Research Note

EFFECT OF NURSERY PRODUCTION METHOD AND PLANTING TECHNIQUES ON TREE ESTABLISHMENT IN URBAN SITES: PRELIMINARY RESULTS

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In recent years, nurserymen have become increasingly aware of the advantages offered by container-grown nursery stock, especially when planting time is limited, when planting during the growing season, or when transplanting to adverse sites. Nursery production techniques can influence plant performance and initial maintenance practices (Gilman 1994) but, while many production methods have been recently developed (Appleton 1995), only a few comparisons have been made on post-transplant growth (Arnold 1994; Gilman and Beeson 1996). Moreover, the results often are contradictory because of varied protocols and their interactions with the physiological condition of the trees at the time of transplanting, climate, microclimate, soil characteristics, and post-transplant care—factors that seldom are consistent among experiments.

Some authors report that container-grown plants frequently establish poorly when moved to the landscape (Costello and Paul 1975; Gilman 1994), while others found no differences in establishment among different production methods, including balled-and-burlapped (B&B) and plastic containers. Gilman (1994) states that trees from a variety of production systems perform almost equally well if regularly irrigated. Thus, water stress after transplanting is the most limiting factor for plant growth and probably the major factor responsible for planting failure (Watson and Himelick 1998).

Numerous cultural practices have been developed to aid establishment. Use of soil amendments to improve backfill soil structure and aeration are common practices, especially in the urban environment (Rose and Smith 1997). However, some research projects showed that amendments may not be beneficial (Watson and Himelick 1998) and could in fact be detrimental.

Among the different soil amendments, composted organic waste material (compost) has shown potential benefits both for soil structure and plant growth (Rose 1997). It is, however, of paramount importance that compost be stable before use.

As to the nonconventional sources of organic matter suitable for soil amendments, different humic-acid-derived materials have improved soil characteristics and plant growth (Obreza and Biggs 1989). The application of leonardite, an oxidized form of lignitic coal (marketed as a humus-based commercial preparation), has increased shoot growth, ion adsorption and accumulation, root growth, and the number of lateral roots produced on some vegetable crops (Duval et al. 1998). However, little research on their use in urban plantings has been done.

The purpose of this study was to evaluate the effects of two different nursery production methods and backfill compositions on tree performance after transplanting in the urban landscape.

MATERIALS AND METHODS

Plant Material

In March 1998, 24 uniform, five-year-old, 4- to 4.5-m-tall (13 to 15 ft), 12- to 14-cm-circumference (5 to 6 in.), balled-and-burlapped, grafted English oak (*Quercus robur* L.) cv 'Select' trees were planted in a public park in Florence, Italy. An additional 24 Airplant® container-grown trees with identical size characteristics were obtained from the same nursery and planted at the same time. The Airplant is a new type of container, suitable for a medium- to large-sized tree cultivation, recently developed by Piante Mati (Pistoia, Italy). Its design is supposed to induce roots to grow downward into the center of the container, an area usually less colonized by roots. This downward growth results in a better root system, with fewer circling and kinking roots and with intact root tips (Fiorino et al. 1998).

Until late 1970s, the park was used as a rubble dump to fill the depression left after the draining of ponds. When filled, the rubble was covered with a 80- to 100-cm-deep (approximately 3 ft) layer of clay soil. Planting holes were two times the width and 1.5 times the depth of the root ball. Trees were placed in the planting holes and backfilled with 1) excavated soil with 50% of high-quality compost obtained through aerobic biostabilization of selected organic residues; 2) excavated soil + leonardite, 2 kg of the commercial product Humisol; or 3) excavated soil + Nitrophoska blu Spezial, 1 kg (12-12-12 with magnesium, sulfur, and some microelements). Holes backfilled with excavated soil were used as the control.

Table 1. Leaf area (LA), shoot length, net photosynthesis (Pn), and water use efficiency (WUE) of English oak (*Quercus robur* 'Select') as affected by different nursery production methods.

Treatment	LA[z] (cm^2)	Shoot length[y] (cm)	Pn[x] (μmol CO_2*m^{-2}*sec^{-1})	WUE[w] (μmol CO_2*mmol H_2O)
Balled-and-burlapped[v]	19.18 b[t]	4.68 a	7.51 a	9.36 a
Airplant[u]	25.95 a	3.65 b	7.34 a	7.85 b

[z]Each value is the mean of 50 leaves per plant.
[y]Each value is the mean of 20 shoots per plant.
[x]Readings were taken on five fully expanded leaves per plant under condition of light saturation (PAR > 1,000 $\mu molm^{-2}s^{-1}$) on two dates and averaged.
[w]WUE was calculated by dividing Pn by E.
[v]Balled-and-burlapped five-year-old, 4- to 4.5-m-tall (13- to 15-ft), 12- to 14-cm-circumference (5- to 6-in.) plants.
[u]Airplant container plants with identical characteristics.
[t]Means within columns followed by different letters are significantly different from each other using LSD test, α = 0.05 level.

