the small containers to the larger container and placed on the container area again.
Transplanting time was either 5. June (Photo xx) or 10.July. A proportion of the seedlings was not transplanted. The seedlings were lifted in January and morphological parameters were determined.

3. RESULTS

3.1. Growing techniques

3.1.1. Elm and beech seedlings performance in Italy

3.1.1.1. Effect of growing system and cultural practices

Results of 2001 vegetation season are reported starting with the time of transplanting, measurements performed during the fall are presented afterwards and, finally, results from analyses conducted after the vegetation period are described. All Figures are presented in Annex 1.

Figure 2 shows the dry weight for the different components (leaf, stem and root) of the seedling as well as height and collar-diameter reached by elm seedlings grown in Jiffy mini-plugs for 5 weeks before transplanting. The same parameters referred to elm seedlings grown in the IHT mini-plug system are presented in Figure 3.

The results clearly demonstrate that the IHT system allowed higher dry weight and height development if compared to the Jiffy system. Dry weight of all components was significantly higher for the IHT system and height at the time of transplanting was also substantially better. Regarding the two different growing densities no differences were detected, except for the dry weight of the leaf portion (higher in 1100 plugs/m^2) of seedlings grown in IHT plugs.

Records referred to seedlings grown for 7 (instead of 5) weeks before transplanting are presented in Figures 4 and 5. As concerns dry weight, the figures show similar results as those reported for seedlings grown for 5 weeks before transplanting (a better development for IHT plugs). In IHT plugs, dry weight was higher in the leaf and in the root system portion, but not in the stem. No differences in height and diameter of seedlings were due to the use of either Jiffy or IHT system. Growing densities did not produce significant differences between treatments, except for what concerns the stem height of the seedlings grown in Jiffy plugs at 2400 plugs/m^2, which proved to be higher than that recorded in the sparser density.

Regarding the experiments carried out on beech, results from the same parameters observed in elm are shown in Figure 6. Significant higher measures of dry weight, stem height and diameter were registered in seedlings grown at the higher density (1400 plugs/m^2).

Root growth potential (RGP) and shoot growth potential (SGP) were measured through all treatments at transplanting time. Results for elm seedlings grown in Jiffy and IHT plugs are presented in Figures 7 and 8.

The figures show a noticeably higher RGP for IHT seedlings if compared with the seedlings grown in the Jiffy system. These differences are particularly manifest in seedlings grown in plugs 5 weeks before transplanting, while values tend to average down in seedlings grown 7 weeks before transplanting. The two different growing system had not influence on the SGP.

For seedlings grown in Jiffy plugs, no relevant differences in RGP were registered between the two growing densities and the two transplanting times. Conversely, SGP was drastically reduced in seedlings grown at the higher density, but was positively affected extending the weeks to transplanting from 5 to 7 weeks.

For seedlings grown in IHT plugs, both RGP and SGP were significantly higher in 1100/m^2 dense seedlings and in 7-weeks-to-transplanting seedlings.

RGP and SGP measurements for the beech seedlings are shown in Figure 9. In general, there were no significant statistical differences between the different growing density regimes.
For detecting possible effects on growth caused by shading, samples of seedlings grown in IHT for 5 and 7 weeks before transplanting in open air, shaded or not-shaded, were lifted at week 41, 45 and 50 after transplanting. At each lifting, root electrolyte leakage (REL) and shoot electrolyte leakage (SEL) were performed and the results used are shown in Figures 10-13.
No differences could be registered, as far as REL records were concerned, between shaded and not shaded seedlings grown for 5 weeks before transplanting. It must be also noted that REL of all treatments grown for 5 weeks before transplanting always decreased during the lifting period, from 22% to 13% (Figure 10). The $REL_{diff\text{-}25}$ (when samples are frozen at –25°C) showed a significant decrease from week 41 to week 45 and then a transient stagnation (shaded) or an increase (no shaded).
At the first lifting, no differences in SEL between shaded and no-shaded seedlings were detected. The REL decreases slightly in shaded seedlings, while it remains unvarying in the no-shaded seedlings up to the second lifting date, then decreases to a value comparable to the other treatment. $SEL_{diff\text{-}25}$ decreased from approximately 52% in the first lifting week to values 40% in week 45 and 19% in week 50 for no-shaded seedlings; $SEL_{diff\text{-}25}$ decreased from approximately 52% in the first lifting week to values 35% in week 45 and 18% in week 50 for shaded seedlings.
Regarding REL measurements in seedlings grown for 7 weeks before transplanting, no differences between the two treatments could be registered at the first lifting. REL tends to decrease during the lifting period in shaded seedlings (from 24% to 15% to 13%); it seems to be stable from week 41 to 45 and then declines to 13% in no-shaded seedlings.
The $REL_{diff\text{-}25}$ showed a decrease from week 41 to week 45 and then a transient stagnation (shaded) or an increase (no shaded) (Figure 12).
From Figure 13, it is noticeable the difference in SEL between shaded and no-shaded seedlings at the first lifting. The difference tends to reduce between the two treatments in the next lifting dates. $SEL_{diff\text{-}25}$ decreased from approximately 58% in the first lifting week to values 39% in week 45 and 20% in week 50 for no-shaded seedlings; $SEL_{diff\text{-}25}$ decreased from approximately 53% in the first lifting week to values 31% in week 45 and 22% in week 50 for shaded seedlings.

3.1.1.2. Experimental plantation results

At the end of the growing season, seedling status, with regard to dry weight, height and stem diameter, was registered for the different elm treatments. Beech was only studied with regard to the development in mini-plugs at different densities until the time of transplanting except for the study of the effect of shading on the hardening process during fall.
Shoot height (top of terminal bud) and stem diameter (2 cm above ground) measured in each treatment soon after out-planting showed marked differences between the miniplugs transplanted into larger containers growing system and the miniplugs transplanted into open nursery beds system (Table 3.1.1). Across all treatments, the miniplugs transplanted into open nursery beds showed better overall height (74.9 cm ± 25.3) and diameter (6.9 mm ± 2.1) being 27% higher and 37% larger in diameter that miniplugs transplanted into open nursery beds system (54.9 ± 12,2 cm high and 4,38 ± 1,49 mm diameter)

Table 3.1.1. Diameter (mm) and height (cm) of seedlings transplanted in containers (Jiffy pots 8 x 8) and in open nursery beds soon after out-planting (nursery) in the plantation area and one year after out-planting (field)

Treatment	Mean diameter ± *1 standard error*		Mean height ± *1 standard error*	
	Mm		**cm**	
	nursery	*Field*	*nursery*	*field*
Container	4.38±*0.22*	13.4±*1.0*	54.9±*2.3*	158.6±*11.8*
Open nursery beds	6.95±*0.26*	20.5±*1.1*	74.9±*5.2*	212.2±*11.5*

Elm plantation one year after outplanting is shown in Plates 33 and 34.

Measures of the means (±1SE) for survival and height and collar diameter growth of elm transplants of different treatments one year after out-planting have been analysed. The analyses of variance will be performed and a more consistent interpretation of the results could be given. Other field observations to consider in interpreting the results will be those regarding the shape of the tree stem and, in particular, the characteristics linked to the nursery container and the growing media rather than to the species in itself.

Seedling survival after one growing season in the field was high: 93.9%. No significant differences in survival were detected between the type of container (95.4 for IHT; 92.4 for Jiffy) (Figure 14). Higher survival was observed in seedlings transplanted into open nursery beds (98.3%) compared to those transplanted to container (89.5%).

The average diameter of the seedlings after one growing season was 16.4 cm (Figure 15). The type of container did not significantly affect the height growth (17 mm for IHT to 15.8 mm for Jiffy). Diameter of seedlings transplanted to open nursery was significantly greater (19.6 mm) than the diameter of those seedlings transplanted to container (13.0 mm). For the seedling raised in Jiffy, shading had negative effect on the diameter, while it did not influence the diameter of seedling raised in IHT.

The average seedling height of the seedlings after one growing season was 186.6 (Figure 16) . The type of container did not significantly affect the height growth (187.9 cm for IHT to 185.4 cm for Jiffy). Transplanting directly to open nursery beds compared to container gave in any case consistently better results for all the parameters considered. Highest height was recorded by seedlings grown in IHT and transplanted to open nursery beds: 219.9 cm. Seedlings grown in IHT and transplanted to container reached 155.8 cm after one year in the field.

Being height growth more influenced by the high plantation density (due to the competing effect), the strong difference showed in diameter growth seems to leave no doubt about the superior efficiency of the transplantation to open nursery beds compared to that to container.

A general impression recorded during the last plantation field measurements, to be confirmed with more detailed and codified field observations, suggested that plants grown initially in Jiffy system often showed a poor stem shape. In fact, in some case the stem was tall, but thin and bended, starting from/at ground level, where root appeared clearly deformed as a consequence of initial (nursery phase) spiralling.

3.1.2. Beech seedlings performance in Denmark

3.1.2.1. Effect of growing system and cultural practices

3.1.2.1.1. Germination phase

The germination was extremely limited in all 6 systems. The germination was restricted because of fungi problems in the seed source and because of high temperatures during germination.
The designing of the plug and plug-tray influenced the root system in the different plug system. No curling was found in IHT and soil pots. However, in Jiffy 22 and 30 curling of the root was found when the root reached the bottom of the tray (Figure 1, Annex 2).
In Jiffy 22 the size of the plug was too small to allow the seedling to rise without affecting the cotyledons, hence damages on the leaves were found (Figure 2).

3.1.2.1.2. Transplanting phase

A difference between the different systems was found after lifting in October. In Table 3.2.*1* the root collar diameter and height are shown for the different systems. A significant higher root collar diameter was found in the Jiffy 30 at low density compared with the higher density. Seedlings in IHT showed a smaller RD although significantly different to the Jiffy 30 at high density. The same differences between the treatments were found in the height of the seedlings. But only small differences were found.
The curling of the roots observed earlier was found after transplanting.

3.1.2.1.3. Shoot and root dry weight

Shoot growth was significantly higher in Jiffy30-360 compared with the other treatments. The lowest shoot DW was found in IHT (Figure 3).
Root growth determined as root DW outside the plug was significantly higher in Jiffy 30 density 360 and soil pots compared with all the other treatments (Figure 3). The IHT at density 1000 had one third of the root DW in Jiffy 30-360.
Transplanting in the field lowered the aboveground growth of the seedlings compared to the seedlings left on the container area (data not shown).
Root length and number of tips were determined in different containerised systems compared with open systems. The results showed that root length and number of root tips were much larger when the seedlings were grown in containers than in open systems during a whole growing season (Figure 4).

Table 3.1.2. Root collar diameter and height of beech seedlings in relation to plug type after lifting in October. Values in each column followed by the same letter are not significant different according to a Duncan's multiple-range test (P=0.05).

	Density	Root collar diameter	Height
	Plant m^{-2}	***Mm***	***Cm***
Jiffy-7 22	860	4.60 ab	12.8 ab
Jiffy-7 30	360	5.12 a	15.8 a
Jiffy-7 30	865	3.65 dc	11.9 b
IHT Beaver 209/40	500	3.84 cd	12.1 ab
IHT Beaver 209/40	1000	3.16 d	10.1 b
Soil pots	275	4.36 abc	13.4
$LSD_{0.95}$		0.783	3.776

3.1.2.1.4. Fertilisation

A significantly increased growth in both height and root collar diameter with the additions of controlled release fertiliser Osmocote Plus was observed compared with conventional fertilizer (Figure 5). The addition of clay in connection with Osmocote decreased both RD and height significantly compared with Osmocote with no clay. Still the RD and height were significantly higher than the conventional fertilizer.

3.1.2.1.5. Covering

Covering with the white shade cloth had no influence on the RD and height compared with no shade (data not shown). No leaf burning was found in either of the seedling types.

3.1.2.2. Seedlings hardening

3.1.2.2.1. Prior to transfer from greenhouse to open field in the spring

3.1.2.2.1.1. Physiological assessments

The stem water potentials were generally high in all treatments (> -0.5 MPa), indicating that none of the seedlings were suffering from water stress at the time of transfer, not even the seedlings in the drought treatments. There was a tendency that seedlings in the 20°C regimes had slightly lower water potentials (more water stressed) than in the other temperature regimes, but this effect was not significant. Stomata conductance prior to transfer was significantly higher in the 20°C control regimes, but this difference disappeared after 4 days under open air conditions (Table 3.2.*2*).

Table 3.1.2. Stem water potential and stomata conductance of beech seedlings raised in a greenhouse under three temperature and two irrigation regimes. ? and gs was measured prior to transfer of seedlings to ambient conditions and gs again 4 days after.

	Control			Drought		
	10 °C	15 °C	20 °C	10 °C	15 °C	20 °C
Stem water potential, MPa	-0.18 a	-0.17 a	-0.23 a	-0.18 a	-0.19 a	-0.26 a
Stomata conductance (7/6)						
mmol $m^{-2}s^{-1}$	135.2 b	112 b	194.4 a	108.3 b	154.4 b	223.2 a
Stomata conductance (11/6) mmol $m^{-2}s^{-1}$	103.0 a	149.4 a	126.8 a	122.1 a	109.3 a	

3.1.2.2.1.2. Morphological assessments

The temperature regimes and irrigation treatments had no significant effect on height growth and stem dry weight and diameter after one growing season (table 3.1.3). However, the effect of irrigation regime on stem dry weight was almost significant ($p = 0.051$), indicating that drought during the greenhouse period may have a positive effect on final biomass yield.

Table 3.1.3. Height increment and final stem dry weight and diameter of beech seedlings after the first growing season.

	Control			Drought		
	10 °C	15 °C	20 °C	10 °C	15 °C	20 °C
Stem height (increment) cm	13.7 a	15.8 a	13.3 a	15.2 a	15.2 a	14.7 a
Stem dry weight (final), g	2.5 a	2.1 a	2.0 a	2.8 a	3.0 a	2.8 a
Stem diameter (final), mm	4.9 a	5.5 a	4.6 a	5.6 a	4.9 a	5.1 a

3.1.2.1.3. Prior to transfer to cold storage in autumn.

Figure 6 shows the development in shoot frost hardiness ($SEL_{diff-25}$) of the beech seedlings described above. For comparison are added similar data describing the development in shoot frost hardiness of field grown bare-rooted beech seedlings lifted during the same period (not described). $SEL_{diff-25}$ decreases with later testing dates as a result of shoot acclimation, and approaches 10% in the second half of November. There seems to be a delay in shoot acclimation of containerised seedlings as compared to bare-rooted.

3.1.2.1.4. Morphological quality in relation to growing media and transplanting time (second year trials)

At lifting morphological quality of the seedlings raised in the three growing media and transplanted at two different times and not-transplanted was compared. Bare-rooted seedlings of the same origin were bought in a Danish nursery and morphological quality of the seedlings was analysed.
Growing media had only little effect on morphology of the seedlings. No significant effect on root collar diameter was found (Figure 7).
A significant larger height of seedlings in Kasper peat of the untransplanted seedlings was found (Figure 8). As the plant density was identical in the three growing media the larger height can be an effect of the growing media. Shoot DW was similarly higher in Kasper of untransplanted seedlings (Figure 9).

Transplanting time had a significant effect on root collar diameter, height and shoot DW. Transplanting after one month significantly improved root collar diameter, height and shoot DW (Figures 10, 11, 12). Transplanting after two month had only limited effect on root collar diameter compared to no-transplanting. However, height and shoot DW were significantly improved by the transplanting after two month.

Transplanting time is very important for morphological quality and an early transplanting time after 1 month of growth improved growth compared with later transplanting or no-transplanting.

Containerised production could produce the same morphological quality as bare-rooted production concerning root collar diameter (Figure 10).The root collar diameter is normally determined at the base of the shoot on bare-rooted seedlings. But when measuring on containerised seedlings standing in the container the root collar diameter is measured a little higher on the stem, which might give a smaller root collar diameter compared with bare-rooted seedlings.

Height and shoot DW were significantly higher in containerised seedlings (Figure s11 and 12).

The shoot DW of bare-rooted seedlings was nearly half the dry weight in containerised seedlings. This might indicate that the root collar diameter was measured lower on the stem in bare-rooted seedlings than on containerised seedlings as discussed above.

The root collar diameter can be used as a quality control of the seedlings as there is a linear relationship between root collar diameter and shoot DW (Figure 13).

Tree seedlings of beech can be produced as containerised seedlings in one year in Denmark and of optimal quality concerning root collar diameter, height, shoot DW.

Bare-rooted seedlings produced in one year is of less height and shoot DW than containerised seedlings.

3.1.3. Birch and beech seedlings performance in Sweden

The results are presented according to when the measurements were conducted during the first vegetation period. That is starting with the time of transplanting followed by measurements during the fall and finally results from analyses conducted after the vegetation period. All the figures referred to in the text are presented in annex 3 together with a figure legend.

Dry weight for leaf, stem and root together with height development at the time of transplanting for birch seedlings grown in Jiffy mini-plugs for 3 weeks before transplanting are presented in Figure 1, Annex 3. The same results for seedlings grown in the IHT mini-plug system are presented in Figure 2.

The results show that the IHT system had better dry weight and height development compared to the Jiffy system. Dry weight was more than twice as high for the IHT system and the height development at the time of transplanting was also considerable better. Regarding different growing densities no differences could be registered between treatments. This was true both for the Jiffy and IHT system.

Results from the same measurements for seedlings grown for 6 weeks before transplanting are presented in Figure 3 and 4. The figures shows the same results as seedlings grown for 3 weeks before transplanting that is a better development for IHT plugs and no differences between growing densities. For seedlings grown for 6 weeks stem diameter was also included in the measurements. After 3 weeks it was not possible to make these measurements since the birch seedlings were to small at that time. The diameter measurements after 6 weeks showed the same result as for the other parameters with a better development for IHT seedlings and no differences between densities.

For beech results from the same measurements as for birch is shown in Figures 5-8. Due to the rapid growth of beech seedlings, the second time chosen for transplanting was 5 weeks instead of 6 weeks after sowing as for the birch seedlings. The results both from 3 and 5 weeks showed no major differences between Jiffy and IHT seedlings this was also true for the different densities used in the trials.

Root (RGP) and shoot (SGP) growth potential was also measured for all treatments at the respective time of transplanting. Results for birch seedlings grown in Jiffy and IHT plugs are presented in Figure 9 and 10. The figures show a higher growth potential for IHT seedlings when transplanting after 3 weeks compared to Jiffy seedlings. After six weeks these differences have been levelled out. As for the other measurements no major differences between the different growing densities could be registered except for one result. For Jiffy seedlings grown for 6 weeks the lower growing density had a positive effect on the RGP and SGP measured.

RGP and SGP measurements for the beech seedlings are shown in Figures 11 and 12. In general growth potential was better for Jiffy seedlings compared to IHT seedlings. There were no differences between the different times to transplanting and the same was also true for the different growing densities.

The results from root (REL) and shoot (SEL) electrolyte leakage, used for analysing possible differences in the hardening process between treatments, are shown in Figures 13 and 14. These treatments comprised birch seedlings For the REL measurements no differences between the different treatments could be registered. This was true both for birch and beech seedlings. For the SEL measurements the REL results was also valid for beech seedlings. For birch though long night treated seedlings grown for 6 weeks before transplanting had a lower SEL value compared to the control indicating a better hardening status.

After the first vegetation period seedling status, with regard to dry weight, height and stem diameter, was registered for the different birch treatments.

The stem weight for the different treatments, after the end of the first vegetation period, is presented in Figures 15 and 16. As can be seen in the figures there were no major differences between treatments except for long-night (LN) treated seedlings grown for 6 weeks before transplanting. These treatments had a lower weight both for Jiffy and IHT seedlings.

When looking at the root weight (Figures 17 and 18) the weight for IHT seedlings were in general higher compared to Jiffy seedlings while there were no major differences between the control and long-night treated seedlings.

Regarding stem height (Figures 19 and 20) the results were similar as for the stem weight. The long-night treated seedlings grown for 6 weeks before transplanting were considerable smaller compared to other treatments. In annex 3 these differences in height is illustrated in a picture taken in the nursery after the first vegetation period.

Finally the results from the measurements, after the first vegetation period, of the stem diam[2]eter are presented in Figures 21 and 22. As can be seen no major differences could be registered between the different treatments.

After cold storage during winter birch seedlings from all treatments were outplanted in a field trial dur-

[2] In the CRAFT project birch was the main species of commercial interest for the Swedish SME. Beech was only studied with regard to the development in mini-plugs at different densities until the time of transplanting except for the study of the effect of shading on the hardening process during fall. For the Danish SME beech was the species of commercial interest. Therefore the presentation in this report from the Danish RTD performer will cover more aspect regarding production of beech using mini-plugs[2] and transplanting technology also including seedling development after transplanting.

ing spring 2002. The shoot and diameter growth results from the field trial, invented in the autumn after the first vegetation period, are presented in Figures 23 and 24.
Both the shoot and diameter growth shows a tendency for better growth regarding long night treated seedlings. Seedlings grown at a high density before transplanting have the same and in some cases better growth than seedlings grown at a lower density. These results validate the growth results obtained during 2001 for the respective treatments. Differences between plug systems were small with a tendency for better shoot growth for the IHT system.

3.2. Economical Analyses

3.2.1. Production cost for conventional and accelerated transplanted elm seedlings in Italy

The current state-of-the-art for producing broadleaved bareroot seedlings starts by the germination from seed sown directly into outdoor nursery seedbeds; after one growing season, bareroot seedlings are lifted from high density seedbeds, culled and replanted into outdoor transplants beds at lower density next spring. To evaluate the economic potential for the introduction of the new technology (miniplug production and transplantation to outdoor nursery beds) compared to conventional transplants production, the following evaluations have been made based on figures from conventional production and the knowledge emerged the project.
The technology proposed (greenhouse transplants or accelerated transplants) has main advantages: reduces production time from two year to one year, makes better use of seeds and other inputs, facilitates mechanisation, results in uniform seedling size, increases flexibility in responding to customers' needs.
Total production cost (direct and indirect) for producing 466,700[3] elm seedlings in 1 ha of land, grown according to state-of-the-art (here defined conventional transplants, 1+1) is around 108,000 Euro, corresponding to 0.23 Euro per plant (Table 3.2.1).
With this methodology, 47.0% over total costs is due to labour costs. Of this item, 36.6% corresponds to cost for harvesting and 28.1% for grading, packaging and storing. Purchasing means and materials covers 16.1% over total cost.
Viceversa, total production cost (direct and indirect) for producing the same amount of seedlings in 1 ha of land according to the new technology developed in this project (accelerated transplants) has been estimated in around 83,500 Euro, corresponding to 0.18 Euro per plant (Table 3.3.*2*). This cost is 22,7% less than the state-of-the-art method, thanks to a considerable cost reduction for purchasing means and materials, for interests and for land property costs.

[3] Transplanting miniplugs at 120 cm^2 cm per plant (shaped 15 cm by 8 cm), considering a 20% reduction because of mortality and grading, and 40% loss of cultivating area because of alleys between nursery beds.

Table 3.2.1. Financial assessment of 1 hectare production of *Ulmus minor* bare-root seedlings: conventional transplants

Operation	Unit	Quantity	Price	Cost		
				Euro	% over item	% over total
1. Labour						
Soil cultivation	hour	20	12,91	258,2	0,51	0,24
Sterilisation and weeding	hour	32	12,91	413,2	0,81	0,38
Fertilisation (mineral and organic)	hour	93	12,91	1.200,8	2,36	1,11
Seed conservation and pre-treatments	hour	100	12,91	1.291,1	2,54	1,20
Sedbeds preparation	hour	154	12,91	1.988,4	3,92	1,84
Sowing	hour	500	12,39	6.197,5	12,20	5,74
Transplantation (by machine)	hour	250	12,91	3.227,9	6,36	2,99
Seedbed protection (net application and removal)	hour	168	12,39	2.082,4	4,10	1,93
Weed, insect pests and desease control	hour	25	12,91	322,8	0,64	0,30
Root culturing	hour	15	12,91	193,7	0,38	0,18
Lifting	hour	60	12,39	743,7	1,46	0,69
Harvesting	hour	1.500	12,39	18.592,4	36,61	17,22
Grading, packaging and storing	hour	1.105	12,91	14.267,1	28,10	13,21
Total				**50.779,1**	**100,00**	**47,03**
2. Means and materials						
2.1 Fertilisers and amendments						
Manure	t	80	10,00	800,0	4,60	0,74
Mineral fertilisers	t	30	237,57	7.127,1	41,01	6,60
2.2 Pesticides						0,00
Sterilisers	kg	800	4,13	3.305,3	19,02	3,06
Fungicides	kg	24	1,91	45,9	0,26	0,04
Herbicides	kg	20	11,88	237,6	1,37	0,22
2.3 Fuels and lubricants						0,00
Diesel oil	l	3200	0,40	1.280,0	7,36	1,19
Lubricants	l	66	4,10	270,6	1,56	0,25
2.4 Materials						0,00
Seed	kg	30	35,00	1.050,0	6,04	0,97
Peat	m3	2	49,58	99,2	0,57	0,09
Sand	m3	2	10,33	20,7	0,12	0,02
Pomice	m3	4	11,36	45,4	0,26	0,04
Nets	m2	6.000	0,70	4.200,0	24,17	3,89
Total				**17.380,5**	**100,00**	**16,10**
3. Interests				**4.836,7**	**100,00**	**4,48**
4. Rates (Mortage, Maintenance, Insurance)						
Buildings and green-house				**4.000,0**	17,30	3,70
Transplanter machine				**900,0**	3,89	0,83
Other machineries and tools				**15.226,0**	65,84	14,10
Coldstore				**3.000,0**	12,97	2,78
Total				**23.126,0**	**100,00**	**21,42**
5. Land property costs				**1.680,0**	**100,00**	**1,56**
6. Direc., Amm., Maintenance				**7.200,0**	**100,00**	**6,67**
7. Overheads and levies				**2.960,0**	**100,00**	**2,74**
Total costs				**107.962,2**		
Vendible Gross Production	#	**466.667**	**0,40**	**186.666,7**		

Table 3.2.2. Financial assessment of 1 hectare production of *Ulmus minor* bare-root seedlings: accelerated transplants

Operation	Unit	Quantity	Price	Cost		
				Euro	% over item	% over total
1. Labour						
Soil cultivation	hour	10	12,91	129,1	0,26	0,15
Sterilisation and weeding	hour	16	12,91	206,6	0,41	0,25
Fertilisation (mineral and organic)	hour	46,5	12,91	600,4	1,20	0,72
Seed conservation and pre-treatments	hour	100	12,91	1.291,1	2,57	1,55
Sedbeds preparation	hour	77	12,91	994,2	1,98	1,19
Sowing	hour	1000	12,39	12.395,0	24,70	14,85
Transplantation (by machine)	hour	250	12,91	3.227,9	6,43	3,87
Seedbed shading (application and removal)	hour	84	12,39	1.041,2	2,07	1,25
Weed, insect pests and desease control	hour	13	12,91	161,4	0,32	0,19
Root culturing	hour	15	12,91	193,7	0,39	0,23
Lifting	hour	30	12,39	371,8	0,74	0,45
Harvesting	hour	1.500	12,39	18.592,4	37,05	22,27
Grading, packaging and storing	hour	850	12,91	10.974,7	21,87	13,15
Total				**50.179,5**	**100,00**	**60,11**
2. Means and materials						
2.1 Fertilisers and amendments						
Manure	t	40	10,00	400,0	3,09	0,48
Mineral fertilisers	t	15	237,57	3.563,6	27,52	4,27
2.2 Pesticides						0,00
Sterilisers	kg	400	4,13	1.652,7	12,76	1,98
Fungicides	kg	12	1,91	22,9	0,18	0,03
Herbicides	kg	10	11,88	118,8	0,92	0,14
2.3 Fuels and lubricants						0,00
Diesel oil	l	1.600	0,40	640,0	4,94	0,77
Lubricants	l	33	4,10	135,3	1,05	0,16
2.4 Materials						0,00
Seed	kg	30	35,00	1.050,0	8,11	1,26
Mini-lugs and trays	n	3.000	1,03	3.098,7	23,93	3,71
Peat	m3	2	49,58	99,2	0,77	0,12
Sand	m3	2	10,33	20,7	0,16	0,02
Pumice	m3	4	11,36	45,4	0,35	0,05
Nets	m2	3.000	0,70	2.100,0	16,22	2,52
Total				**12.947,2**	**100,00**	**15,51**
3. Interests				**2.418,4**	**100,00**	**2,90**
4. Rates (Mortage, Maintenance, Insurance)						
Buildings and green-house				2.000,0	16,65	2,40
Transplanter machine				900,0	7,49	1,08
Other machineries and tools				7.613,0	63,37	9,12
Coldstore				1.500,0	12,49	1,80
Total				**12.013,0**	**100,00**	**14,39**
5. Land property costs				**840,0**	**100,00**	**1,01**
6. Direc., Amm., Maintenance				**3.600,0**	**100,00**	**4,31**
7. Overheads and levies				**1.480,0**	**100,00**	**1,77**
Total costs				**83.478,1**		
Vendible Gross Production	**#**	**466.667**	**0,40**	**186.666,7**		

Labour cost of transplantation is equivalent to 3,228 Euros. To these costs, expenses for fuel and lubricants and maintenance are to be added, totalling a direct cost of 3563 Euros. The cost for the machine is nearly 180 Euros/ha/yr (considering a yearly cost of 900 Euros[4], divided by 5, because of an average size of the nursery of 5 hectares). When adding to this cost other indirect expenses (insurance, interests, etc.), the total indirect costs are equivalent to 320 Euros. Thus, the total cost of transplantation is 3703 Euros, equivalent to 0.006 Euro per seedling.

As can be seen from previous Tables 3.2.1 and 3.2.*2* there is a huge potential for improved cost efficiency in production of broad-leaved forest seedlings when using the accelerated transplanting technology. The reason for this is mainly due to the possibility to execute production in one year and consequent reduction of costs for labour, means and materials, interests and rates; in addition, compared to the conventional production, the operation of lifting is limited to one year. Percentages of direct and indirect production costs over total cost for elm seedling accelerated transplants are illustrated in Figure 17 of Annex 1 - APAT.

3.2.2. Production cost for beech seedlings in Denmark

The calculations below are made on a production of containerised seedlings, where the seeds are sown directly with a sowing machine in the big containers and placed on the container area without no greenhouse phase. The containers are put on rolling tables with net in the bottom to decrease labour costs and ensure a better working environment for the gardeners. Irrigation booms are installed and a fertilisation unit added.

Production of containerised seedlings requires investments which are listed in Table 3.2.3.

Table 3.2.3. Investments for production of containerised seedlings.

Equipment	**App. price in Dkr./m²**
Container area including drainage, roads, wind break	200
Rolling tables	250
Irrigation boom	20
Fertilisation unit	2
Sowing machine	10
Container system (18 Dkr/system)	120
Other equipment	20
Sum	**622**

The turnover time will be 10 years, which means 62.2 Dkr/year/m^2.

Coefficient of utilisation of the container area will be app. 70%, which means that the investment will be app. 89 Dkr/year/used container area.

Consumables each year are listed in the next Table 3.2.4.

[4] The cost of the transplanting machine is about 9000 Euro and 10 years is the life expectation for it.

Table 3.2.4. Consumables for production of beech seedlings.

Consumables	App. Price in Dkr./m²
Seeds	92
Peat	22
Fertiliser	7
Others	33
Total	154

The container system used has a plant density of 368 seedlings/m^2.
Personal will consist of gardener with skills in propagation, irrigation, fertilisation and quality control. The sowing and the delivery of the seedlings will take more time than the nursing of the seedlings. Approximately 1 person is used per ha per year with an expense per hour at app. 140 Dkr including all (social security, holiday payment, week-end payment).
Not all seedlings will be of the highest quality, app. 75% will be of sales quality.

Table 3.2.5. Production price per seedling with a turn-over time on 10 years and 75% sales quality.

Expenses	App. Dkr./seedling
Investment	0.32
Consumables	0.55
Manpower	0,15
Total	**1.02**

If the percentage of sales quality is lower, the price will increase.
Production price of containerised seedlings is a little higher than that of the bare-rooted seedlings, mostly because the investment in container area is high. Therefore to introduce the containerised seedlings the percentage of seedlings with sales quality should be higher than 75%.

3.2.3. Production cost for birch seedlings in Sweden

To evaluate the economic potential for the introduction of the new technology compared to state-of-the-art the following calculations have been made based on figures from conventional production and the knowledge obtained so far in this project.
Production cost for conventional production of a one-year old containerised birch seedling during 2003:

- Growing density 300 seedlings per square meter.
- Germination and growth for 2 months in a greenhouse followed by 4 months of growth at the open field.

Total production cost (direct and indirect) in the greenhouse is equivalent to 22.00 Euro per square meter and month. For 2 months of growth at a density of 300 seedlings per square meter the production cost for the greenhouse phase will be equivalent to 0.15 Euro per seedling.
Total production cost (direct and indirect) at the open field is equivalent to 1.10 Euro per square meter and month. In 4 months of growth, at a density of 300 seedlings per square meter, the production cost for the open field growth will be equivalent to 0.015 Euro per seedling.
Total production cost for a one-year old containerised birch seedling, grown according to state-of-the-art, will be equivalent to 0.165 Euro.

