Scientia Horticulturae 178 (2014) 124–131

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Influence of nursery production system on water status in transplanted trees

Anna Levinsson[a,*], Arne Sæbø[b], Ann-Mari Fransson[a]

[a] Department of Landscape Architecture, Planning and Management, Swedish University of Agricultural Sciences, Slottsvägen 5, SE-230 53 Alnarp, Sweden
[b] Department of Horticulture and Urban Greening, Bioforsk Vest, 4353 Klepp, Norway

ARTICLE INFO

Article history:
Received 19 May 2014
Received in revised form 18 August 2014
Accepted 22 August 2014
Available online 7 September 2014

Keywords:
Leaf surface area
Prunus avium
Quercus rubra
Shoot water potential
Urban tree establishment

ABSTRACT

The objective of this study was to investigate the influence of the nursery production system on post-transplant water uptake and stress in urban trees during the establishment phase. Field-grown trees of sweet cherry (*Prunus avium* L) and red oak (*Quercus rubra* L) were either transplanted as bare-rooted or balled & burlapped, or subjected to fine-root-stimulating measures (in so called pre-establishing systems) as root-pruning, air-potting or fabric-container-cultivation in the nurseries one year prior to transplanting. All trees were planted at two sites: one occasionally dry site in the city of Malmö and one with adequate water supply at all times, at an experimental rural site at Alnarp campus, both in Sweden. Shoot water potential was determined every third week at midday and pre-dawn the following morning during the three first years after transplanting. Leaf surface area was measured annually. The red oak trees from the pre-establishing systems showed higher water potentials at every measuring occasion compared to that of bare-rooted red oak trees at the rural site during the first year. The air-potted sweet cherry trees at the rural site had higher midday water potential than the bare-rooted trees at every measuring occasion during the first year. Leaf surface area was larger for air-potted red oaks than bare-rooted red oaks during the first post-transplant year ($p < 0.001$, both sites). The differences between the production systems did not persist during the following two years. Leaf surface area was restored to pre-transplant size in all trees at the rural site after three years but still reduced at the urban site. These results suggest that the pre-establishing systems do have an impact on water status when soil water availability is sufficient, but less significance in typically urban areas, with limited soil water during the initial post-transplant phase. The results indicate that red oak and sweet cherry trees planted in an urban context, with occasionally low soil water amounts, are not favored by cultivation in pre-establishing systems prior to transplant, and that low water availability cannot be compensated for by high amounts of fine roots. Good establishment management is required also for trees submitted to pre-establishing measures.

1. Introduction

Most of the benefits associated with trees in urban areas increase with tree size and age (Akbari, 2002; Fowler et al., 1989; Tyrvainen et al., 2007). Securing and improving the establishment of urban trees is essential for both initial survival and long-term development toward an old and fully-sized tree. Water uptake after transplanting is crucial for a successful establishment, and is dependent on both the water availability at the transplanting site and the water uptake capacity of the root system. Water availability is often limited in urban areas, increasing the need of a highly capable root system at transplanting to avoid planting failure. Failure constitutes an economic loss for the companies or cities involved, as well as being a waste of resources.

Water availability is often lower in urban soils than in park or woodland soils due to restricted root space, poorer soil quality, drainages and impervious surfaces, especially paved areas, which prevent infiltration (Harris, 2007; Ugolini et al., 2012; Whitcomb, 1979). In addition, atmospheric evaporative demand is often higher in urban areas due to higher temperatures than in less harsh growing sites. These factors often result in drought stress, driven by negative above- and below-ground abiotic conditions (Cregg and Dix, 2001; Grossnickle, 2005; Oke, 1982).

During the establishment phase trees generally have a low vitality, are less resistant to drought, and are vulnerable to both disease and temperature fluctuations outside the normal range (Kozlowski, 1991). Poor establishment of trees in urban areas has been widely reported, and is strongly related to a deficit of water (Harris, 2007;

* Corresponding author. Tel.: +46 40415154.
E-mail address: anna.levinsson@slu.se (A. Levinsson).

http://dx.doi.org/10.1016/j.scienta.2014.08.020
0304-4238/

Watson, 1996). When a tree is taken from the nursery and transplanted at a new site, the water uptake of the roots is inevitably disrupted, due to a reduction in the amount of fine roots, or by temporary loss of root–soil contact (Burdett, 1990; Rietveld, 1989). To become established at the new growing site, the trees need get fully coupled to the hydraulic cycle of the site by root-exploration of the new soil (Grossnickle, 2005). However, before that, during the initial post-transplant period, trees have to rely on their existing root system for water uptake and further initiation of root regeneration to develop a functional root-shoot balance for the new conditions (Brouwer, 1983; Larson and Whitmore, 1970). The quality of the root system at transplanting and the water availability at the site are, therefore, crucial factors for the survival and development of newly planted trees (Gilman, 2004; Grossnickle, 2005; Rietveld, 1989).

Red oak has been shown to reduce its leaf surface area in response to drought stress, thereby diminishing its evaporative surface (Jacobs et al., 2009; Struve and Joly, 1992). Although a reduction in the transpiring surface decreases the risk of severe water stress under the establishment phase, restoration of the root-shoot balance suffers as photosynthesis decreases. Therefore, a production method that provides a tree with a highly functional root system immediately after transplanting, without a significant reduction in leaf size, could improve the probability of the tree recovering from planting stress and becoming fully established.