Six single-plant replicates of two production methods and four with the backfilling material were planted in a completely randomized design. Trees were watered, and some soil was added to compensate for settling. Trees were irrigated once a week during spring and summer 1998 with 40 to 50 L (11 to 13 gal) per plant.

Data Collection

From budbreak (April) to the end of June (when no further shoot elongation was detected), shoot length was determined biweekly on 20 shoots per plant. Trunk diameter was measured at planting and the following winter at 30 and 120 cm (12 to 47 in.) from the ground. Leaf area was calculated by measuring the area of 50 leaves per plant with a CID CI-203 leaf area meter (CID Inc., Vancouver, WA). Instantaneous net photosynthesis (Pn), transpiration rate (E), and water use efficiency (WUE, calculated by dividing Pn by E) were measured 100 and 123 days after planting, using the ADC-LCA-2 portable infrared gas analyzer. The readings were taken 17 June and 10 July between 800 and 1100 hours on five fully expanded leaves (chosen from the outer part of the crown and at different heights) per plant under conditions of light saturation (PAR > 1,000 μmol $m^{-2}s^{-1}$).

Data Analysis

Data were analyzed using the multifactor analysis of variance (production method × backfill soil) using SPSS (Release 8.0 for Windows 95). Treatment means were separated by LSD, with an $\alpha \leq 0.05$ level of significance.

RESULTS AND DISCUSSION

Results indicate that shoot growth was statistically higher in the B&B plants than in plants produced in the Airplant system. The authors feel that reduced growth of Airplant material might be the result of increased drought stress susceptibility even when irrigated once a week (Table 1). Trees that received compost grew significantly better than trees backfilled with leonardite (Table 2). Leaf area was significantly higher in the Airplant trees and in the fertilization treatment than in compost-added and control trees. No interactions were found between backfill × plant production systems.

No statistical differences were detected in photosynthesis among the different treatments (Table 1 and Table 2). Balled-and-burlapped trees used water more efficiently than did the Airplant trees (Table 1). Compost addition to backfill increased WUE. The presence of compost in the planting hole might have increased the water-holding capacity of the backfill, thus allowing plants to prolong shoot extension in spite of high temperatures and no rain following transplanting.

Results of this experiment are to be considered preliminary. Further research is needed both to confirm these results and to understand the long-term effects of the different planting-hole backfill mixes on soil chemical and physical properties and on tree physiology.

Table 2. Leaf area (LA), shoot length, net photosynthesis (Pn), and water use efficiency (WUE) of English oak (*Quercus robur* 'Select') as affected by different planting-hole backfill mixes.

Treatment	LA[z] (cm^2)	Shoot length[y] (cm)	Pn[x] ($\mu mol\ CO_2 * m^{-2} * sec^{-1}$)	WUE[w] ($\mu mol\ CO_2 * mmol\ H_2O$)
Compost[v]	20.80 br	4.73 a	7.81 a	9.46 a
Fertilization[u]	24.99 a	4.40 ab	7.40 a	8.42 ab
Leonardite[t]	22.02 ab	3.89 b	7.21 a	7.31 b
Control[s]	20.85 b	4.02 ab	7.22 a	8.89 ab

[z]Each value is the mean of 50 leaves per plant.
[y]Each value is the mean of 20 shoots per plant.
[x]Readings were taken on five fully expanded leaves per plant under condition of light saturation (PAR > 1,000 $\mu molm^{-2}s^{-1}$) on two dates and averaged.
[w]WUE was calculated by dividing Pn by E.
[v]Excavated soil with 50% of high quality compost.
[u]Excavated soil + Nitrophoska blu Spezial, 1 kg.
[t]Excavated soil + leonardite, 2 kg of commercial product Humisol.
[s]Holes backfilled with excavated soil.
[r]Means within columns followed by different letters are significantly different from each other using LSD test, α = 0.05 level.