Production cost for a one-year old containerised seedling produced according to the new technology developed in this project.

- Growing density 3000 seedlings per square meter in the multiple floor germination facility. After transplanting 300 seedlings per square meter during open field growth.
- Germination and growth for 1 month in the multiple floor facility followed by 5 months of growth at the open field.

Total production cost (direct and indirect) in the compact multiple floor germination facility is equivalent to 18.00 Euro per square meter and month. In 1 month of growth, at a density of 3000 seedlings per square meter, the production cost will be equivalent to 0.006 Euro per seedling.

Total transplanting cost (direct and indirect) is equivalent to 435 Euro per day. When calculating with a transplanting capacity of 75 000 seedlings a day the cost for transplanting will be equivalent to 0.006 Euro per seedling.

The cost for the open field growth will be the same as for conventional production. That is 5 month of growth at a cost of 1.10 Euro per square meter and month and at a density of 300 seedlings per square meter. The total production cost (direct and indirect) for the open field growth will therefore be equivalent to 0.018 Euro per seedling.

Total production cost for a one-year old containerised birch seedling, grown according to the new technology developed in this project, will be equivalent to 0.030 Euro compared to the cost for conventional production of 0.165 Euro per seedling.

As can be seen from these calculations there is a huge potential for improved cost efficiency in production of broad-leaved forest seedlings when using the new transplanting technology. The reason for this is mainly due to the possibility to exclude the greenhouse phase in the cultural practices. The cost for a conventional production during this phase is very high as a result of starting the germination early in the spring in a cold climate using greenhouses with a low heat insulation in combination with a containerised system with few seedlings per square meter.

4. DISCUSSION

4.1. Elm and beech in Italy

Concerning the shoot and root system structures, the results indicate a superior root and shoot development for seedlings grown in IHT system compared to the Jiffy one at the time of transplanting. One reason for these results could be the different initial root spreading in the respective plug system (Plates 28-29).
For IHT plugs it was evident that the first tap root developed from the root meristem or radical in the embryo penetrated the plug right through the central part of the plug. This could be the effect of a homogeneous growth substrate in combination with evenly distributed water content within the plug.
Due to the effect of air-pruning, when the root tip reached the bottom of the plug, an effective formation of lateral roots was initiated. This resulted in an unsuberised white root system with a lot of active root tips that effectively could support the expanding shoot with water and nutrients.
In Jiffy plugs the first *tap-trot* often did not penetrate the plug right through. Instead the root in many cases came out at the side surface at about half the plug height between the substrate and the net holding it together.
This situation could, in contrast to the IHT plug, be related to irregularly water allocation inside the substrate.
Regarding growing densities, no differences in growth could be registered between the treatments. This result shows that for a growing period up to 5 weeks before transplanting, in the densities studied, no competition for light, water and nutrients have been present. It could be possible to use higher dense sowing density, up to 3000/m^2. This proves that the densities used in the experiments do not affect development of seedlings and that the higher densities should be preferred since they are cost-effective.
Due to the vigorous root development combined with an unsuitable bottom design of the support tray for the Jiffy seedlings, severe root deformations, such as spiralling, could be registered, both after 5 and 7 weeks of growth before transplanting (Plate 29). This kind of deformations persisted and were amplified after transplanting, both in containers and in open nursery beds. In Plate 30 the root system of elm seedling grown in a root study box is presented.
Equally with elm, there were no differences in the growth of beech seedlings related to various growing densities. Nonetheless, it must be said that due the scarce germination of the seedlot, there wasn't condition for competition for light.
As stated by the Swedish RTD partner, RGP and SGP are reliable performance attribute to evaluate the quality of planting stock. In this study, when transplanting after 5 weeks since sowing, IHT seedlings showed higher values of RGP and SGP compared to Jiffy seedlings. After 6 weeks before transplanting these differences had averaged down[5].
REL and SEL have been used in many studies to analyse level of dormancy and other physiological status for many species (Dexter *et al*., 1930; Wilner, 1955; Lapkins, 1961; Johnson and Havis, 1971;

[5] For explanation see "4.3. Birch and beech in Sweden"

Lindström and Nyström, 1987; McKay, 1992), included broadleaves; but—to our knowledge—not for *Ulmus campestris*.
After sowing, 5 weeks of permanence in greenhouse or protected areas is sufficient to consent to the seedlings to reach appropriate morphological and physiological characteristics. During that time, in a compact germination facility, temperature should be in the interval of 20-22 °C and the relative air humidity 80% for the first week and then reduced to 60%. Fertilisation should be added during these 5 weeks before transplanting.
A second factor which appeared important for a successful transplanting was the growing system being the bare-root technique better than container transplanting option. Actually, containerised seedlings dried out much more rapidly than seedlings transplanted directly in open nursery beds in spite of the fact that an identical irrigation regime was employed. Moreover, the second option could profit from a greater nutrient availability from the soil.
Transplanting miniplugs into open nursery beds appears more appropriate for Mediterranean and Italian conditions, should the selected irrigation regime be adequate. Moreover, such a growing technique reduces peat consumption in nursery activities and leads to beneficial economical and friendly environmental trends.
On the other hand, the limit to this technology seems to be the production of species with considerable big seeds (*Castanea, Juglans, Quercus*, etc), exceeding the diameter of mini-plugs, or with winged seeds which cannot be subjected to dewinging because tend to be damaged by this operation. However, this inconvenience may be solved by enterprises which produce mini-plugs by making a cavity able to contain big or winged seeds.

4.2. Beech in Denmark

The sowing of the beech seeds were severely delayed because of the EU approval processes had not ended. Hence the temperature had raised above optimal level for the germination of the seeds. The very low germination was followed by fungi problems in the seed lot. The designing of the plug and plug-tray influenced the root system in the different plug system. Curling of the root was found in Jiffy where the bottom of the tray allowed the roots to curl. This curling of the roots was found after transplanting emphasising that the tray should be modified. No curling was observed in the IHT system and the soil pot system. Density seemed to have only little influence on the small seedlings except for the Jiffy-30 but other effects might have influenced the results.
The plugs used in the experiment were fertilised with liquid fertilizer during the germination phase. However, the transpiration from the small seedlings is very small in the beginning, which makes it difficult to add fertilizer together with the irrigation. Other results showed that use of controlled release fertilizer can increase growth (root collar diameter and height), probably because of a high NH4-N/NO3-N ratio and the slow but constant supply of nutrients. Hence, addition of controlled release fertilizer in the plug should be considered.
No effect of covering was found probably because the seedlings were moved outside on a cloudy day. Covering decreases transpiration, which could have an influence on sunny days with high wind (Andersen et al, 1999).
The drought and temperature treatments were apparently not sufficiently severe to alter the physiological state of the seedlings and, hence, the effect on seedling growth was limited. The results indicate, however, that the effect of drought seem to be more significant than the effects of temperature.

The results showed that the $SEL_{diff-25}$ values can be used to predict the optimal time for storing of beech as shown earlier for oak (Brønnum 1999).

4.3. Birch and beech in Sweden

The results showed a better root and shoot development for seedlings grown in IHT plugs compared to Jiffy plugs at the time of transplanting. One reason for these results could be the initial root penetration in the respective plug system. For IHT plugs it was obvious that the first tap root developed from the root meristem or radicale in the embryo penetrated the plug right through the central part of the plug. This could be the effect of a homogeneous growth substrate in combination with evenly distributed water content within the plug. Due to the effect of air-pruning, when the root tip reached the bottom of the plug, an effective formation of lateral roots was initiated. This resulted in an unsuberised white root system with a lot of active root tips that effectively could support the expanding shoot with water and nutrients.

In Jiffy plugs the first tap root often did not penetrate the plug right through. Instead the root in many cases came out at the side surface at about half the plug height between the substrate and the net holding it together. This situation could, in contrast to the IHT plug, be related to unevenly water distribution and/or the substrate in the plug.

When the tap-root then continued to grow under the net along the side of the plug it was exposed to light. This situation implied a suberisation or browning of the outer cortical tissues of the root seriously affecting the possibility of an effective lateral root formation.

Regarding growing densities no differences in growth could be registered between the birch treatments. These results show that for a growing period up to 6 weeks before transplanting, in the densities studied, no competition for light, water and nutrients have been present.

In contrast to birch the beech seedlings had similar root and shoot development, up to the time for transplanting, for both Jiffy and IHT seedlings. These results could perhaps be related to the very aggressive initial tap-root growth of beech seedlings. Perhaps this situation made minor differences in water distribution and formation of the growing substrate between the plug systems of less importance for the early root and shoot development.

Due to the aggressive root development combined with an unsuitable bottom design of the support tray for the Jiffy seedlings severe root deformations in the form of root spiralling could be registered both after 3 and 5 weeks of growth before transplanting. These deformations are not acceptable since they will affect the future growth and stability of the seedling after transplanting. Therefore if the Jiffy plug should be used for the production of beech seedlings the design of the support tray must be changed in a way that prevents these deformations.

As for birch there were no differences in the growth of beech seedlings related to various growing densities. This is, like stated above, the result of the lack of environmental stress between treatments grown at different densities.

Root (RGP) and shoot (SGP) growth potential has often been used as a performance attribute for quality evaluation (Feret and Kreh, 1985; Ritchie and Tanaka, 1990; Mattsson, 1991). For example the potential for new root growth is important for a rapid resumption of water and mineral uptake after outplanting (Burdett *et al.*, 1984).

In this study RGP and SGP showed higher values for IHT seedlings when transplanting after 3 weeks compared to Jiffy seedlings. After 6 weeks before transplanting these differences had levelled out.

The result must be related to the discussion above regarding the differences in early root penetration of the IHT and Jiffy plug. The effective lateral root formation in the IHT plug has most certainly affected the amount of active root tips leading to better conditions for rapid root egress also affecting the shoot growth potential in a positive way.

One can assume that these differences are more pronounced in the early stages of root penetration of the respective plug. For a longer growth period in a mini-plug, with a very small volume, the total amount of active root tips will be levelled out. This can be one explanation for the results of the RGP and SGP measurements regarding birch seedlings grown for 6 weeks before transplanting.

For beech seedlings RGP and SGP was in general at the same level or better for Jiffy seedlings compared to IHT seedlings. This could perhaps be explained by the very aggressive and rapid tap-rot formation mentioned before regarding beech seedlings. In addition the lowest density for Jiffy seedlings were also almost half of the lowest density for IHT seedlings. These differences in density and the related substrate volumes of the respective plug must have had an influence regarding the results presented.

Electrolyte leakage has been used in many studies to analyse the freezing tolerance and the related hardiness process for many species (Dexter *et al.*, 1930; Wilner, 1955; Lapkins, 1961; Johnson and Havis, 1977; Lindström and Nyström, 1987; McKay, 1992). In this study no major differences between treatments could be registered. Therefore one can assume that the different cultural practices for the respective species have had no influence on the hardening process during fall. In one case long-night treated birch seedlings had lower SEL values than the control. This indicates that long-night treatment of birch can affect the shoot hardiness although the hardiness of the root is not affected.

At the end of the vegetation period in the nursery all treatments were analysed with regard to dry weight, height and stem diameter for birch seedlings. In general the differences were small between treatments indicating minor effects of different cultural practices with regard to these seedling attributes. In contrast to this the long-night treated seedlings had lower weights and height than the control showing that the treatment have been effective in affecting the birch seedlings with regard to morphology and shoot hardiness.

Finally root weights were in general higher for IHT seedlings compared to Jiffy seedlings. Again this can be related to the effective lateral root formation for IHT seedlings due to the effective tap-rot penetration earlier described.

The following conclusions can be drawn from the discussion above regarding the biological results from the first year. These conclusions are based on the biological results without taking economic aspects into consideration. These aspects will be focused during the next year of the project to find the most cost-effective technology still based on reliable biological cultural practices.

For birch seedlings the results show that IHT seedlings had an initially better and more uniform root development than the Jiffy seedlings. The early root development in very small substrate volumes, as in the mini-plugs tested, must be considered as very important for the root configuration and development after transplanting. Therefore the results in this study show that the IHT plugs is to be preferred when compared to Jiffy plugs.

Regarding growing density the results from all biological parameters tested showed minor differences. Due to economic reasons the higher densities tested is therefore to prefer. That is for birch a density of about 2500 plugs/m^2.

When looking at the time to transplanting, seedlings grown for 3 weeks performed just as well as seedlings grown for 6 weeks. Also due to economic reasons the shorter growing time, in an expensive growing environment, is therefore to be preferred.

For beech differences in growing performance, until the time of transplanting, were small between IHT and Jiffy seedling. Despite this the results show that the IHT plug is to be preferred to the Jiffy plug. This due to the severe root deformations experienced in Jiffy plugs introduced as a combination of the aggressive tap-root formation for the species and an unsatisfactory bottom design of the support tray for the plugs.
As for birch differences between growing densities were small. This was true all the way up to 1500 plugs/m2. Therefore this density can be recommended, within the times tested before transplanting, for a cost-effective production of beech.
Finally regarding results from the first vegetation period the different time to transplanting tested for beech seedlings show minor differences in seedling performance. It can therefore be recommended to grow beech at densities mentioned above for 3 weeks before transplanting.

5. CONCLUSIONS

For the transplanting to the open field it can be concluded it is extremely important to select the correct time for transplanting, in order to avoid the warmer summer period in Italy as hotter temperatures, warm winds and lower air humidity caused a rapid and severe drying out of the seedlings, reducing their growth and vitality. To combat a suddenly increase of temperature or a long drought period irrigation and shading should be perfectly set. In some cases shading is essential for those species (i.e. beech) which are not being grown in their ideal climate.

As for transplanting from container to container the results showed that mini-plugs with high densities can be used if the seedlings are transplanted 3-5 weeks after germination. Important is that the roots can develop freely and be air-pruned beneath to avoid curling of the roots. A combination of a rapid root and shoot growth in the mini-plug before transplanting, and the beneficial seedling development in the larger container after transplanting gives a large effect on plant growth. These factors must have been of decisive importance for the rapid establishment and superior subsequent field growth registered with the new technology.

The economical calculations of the new methods developed in the project showed that the production price in Italy would be lower than the conventional method (27%), whereas in Denmark and Sweden the price will be equal to the conventional method. However, the price will decrease if a large scale production is developed.

6. EXPLOITATION AND DISSEMINATION OF RESULTS

6.1. Exploitation

The results emerged from the project will be exploited first of all from the SMEs involved in the consortium in the next years, with the aim to improve nursery practices and plant stock quality and diversify production.
The Italian SME before the start off of the project had very little production of nursery stock for specific forest uses. The participation to the project has represented a excellent opportunity to gain know-how on forest nursery stock production methods and to diversify the offer. As a result, it is intention of the Italian SME to expand considerably the production of forest nursery stock and to be present in a market that is expanding significantly worldwide. This is particularly important in a national perspective. Moreover, the methods developed will be extrapolated to ornamental species, in order to improve quality of the planting stock and to reduce costs of production. The greatest benefits from this type of crop scheduling is that more seedlings per greenhouse area can be germinated and raised, and transferred outside. It will result that greenhouse space is made available for other crops.
In Italy, the Regione Lombardia forest nurserymen, to which the project and relative results were depicted, show interest and willingness to adopt the method of producing broadleaved forest nursery stock by the accelerated transplants production method.
Forest officials of other regional authorities in Italy, after a discussion at the Conference held in Padua (see paragraph below, pag. 114) confirmed their interest in taking on the mini-plug container production systems and transplanting procedures.
The results obtained in Broad-Tech have been spread to Danish nurseries producing broad-leaved forest tree seedlings. Some of the nurseries are interested in producing containerised seedlings and have used the results from the project in there production already. Especially, the knowledge about producing beech has been adapted by the nurseries. The production of containerised broad-leaved seedlings is still small compared to the bare-root production, as the investments in production facilities are big, and the prices on broad-leaved seedlings in Northern Europe are decreasing.
The Swedish SME, after years of searching for procedures to produce bigger container plants to compete with the so-called ‘plug+1’ or ‘greenhouse transplants’, produced in two growing seasons[6], since 2003 is exploiting the results of the project, raising plants in two types of bigger container (V 120 and V 150 cm^3), in a single growing season.
It is plan of the SMEs after the know-how acquired on the plant quality assessment tests to expand their use to other stock types produced, with the aim to ensure inside quality control and enhance confidence between nurserymen and customers.
Based on the know-how acquired during the development of the project and mutual growth cropped up from the CRAFT teamwork, the partners are willing to continue in their cooperation. It will reside, *inter alia*, in the preparation of a new EC CRAFT proposal within the VI Framework Research Programme, involving new associates, both from the side of RTD performers and SME partners, especially from South European countries.

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[6] Germinated and grown in greenhouse, then lifted, culled and replanted into transplant beds.

6.2. Dissemination

The project was firstly broadly exposed during a IUFRO (International Union of Forest Research Organisations) international conference, titled *Nursery Production and Stand Establishment of Broadleaves to Promote Sustainable Forest Management* (Rome, Italy, May 7 - 10, 2001). During the field visit, within the same conference, the Broad-Tech experiments, carried out at the Italian SME Vivai Torsanlorenzo, were visited by the congress participants.
The project was presented during a seminar given within a post-graduate course titled "Sustainable development e management of agroforestry systems", organised by the University of Bologna (6th June 2001).
At a meeting of representative of the Regional Environmental Protection Agencies, the project was presented as well.
During ten seminars organised by FORMEZ (an Italian Institute for the Development of the South) aimed at training forestry personnel working for the Forest Service, the project was conferred.
Two papers ("*Broad-Tech: un progetto finanziato dalla Comunità Europea. Lo sviluppo di nuove tecniche di produzione di semenzali di latifoglie per promuovere una gestione forestale sostenibile* [Broad-tech: a project financed by the European Commission. The development of new techniques to produce seedlings of broadleaves to promote a sustainable forest management] and "Quelle imprevedibili e bizarre latifoglie. Broad-tech. Un progetto di ricerca CE per produrle è giunto alla fine del primo anno" [Unpredictable broadleaves: a EC research project to produce them after the first year of activities] were produced on the Italian magazine Torsanlorenzo Informa (Torsanlorenzo Informa 4-5/2001: 19-22 and Torsanlorenzo Informa 6-7/2001: 25-26). The magazine is mainly aimed at nurserymen.
The following two speeches about the project was disseminated jointly by the Italian RTD and SME in two conferences: Broad-Tech: un progetto del V Programma Quadro di Ricerca della CE [Broad-tech, a research project funded by the EC to develop a new method for growing broadleaved nursery stock]. During the congress: Pensare ed agire con gli alberi - Il contributo delle attività forestali per risolvere le sfide ambientali del 21° secolo, the 22th of February 2002. 2002 Agriculture Padua Fair.
"Broad-Tech, un progetto finanziato dalla commissione europea per la produzione eco-sostenibile di latifoglie "within the Conference "Scopri Roma-Natura 2002", organised by Roma Natura, Ente regionale per la gestione del sistema delle aree naturali protette nel comune di Roma, held the 25th of May 2002.
A paper about Craft programme and the Broad-Tech project has been sent to "La Stampa", Italy's major newspaper and will be published in the next weeks.
The results have been shown to the project group during the management meetings in Denmark. Furthermore the results from the project have been shown to visitors from nurseries in DK and outside DK. At an exhibition with more than 1000 people in Aarslev the different systems were shown.
Between the intermediate and final report results from this project have been disseminated in different ways in Sweden. At three different times during the first year information from the project have been presented at informal meetings with executives from all together 4 major Swedish forest companies.
Information has also been presented at a major horticulture fair in the Netherlands.
Also the Swedish board of forest seed collection and seedling production strategies has been briefed about the project at a general directory meeting.

At a visit to Garpenberg the Danish board of regeneration strategies was also briefed about the project.
In addition the project has also been presented in South Africa (November 2001) at an informal meeting with representatives from research organisations and forest companies. This information was given during an invited trip for representatives from Dalarna University, regarding future co-operation in forest research and education between Sweden and South Africa, hosted by University of Natal.
The Craft project has also been presented at an international conference called "Forest research a challenge for an integrated European approach" arranged in Thessaloniki by the National Agricultural Research Foundation in Greece. The conference was sponsored by the European Commission and assembled over 200 experts coming from research institutions, public organisations and companies all over Europe. The information presented is published in the proceedings of the conference (Mattsson, 2001).
An article about the project will also be published during 2003 in a Swedish journal called "Plantaktuellt". This journal is distributed to all major forest organisations and companies, including forest nurseries, in all the Scandinavian countries including Iceland.
The 19th of February 2003, beside the project business meeting in Italy, the workshop "Broadleaved forest nursery stock production and sustainable forestry: results of the broad-tech project, funded by the European Commission" was held at Vivaitorsanlorenzo nursery. Almost 80 people attended it, from nurserymen to researchers, from managers of parks to officials of State and Regional Forest Service, from students to teachers. During the workshop, M. Varvesi (APRE, Italian Agency for the Promotion of Research in Europe, Italy's Ministry of University and Research) and G. Rossi (CIRCE, Central Italy Innovation Relay Centre) gave a presentation about the opportunities provided by the 6th Framework Programme for the involvement of SMEs in research projects. A report of the workshop has been published on the APRE newsletter (Issue 34, May 2003, available at www.apre.it).
Few days later, two presentations about "Broad-Tech" project were given by Anders Mattsson and Lorenzo Ciccarese at the international conference "Forestry", held within the Padua Fair of Agriculture.
A demonstration in April 2003 (Annex 7) at the nursery of the Swedish SME of the new technology developed in the project together with a presentation of the EU project. The meeting and practical demonstration was attended by all the major growers of forest nursery stock in Sweden.
An article, *Produzione vivaistica di semenzali di latifoglie forestali: un nuovo metodo con il progetto CRAFT* [Producing broadleaved forest seedlings: a new method through a CRAFT project], about the project and its first results has been published in an Italian journal called "Shewood". This journal is circulated to forestry students and researchers, forest practitioners, forest organisations and companies, including forest nurseries.
A poster of the project has been presented at the XXII IUFRO World Congress, Brisbane, Australia (8-13 August 21005) and an article will be published on the magazine of Justanable of Sustainable Foresty.

7. POLICY RELATED BENEFITS

The project has increased the co-operation between SMEs representing different regions in Europe from south to north and intensified the co-operation between nurseries and RTD performers, which is essential to create a critical mass for developing competitiveness in this area.

In the EU policy for sustainable development of the European Union the sustainable and competitive management of the forest resources is an important issue. The results in the project have contributed to this by development of a manual for producing broad-leaved seedlings on a competitive basis. The manual is the first step in a certification of the production of broad-leaved seedlings.

The economical calculations in the project showed that the production of broad-leaved seedlings can be competitive to the bare-rooted seedlings, if the new technology introducing growing facilities like protected climate, controlled irrigation and fertilisation and machinery for transplanting. The introduction of the technologies in the nurseries outside the SMEs part of the projects has been made, but still the implementation of the technologies in the nurseries is to be done.

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9. DELIVERABLES

Within the project 5 tasks, 8 deliverables have been identified. Seven of them relate to technical aspects, one to dissemination (see paragraph 6.2 of this report).

9.1. Protocols for cultural practices regarding the three species studied

APAT - Protocol for cultural practices regarding elm

Elm seedlings can be conveniently produced starting from a high-density cultivation in a mini-plug system, suitable for subsequent working transplanting at the definitive density. The system may allow a rapid and uniform root development, without the risk of causing root deformations of any kind. In this study the IHT system has proven to be a suitable system considering the different biological aspects studied and the flexibility it offers to regulate sowing density.
The mini-plug system, used for later transplanting, should be watered to field capacity before sowing and the seed should be placed in the centre of the plug using a well defined sowing hole with a diameter and depth of 0.3 cm respectively. Due to the size of the elm seed, it is suggested to allocate only one seed plug (this is a more reason to have high quality seedlot).
The growing density should be at least 2100 plugs/m^2, but it can probably be up to 3000 plugs/m^2 when using a short time for germination and early growth before transplanting. Besides the density of the plug system the following dimensions are to be preferred: diameter 2.0 cm, height 5.0 cm, where the minimum limit for diameter is manly due to the size of the seed.
The sowing time, with regard to Italy, should be end of March, in order to allow seedlings to be transplanted and moved to open field before mid-May, after the completion of germination and early growth, without the risk of introducing damages due to late “spring” frost or, when transplanting is delayed, desiccation.
After sowing, 5 weeks of permanence in greenhouse or protected areas are sufficient to allow the seedlings to reach appropriate morphological and physiological characteristics (7-10 cm of stem height). During that time, in a compact germination facility, temperature should be in the interval of 20-22 °C and the relative air humidity 80% for the first week and then reduced to 60%.
Fertilisation should be added during these 5 weeks before transplanting, giving the seedlings a total of about 2 g nitrogen/m^2/week distributed at two different times during the week. The fertilisation will continue with the same amount of nitrogen per week until the elm has lost its leaves after witch no more fertilisation will be conducted.
Water management is crucial during this phase: small miniplugs require more regular and gentle waterings and short delays in irrigation can cause desiccation damage to young plants.
After the period in protected area, seedlings are transplanted in open nursery beds, about mid-May, provided the soil is moist at the time of transplanting.
Nursery beds can be formed by hand or with a bed former machine. Transplantation can be done by hand or, preferably, by machine. Open nursery seedbeds should be 1.1 - 1.2 m wide with alleys or paths between beds 0.5 m wide. Beds are raised above alleys which define them and provide drainage channel and facilitate subsequent root culturing (notably undercutting and wrenching).

Beds need to be raised 10-15 cm above the path level, and afterwards go down 2.5 to 5 cm, owing to transplanting operation.
Beds must be well consolidated before transplanting and incorporation of fertilisers (initial fertiliser dressing) is necessary and it must be done 3-4 weeks before lining out. Fertilisers prescriptions relate the nutrient status of the soil—which needs to be validated by soil tests—to the desirable levels. As general guidelines, the fertiliser application rates applied before transplanting should be 50 kg ha^{-1} of Nitrogen, 40 kg ha^{-1} of Phosphorus, 90 kg ha^{-1} of Potassium (expressed in elemental form). Rates of top dressing application of fertilisers after transplantation are 80 kg ha^{-1} of Nitrogen and 40 kg/ha of Potassium (elemental form). These rates should be distributed in 3 application, starting 5-6 weeks after transplantation.
Protection of the beds with grid against mice (that could eat the tip of the seedlings and cause serious damages) and other animals, such as rabbits, is necessary, especially in the first part of the growing season.
For elm adequate spacing to obtain sturdy plants, with a well balanced shoot/root ratio, is 120 cm^2 cm per plant, shaped 15 cm (between rows) by 8 cm (on the row).
Undercutting (one or two during the growing season) is a very important operation in order to promote formation of second-order lateral roots and to make easier final lifting.
Lifting has to be done during winter, when plants are dormant. The results of REL measurements on elm seedlings, at three different growing steps (41^{st}, 45^{th} and 50^{th} week of the year), suggest that the best period for lifting from open nursery beds (for subsequent out-planting in the plantation area) starts from the 45^{th} week of the year (early November). Before that time the REL figures are too high (suggesting the possibility of damages) while later on REL data remain stable.
Bare-root stock can be transferred to cold storage (1°C) during winter to be used for spring planting from the middle of April until the end of May. Alternatively, it can be heeled in, in shaded and well-drained soils.

DIAS - Protocol for cultural practices regarding beech

Seed pre-treatment
European beech seeds have to be kept at 5ºC at water content 32% in app. 3 months to release dormancy. This pre-treatment can be done by the seed company, when the seeds are harvested.
Pre-treatment includes a grading of the seeds to exclude empty and dead seeds.
Seeds can be treated with a fungicide if necessary.
Systems for transplanting
To increase the exploitation of space and other resources sowing in small plugs can be used. In the present experiment Jiffy-22 Jiffy-30, IHT and soil pots have been used.
Beech seeds are generally large compared to birch and others, and the size of the plug should be considered in relation to the size of the seed. Small plugs like Jiffy-22 can damage the cotyledons when they raise above the soil. The best results concerning root-collar diameter and height were obtained in the plugs with the largest volume, Jiffy-30. However in Jiffy root curling was observed (Figure 1). Results have shown that use of controlled release fertiliser in the plug systems can increase the growth of the seedlings.
Systems without transplanting
Systems with larger volumes can be used without transplanting. Different systems with either closed or open systems are on the market (www.bbc.se; www.herkuplast.de; www.roottrainers.uk; www.jiffy.no).

No difference in plant growth has been observed in relation to the volume of the container in the closed systems, where systems with volumes from 150 to 265 cm^3 have been evaluated. However, the importance of the volume in relation to water content should be stressed in connection with the irrigation possibilities.

In the open systems without container walls the results in beech seedlings were poorer concerning root-collar diameter and height compared with the results in closed systems.

Germination period

Sowing of the seeds can be done during autumn, when the seeds have been harvested in November. Pre-treatment will be done during the plug-period. The plugs can be kept in a greenhouse with no heat or in a coldstore. Disadvantages with this method is that no grading of the seeds can be done before sowing. Advantages are the seeds are pre-treated and ready to germinate when the plugs are moved from the coldstore.

Sowing in March or earlier indoors is recommended if the temperature can be kept below 20 degrees during the germination process. Beech seeds can go into secondary dormancy when germination temperature is above 20∞C.

Germination outside at the container area

After sowing the plugs can be placed directly at the container area when the risk of frost is over. In Denmark sowing in the beginning of May is recommended. In Italy the sowing will be app. one month earlier and in Sweden one month later.

Temperature during germination

As shown above temperature should be kept below 20 ºC during the day and lower during the night.

Irrigation and Fertilisation

Irrigation with a irrigation boom with spraying nozzles gives the smallest amount of water per time compared to other irrigation systems. Amount of water per time depends on the climate, in DK 2 mm per time is used. Irrigation once or more times a day is recommended to avoid desiccation. Growing media can be limed peat (pH 5.5) with a low particle density.

Transplanting

Transplanting to the open field or containers can be done after 3-4 weeks after germination. After transplanting the beech seedlings should be protected against wind and sun for 4 weeks to avoid water stress on the roots. Irrigation and fertilisation after transplanting is important.

Pests

The biggest problem concerning pests is beech aphids which are spread from older seedlings or from beech trees. Spraying with a insecticide is necessary.

DU - Protocol for cultural practices (including transplanting) regarding birch

Birch should be sown in a mini-plug system, suitable for subsequent operational transplanting, that allows a rapid and uniform root development without the risk of introducing root deformations of any kind. In this study the IHT system has proven to be a suitable system considering the different biological aspects studied.

The mini-plug system, used for later transplanting, should be watered to field capacity before sowing and the seed should be placed in the centre of the plug using a well defined sowing hole with a diameter and depth of 0.3 cm respectively.

The growing density should be at least 2 500 plugs/m^2. But can probably be up to 3 500 plugs/m^2 when using a short time for germination and early growth before transplanting. Besides the density

of the plug system the following dimensions are to be preferred: diameter 1.5 cm, height 3.0 cm. This implies a substrate volume of about 7 cm^3.
The sowing time, with regard to Sweden, should be about the 15^{th} of May to allow seedlings to be transplanted and moved to open field, after the completion of germination and early growth, without the risk of introducing frost damages.
After sowing the growing time to transplanting should be 3 weeks. During that time, in a compact germination facility, temperature should be in the interval of 20-22^oC and the relative air humidity 80% for the first week and then reduced to 60%. The photoperiod should be 18 hours at a photon flux density of 325 mmol m^{-2} s^{-2}. No fertilisation should be added during these 3 weeks before transplanting.
After transplanting to another container system, seedlings will be transferred to open field about the middle of June and grown on raised pallets to achieve an effective air pruning of the roots. A suitable transplanting container system for birch should have a density of about 300-500 plugs/m^2 and a container volume of about 120-150 cm^3.
Immediately after transplanting the fertilisation will start, giving the seedlings a total of about 3 g nitrogen/m^2 and week distributed at two different times during the week. The fertilisation will continue with the same amount of nitrogen per week until the birch has lost its leaves after witch no more fertilisation will be conducted.
The long-night treatment in open field, using blackout equipment, should start in the middle of July and continue for 4 weeks. During this period the photoperiod will be reduced to 8 hours using the blackout equipment between 4 pm to 8 am.
If the seedlings are to be used for fall planting a suitable time for outplanting will be between the middle of August to the end of September. Otherwise the seedlings will be transferred to cold storage (1^oC) in air-tight plastic bags and stored during winter to be used for spring planting from the middle of April until the end of May.

