Available online at www.sciencedirect.com

SCIENCE DIRECT®

Forest Ecology and Management 214 (2005) 28–39

Forest Ecology and Management

www.elsevier.com/locate/foreco

Growth and nutritional response of hardwood seedlings to controlled-release fertilization at outplanting

Douglass F. Jacobs [a,*], K. Francis Salifu [a], John R. Seifert [b]

[a] *Department of Forestry and Natural Resources, Hardwood Tree Improvement and Regeneration Center, Purdue University, West Lafayette, IN 47907-2061, USA*

[b] *Southeast Purdue Agricultural Center, Department of Forestry and Natural Resources, Purdue University, Butlerville, IN 47223-0216, USA*

Received 13 October 2004; received in revised form 14 March 2005; accepted 16 March 2005

Abstract

Hardwood bareroot seedlings typically undergo transplant shock immediately following afforestation planting associated with moisture or nutrient stress. Broadcast field fertilization at outplanting with readily available nutrients has shown limited capacity to reduce nutrient stresses. Furthermore, the rapid nutrient release characteristic of broadcast fertilization leads to high levels of nutrient leaching and may stimulate growth of competing vegetation more than target trees. Application of controlled-release fertilizer (CRF) in the outplanting hole could be a useful alternative to help improve fertilizer use efficiency and alleviate competition problems associated with broadcast fertilization, thereby promoting early regeneration success of outplanted seedlings. We tested growth and nutritional response of black walnut (*Juglans nigra* L.), white ash (*Fraxinus americana* L.), and yellow-poplar (*Liriodendron tulipifera* L.) to 6 rates (0, 15, 30, 45, 60, and 75 g plant^{-1}) of polymer-coated CRF applied to the root zone at outplanting in southern Indiana, USA. Fertilizer release was evenly distributed between years 1 and 2. Seedling survival was above 85% for all treatments. Compared to non-fertilized seedlings, the 60 g seedling^{-1} rate accelerated mean height and root-collar diameter (RCD) growth by 52 and 33% in year 1 and 17 and 21% in year 2. Nitrogen (N) and potassium (K) uptake were increased 40 and 30% at the 60 g rate compared with controls. Height and RCD growth were greater by 543 and 200% in white ash and 300 and 233% in yellow-poplar, relative to black walnut. Uptake of N and K was increased by 79 and 22% in yellow-poplar and 93 and 56% in white ash, compared to black walnut. Results suggest CRF has potential to improve early establishment success of hardwood afforestation plantings.

Keywords: Afforestation; Fertilizer release; Nutrient uptake; Plantation establishment; Polymer-coated fertilizer

1. Introduction

Hardwood bareroot seedlings typically undergo significant transplant shock immediately following outplanting. Such plant response is generally associated with moisture and (or) nutrient stress (Becker

* Corresponding author. Tel.: +1 765 494 3608; fax: +1 765 494 9461.

E-mail address: djacobs@purdue.edu (D.F. Jacobs).

0378-1127/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.foreco.2005.03.053

et al., 1987; Kozlowski, 1987; Struve and Joly, 1992; McMillin and Wagner, 1995). In addition, competition from non-crop vegetation and deer browsing limits afforestation success (Kolb et al., 1990; Gillespie et al., 1996; Martin and Baltzinger, 2002). Consequently, growth of bareroot seedlings is often slow during the first 1 or 2 years after outplanting until root systems can establish to exploit site resources (Rietveld, 1989). In addition to slow growth, transplant shock often leads to high mortality of outplanted hardwood seedlings during the establishment period (Jacobs et al., 2004b).

Susceptibility to nutrient stress can be reduced by traditional approaches such as fertilization at outplanting to supplement nutrients (Burdett et al., 1984) and (or) herbicide application to reduce competition for nutrients (Campbell, 1990; McGill and Brennman, 2002). Fertilization at outplanting has potential to stimulate seedling growth, helping to facilitate free-to-grow status (Brockley, 1988). However, the practice is rarely recommended (Ponder, 1996) and often discouraged (Beineke, 1986) for hardwood seedlings because of inconsistent reports of neutral or negative effects from the practice. For instance, field fertilization reduced survival and growth of outplanted black walnut (*Juglans nigra* L.) seedlings (Williams, 1974). Additionally, height and diameter at breast height growth of black walnut 12 years after fertilization at intervals of 1, 2, and 6 years after outplanting were similar to controls (Braun and Byrnes, 1982).

The above inconsistencies in growth response to nutrient enrichment at plantation establishment could partly be associated with fertilizer type and method of application. Broadcast field fertilization of traditional agronomic fertilizers releases nutrients immediately upon application with generally low rates of fertilizer use efficiency. For example, broadcast field fertilization stimulated growth and nutrient uptake of competing vegetation more than outplanted seedlings (van den Driessche, 1991; Chang et al., 1996; Staples et al., 1999; Chang and Preston, 2000; Imo and Timmer, 2001).

In contrast, controlled-release fertilizer (CRF), designed to release nutrients slowly over longer time frames for plant uptake, offers an alternative to broadcast fertilization. With a single application, CRF may provide plants with enhanced mineral nutrition for extended periods, ranging from about 3 to 18 months. The gradual release pattern of CRF acts to provide a more consistent and sustained nutrient supply that may better match plant demand (Donald, 1991) and helps to minimize nutrient leaching, reduce plant damage, and improve overall fertilizer use efficiency. For instance, application of CRF 5–7 cm from roots improved fertilizer use efficiency compared to comparable reports for broadcast fertilization (Hangs et al., 2003). Incorporation of CRF to root plugs of container seedlings or CRF application using in-hole or adjacent planting-hole placement promoted early growth of outplanted seedlings (Carlson, 1981; Carlson and Preisig, 1981; Brockley, 1988; Arnott and Burdett, 1988; Fan et al., 2004).

Although CRF has been effective in facilitating seedling growth in some cases, field response has been variable (Brockley, 1988). CRF resulted in slow relative growth rates with western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) (Arnott and Burdett, 1988). A relatively high CRF rate applied to the outplanting hole increased Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedling water stress relative to non-fertilized plants (Jacobs et al., 2004a), likely due to injury incurred by elongating root tips associated with elevated salt concentrations in the zone of fertilizer placement (Jacobs et al., 2003b). Observed differences in response could be associated with type of CRF product used and application rates, along with site interactions. Many different CRF types are available, primarily differing in terms of nutrient formulations, estimated product longevities, and mechanisms of nutrient release (Goertz, 1993; Jacobs et al., 2003a).

Although CRF has been useful in stimulating field growth of conifer species in the western USA (Carlson, 1981; Carlson and Preisig, 1981; Haase et al., in press), there is little information on its use in hardwood afforestation plantings in the eastern USA. The increased interest in using CRF for tree plantings (Haase and Rose, 1997) suggests the need for a better understanding of how hardwood species respond to CRF at plantation establishment. The primary objective of this study was to evaluate growth and nutritional response of black walnut, white ash (*Fraxinus americana* L.), and yellow-poplar (*Liriodendron tulipifera* L.) to 6 rates of polymer-coated CRF applied to the root zone at time of outplanting on a field site in southern Indiana, USA. Additionally, we examined nutrient release rates over time associated with the CRF product. In this new contribution, we