Most trees in Swedish nurseries are cultivated as field-grown and are traditionally harvested short before transplanting. The trees may then be delivered bare-rooted or balled & burlapped. More recently, production systems that are intended to increase the fine-root amounts of field-grown trees before transplanting have been introduced. These production systems are referred to as pre-establishing systems by the industry (LRF, 2012). In the pre-establishing systems, traditionally field grown trees are harvested and then cultivated in pots constructed to increase fine root formation and avoid girdling in a root-growth stimulating media one or two years prior to transplanting. Two recognized pre-establishing systems are air pruning pots and fabric containers. Yet another system intended to increase the amount of fine roots in trees' root systems before planting, is root pruning in the field. Today, trees produced in all of the different systems mentioned above are coexisting in the market and although large variations exist among the systems in labor intensity and thus price, potential differences in post-transplant performance have been little investigated.

Previous comparisons of trees from different nursery production systems have shown that growth and water uptake are affected by the treatments of the roots in the nursery (Carlson and Miller, 1990; Johnson et al., 1984; Marshall and Gilman, 1998; Struve et al., 1989). In forestry, the impact of root volume on seedling post-transplant performance has been studied in several experiments. When categorizing seedlings based on the density of the root system, Jacobs et al. (2005) found better above-ground performance in seedlings with higher root density. However, Krasowski and Caputa (2005) did not find that root surface area reflected the seedlings' ability to absorb and transport water. In drought stress tests, Jacobs et al. (2009) found a positive correlation between root system volume and level of stress in transplanted red oak seedlings when there was a water deficit, showing that seedlings with the higher root density became more water stressed under dry conditions. Gilman et al. (2010), on the other hand, found that field-grown trees had a more negative post-transplant xylem water potential when irrigation was withheld during establishment, than container-grown trees, with denser root. In a related study, we showed that cultivation of trees in pre-establishing systems increased the amounts of fine-roots before transplanting and that the responses to the systems varied with species (Levinsson, 2013). In this study, we used the definition of Grossnickle (2005) stating that trees need to be coupled to the hydraulic cycle of the transplanting site to become fully established. Therefore, we wanted to investigate if trees from different production systems were equally able to support the trees with sufficient amounts of water. Based on the results of the previous studies, we formulated the following hypotheses: (1) trees subjected to fine-root-stimulating measures in the nursery one season before transplanting experience less post-transplant stress than traditionally produced trees, and (2) post-transplant advantages associated with higher root density are more pronounced at planting sites where water availability is high during the first post-transplant years.

2. Materials and methods

2.1. Setup and background

The study was conducted from 2007 to 2010. Seventy field-grown sweet cherry trees (*Prunus avium* L.) were selected at a Swedish nursery and 70 field-grown red oak trees (*Quercus rubra* L.) were selected at another Swedish nursery in the Spring of 2007. All trees within one species originated from the same seed source. The trees were seeded in 1998–1999 and replanted three times before the study started. The selection of the trees was based on stem circumference and general appearance, with the aim of choosing uniform plants for the study. The stem circumference was 14–17 cm one meter above the root collar, and the height of the trees was approximately 4 m.

The trees were randomly divided into five groups: (1) bare-rooted (BR) trees, (2) balled & burlapped (B&B) trees, (3) root-pruned (RP) trees, (4) air-potted (AP) trees and (5) fabric-container-grown (FC) trees. All trees were kept in the nurseries during one growing season (2007) and treated according to standard Swedish practices for the selected production systems (LRF). Trees that were to be delivered as traditional BR or B&B trees were left undisturbed in the fields. The RP trees were root pruned in the fields and also left on their original planting spot. The AP trees were harvested from the fields, balled & burlapped with a root ball diameter of approximately 0.5 m, and moved to another nursery for installation in air-pots. At installation, the trees were placed on a polypropylene ground cloth, the burlapping was left on the root ball and the root systems were wrapped with a 0.60 m high sheet of Superoots® plastic (The Caledonian tree Co., Edinburgh, UK), forming an Air-Pot® one meter in diameter. The pots were filled with a peat-sand mixture. The trees in the FC group were harvested and delivered to the new nursery as bare-rooted trees. The FC trees were root-pruned and replanted in peat-filled fabric containers (Smart Pot®, High Caliper, OK, USA) with a diameter of 0.45 m and a height of 0.35 m at the new nursery. The FC trees were then planted in the fields of the nursery.

All trees cultivated in a particular production system were equally fertilized. The trees left in the fields (BR, B&B and RP trees) received approximately 0.084 kg 8N-7P-16K per tree, distributed as 300 kg/10,000 m^2 in the Spring of 2007. The AP trees were fertilized one month after installation in the production system with approximately one kg 21N-3P-10K per tree. At the installation of the FC trees, 0.22 kg Osmocote® Pro 16N-11P-10K, released over 8–9 months was included in each bag. All trees in the study were maintained in drip-irrigation systems, and crown irrigation was also installed for each of the AP trees.

All trees were harvested from the nurseries and transplanted to the experimental sites in the spring of 2008, before bud burst. Four trees from each production system were planted in the city of Malmö, and six were planted at the experimental fields of the Swedish University of Agricultural Sciences, Alnarp. Malmö (55°36′21″N, 13°0′9″E) has a mean annual precipitation of