9.2. Compact germination facility adapted to mini-plug systems

Out of the 8 deliverables identified in the project, deliverable II have not fully been accomplished within the project. This due to the fact that development of such a facility to a fully operational level has proven to be a process that will need more time than the two year period for this project. The extensive research work performed within the project has nevertheless been the basis for the current work of identifying a prototype that will be developed into an operational production unit in a near future.
The prototype facility is based on the principle of a compact multiple floor unit were broad leaf seeds can be germinated and grown at high densities for a period of 3-6 weeks before transplanting. The specially designed mini plug cassettes, ranging in densities from 1000-4000 seedlings per square meter depending in species, will be exposed to light and watering conditions that will optimise the prerequisites for germination and growth.
In the closed production system no pesticides or insecticides will be used and the fertiliser recycled. The system is also based on low energy and water consumption combined with recycling.
During 2003 the compact germination facility will be developed in co-operation between the participating SMEs to an operational system. This ongoing process involves the support from special technical expertise and the process of protecting the new technology developed.

9.3. Mini-plug system adapted to broad-leaved forest seedlings

In the project a lot of emphasis has been focused on the development of a proper mini-plug system for germination and growth of broad-leaved seedlings. To be able to mechanically transplant the mini-plug the plug had to be stabilised also without the stabilising effect of the root system. This due to the fact that root growth in the plug will be limited since the seedlings will only be grown for a short period of time before transplanting.

Two possible principles for stabilising the plug were studied in the project. The first principle was to hold the peat substrate together with an adhesive substance like a polymer or glue. The second principle was to use a net that will keep the peat together. Both principles were studied thoroughly as can be seen in the result and discussion chapters together with the figures presented in this report.

From the results obtained in this project it can be concluded that both principles have worked in an operational transplanting system but that the first principle have given the best biological results. Considering the economical analysis presented the differences in cost between the two principles can be neglected. This due to the effect of the high density of seedlings per square meter making the substrate cost for each plug a very small portion of the total production cost for the seedlings produced.

Therefore it can be concluded that in a transplanting system for broad-leaved seedlings grown in mini-plugs the system of stabilising the peat plug with a adhesive substance is to prefer due to the better biological results obtained in this study. As a result from this project suitable mini plug systems for broad-leaved seedlings have also been commercially introduced by a couple of manufacturers.

9.4. Transplanting technique for broad-leaved forest seedlings, including both container to container and open field transplanting

The transplanting technique is the third component in the new production system for broad-leaved seedlings developed within this project. In the work to integrate this component with the other two components, that is the compact multiple floor facility for germination and early growth (deliverable II) and the mini-plug system (deliverable III), both technology for container to container and container to open field transplanting have been analysed.

In co-operation with proper manufactures both of them have been developed into operational systems as a part of the total production system for broad-leaved seedlings. The technology for container to container transplanting is displayed in the first part of Annex 7.

The technology identified can be adapted to various densities in the mini-plug system and also to any design and density of the end container used for the transplanting operation. The transplanting equipment is very flexible and can easily be moved to different nurseries using a standard car trailer.

Analyses within the project have shown that the transplanting capacity corresponds to 25,000 seedlings per hour independently on the density of the mini-plug and finale container system. Calculated over a 6 hours effective transplanting period a day the transplanting cost can be calculated as follows:

Direct costs: 375 euro

Indirect costs: 75 euro

These costs refers to a total of 150 000 seedlings transplanted over a 6 hour period giving a trans-

planting cost per seedlings of 0.003 Euros making the system very cost efficient.
The technology for container to open field transplanting is displayed in the second part of annex 7.
For carrying out transplanting from miniplug to open air nursery beds, a new transplanting machine available at the Italian SME was used. The machine attached to the tractor has three transplanting tools (see Annex 7, pictures from the introduction, at the Italian SME nursery, of the new technology). In spring 2002, seedlings of elm, grown for 5 weeks in IHT miniplugs, were used for assessing the technical and economical possibilities to carrying out the mechanical transplanting method.
In this case, the analyses carried out on the project trials have shown that the transplanting capacity correspond to 12,000 seedlings per hour independently on the density of the mini-plug and finale container system. Considering that on 1 hectare of open nursery beds about 583,300 seedlings are transplanted (at the density of 120 plants/m^2, 8 cm by 15 cm), the machine has to operate about 50 hours (49 calculated). Apart from the driver, a staff of 4 workers are in action during transplantation (3 for positioning the seedling into the transplanting tool and 1 for checking the seedling are transplnated properly). The transplanting cost can be calculated as follows:
Direct costs: 3382 Euro
Indirect costs: 180 Euro
Total costs: 3563 Euro
These costs refers to a total of 583,300 seedlings transplanted over a 50 hour period giving a transplanting cost per seedlings of 0.006 Euros, making the system very cost-effective.

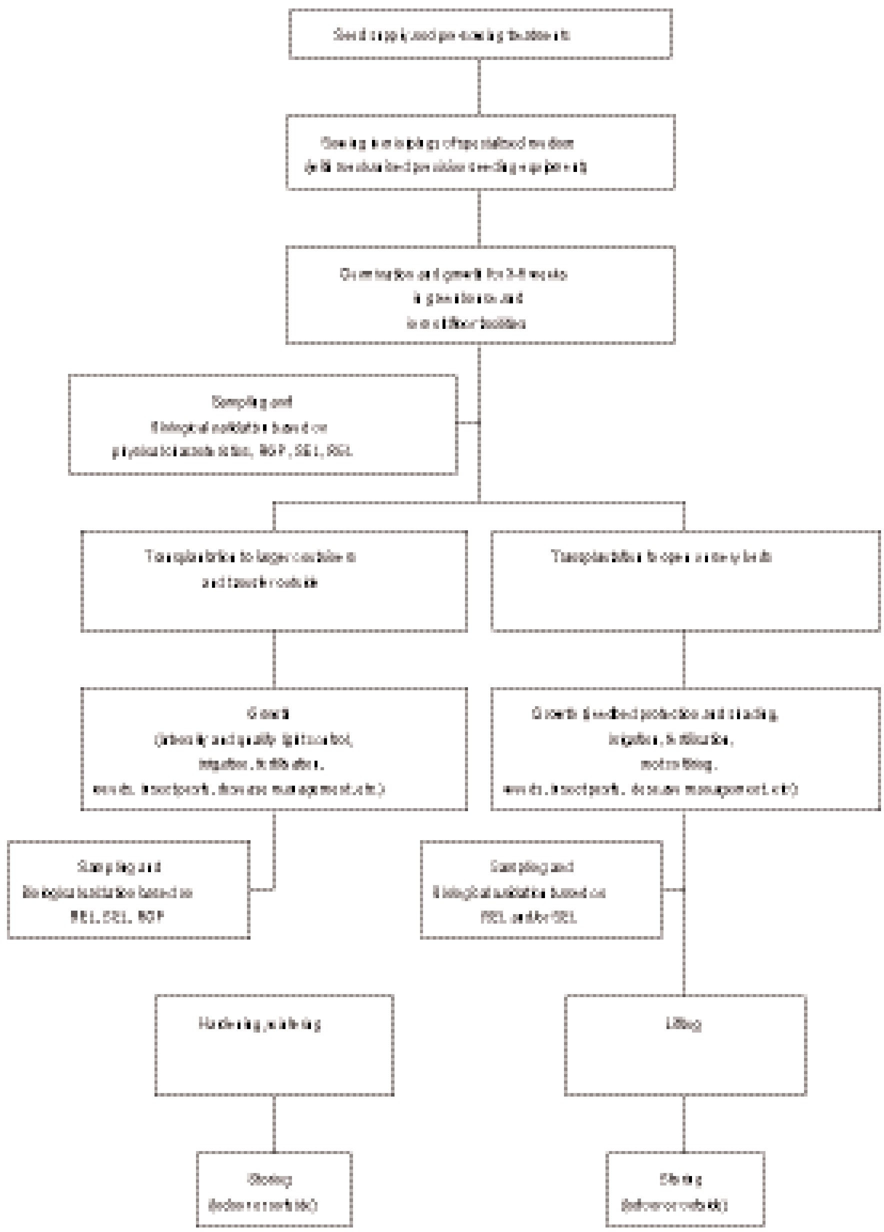
9.5. Production systems positively correlated to growth performance

The biological validation of the production system developed within this project is presented under the headings of “Results”, “Discussion and conclusions” and in the respective figures annexed. From the validation it can be concluded that the biological results regarding production of forest broad-leaved seedlings using the new technology developed in all aspects are positively correlated to growth performance.
For the species studied the system with mini-plugs where seedlings are germinated and grown for a short period in compact multiple floor facilities before mechanical transplanting have implied a subsequent growth performance superior to state-of-the-art.

9.6. New operational technology for production of broad-leaved forest seedlings.

Based on the protocols for cultural practices (deliverable I), the respective technical components in the project (deliverables II-IV) and the biological validation (deliverable V) the new production system for broad-leaved seedlings developed within this project is presented as a complete operational system in the following flow chart. The presentation includes both container to container and container to open field transplanting technology.

Flow chart of the respective components in the new production system for broad-leaved seedlings were the chart starts with the same components and then is divided into both container to container and container to open field transplanting.



9.7. Manuals for operational use adapted to the respective species studied

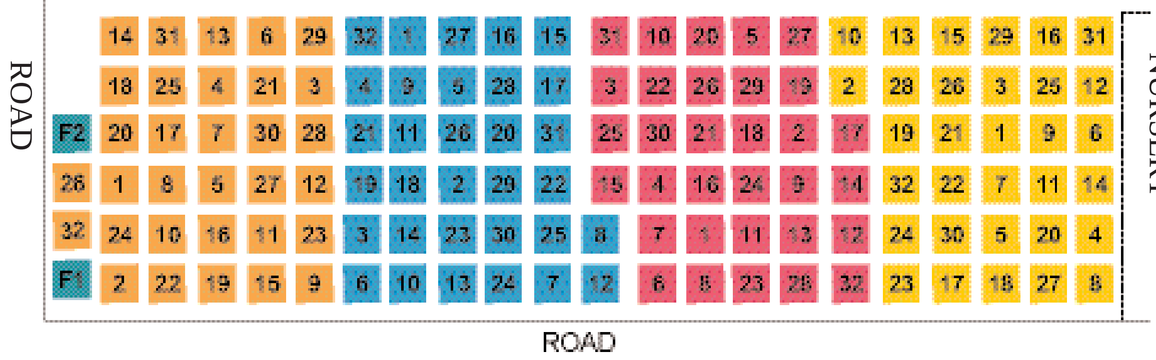
The outline of the manuals for operational use is based on the protocols for cultural practices for the respective species (deliverable I). The production manuals for elm, beech and birch are presented in annex 4-6.

ANNEXES

In annexes 1-3 all the relevant figures, tables and photos referred to in the text are presented. Annexes 4-6 present the production manuals for elm, beech an birch.

ANNEX 1

<u>APAT</u>



Treatment number

N°	Species	Container type	Density	Growing weeks	Transplanting technique	Growth Technique
1	Elm	S-PJHT 504	2100	5	C+C	No shade
2	El m	S-PJHT 504	2100	5	C+C	Shade
3	Elm	S-PJHT 504	2100	5	C+ONB	No shade
4	El m	S-PJHT 504	2100	5	C+ONB	Shade
5	Elm	S-PJHT 504	2100	7	C+C	No shade
6	El m	S-PJHT 504	2100	7	C+C	Shade
7	Elm	S-PJHT 504	2100	7	C+ONB	No Shade
8	El m	S-PJHT 504	2100	7	C+ONB	Shade
9	Elm	S-PJHT 285	1200	5	C+C	No shade
10	El m	S-PJHT 285	1200	5	C+C	Shade
11	Elm	S-PJHT 285	1200	5	C+ONB	No shade
12	El m	S-PJHT 285	1200	5	C+ONB	Shade
13	Elm	S-PJHT 285	1200	7	C+C	No shade
14	El m	S-PJHT 285	1200	7	C+C	Shade
15	Elm	S-PJHT 285	1200	7	C+ONB	No shade
16	El m	S-PJHT 285	1200	7	C+ONB	Shade
17	Elm	JIFFY	2400	5	C+C	No shade
18	Elm	JIFFY	2400	5	C+C	Shade
19	Elm	JIFFY	2400	5	C+ONB	No shade
20	Elm	JIFFY	2400	5	C+ONB	Shade
21	Elm	JIFFY	2400	7	C+C	No shade
22	Elm	JIFFY	2400	7	C+C	Shade
23	Elm	JIFFY	2400	7	C+ONB	No shade
24	Elm	JIFFY	2400	7	C+ONB	Shade
25	Elm	JIFFY	1200	5	C+C	No shade
26	Elm	JIFFY	1200	5	C+C	Shade
27	Elm	JIFFY	1200	5	C+ONB	No shade
28	Elm	JIFFY	1200	5	C+ONB	Shade
29	Elm	JIFFY	1200	7	C+C	No shade
30	Elm	JIFFY	1200	7	C+C	Shade
31	Elm	JIFFY	1200	7	C+ONB	No shade
32	Elm	JIFFY	1200	7	C+ONB	Shade

Figure 1 – Randomized block design of the out planting trial

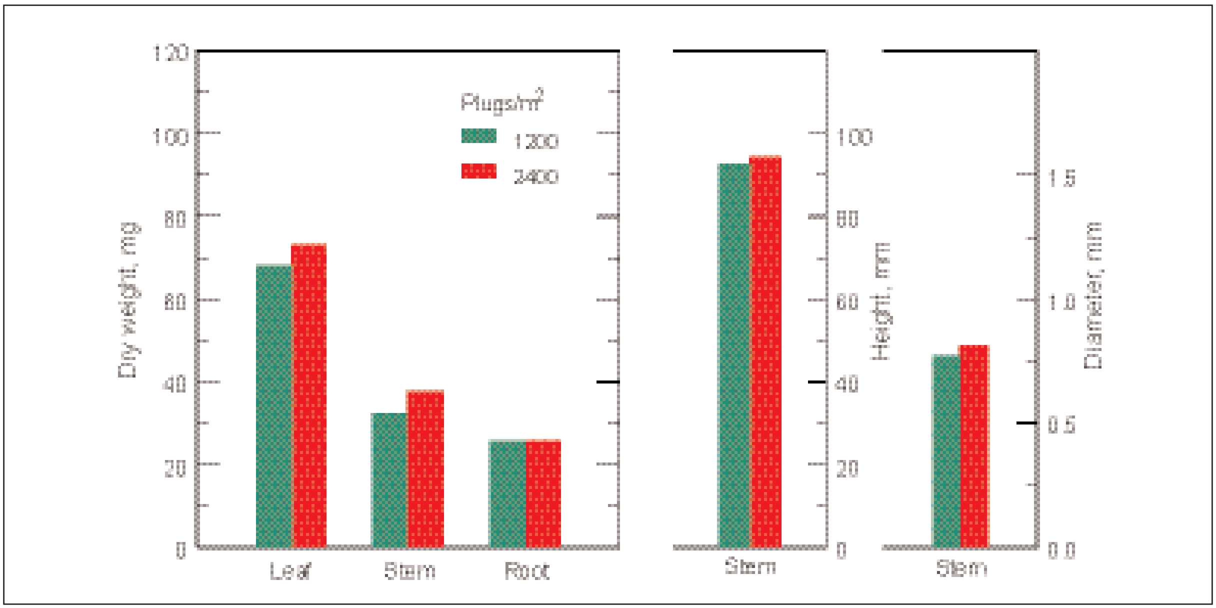


Figure 2 – Dry weight, height and diameter at the time of transplanting for elm seedlings sown May in Jiffy plugs and grown at two densities for 5 weeks before transplanting.

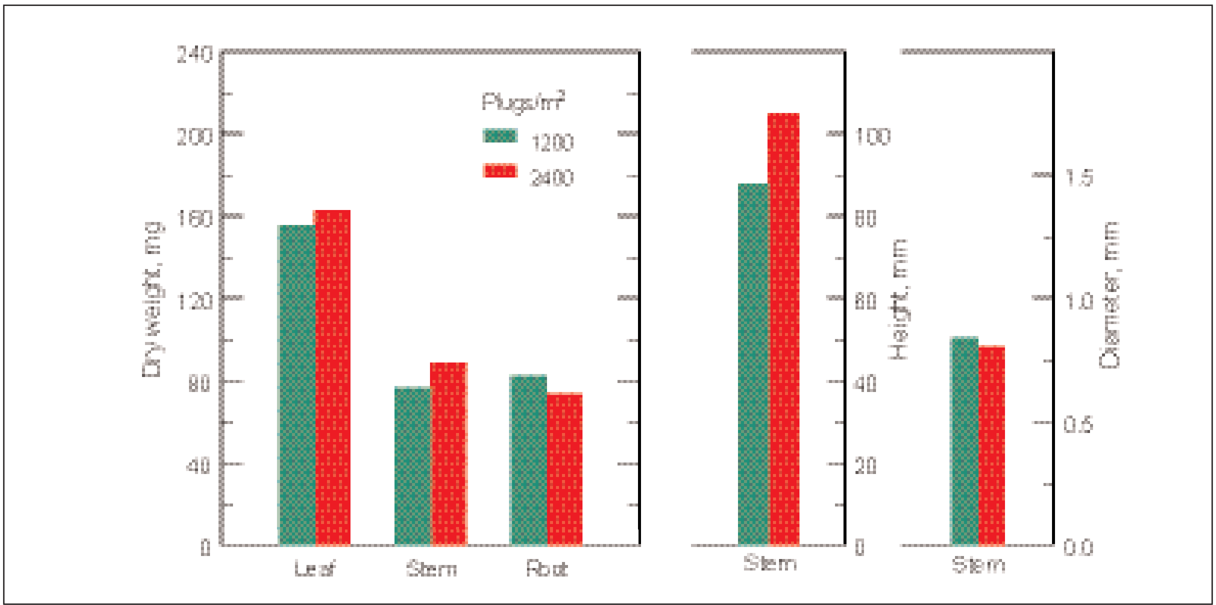


Figure 4 – Dry weight, height and diameter at the time of transplanting for elm seedlings sown May in Jiffy plugs and grown at two densities for 7 weeks before transplanting

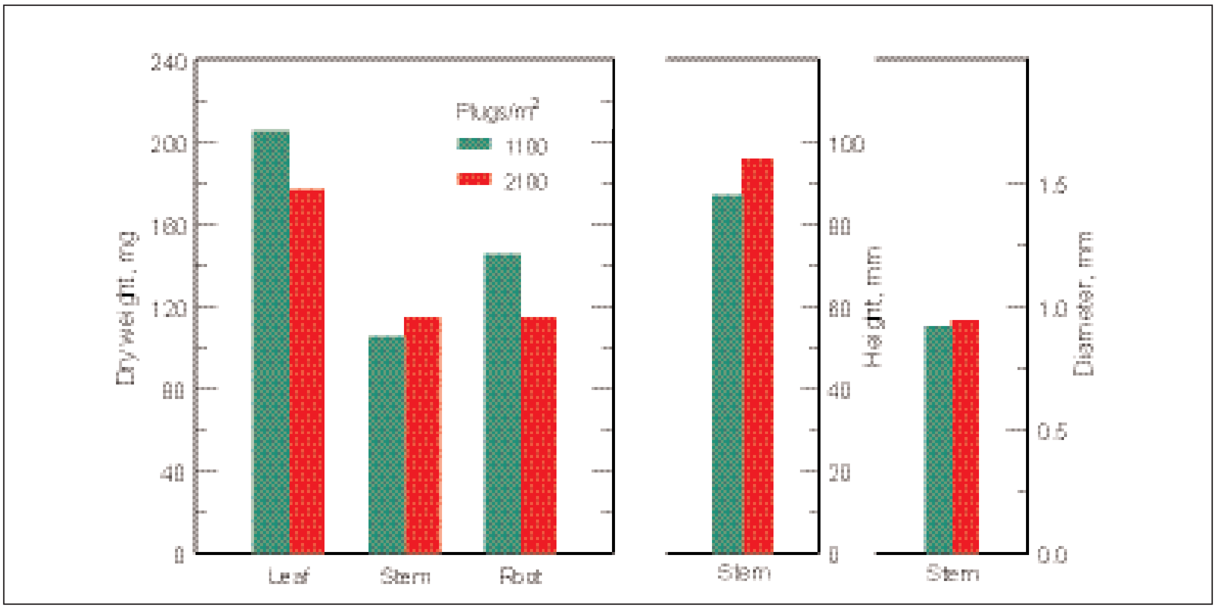


Figure 5 – Dry weight, height and diameter at the time of transplanting for elm seedlings sown May in IHT plugs and grown at two densities for 7 weeks before transplanting

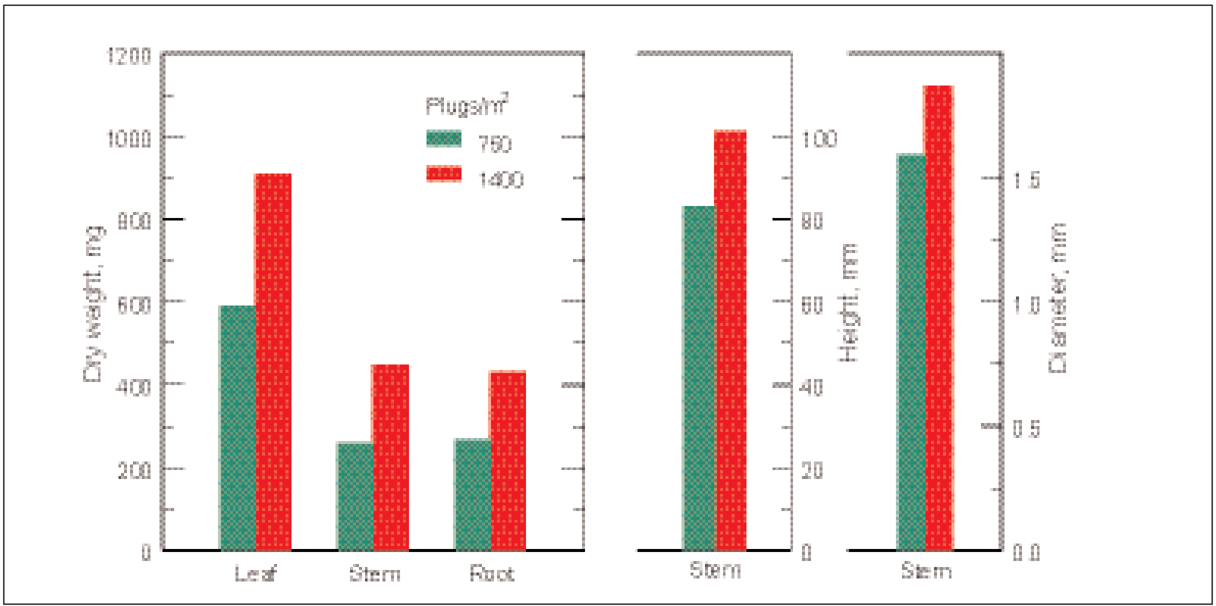


Figure 6 – Dry weight, height and diameter at the time of transplanting for beech seedlings sown May in IHT plugs and grown at two densities for 7 weeks before transplanting

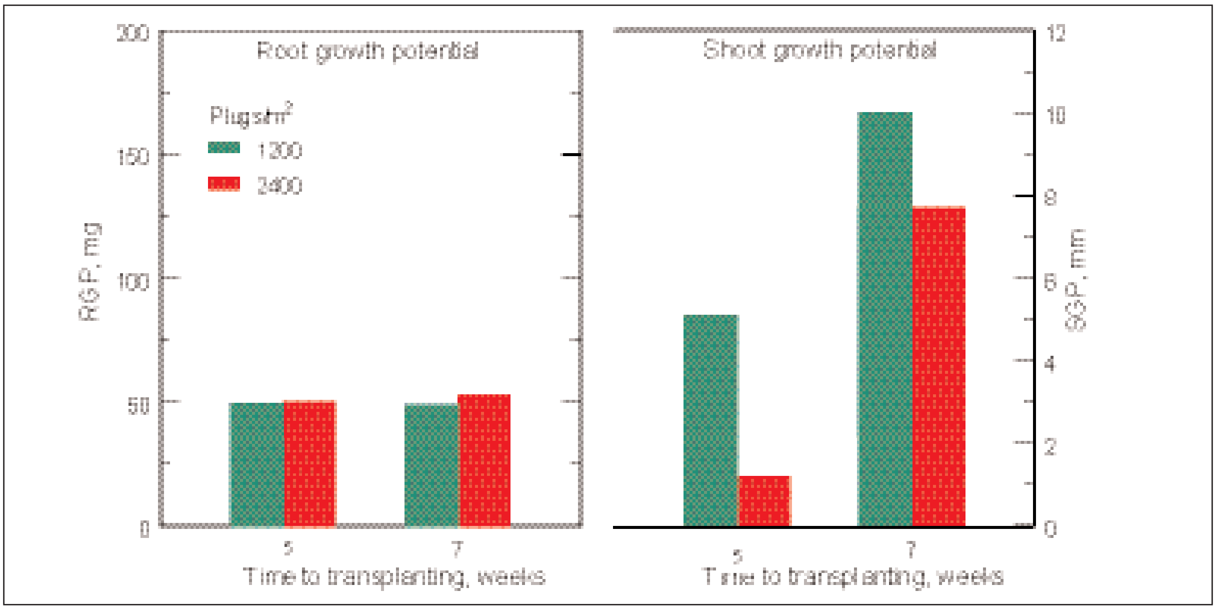


Figure 7 – Root and shoot growth potential at the time of transplanting for elm seedlings sown in May in Jiffy plugs and grown at two densities for 5 and 7 weeks before transplanting

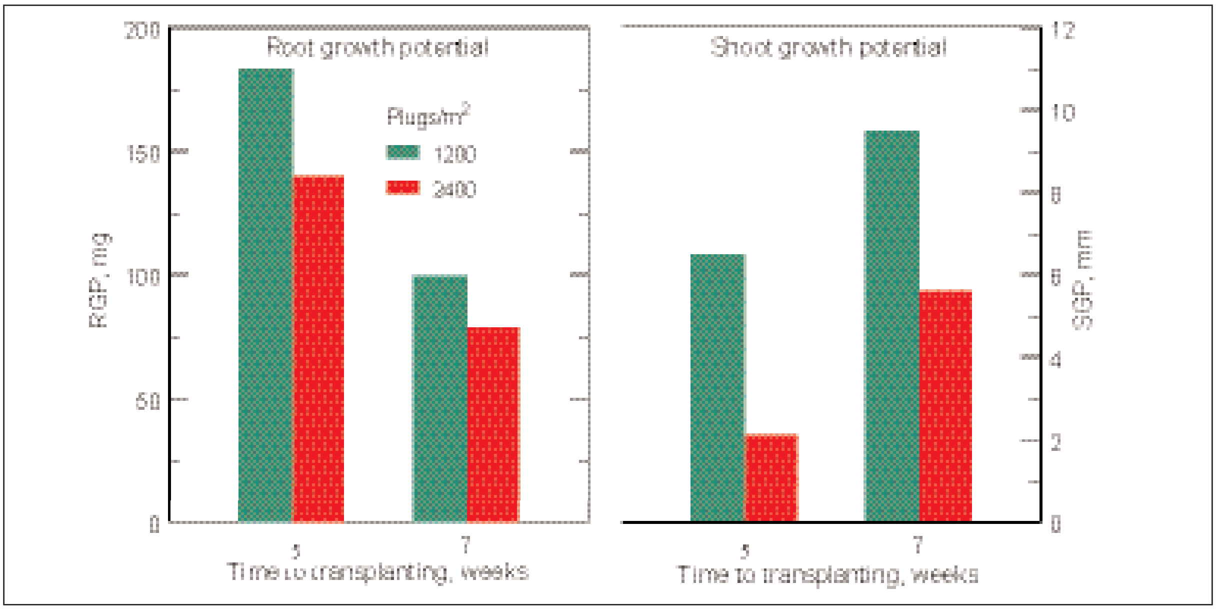


Figure 8– Root and shoot growth potential at the time of transplanting for elm seedlings sown in May in IHT plugs and grown at two densities for 5 and 7 weeks before transplanting

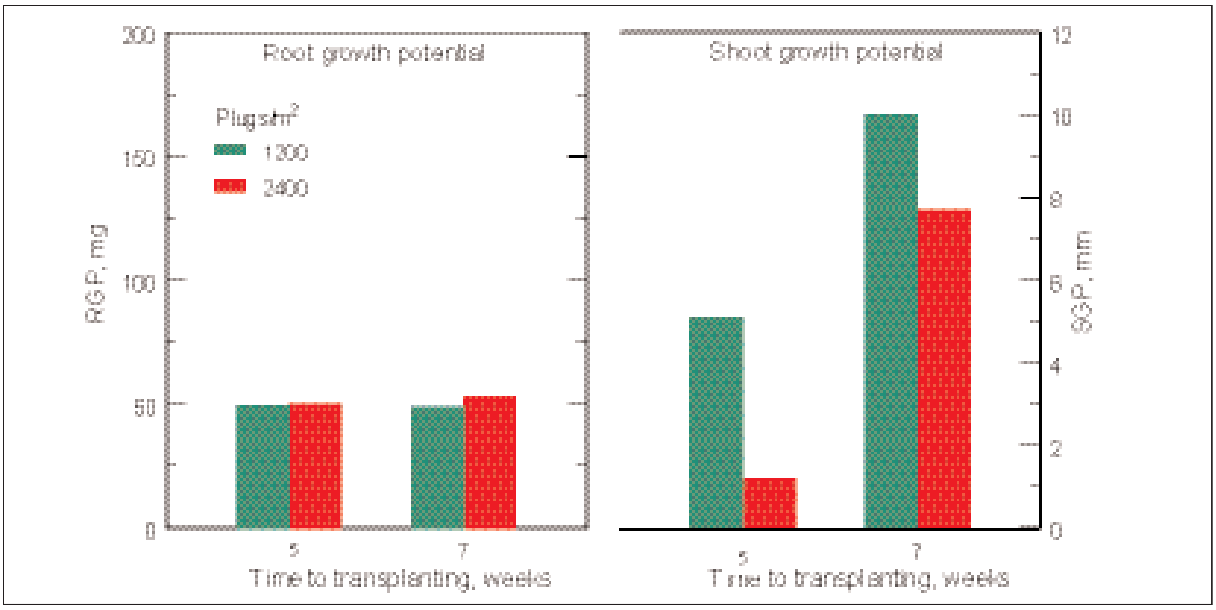


Figure 7 – Root and shoot growth potential at the time of transplanting for elm seedlings sown in May in Jiffy plugs and grown at two densities for 5 and 7 weeks before transplanting

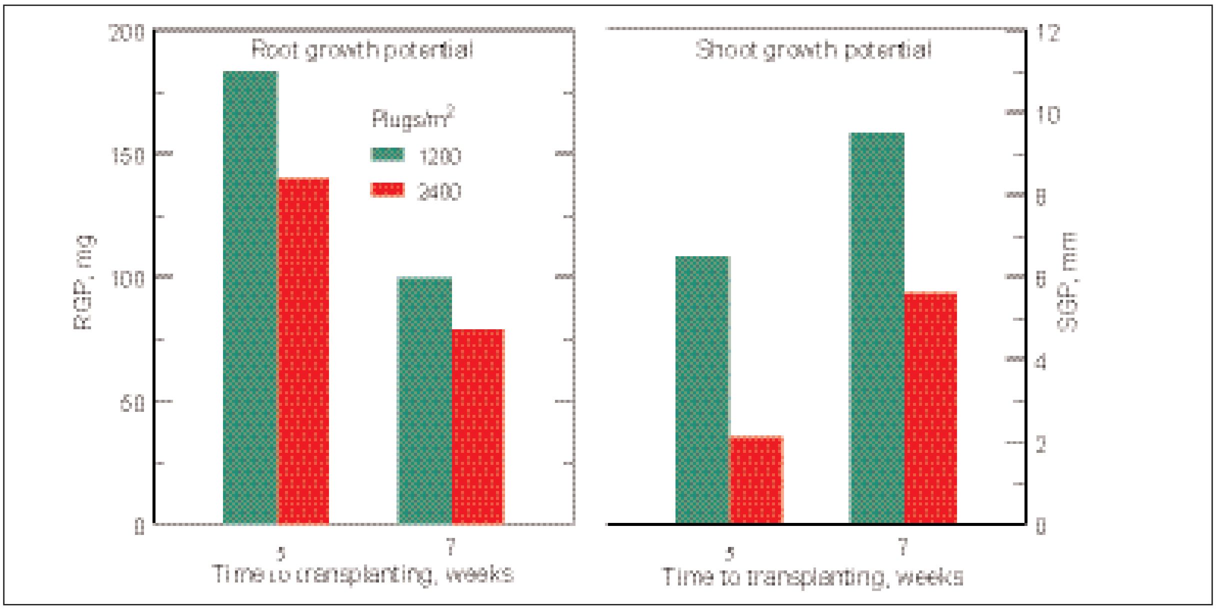


Figure 8 – Root and shoot growth potential at the time of transplanting for elm seedlings sown in May in IHT plugs and grown at two densities for 5 and 7 weeks before transplanting