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Zusammenfassung. Im ersten Jahr nach der Verpflanzung in eine Stadtumgebung wurde das Wachstum im Anschluß an die Verpflanzung und die Physiologie von Englischen Eichen bewertet. Es wurden zwei Pflanzenproduktionsmethoden, "Airplant®", ein kürzlich entwickelter Plastikcontainer, und balliert und eingeschlagen (B&B), und vier Rückfüllmaterialien studiert: a) ausgebaggerter Boden + 50 % Grünkompost, b) Boden + kommerziell produziertes Leonardite auf Humusbasis, c) mit Nitrophoska Blu Spezial gedüngten Boden. Die Pflanzgruben nur mit Boden verfüllt wurden als Kontrollgruben verwandt d). Der Stammdurchmesser, Triebwachstum, Blattfläche und das Frisch- und Trockengewicht der Blätter wurde gemessen. Die Effekte der Behandlungen auf die Pflanzenphysiologie wurde durch Messung der Photosynthese und Transpirationrate charakterisiert. Mit "Airplant" kultivierte Bäume zeigten eine größere Blattfläche, Trocken- und Frischgewicht und niedrigeres Triebwachstum und Netto-Photosynthese im Vergleich zur B&B Methode. Die Reaktionen der Bäume auf die Verfüllung variierte in Beziehung zu den vorgegebenen Parametern. Trotzdem stand bei unseren Ergebnissen im Vordergrund, daß die Zugabe von Kompost positive Auswirkungen auf Pflanzenwachstum und Physiologie hatte. Diese Studie, obwohl eingeschränkt, zeigte einige Differenzen in der Baumentwicklung, die verdeutlichen, wie sehr Baumschulproduktionsmethoden und Rückfüllmaterialien die Etablierung von Bäumen in der Landschaft beeinflußen. Eine weitere Forschung soll die Effekte von Rückfüllmaterialien auf verschiedenen Böden und auf die Baumphysiologie untersuchen.

Résumé. La croissance post-transplantation et la physiologie de chênes pédonculés plantés dans les aménagements paysagers urbains ont été évalués au cours de la première année suivant la transplantation. Deux types différents de production de plants, soient Airplant® (une technique de production en contenant de plastique récemment développée) et en motte, ainsi que quatre types différents de matériaux de remblais des fosses de plantation ont été étudiés, soient pour ces derniers: a) sol d'excavation + 50% de compost vert, b) sol d'excavation + préparation commerciale à base d'humus de leonardite, c) sol d'excavation fertilisé avec le Nitrophoska Blu Spezial, d) sol d'excavation seulement pour les arbres témoins. Le diamètre du tronc, la croissance des pousses, la surface foliaire ainsi que la masse humide et sèche des feuilles ont été mesurés. Les effets des traitements sur la physiologie des plantes ont été caractérisés par des mesures de taux de respiration et de photosynthèse. Les arbres cultivés par Airplant® avaient une plus grande surface foliaire tout comme des masses sèches et humides, de même qu'une croissance des pousses et une photosynthèse nette plus faibles par rapport aux arbres en motte. Les réponses des arbres au matériel de remblai ont été variables en fonction des divers paramètres considérés. Néanmoins, nos recherches ont mis en évidence que l'ajout de compost avait des effets positifs sur la croissance des plantes et leur physiologie. Cette étude, bien que préliminaire, a exposé certaines différences dans la performance des arbres, ce qui révèle comment les méthodes de production des arbres en pépinière ainsi que le matériaux de remblai utilisés peuvent affecter la reprise dans les aménagements. Des recherches futures vont étudier les effets des divers matériaux de remblai sur les propriétés du sol et la physiologie de l'arbre.

Resumen. Fue evaluado el crecimiento post-trasplante y la fisiología de árboles de roble inglés plantados en el paisaje urbano durante el primer año después del trasplante. Se estudiaron dos métodos de plantación: "Airplant®", un contenedor de plástico desarrollado recientemente y el de bola en arpillera (B&B); y cuatro materiales de relleno del hoyo de plantación: a) suelo excavado + 50% de compost verde; b) suelo excavado + preparación comercial basada en humus de leonardite; c) suelo excavado fertilizado con Nitrofoska Azul Especial. Los hoyos llenos solamente con suelo excavado fueron usados como control (d). Se midió el diámetro del tronco, el crecimiento de los brotes, el área foliar y el peso fresco y seco del follaje. Los efectos de los tratamientos sobre la fisiología de las hojas estuvieron caracterizados por las mediciones de la fotosíntesis y la tasa de transpiración. Los árboles cultivados con Airplant mostraron una mayor área foliar y peso fresco y seco, y menor crecimiento de los brotes y fotosíntesis neta, comparados con los B&B. La respuesta de los árboles al material de relleno fue variable con relación al parámetro considerado. Sin embargo, nuestros hallazgos destacan que la adición de compost tuvo efectos positivos sobre el crecimiento de las plantas y su fisiología. El estudio, aunque preliminar, mostró algunas diferencias en el comportamiento de los árboles, los cuales revelaron cómo los métodos de producción en viveros y los materiales de relleno afectan el establecimiento de los árboles en el paisaje. La investigación en el futuro estudiará los efectos de los materiales de relleno sobre diferentes propiedades del suelo y sobre la fisiología del árbol.