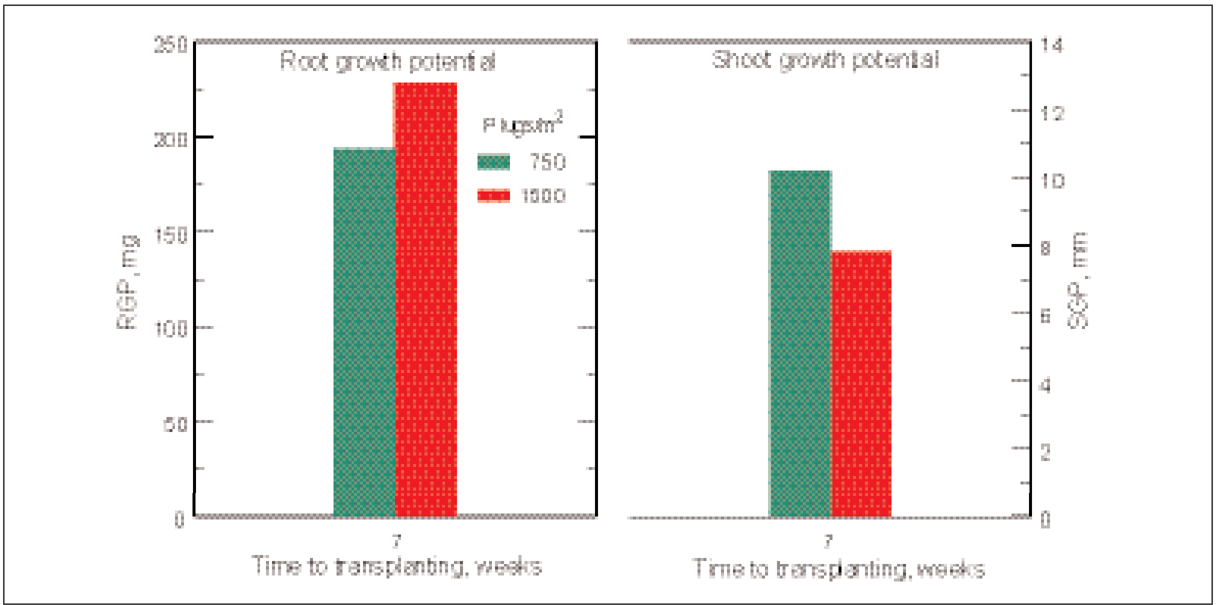


Figure 9 – Root and shoot growth potential at the time of transplanting for beech seedlings sown in May in IHT plugs and grown at two densities for 7 weeks before transplanting

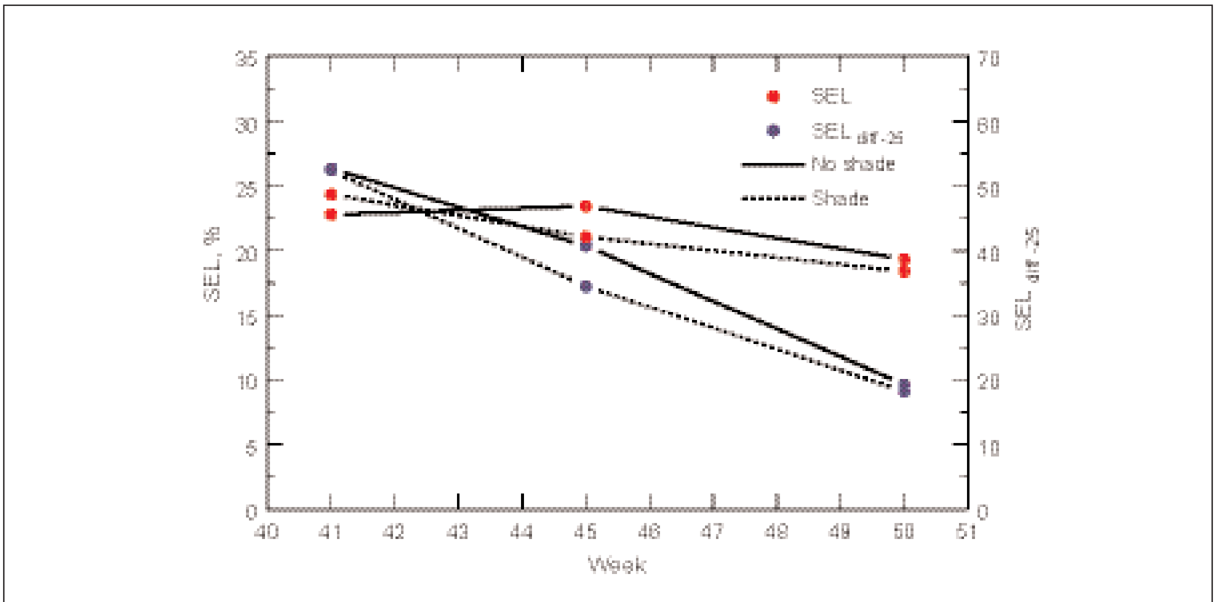


Figure 10 – Shoot electrolyte leakage (SEL) during autumn for elm seedlings sown in IHT plugs and grown for 5 weeks before transplanting. After transplanting half of the planting stock were shaded on open land

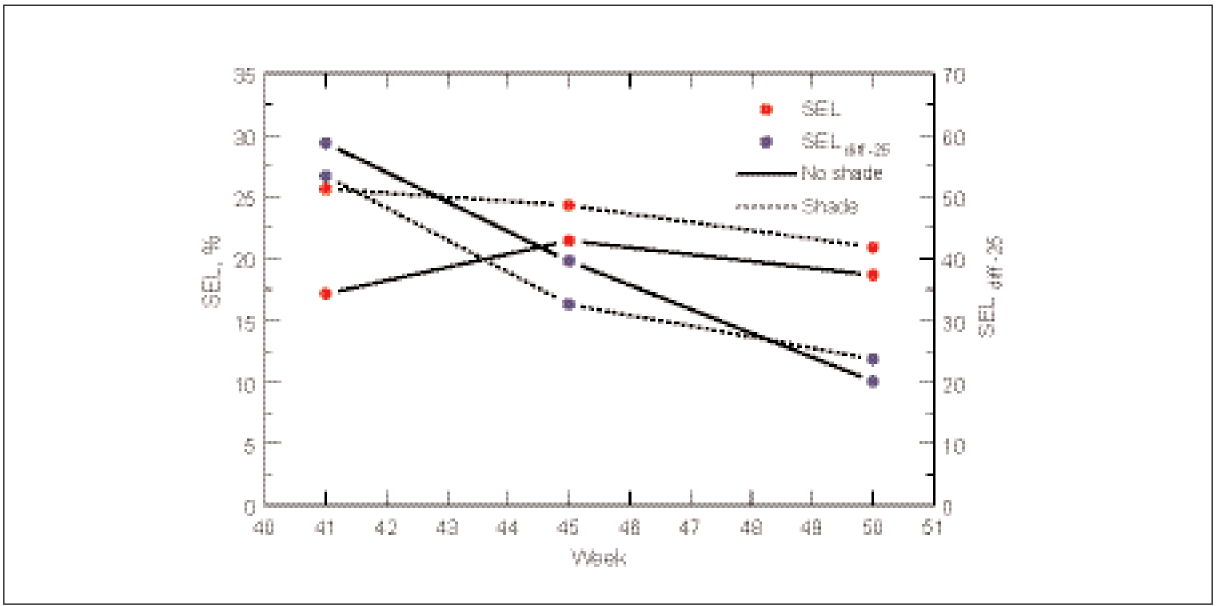


Figure 11 – Shoot electrolyte leakage (SEL) during autumn for elm seedlings sown in IHT plugs and grown for 7 weeks before transplanting. After transplanting half of the planting stock were shaded on open land

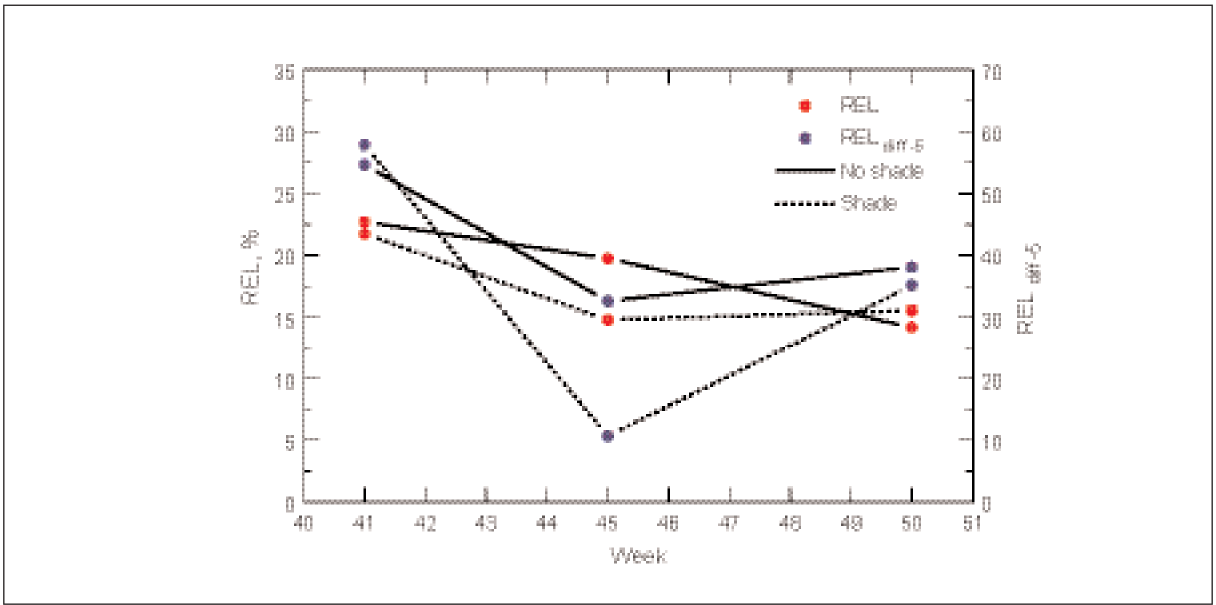


Figure 12 – Root electrolyte leakage (REL) during autumn for elm seedlings sown in IHT plugs and grown for 5 weeks before transplanting. After transplanting half of the planting stock were shaded on open land

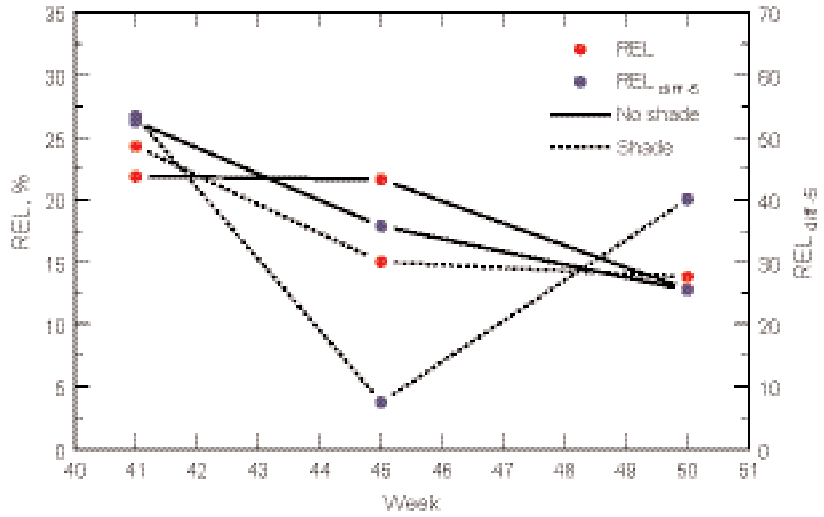


Figure 13 – Root electrolyte leakage (REL) during autumn for elm seedlings sown in IHT plugs and grown for 7 weeks before transplanting. After transplanting half of the planting stock were shaded on open land

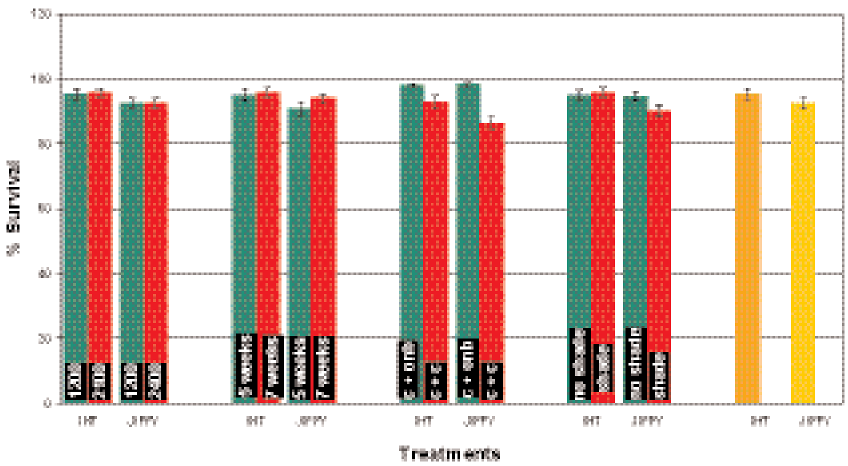


Figure 14. Field performance of elm seedlings: survival after one growing season.
Vertical bars are ±1SE

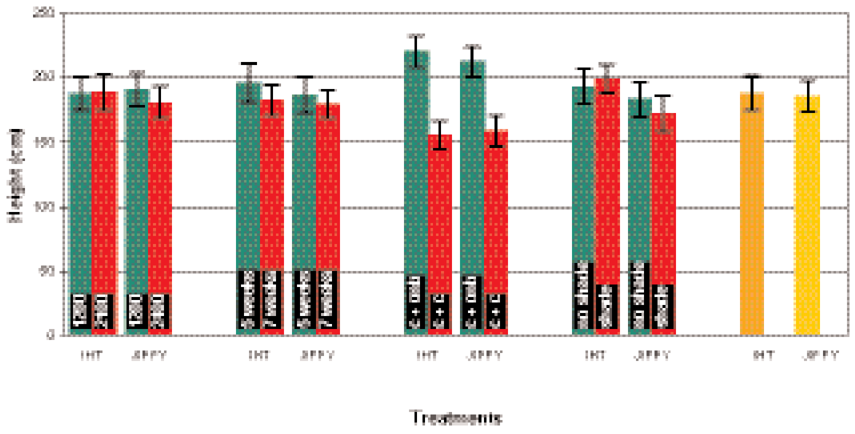


Figure 15. Field performance of elm seedlings: height after one growing season.
Vertical bars are ±1SE.

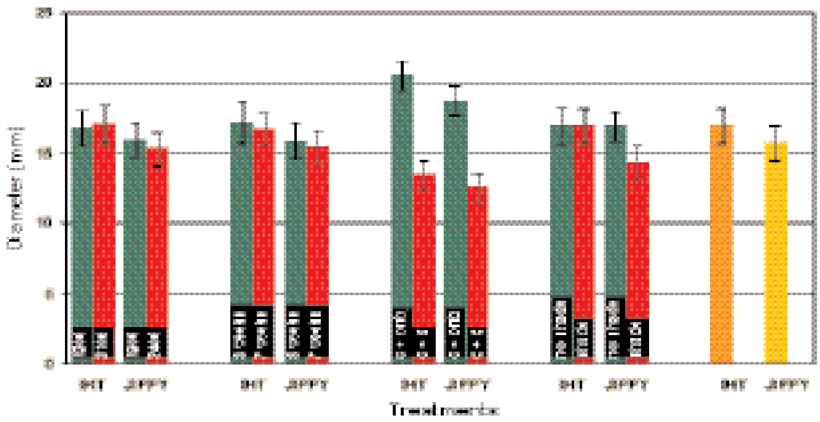


Figure 16. Field performance of elm seedlings: diameter after one growing season.
Vertical bars are ±1SE

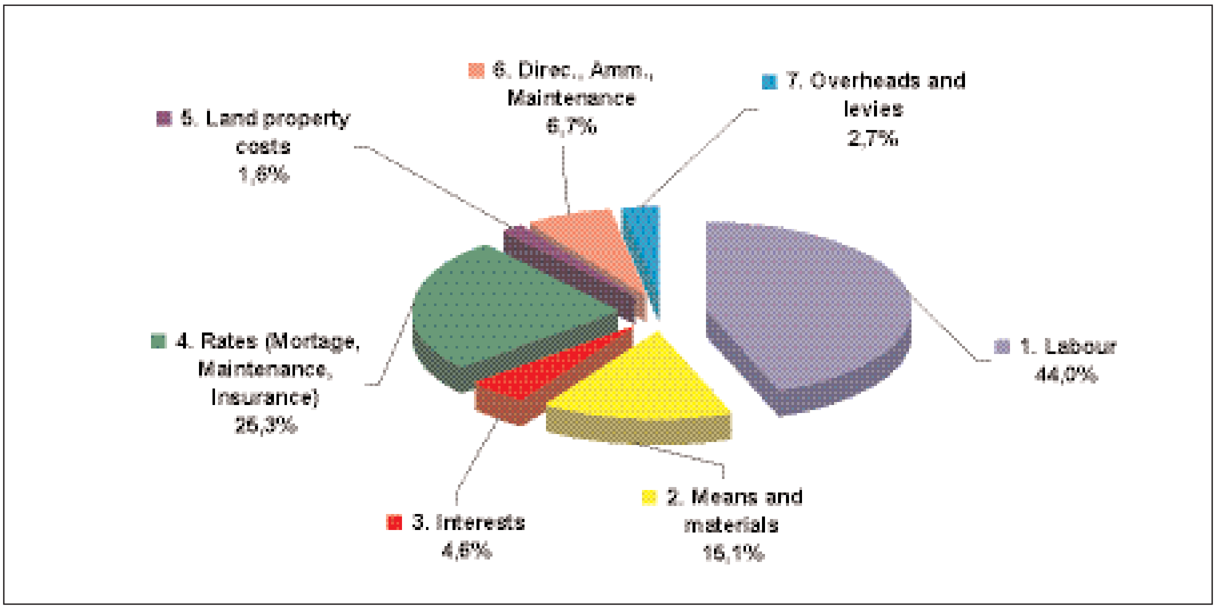
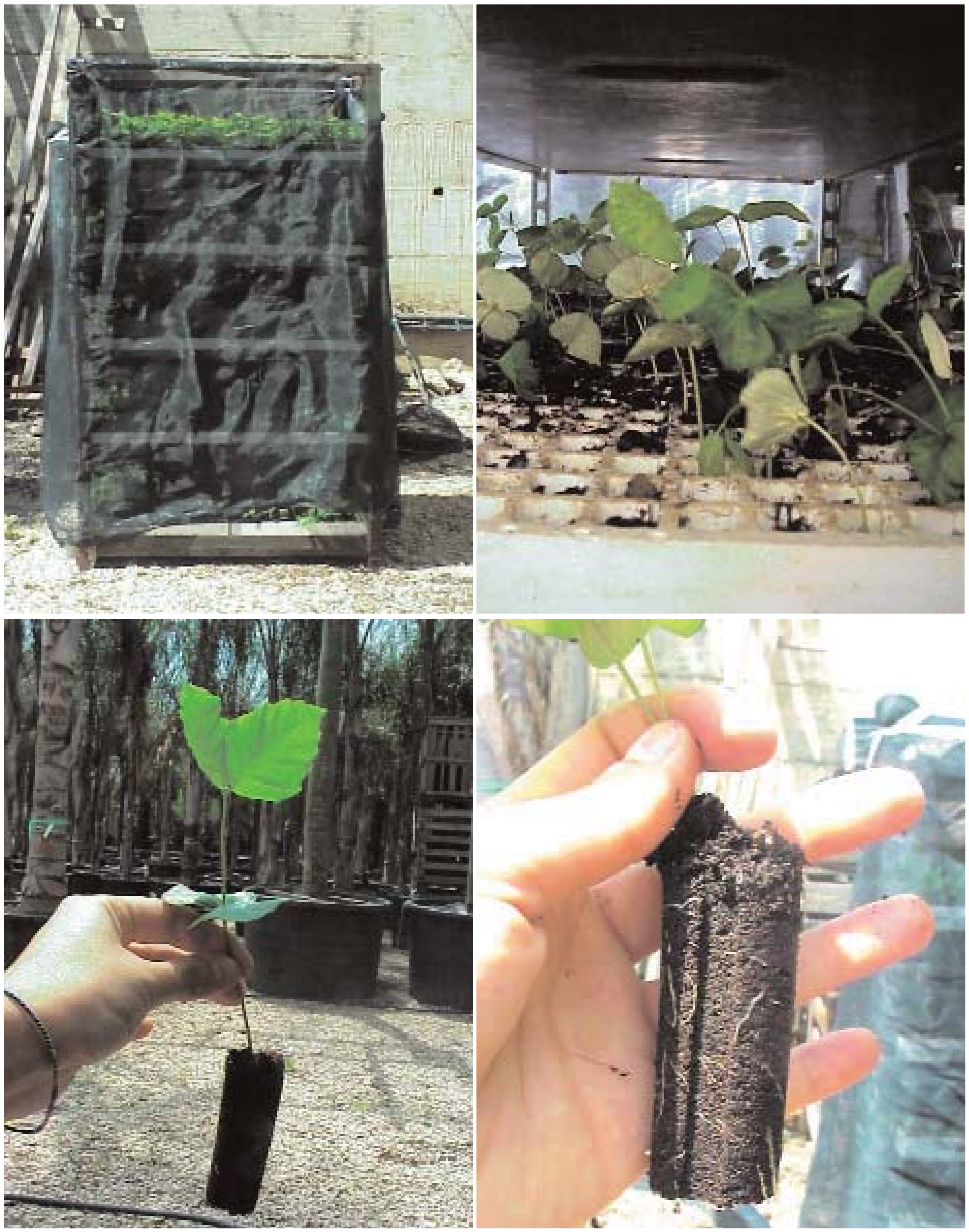


Figure 17. Proportion of direct and indirect production costs for elm seedling 1+1.
Cost production per seedling is 0,18 Euro (accelerated transplants)


Plate 1. Germination of elm in Jiffy pellets at 1200/m^2 density



Plates 2-5. Beech seedlings grown in IHT during Spring 2002

Plate 6. Germination of elm in IHT plugs at 2100/m^2 density.

Plate 7. Beech seeds in IHT plugs at 1400/m^2 density

Plate 8. Elm seedlings growing in IHT plugs at two different densities


Plate 9. Beech seedlings growing in IHT at two different densities

Plates 10-13. Torsanlorenzo nursery's greenhouse: establishment of trials

Plates 14 and 15. Transplanting elm in open nursery beds

Plate 16. Elm seedlings transplanted in container and shaded

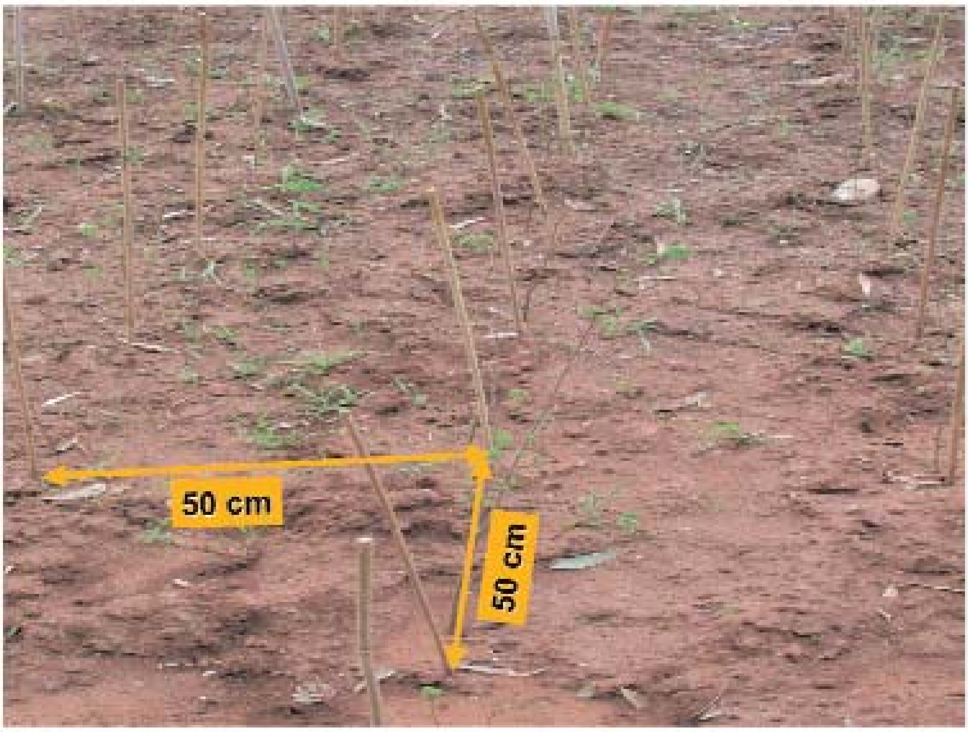
Plate 17. Beech seedlings transplanted in a open nursery bed

Plates 18-21. Transplantation of ash seedlings grown in IHT miniplugs, in Spring 2002

Plate 22. Overview of ash nursery beds established in Spring 2002

Plates 23 and 24. Shading of transplanted elm seedlings

Plate 25. Elm seedlings in nursery beds at the end of the growing season.



Plates 26 and 27. Establishment of the field performance nursery trial.

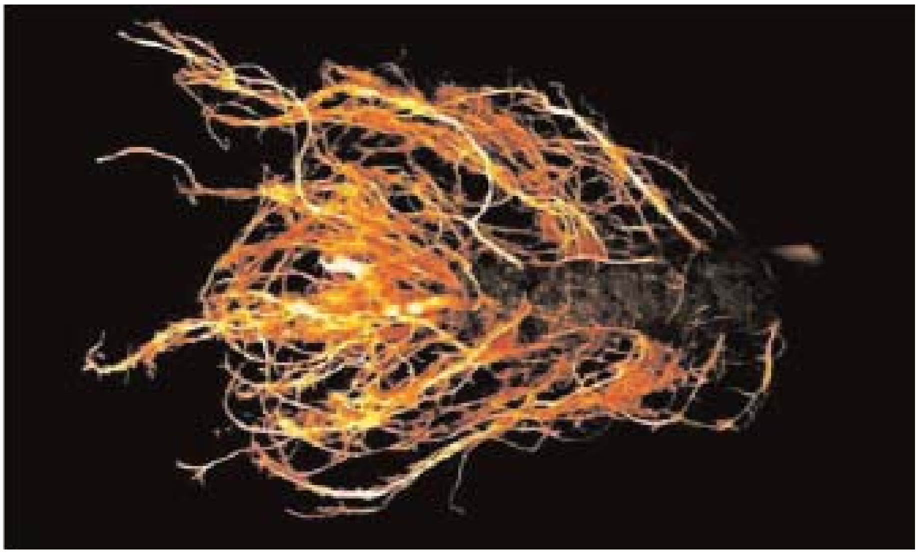
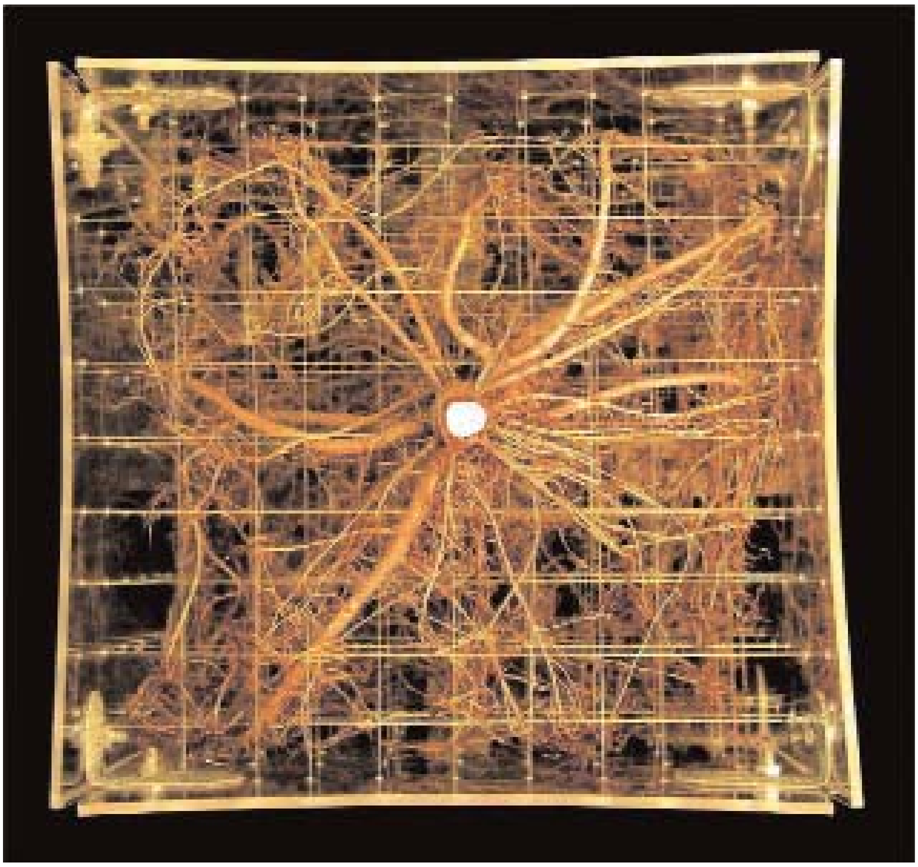


Plate 28. Root system of elm seedling grown in IHT plug.

Plate 29. Root system of elm seedling grown in Jiffy plug.


Plates 30. Root system of elm seedling grown in a root study box

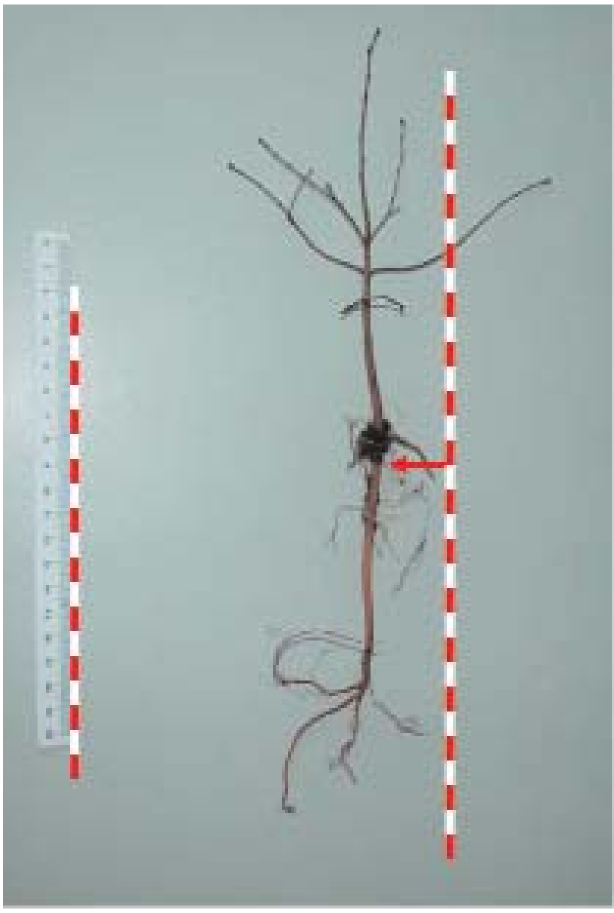


Plate 31. *Ulmus minor* seedling grown in IHT and transplanted in open nursery bed

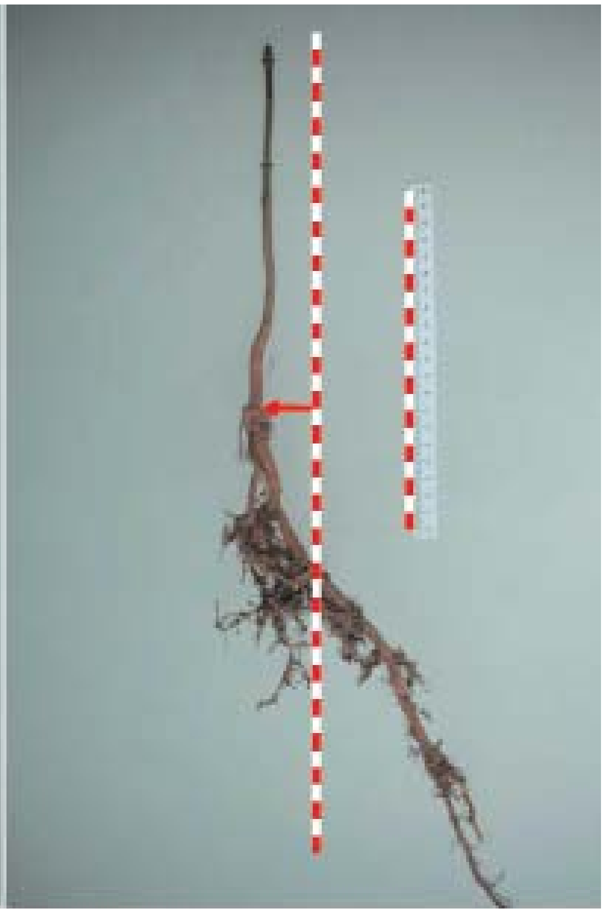


Plate 32. *Fraxinus excelsior* seedling grown in IHT and transplanted in open nursery bed

Plate 33. Field performance of elm seedling: one year after outplanting

Plate 34. Field performance of elm seedling: one year after outplanting

ANNEX 2

DIAS

Figure legends

Figure 1. Curling of the roots in Jiffy.
Figure 2. Damages to the cotyledons in Jiffy 22.
Figure 3. Shoot and root DW (exclusive root DW in plug) after transplanting for one growing season in relation to plug-system during germination. Values in each column followed by the same letter are not significant different according to a Duncan's multiple-range test (P=0.05).
Figure 4. Root length and number of root tips in closed versus open systems.
Figure 5. Height and RD in relation to fertiliser and clay addition.
Figure 6. Development of shoot frost hardiness of containerised and bare-rooted beech seedlings in relation to storage occasions. Lillie, please, figure legends from 7 to 14.

Figure 1

Figure 2

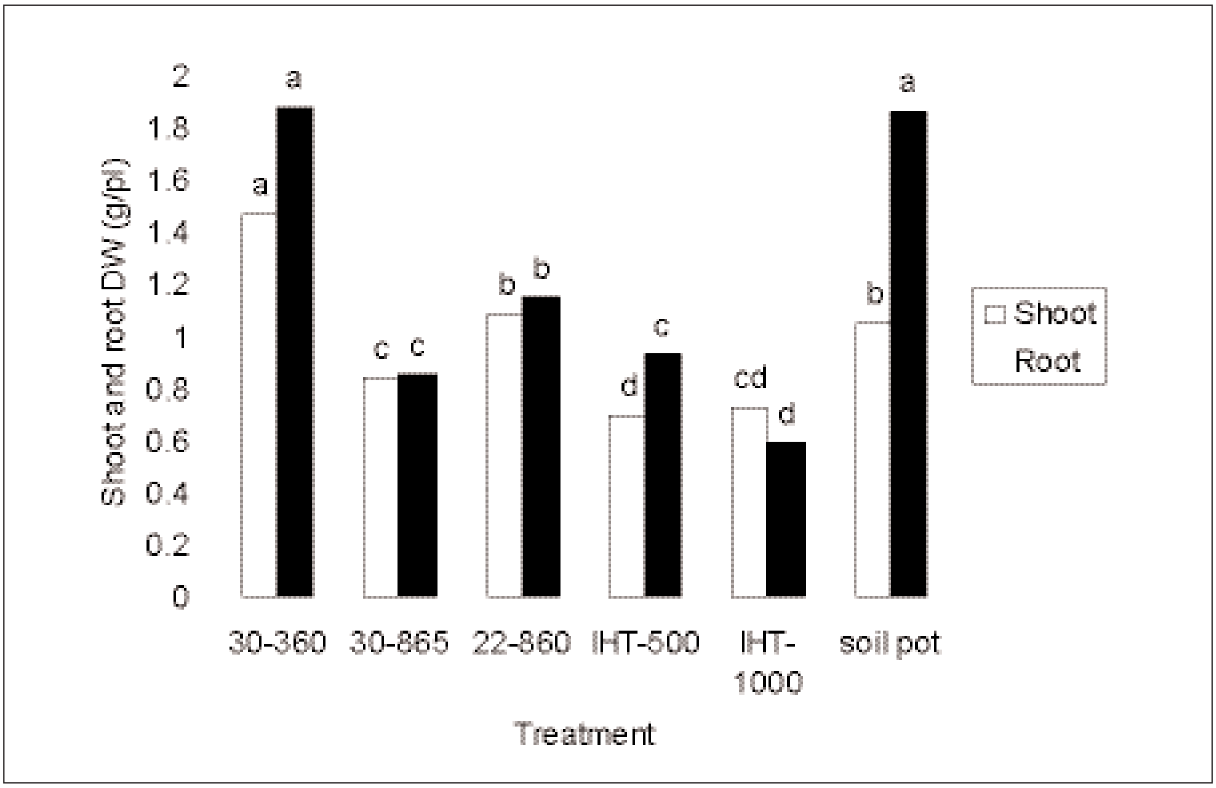


Figure 3

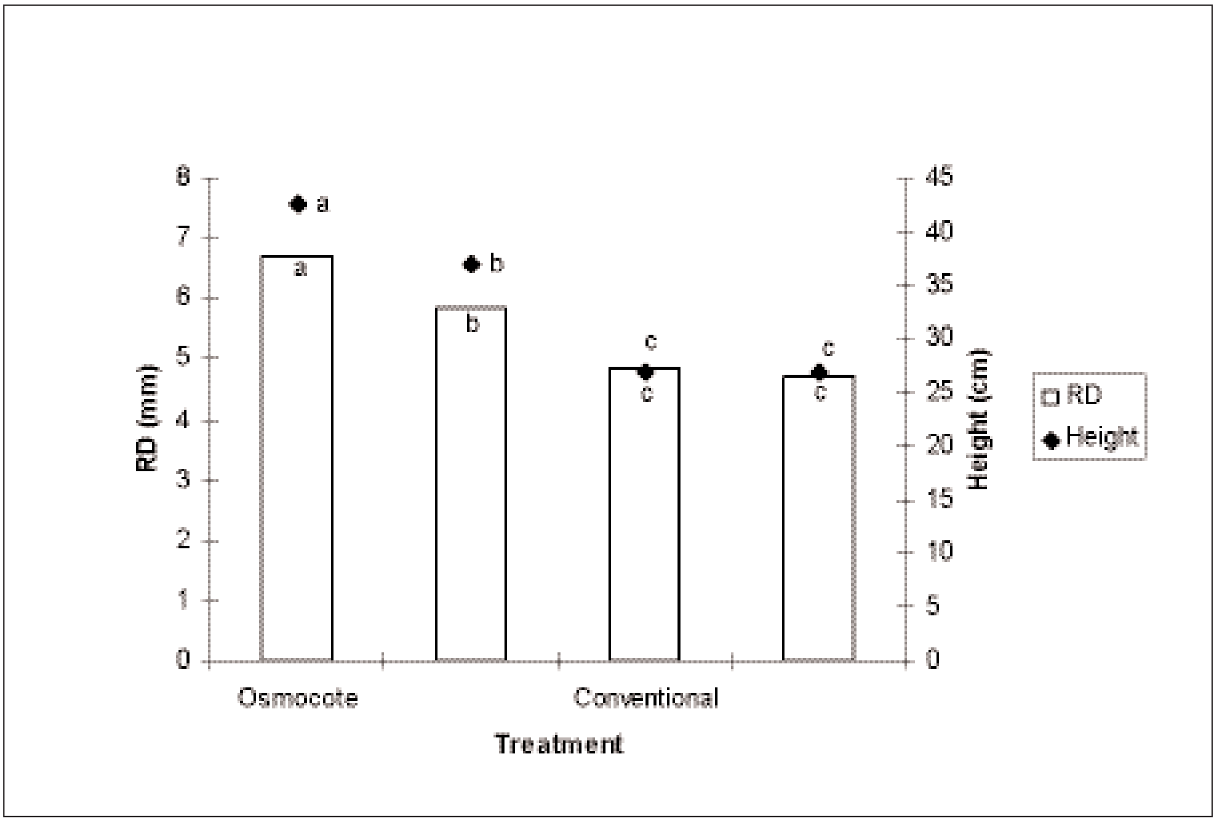


Figure 4

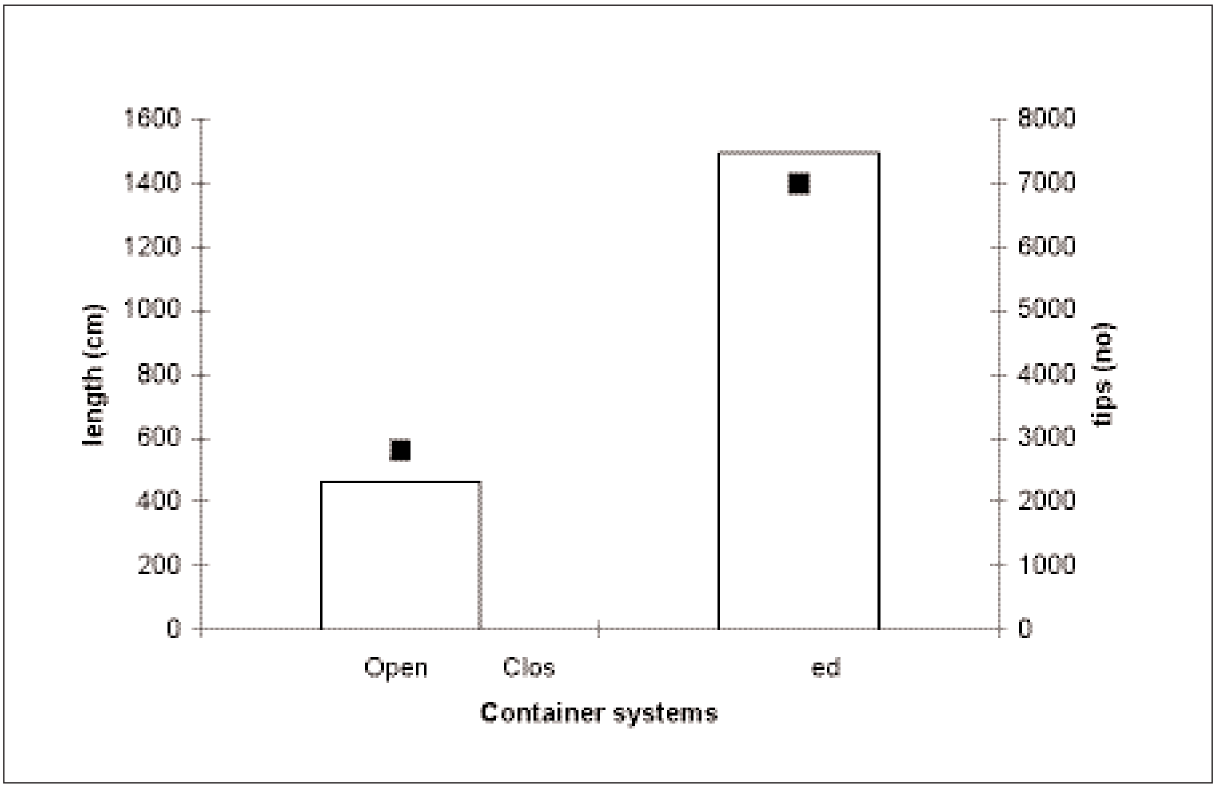


Figure 5

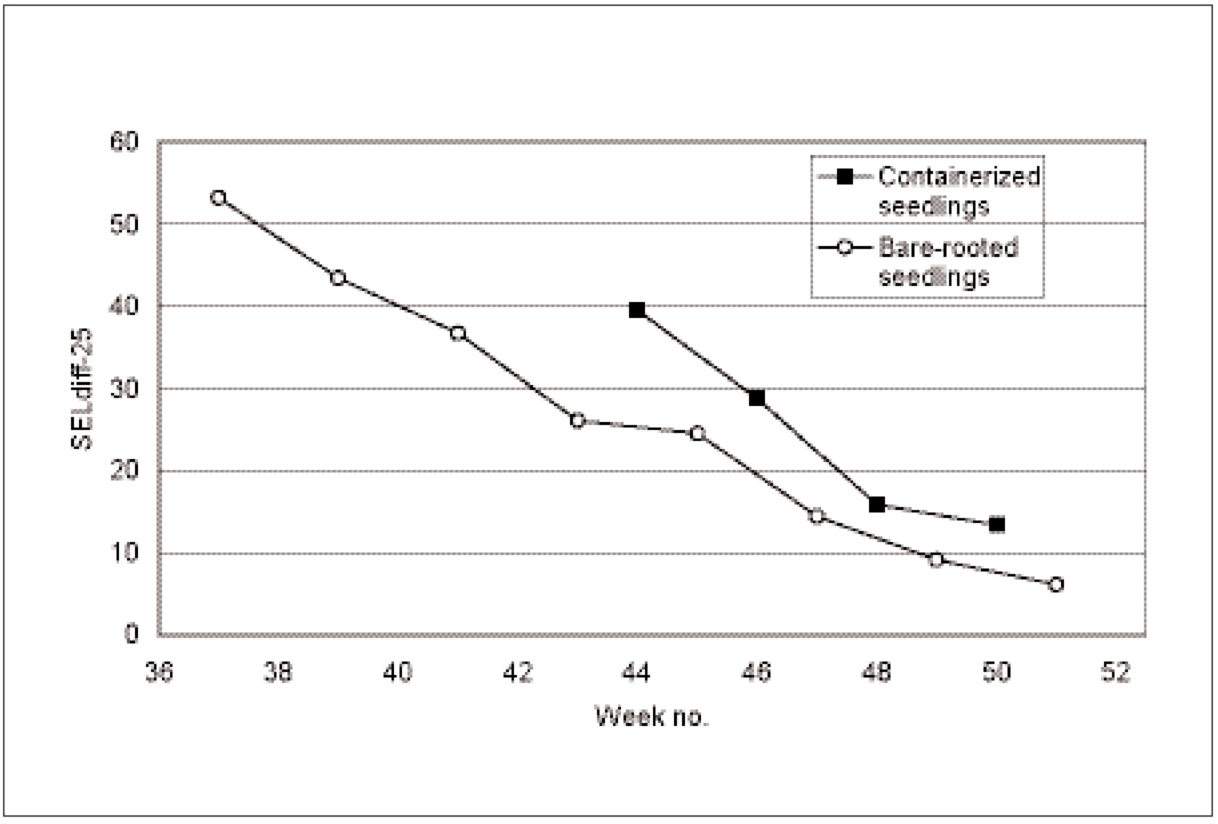


Figure 6

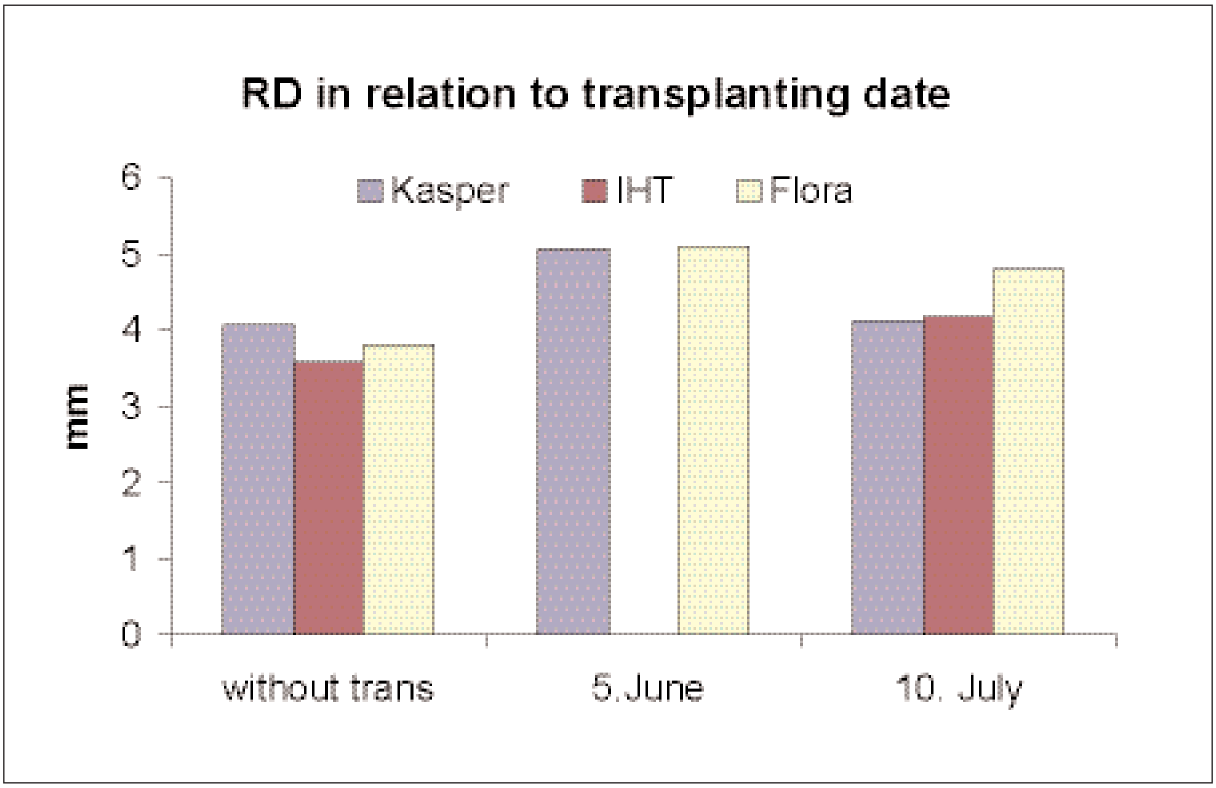


Figure 7

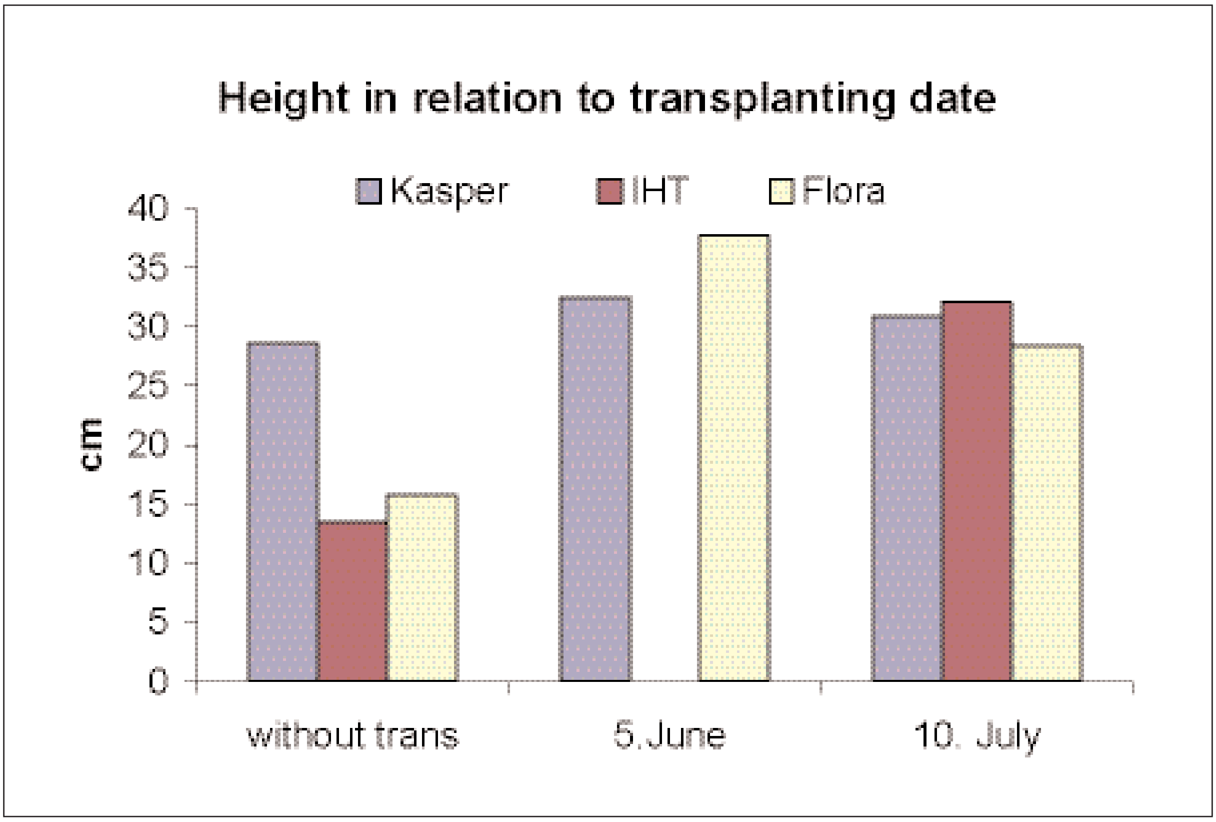


Figure 8

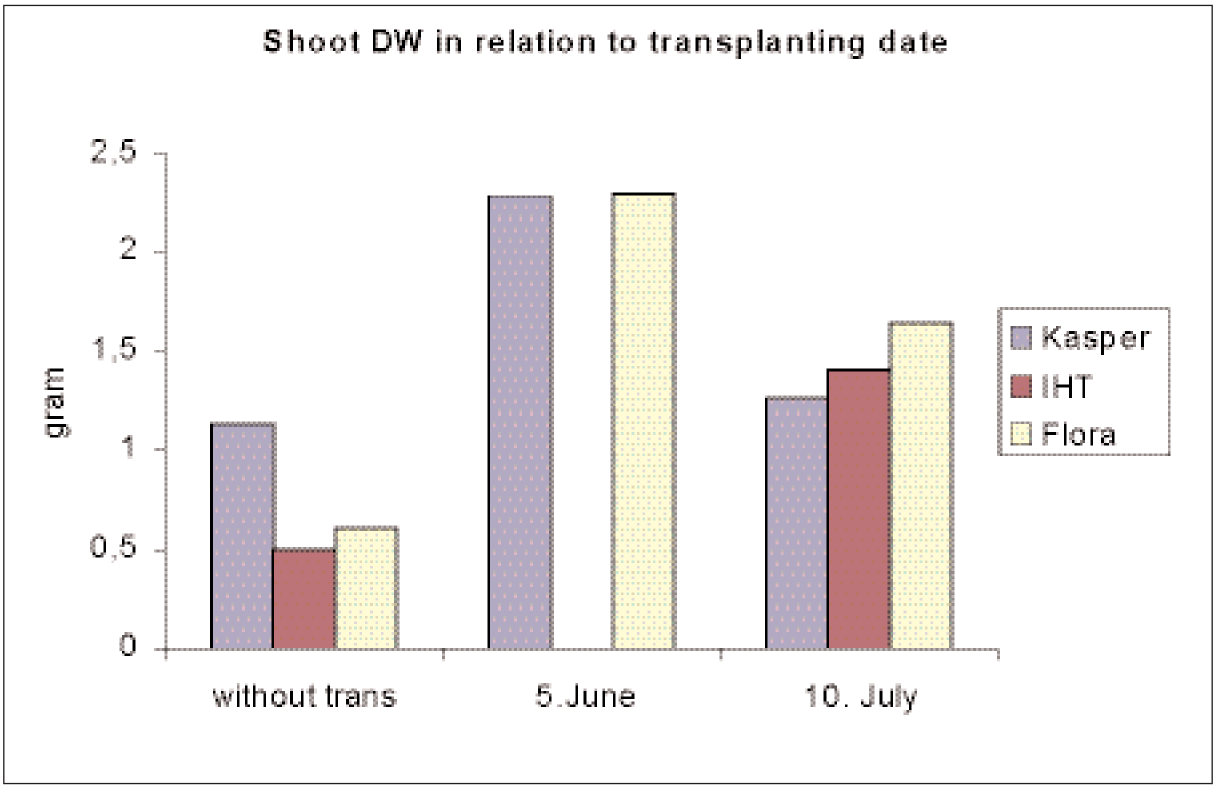


Figure 9

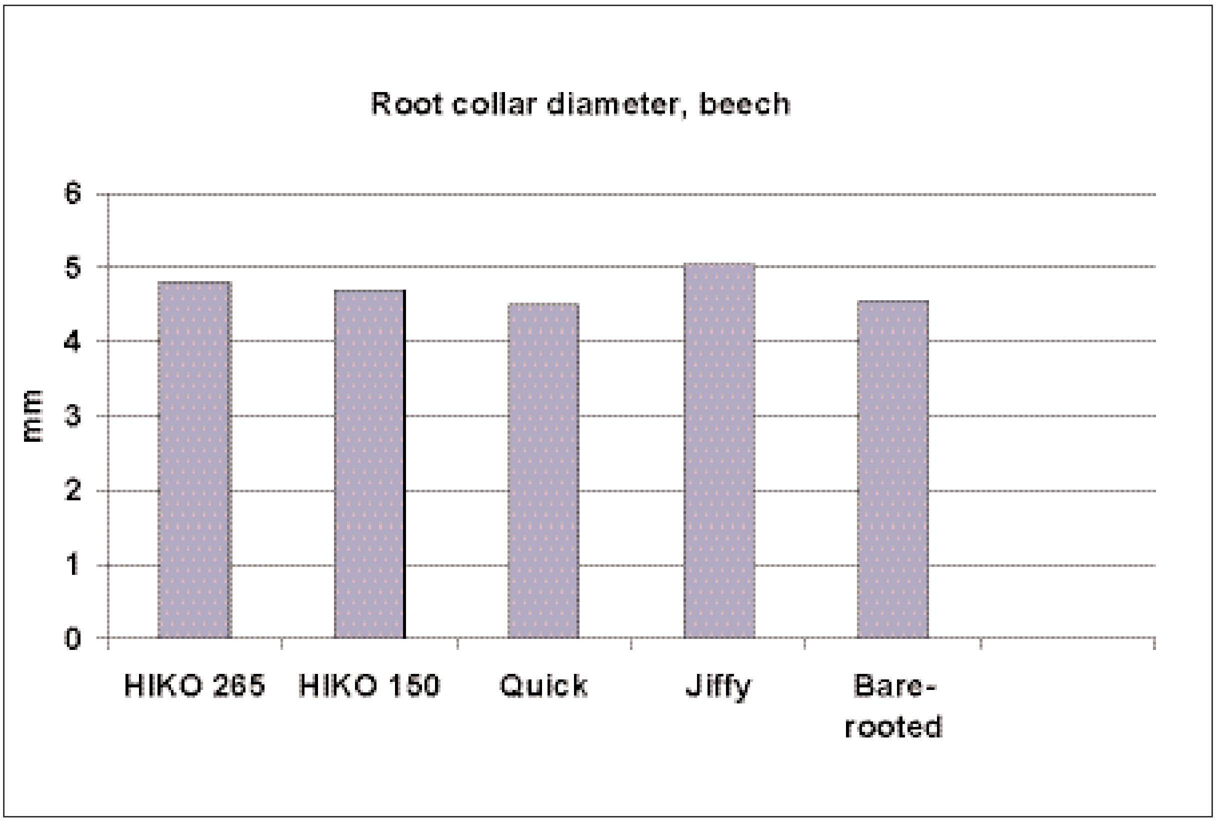


Figure 10

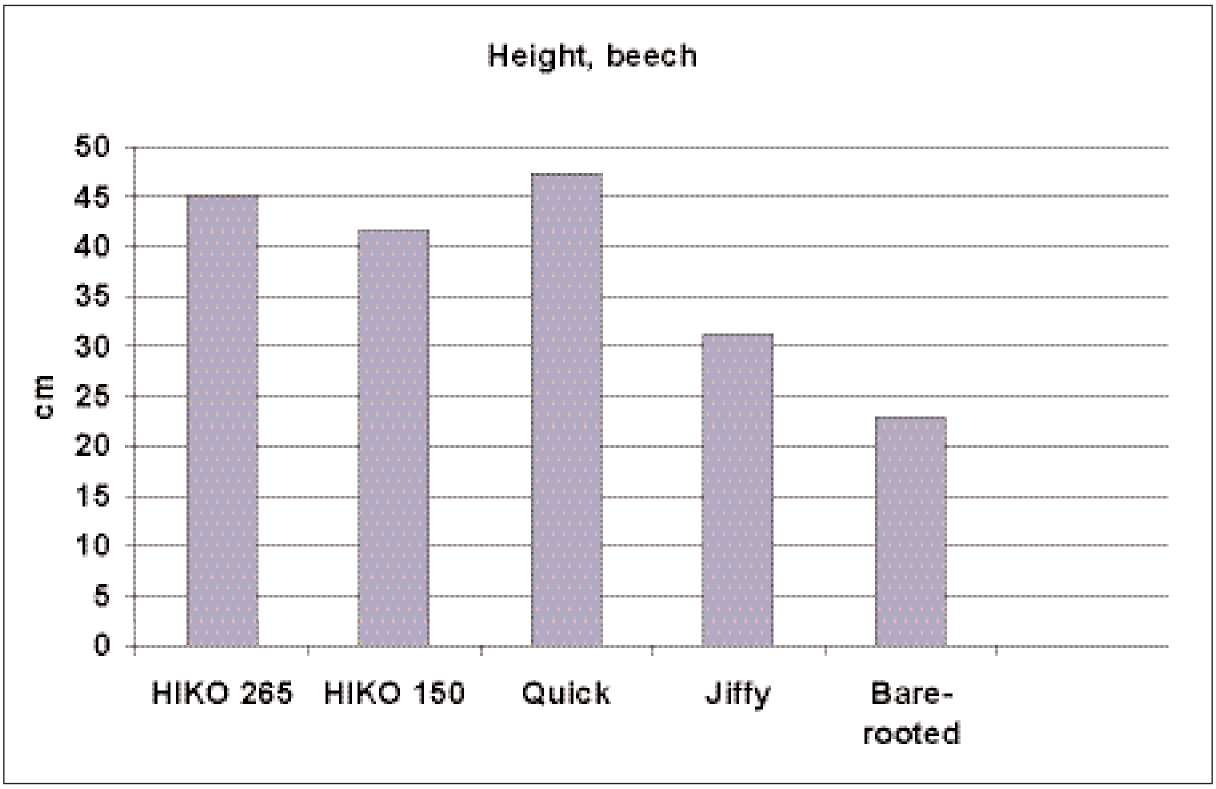


Figure 11

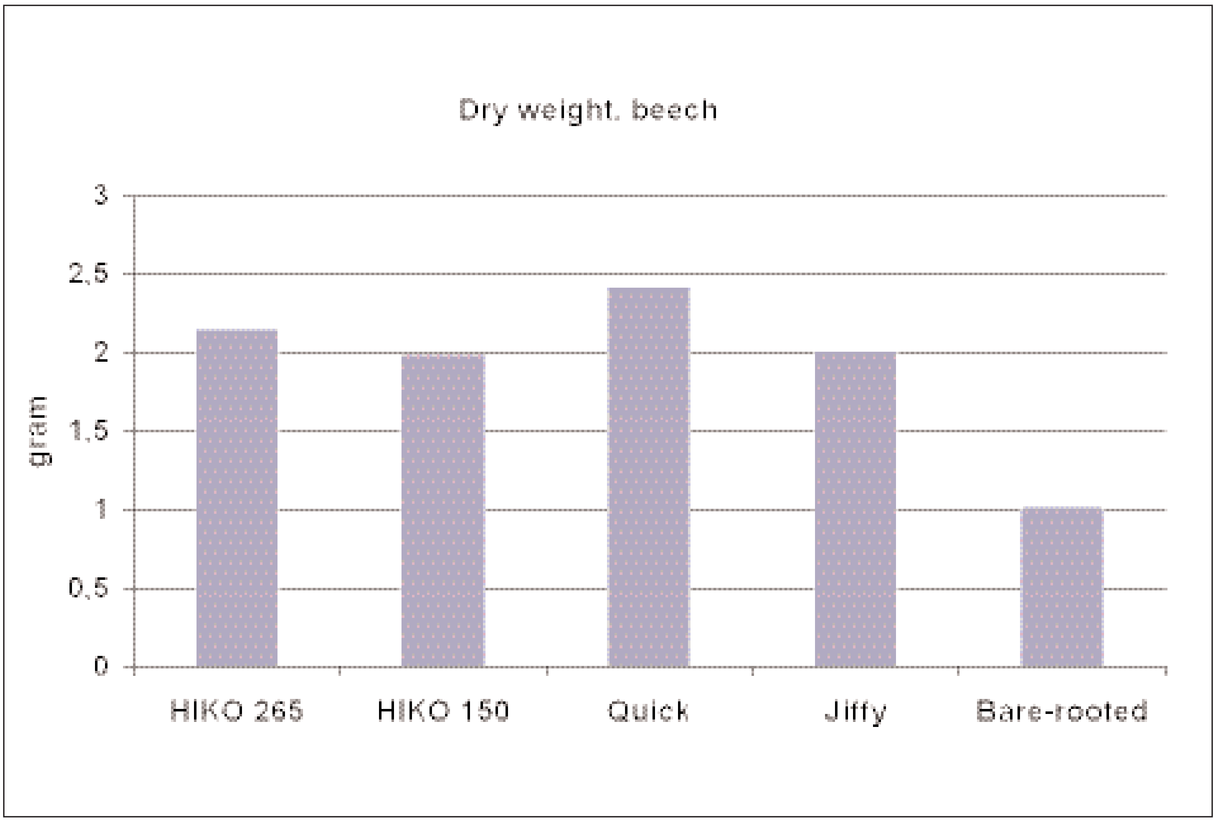


Figure 12

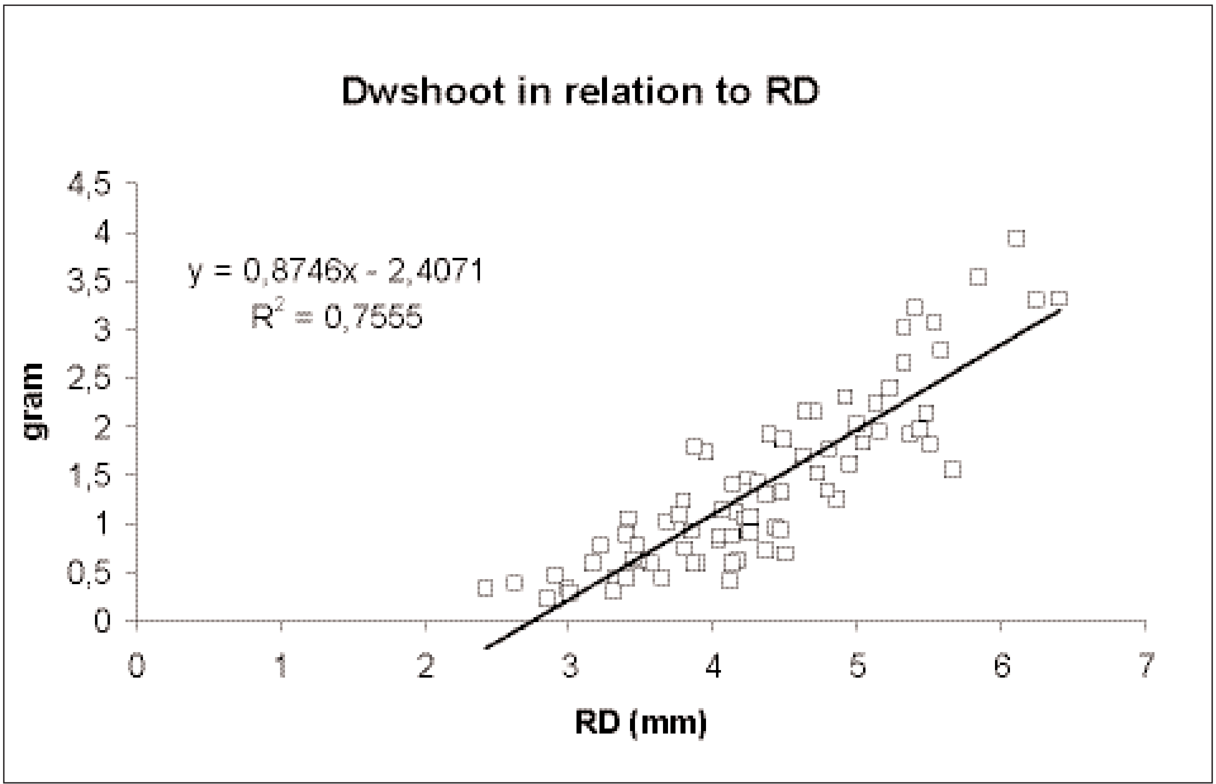


Figure 13

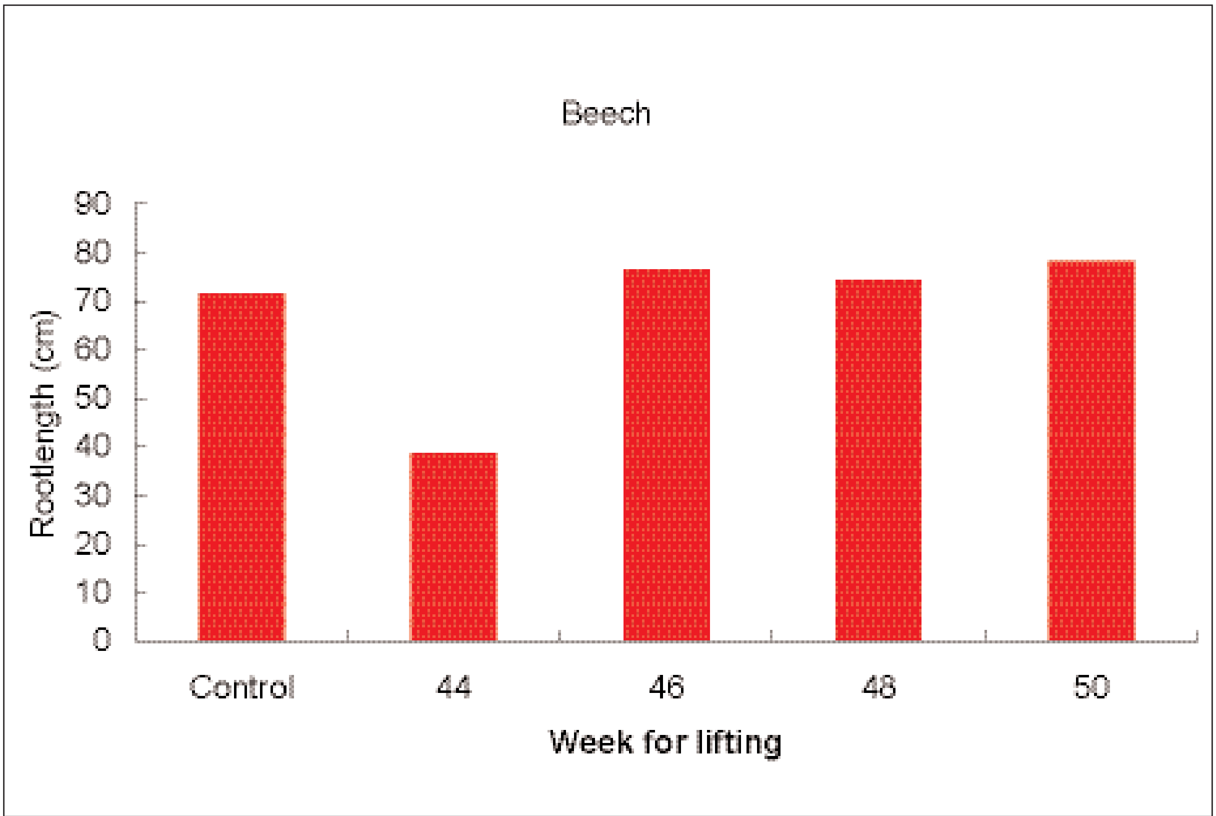


Figure 14

ANNEX 3

DU

Figure legends

Figure 1. Dry weight and height at the time of transplanting for birch seedlings sown May 23 in Jiffy plugs and grown at two densities for 3 weeks before transplanting.

Figure 2. Dry weight and height at the time of transplanting for birch seedlings sown May 23 in IHT plugs and grown at two densities for 3 weeks before transplanting.

Figure 3. Dry weight, height and diameter at the time of transplanting for birch seedlings sown May 23 in Jiffy plugs and grown at two densities for 6 weeks before transplanting.

Figure 4. Dry weight, height and diameter at the time of transplanting for birch seedlings sown May 23 in IHT plugs and grown at two densities for 6 weeks before transplanting.

Figure 5. Dry weight, height and diameter at the time of transplanting for beech seedlings sown June 1 in Jiffy plugs and grown at two densities for 3 weeks before transplanting.

Figure 6. Dry weight, height and diameter at the time of transplanting for beech seedlings sown June 1 in IHT plugs and grown at two densities for 3 weeks before transplanting.

Figure 7. Dry weight, height and diameter at the time of transplanting for beech seedlings sown June 1 in Jiffy plugs and grown at two densities for 5 weeks before transplanting.

Figure 8. Dry weight, height and diameter at the time of transplanting for beech seedlings sown June 1 in IHT plugs and grown at two densities for 5 weeks before transplanting.

Figure 9. Root and shoot growth potential at the time of transplanting for birch seedlings sown May 23 in Jiffy plugs and grown at two densities for 3 and 6 weeks before transplanting.

Figure 10. Root and shoot growth potential at the time of transplanting for birch seedlings sown May 23 in IHT plugs and grown at two densities for 3 and 6 weeks before transplanting.

Figure 11. Root and shoot growth potential at the time of transplanting for beech seedlings sown June 1 in Jiffy plugs and grown at two densities for 3 and 5 weeks before transplanting.

Figure 12. Root and shoot growth potential at the time of transplanting for beech seedlings sown June 1 in IHT plugs and grown at two densities for 3 and 5 weeks before transplanting.

Figure 13. Root and shoot electrolyte leakage in the middle of September for birch seedlings sown May 23 and grown for 3 and 6 weeks before transplanting. The long night treatment was carried out during 3 weeks after transplanting.

Figure 14. Root and shoot electrolyte leakage in the middle of September for beech seedlings sown June 1 and grown for 3 and 5 weeks before transplanting. The shading treatment was carried out during 3 weeks after transplanting.

Figure 15. Stem weight after one vegetation period in the nursery for birch seedlings sown in Jiffy plugs and grown at two densities for 3 and 6 weeks before transplanting. After transplanting half of the planting stock was long night (LN) treated.

Figure 16. Stem weight after one vegetation period in the nursery for birch seedlings sown in IHT plugs and grown at two densities for 3 and 6 weeks before transplanting. After transplanting half of the planting stock was long night (LN) treated.

Figure 17. Root weight after one vegetation period in the nursery for birch seedlings sown in Jiffy plugs and grown at two densities for 3 and 6 weeks before transplanting. After transplanting half of the planting stock was long night (LN) treated.

Figure 18. Root weight after one vegetation period in the nursery for birch seedlings sown in IHT plugs and grown at two densities for 3 and 6 weeks before transplanting. After transplanting half of the planting stock was long night (LN) treated.

Figure 19. Height after one vegetation period in the nursery for birch seedlings sown in Jiffy plugs and grown at two densities for 3 and 6 weeks before transplanting. After transplanting half of the planting stock was long night (LN) treated.

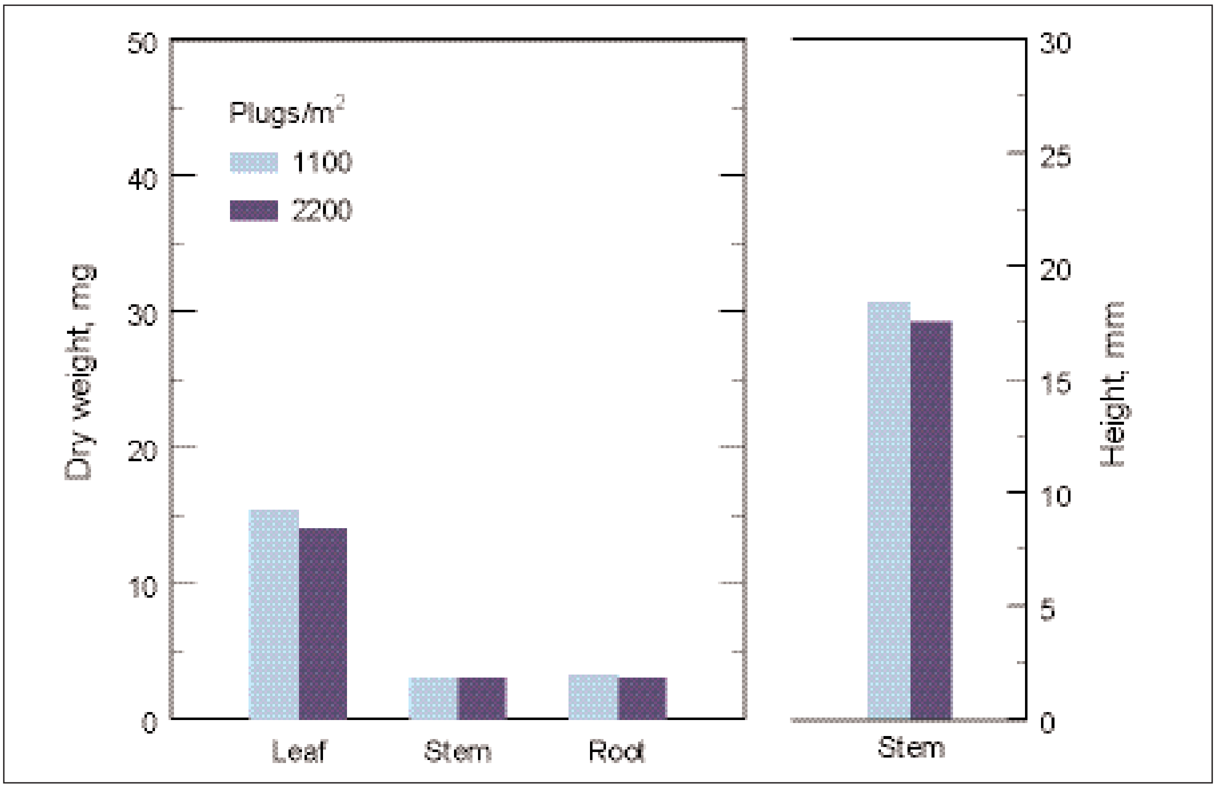
Figure 20. Height after one vegetation period in the nursery for birch seedlings sown in IHT plugs and grown at two densities for 3 and 6 weeks before transplanting. After transplanting half of the planting stock was long (LN) treated.

Figure 21. Stem diameter after one vegetation period in the nursery for birch seedlings sown in Jiffy plugs and grown at two densities for 3 and 6 weeks before transplanting. After transplanting half of the planting stock was long night (LN) treated.

Figure 22. Stem diameter after one vegetation period in the nursery for birch seedlings sown in IHT plugs and grown at two densities for 3 and 6 weeks before transplanting. After transplanting half of the planting stock was long night (LN) treated.

Figure 23. Shoot growth after one vegetation period in the field for birch seedlings sown in 2 different mini plug systems and grown at 2 densities for 3 weeks before transplanting. After transplanting half of the planting stock for each density and plug system were long night (LN) treated. As a control birch seedlings from traditional production without transplanting were also included in the field trial. Bars with the same letter are not significantly different.

Figure 24. Diameter growth after one vegetation period in the field for birch seedlings sown in 2 different mini plug systems and grown for 3 weeks before transplanting. After transplanting half of the planting stock for each density and plug system were long night (LN) treated. As a control birch seedlings from traditional production were also included in the field trial. Bars with the same letter are not significantly different.



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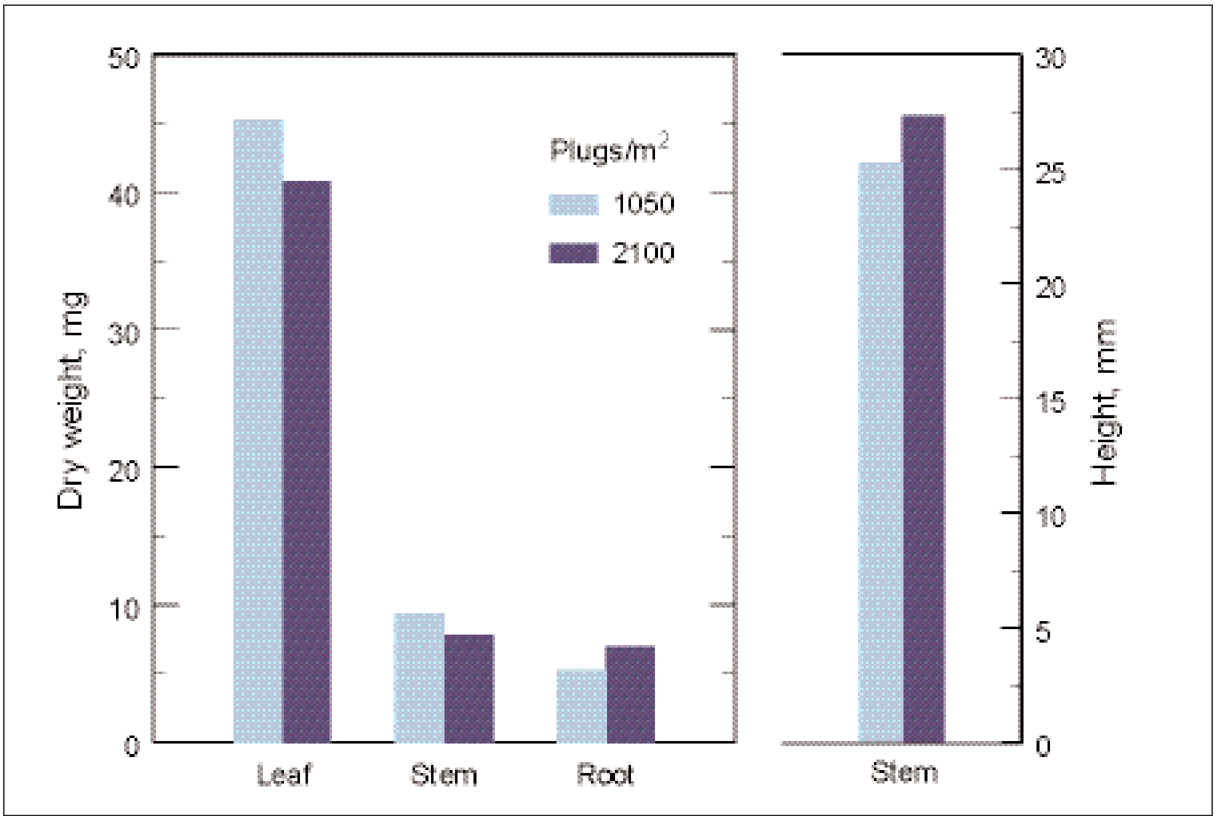

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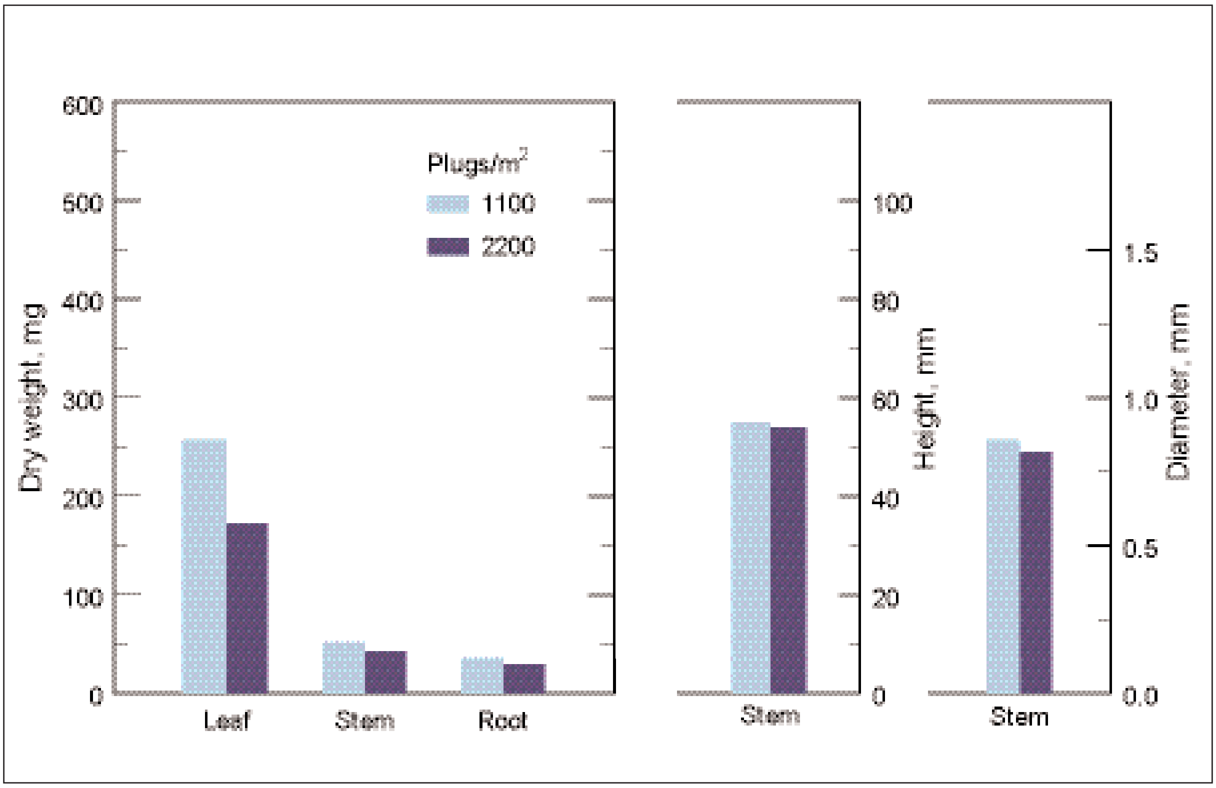

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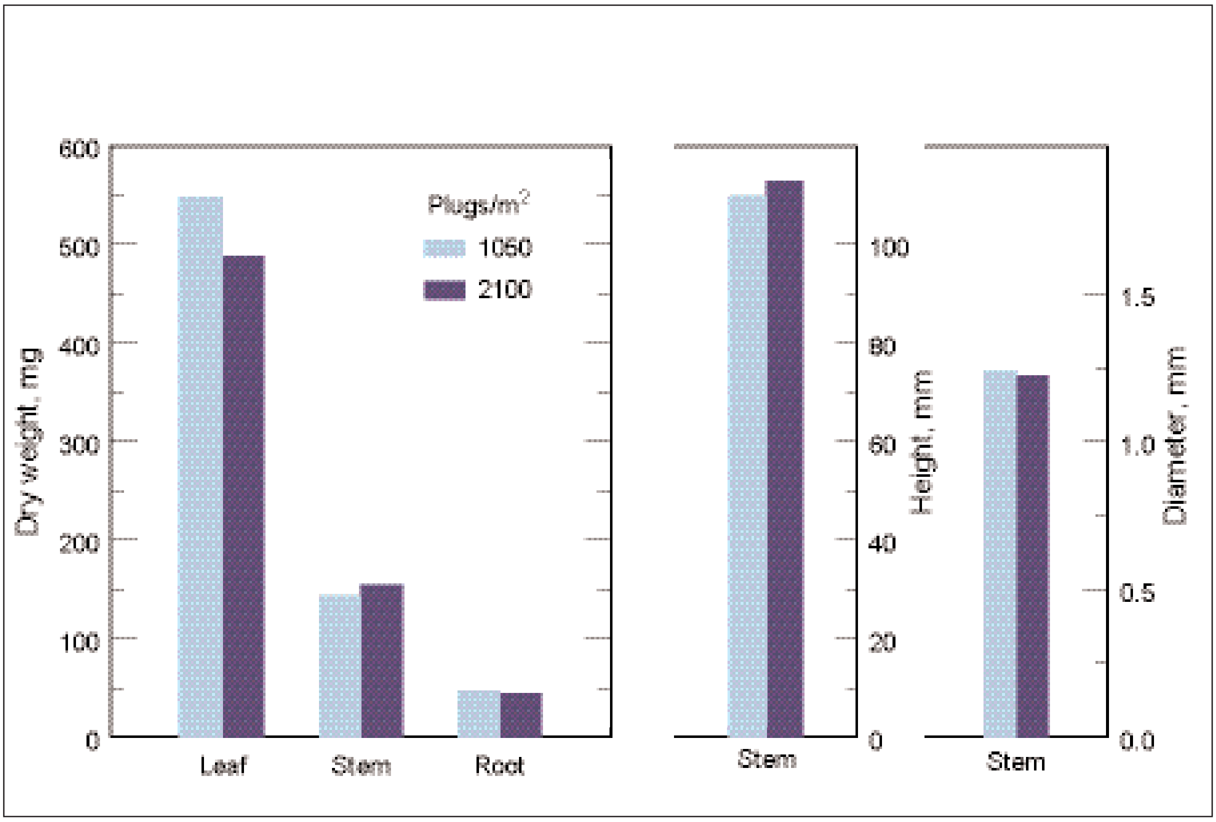

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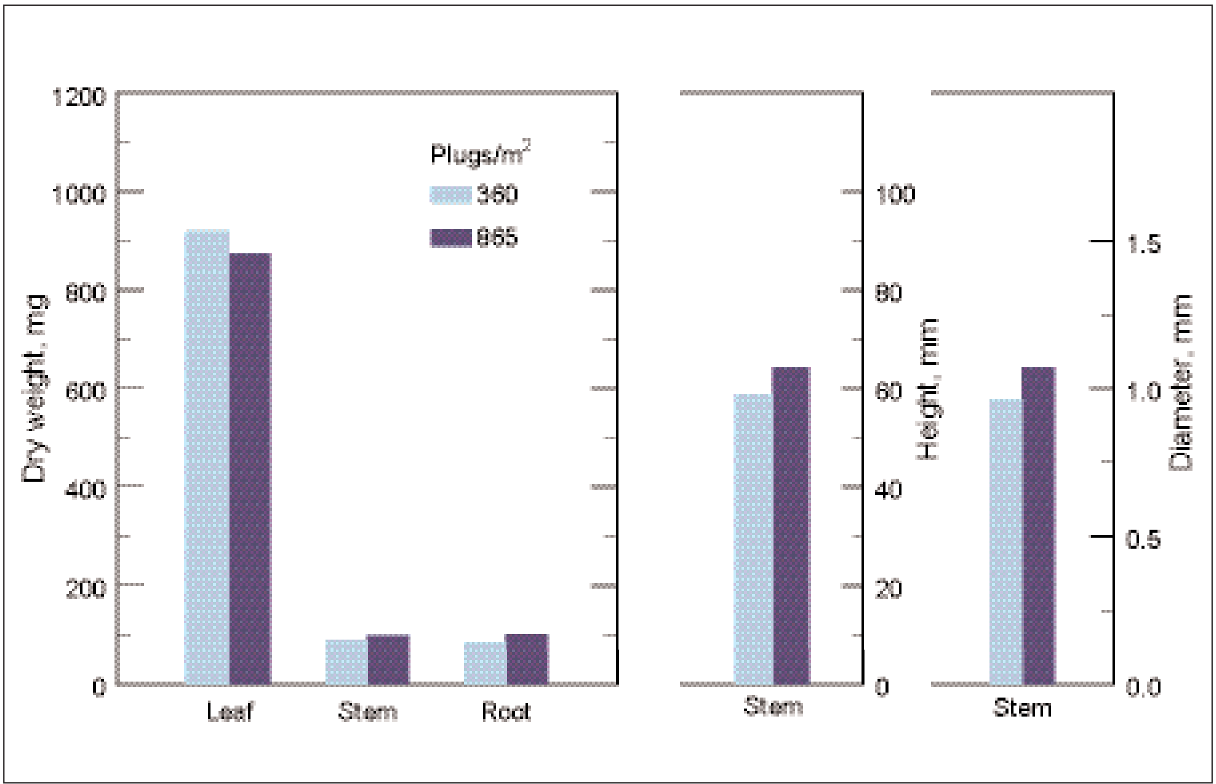

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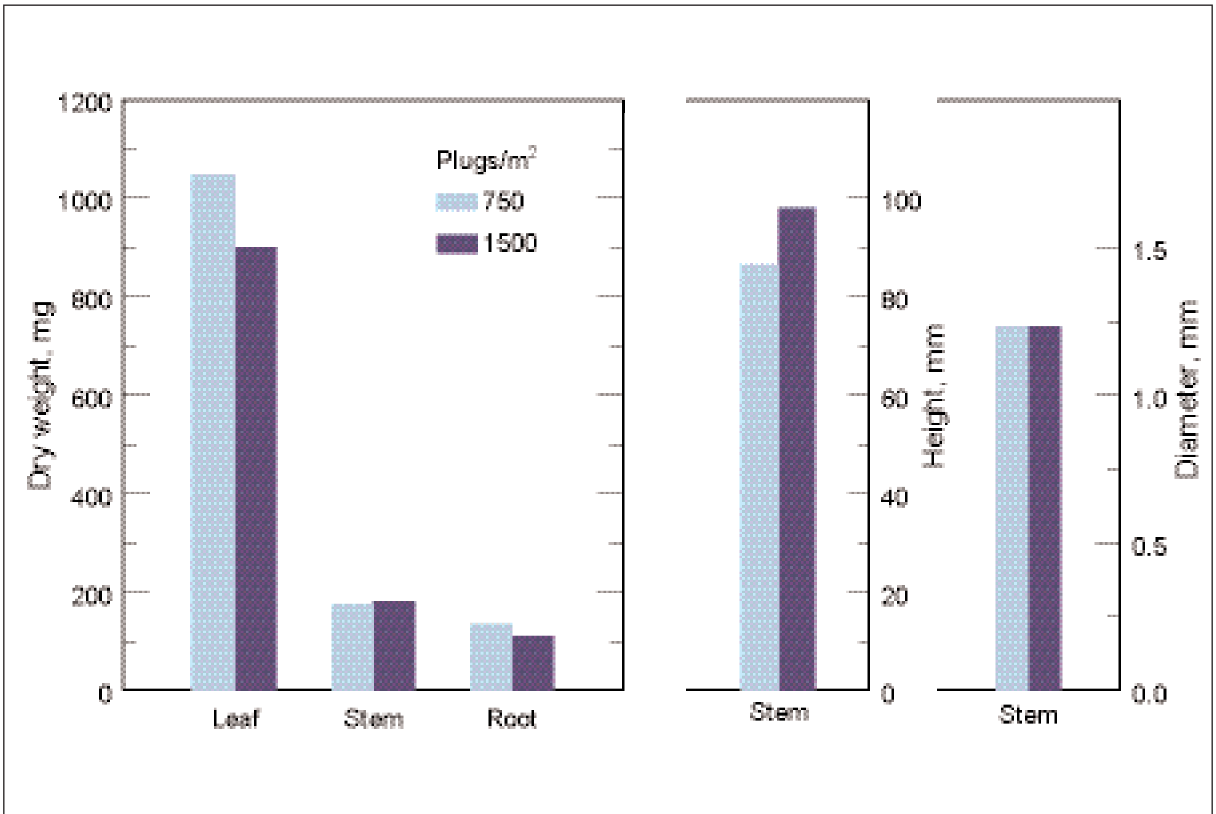

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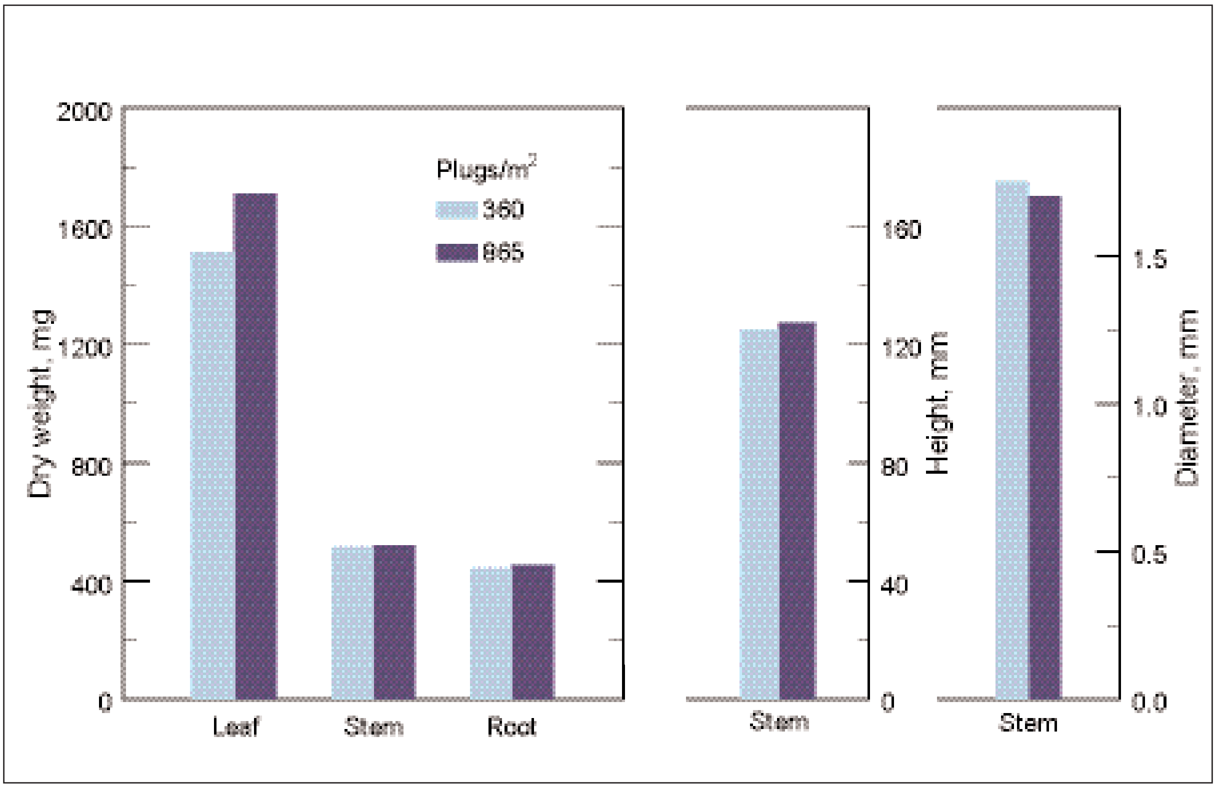

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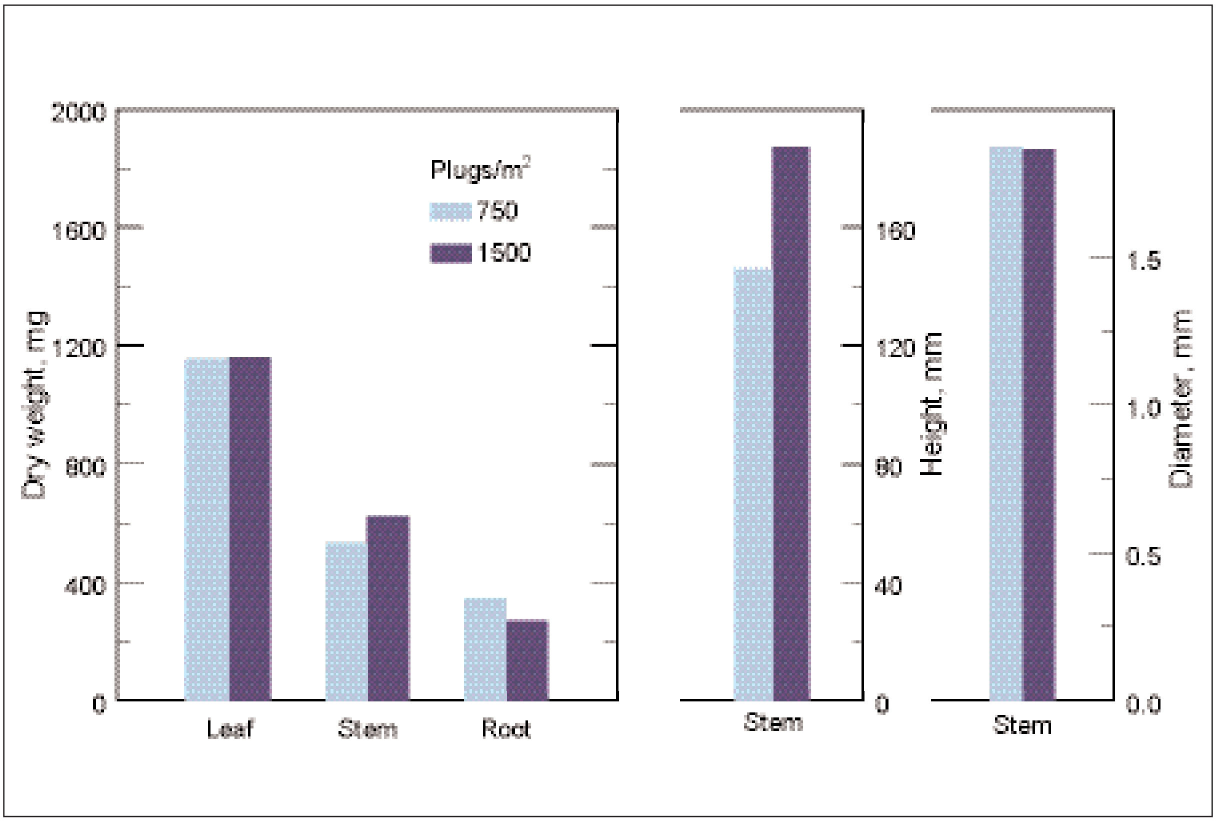

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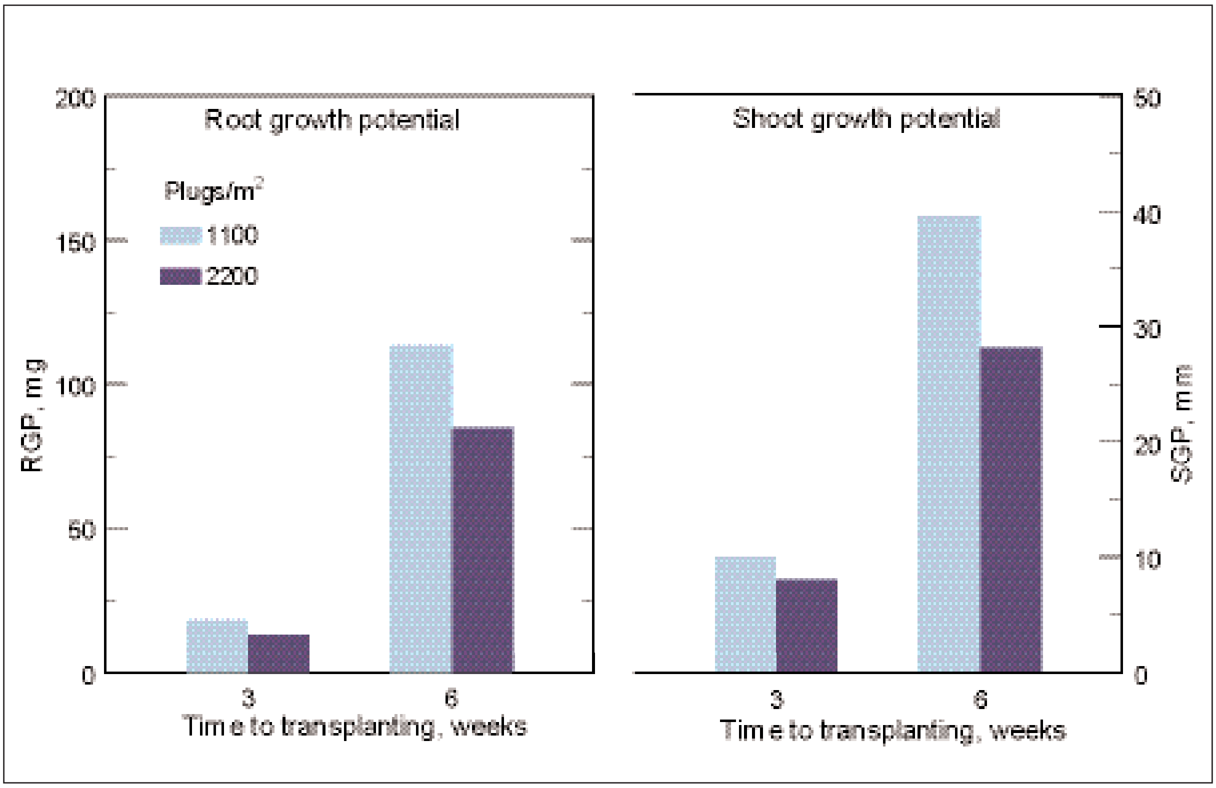

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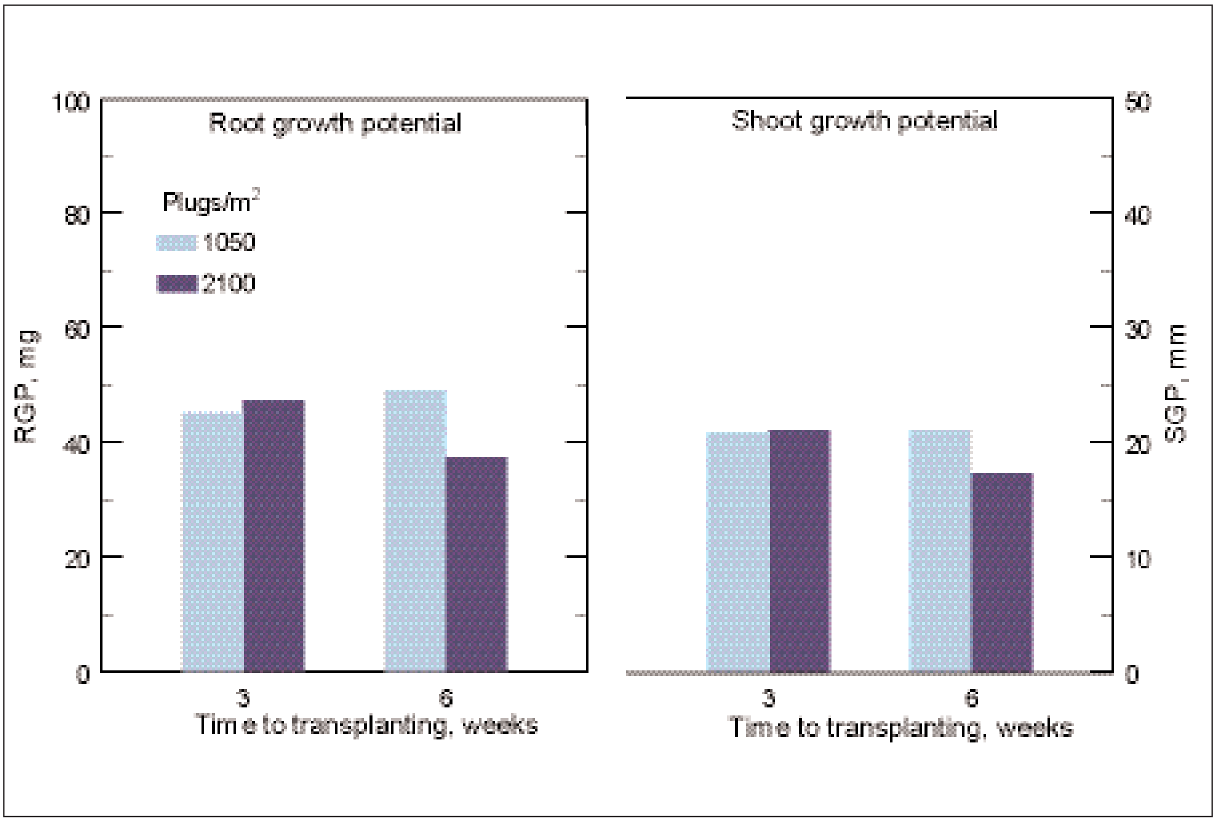

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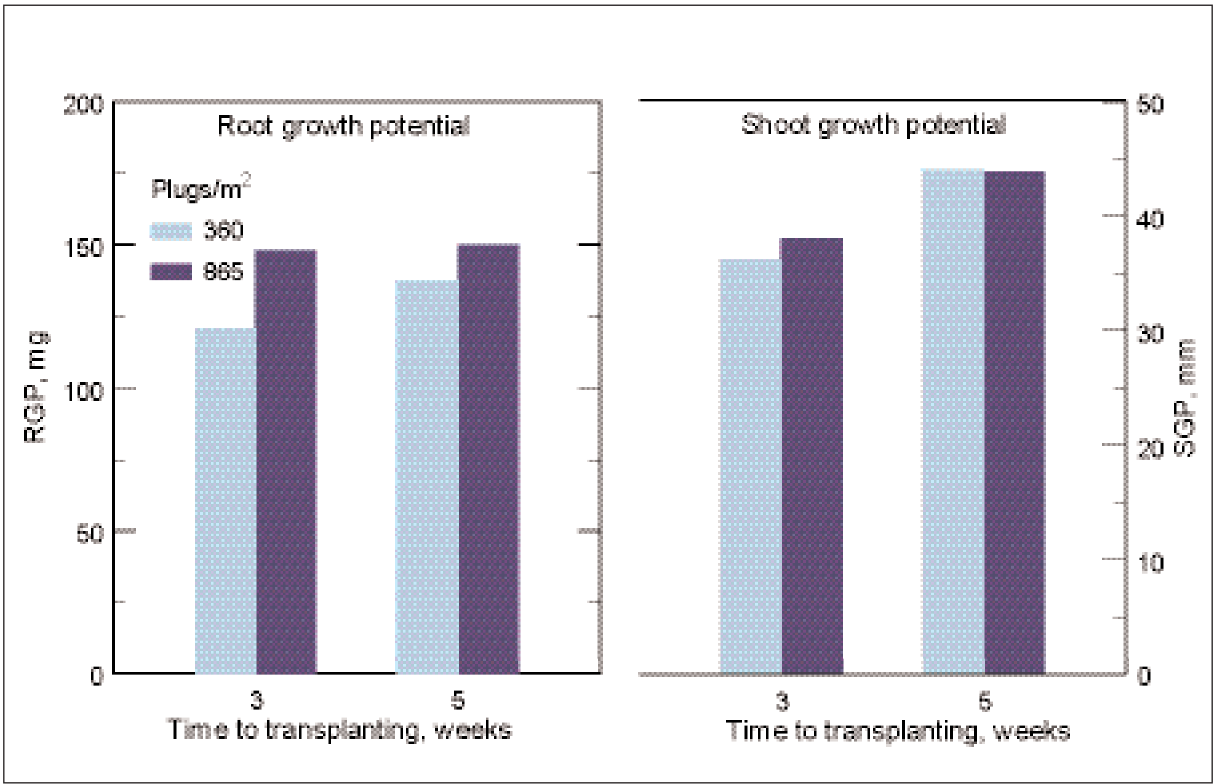

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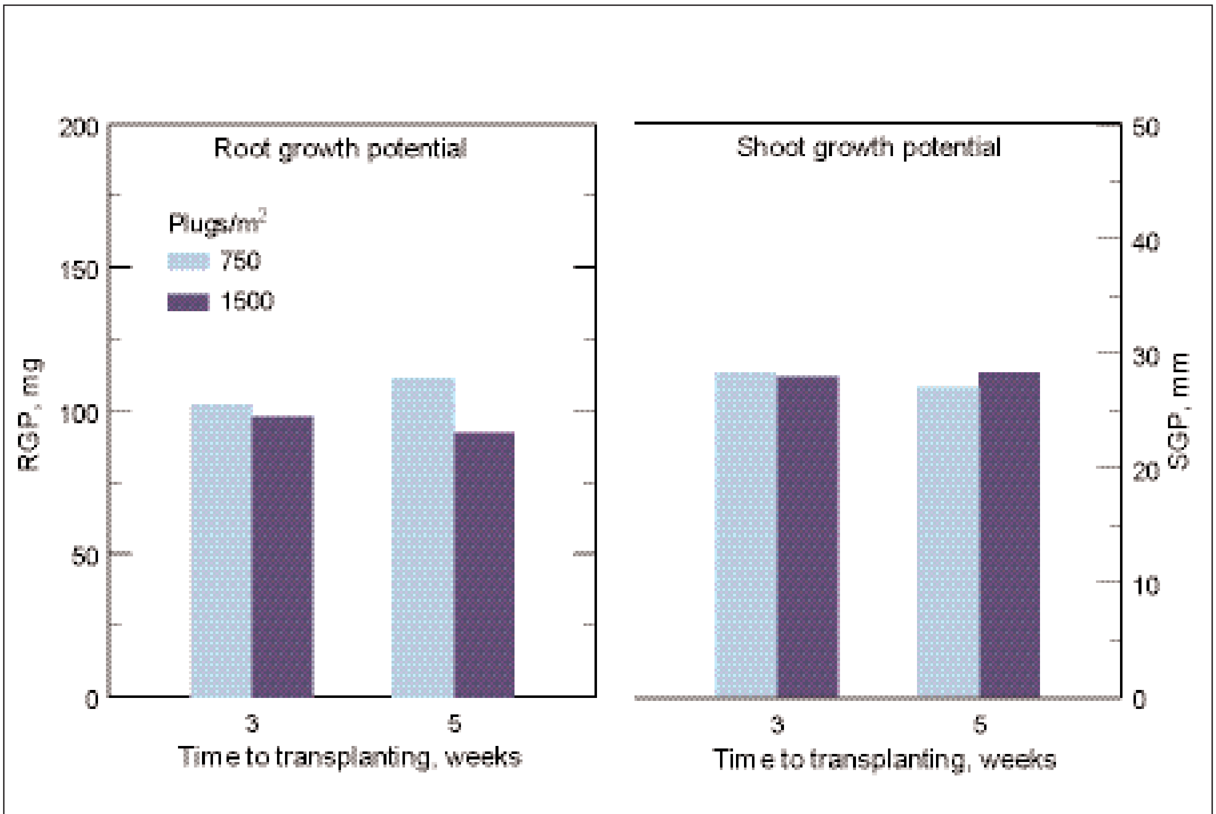

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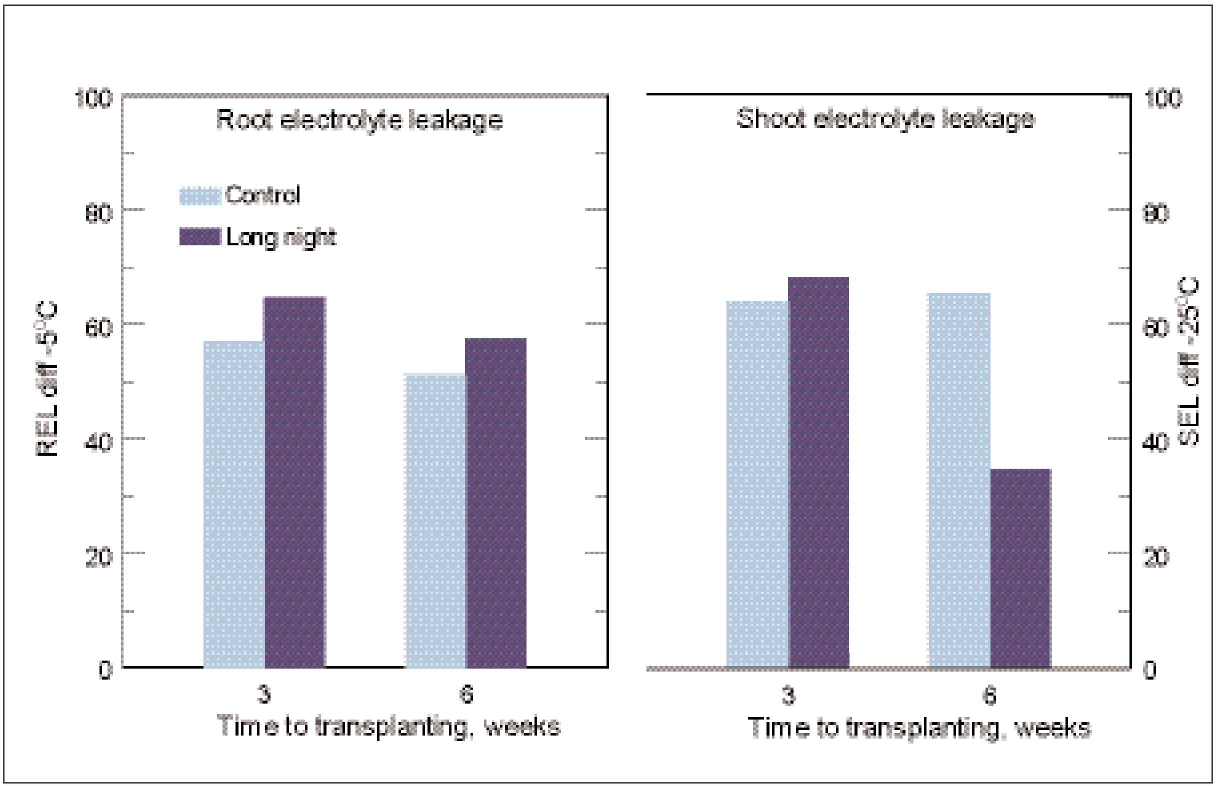

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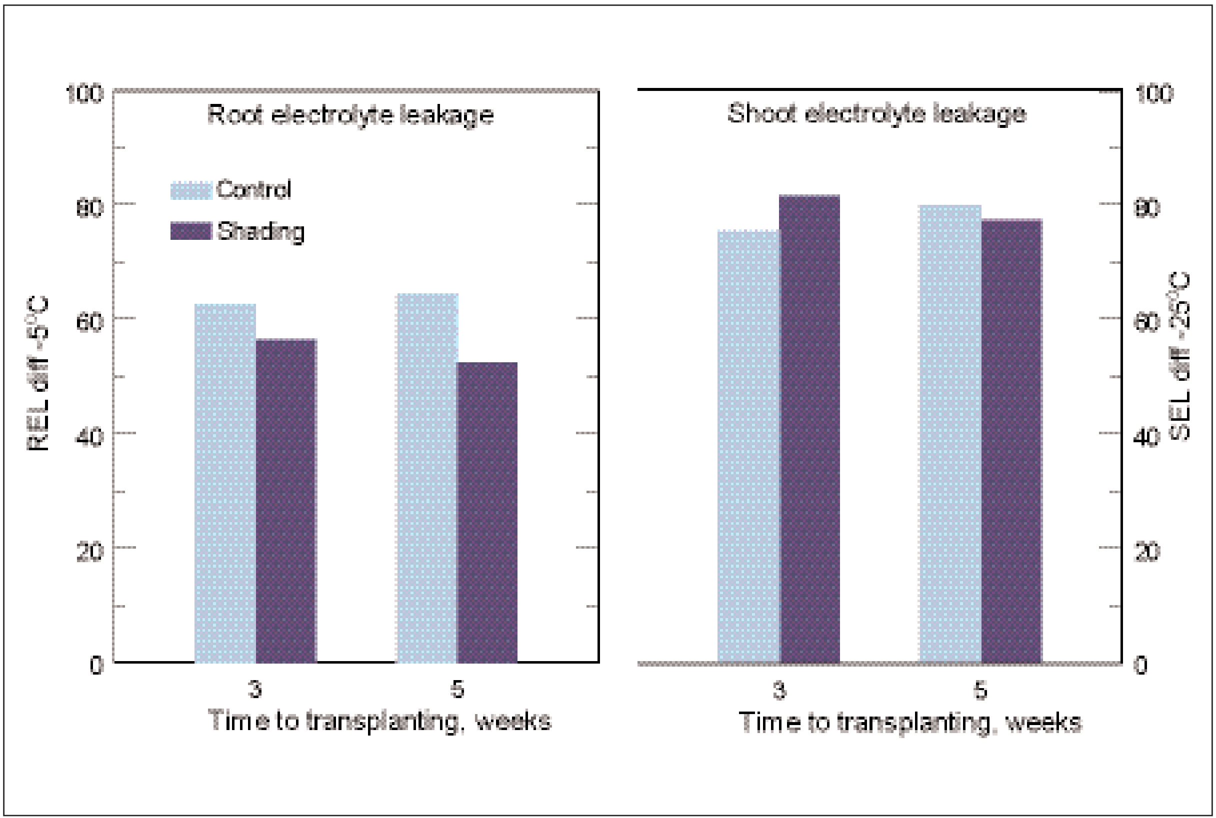

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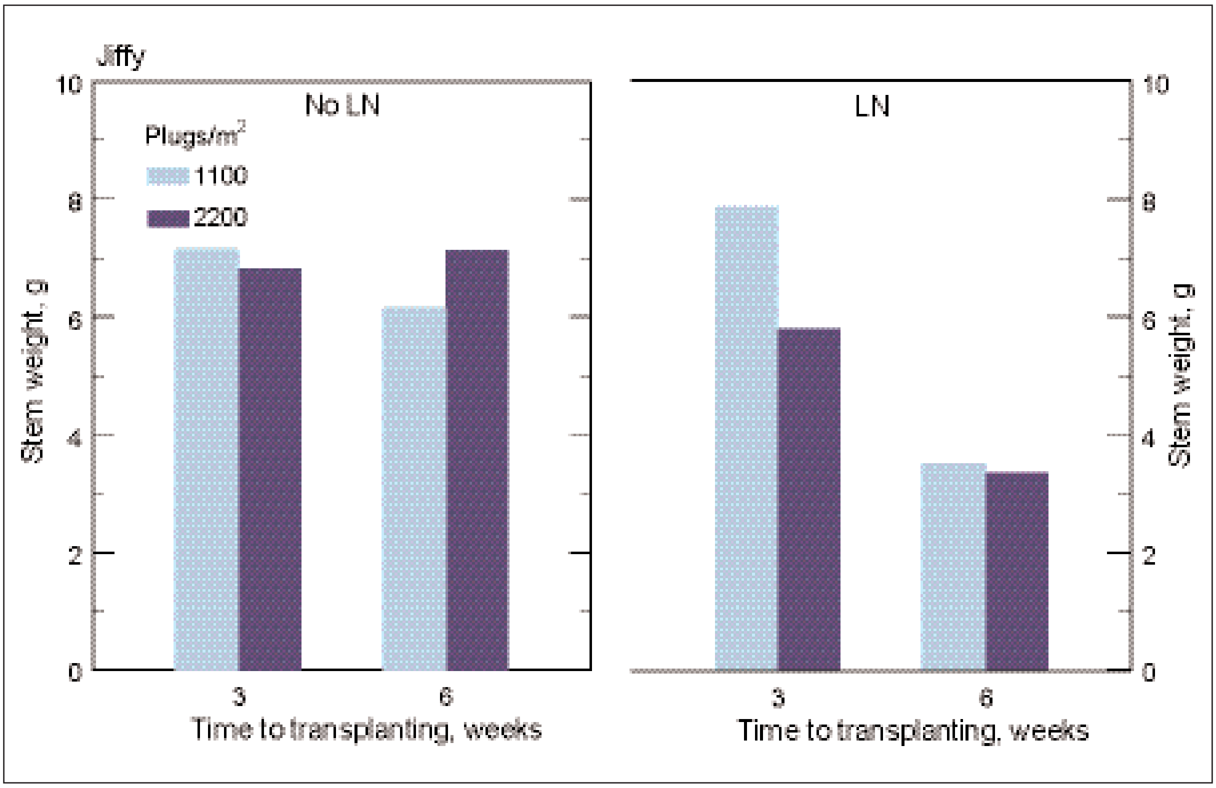

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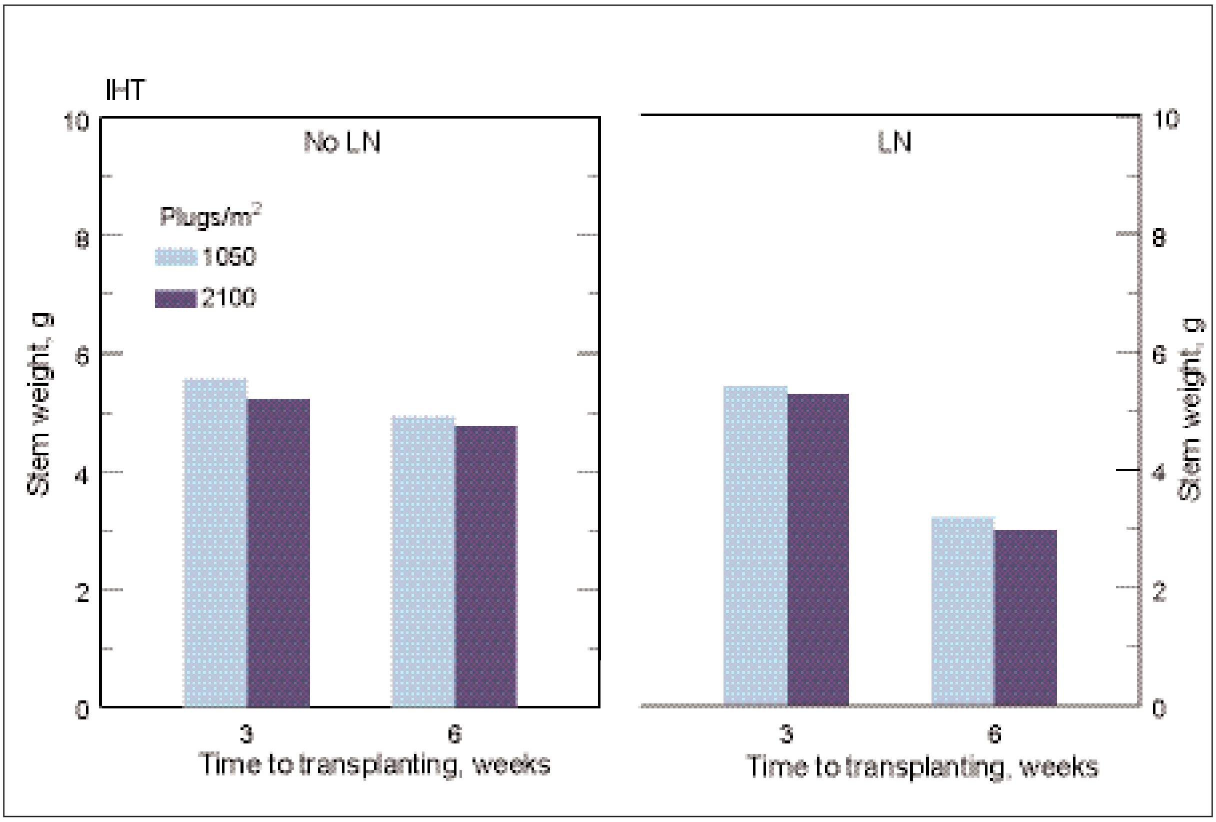

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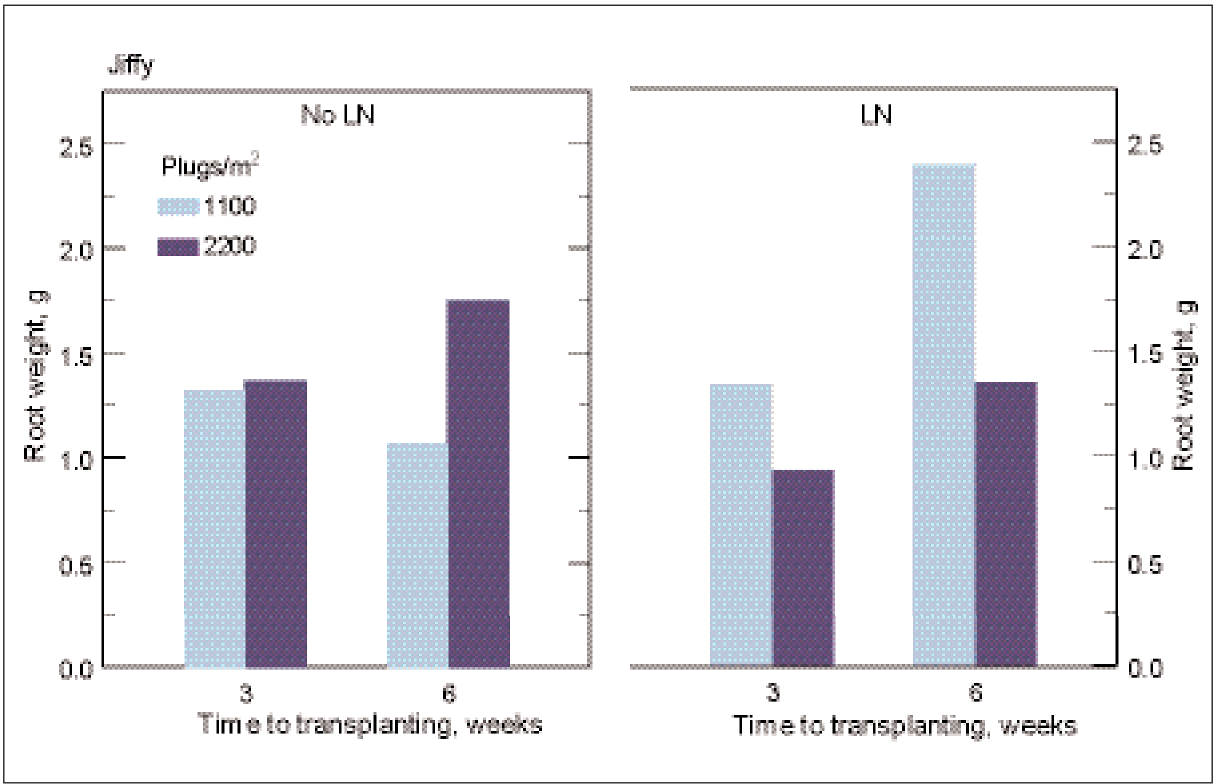

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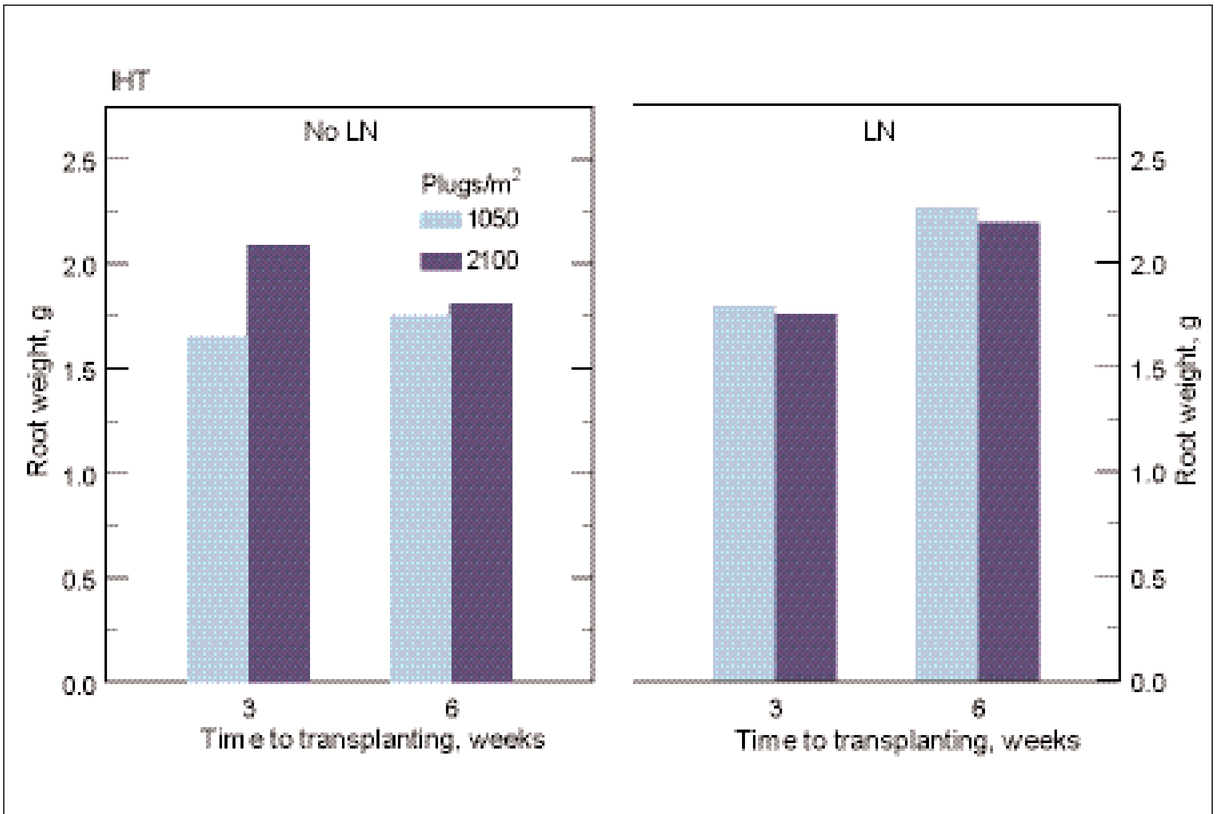

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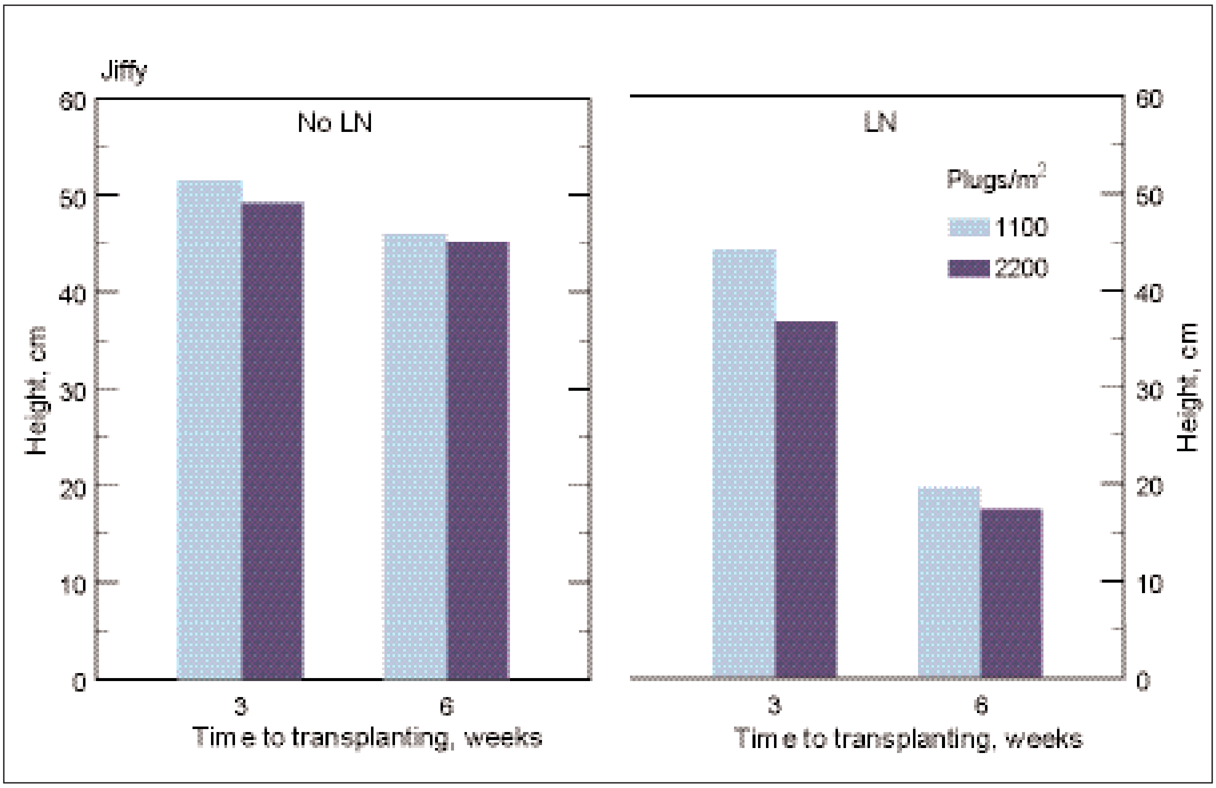

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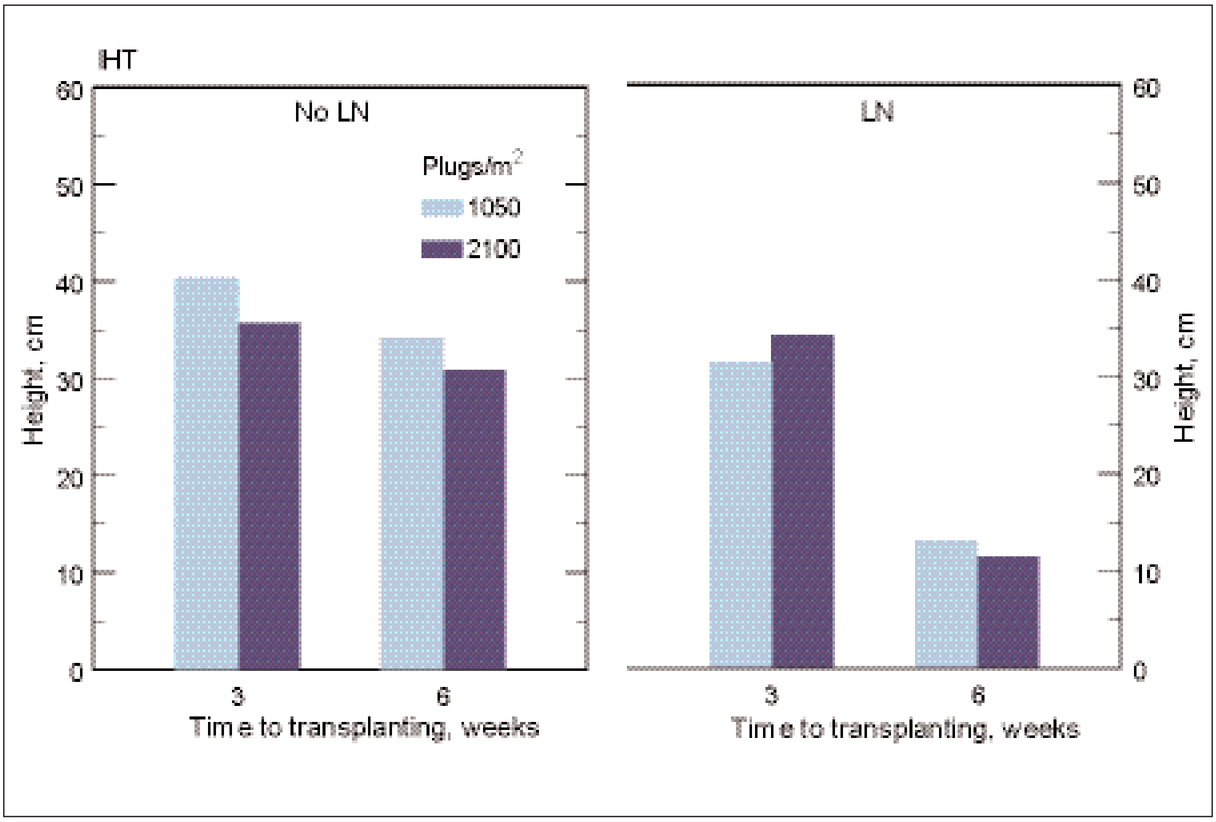

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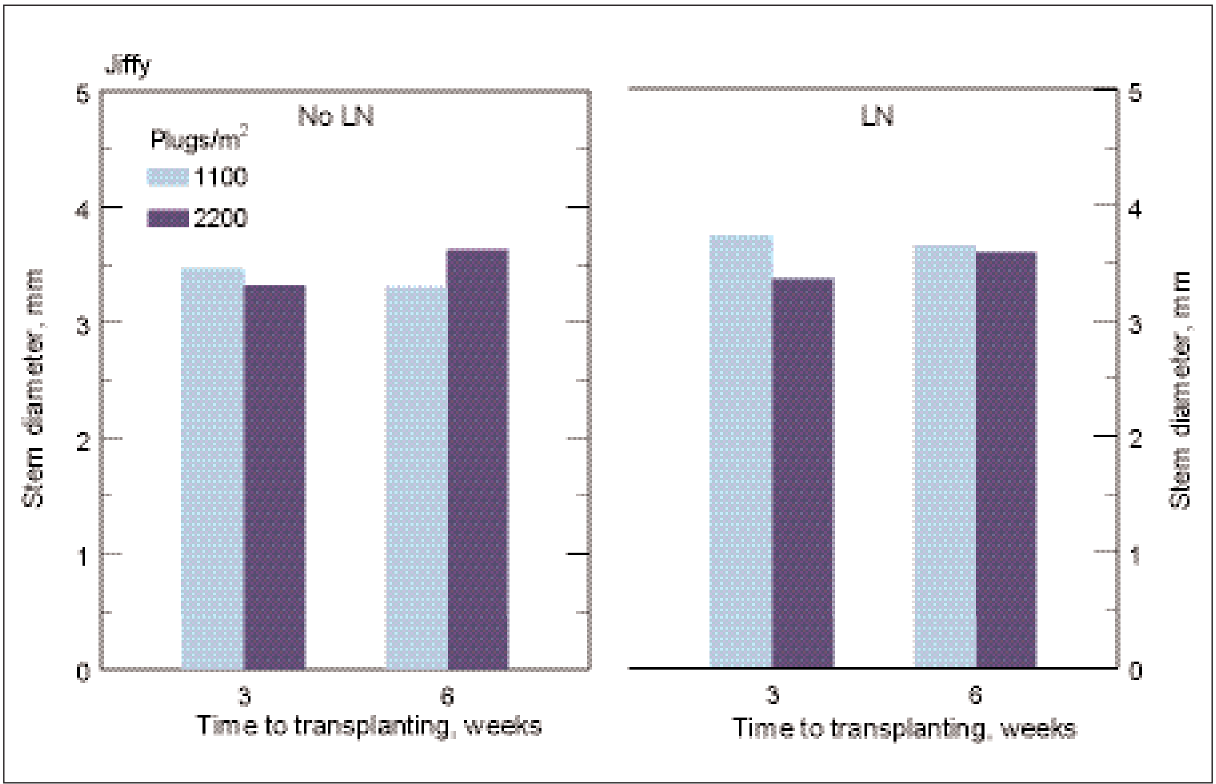

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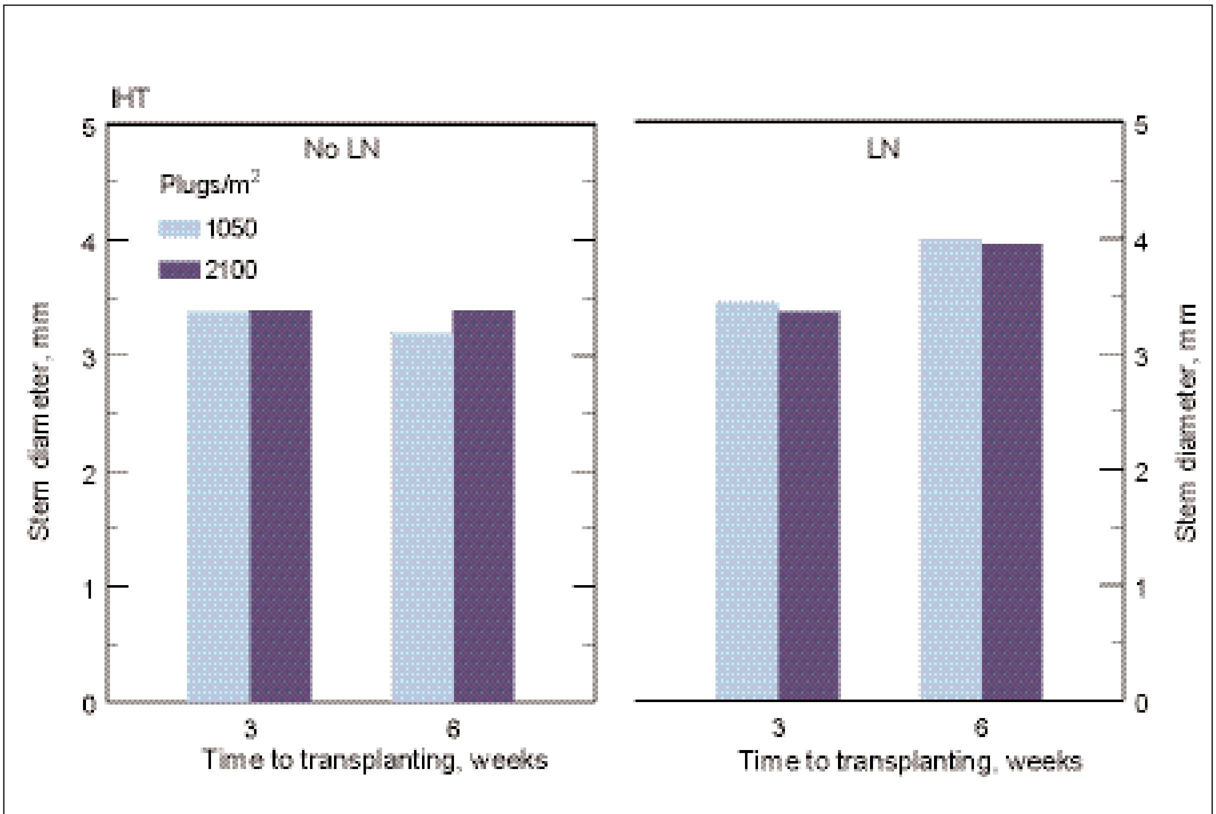

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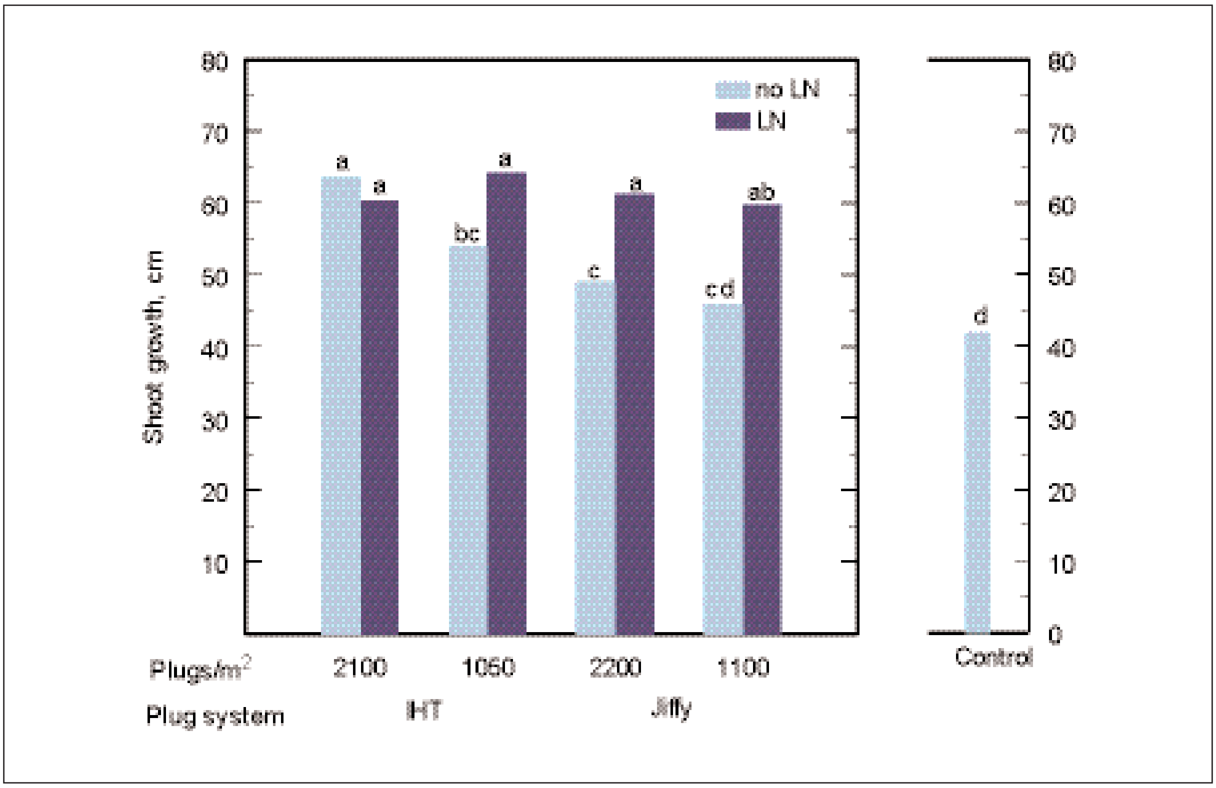

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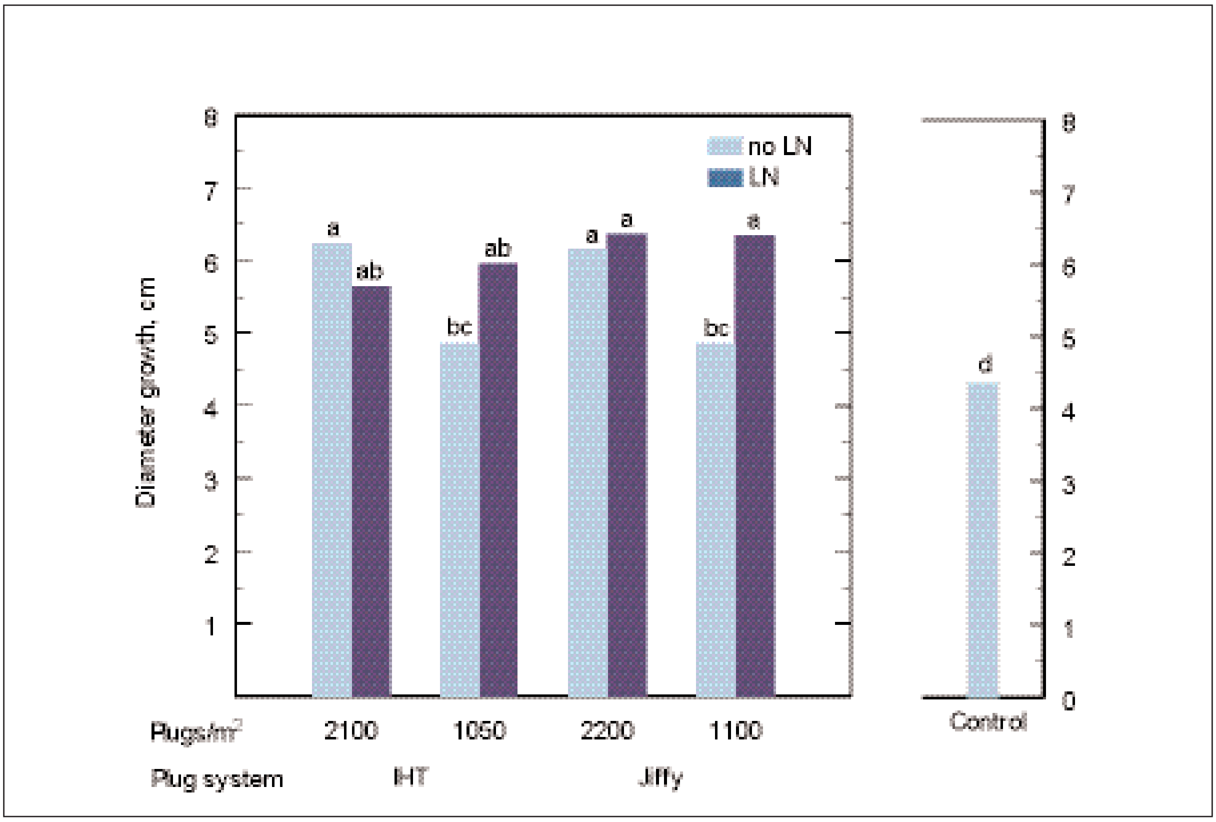


Figure 24

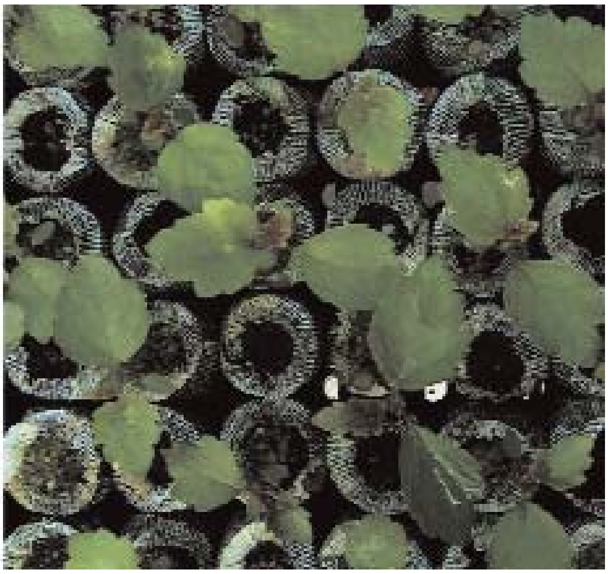
The IHT (left) and Jiffy (right) mini plug system

This picture shows the two mini plug systems tested in the project. They represent two principles for a mini plug that can be used during a short growing time before transplanting where the plug could be transplanted without any demand for a root development intense enough to hold the substrate together by itself.

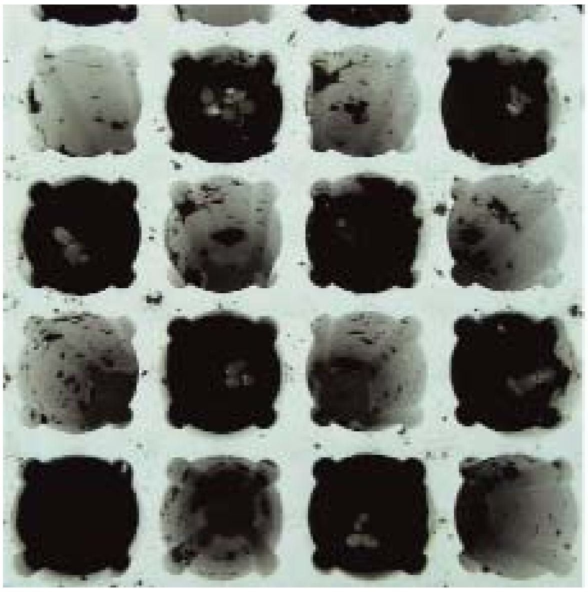
The first principle (IHT) represent a system where the substrate holds together by the application of a special binding agent and the second (Jiffy) by a special net holding the substrate together.

For birch a suitable size, identified in the project for the respective mini plug system correspond to a height of 3 cm and a diameter of 1.5 cm implying a volume of about 7 ml and a density of about 3 500 seedlings per square meter.

Birch, Jiff



Birch, IHT

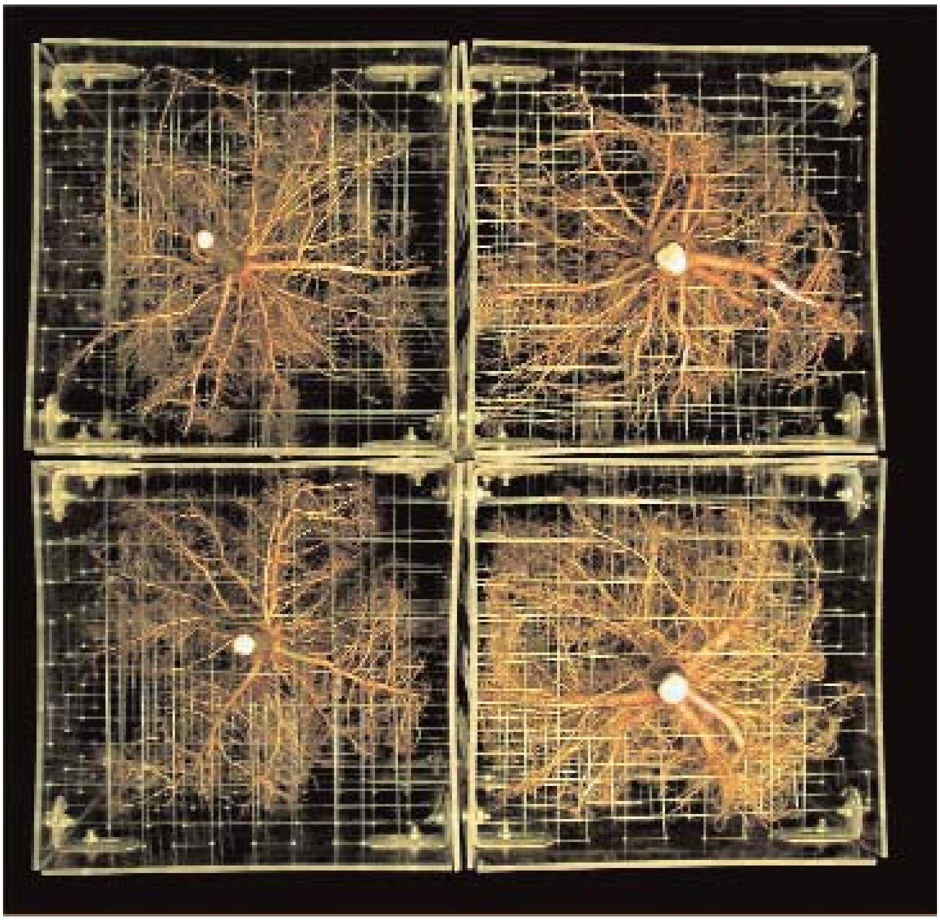


Birch seedlings grown in the two mini plug systems tested (Jiffy and IHT) using different support trays for the respective plug.

Effects of long-night treatment of birch

Birch seedlings sown and transplanted at the same time but later grown without (left) and with (right) a cultural practice including long-night treatment. As can be seen from the picture the long-night treatment had a major impact on the morphological development of the seedling.

Root development for birch seedlings grown in mini plugs and planted in root study boxes



The picture shows the technology of using root study boxes for the analyses of root growth and root architecture for seedlings grown in mini plugs. The boxes were used to identify differences in root development when using various cultural practices with regard to mini plug system, seedling density and growing time to transplanting.

ANNEX 4

Production manual regarding pre-cultivation and transplanting of elm

Growing medium

A stabilised growing medium should be used in the first phase of growth to allow mechanical transplanting.

Growing density and plug volume

The growing density for a cost efficient pre-cultivation of elm seedlings should be about 2,500 plugs per square meter, with a plug volume of about 5 cm^3.

Seed

Elm seeds used for sowing in mini-plugs should be of high quality to allow sowing of one seed per cavity.

Sowing

Before sowing an adequate sowing hole with a depth of about 0.3 cm should be made in the middle of the growing medium for each plug in order to accommodate the seed.

Sowing time

Since the cultivation period for miniplugs from sowing to transplanting is 5 weeks, to allow seedlings to be transferred to open land after transplanting, without the risk of drought, in Italy sowing should take place not later than end of March.

Germination phase

During the germination phase the growing medium should be watered to field capacity. Temperature at seed level should be in the range of 23-25 centigrade and the relative air humidity close to 100%. No fertiliser should be added during the germination phase. Normally the germination phase covers a period of two days.

Growth phase in mini-plugs

During the growth phase watering should be adjusted so that the growing medium is kept at field capacity. Temperature at plant level should be in the range of 20-22 centigrade and the relative air humidity in the range of 60-80%. No fertiliser should be added during the growth phase. Normally the germination phase covers a period of 5 weeks.

Growth phase after transplanting

After transplanting to any optional container system used by the respective nursery, seedlings should be placed on raised pallets and moved to an open field area at the nursery. The watering regime should still allow the growing medium to be kept at field capacity. Fertilisation should start after transplanting and be adjusted to a level of 3g nitrogen per square meter and week until the leaves has fallen.

The second, preferable, option for transplanting miniplugs outdoor nursery beds should take place not later than Mid-May. The watering regime should still allow the growing medium to be kept at field capacity.

ANNEX 5

Production manual regarding pre-cultivation and transplantation of beech

Growing medium

A stabilised growing medium should be used in the first phase of growth to allow mechanical transplanting.

Growing density and plug volume

The growing density for a cost efficient pre-cultivation of beech seedlings should be about 2500 plugs per square meter, with a plug volume of about 5 cm^3.

Seed

Beech seeds used for sowing in mini-plugs should be of high quality (germination > 90%) to allow sowing of one seed per cavity.

Sowing

Before sowing an adequate sowing hole with a depth of about 0.5 cm should be made in the middle of the growing medium in each plug in order to accomodate the seed.

Sowing time

Since the cultivation period for miniplugs from sowing to transplanting is 4-5 weeks, sowing in March in Italy and in April or May in Denmark is recommended as the temperature can be kept low during the germination process.

Germination phase

During the germination phase the growing medium should be watered to field capacity. Temperature at seed level should be in the range of 15-20 centigrade and the relative air humidity close to 100 %. Beech seeds can go into secondary dormancy when germination temperature is above 20*C. No fertiliser should be added during the germination phase. The germination phase covers a period of 1 week, depending on the seed source.

Growth phase in mini-plugs

During the growth phase watering should be adjusted so that the growing medium is kept at field capacity.

Irrigation with a irrigation boom with spraying nozzles gives the smallest amount of water per time compared to other irrigation systems. Irrigation once or more times a day is recommended to avoid desiccation. Growing media can be limed (pH 5.5) and with controlled release fertiliser added.

Normally the growth phase covers a period of 4 weeks.

Growth phase after transplanting

After transplanting to any optional container system or to the field depending on the country and the nursery, seedlings should be irrigated regularly and kept at field capacity.

After transplanting the beech seedlings should be protected against wind and sun for 4 weeks to avoid water stress on the roots.

Transplanting to the forest can be done from September and until frost in December.

ANNEX 6

Production manual regarding pre-cultivation and transplanting and of birch

Growing medium

A stabilised growing medium should be used to allow mechanical transplanting.

Growing density and plug volume

The growing density for a cost efficient pre-cultivation of birch seedlings should be about 3,500 plugs per square meter with a plug volume of about 5 cm^3.

Seed

Birch seeds used for sowing in mini-plugs should be coated pellets to allow precision sowing of one seed per cavity.

Sowing

Before sowing an adequate sowing hole with a depth of about 0.3 cm should be made in the middle of the growing medium for each plug. One seed should then be distributed to the bottom of each sowing hole by the sowing machine.

Sowing time

To allow seedlings to be transferred to open land after transplanting, without the risk of frost damages, pre-cultivation should start in Sweden by sowing the mini-plugs in the middle of May.

Germination phase

During the germination phase the growing medium should be watered to field capacity. Temperature at seed level should be in the range of 23-25 centigrade and the relative air humidity close to 100%. No fertiliser should be added during the germination phase. Normally the germination phase covers a period of one week.

Growth phase in mini-plugs

During the growth phase watering should be adjusted so that the growing medium is kept at field capacity. Temperature at plant level should be in the range of 20-22 centigrade and the relative air humidity in the range of 60-80%. Light supply should allow a photoperiod of 18 hours at a minimum level of 15,000 lux. No fertiliser should be added during the growth phase. Normally the germination phase covers a period of 2 weeks.

Growth phase after transplanting

After transplanting to any optional container system used by the respective nursery, seedlings should be placed on raised pallets and moved to an open field area at the nursery. The watering regime should still allow the growing medium to be kept at field capacity. Fertilisation should start after transplanting and be adjusted to a level of 3g nitrogen per square meter and week until the leaves has fallen.

Long-night treatment

For those Swedish nurseries that want to use long-night treatment in the production of birch

seedlings they should use the following regime:
Long-night treatment should start in the middle of July by covering the seedlings on the open field area by using the blackout equipment from 4 pm to 8 am leaving a photoperiod for the seedlings of 8 hours. This treatment will then continue for 4 weeks with watering and fertilisation regimes in accordance with the growth phase after transplanting.

ANNEX 7

Pictures from the operational introduction of the new technology developed in the Craft project for production of broad-leaved seedlings. The new technology involves a mini-plug system in combination with a compact multiple-floor germination and growth facility. After a growing period of 3 weeks at optimal conditions the mini-plugs are transplanted to a larger container for cultivation on raised pallets or directly into open field.
Pictures from the introduction, at the Swedish SME nursery, of the new technology (container to container transplanting).

Birch mini-plug seedlings germinated and grown in a compact multiple-floor facility at a density of 3 500 seedlings per square meter for 3 weeks. The picture shows the seedlings being automatically transplanted to a larger container system using a new mobile robot, adapted to the system, with a capacity of 25 000 seedlings per hour.

Birch mini-plug seedlings transplanted into a larger container system at a density of 500 seedlings per square meter

The Swedish partners in the Craft project (left: Anders Mattsson, RTD performer, Dalarna University, right: Staffan Nilsson, SME proposer, Södra Skogsplantor) inspecting the result from the first operational test of the new production technology developed within the project.

The introduction at the nursery also attracted a lot of interest from other invited growers of forest nursery stock.

Close-up picture of the birch seedlings from the mini-plug system transplanted into the larger container system used by the Swedish SME.

Pictures from the introduction, at the Italian SME nursery, of the new technology (container to open field transplanting)

Elm seedlings ready to be transplanted by machine.

Transplanter used for mechanical transplantation in 2002.

Transplanter in action

Close up of seedlings after transplantation

Checking seedlings status after transplantation

Sprinkler irrigation installation