Facilitating Nutrient Acquisition of Black Walnut and Other Hardwoods at Plantation Establishment

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ABSTRACT—Bareroot hardwood seedlings typically undergo transplant shock immediately following planting before root systems are established. Fertilization at planting may act to minimize transplant shock by reducing nutrient stresses. However, previous work with fertilization of hardwoods at planting has generally relied on fertilizers with nutrient forms immediately available. These fertilizers have relatively low rates of fertilizer use efficiency, as the vast majority of applied nutrients are not available for plant uptake. Thus, response of hardwood seedlings to fertilization at planting has traditionally been minimal and is rarely recommended operationally. Controlled-release fertilizer (CRF) is a relatively new technology available for reforestation in which nutrients are slowly released over the course of one to two growing seasons. We tested the use of Osmocote® Exact 15N-9P-10K plus minors (16 to 18 month release) polymer-coated CRF applied to the root zone at planting with three hardwood species: black walnut, white ash, and yellow-poplar in southern Indiana. Application of 60 g per seedling accelerated first-year height growth by 52% and diameter growth by 37% compared to controls (averaged over species). These preliminary results indicate that CRF may provide a previously untested means to improve hardwood afforestation planting success.

Bareroot seedlings typically grow slowly during the first 1 or 2 years following planting until root systems can establish and proliferate through the soil to exploit site resources (Rietveld 1989). While water limitations are often noted as a major barrier to transplanting success (Burdett and others 1984), nutrient limitations may also slow initial seedling growth. Fertilization at the time of planting has been recommended for conifer seedlings as a means to minimize transplant shock and facilitate rapid growth above competing vegetation and the level of deer browse (Carlson and Preisig 1981).

Fertilization at planting is rarely recommended (Ponder 1996) and often discouraged (Beineke 1986) for hardwood seedlings, likely due to previous studies reporting neutral or negative effects from the practice. Williams (1974) reported reduced survival and growth of planted black walnut (*Juglans nigra* L.) seedlings that received fertilization. Black walnut fertilized at 1, 2, and 6 years after planting on a good site exhibited no differences in height or diameter at breast height after 12 years (Braun and Byrnes 1982). Previous studies, however, have generally relied upon surface application of traditional agronomic fertilizers (e.g., urea or ammonium nitrate), which release nutrients immediately upon application. These fertilizers typically have relatively low rates of nutrient recovery by crop species, termed fertilizer use efficiency. Additionally, surface application of fertilizer may act to stimulate growth of competing vegetation which is a predominant reason that fertilization at planting has been discouraged (Ponder 1996).

Controlled-release fertilizer (CRF) offers an alternative to standard agronomic fertilizers. With a single application, CRF may provide plants with enhanced nutrition for extended periods, typically ranging from 3 to 18 months. This acts to provide a more consistent and sustained nutrient supplies that may better coincide with the developmental needs of tree species (Donald 1991). The gradual

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release pattern of CRF may also minimize nutrient leaching, reduce plant damage, and improve overall fertilizer use efficiency. Hangs and others (2003) reported that < 1% of nitrogen from Polyon®, a polymer-coated CRF, applied to conifer seedlings at planting was lost to leaching after two growing seasons. CRF may be particularly effective when applied to the seedling root zone, as CRF applications of 5 to 7 cm from roots resulted in substantially greater fertilization use efficiency than surface application (Hangs and others 2003). Many different types of CRF are available, primarily differing in terms of nutrient formulations, estimated product longevities, and mechanisms of nutrient release (Jacobs and others 2003b).

Although use of CRF has traditionally been limited to the horticultural industry, interest in using these fertilizers for tree plantings has increased in the past decade (Haase and Rose 1997). Some impressive results have been reported when incorporating CRF into tree plantings with conifer species (Carlson 1981, Carlson and Preisig 1981, Nursery Technology Cooperative 2001). However, we know of no reports examining the use of CRF in hardwood afforestation plantings in the eastern United States. Thus, the purpose of this trial was to study the response of three hardwood species to CRF applied to the root zone at planting. In this paper, we present preliminary, first-year observations indicating that CRF accelerated initial plantation establishment of these three hardwood species.

MATERIALS AND METHODS

Bareroot (1+0) seedlings of three species [black walnut, white ash (*Fraxinus americana* L.), and yellow-poplar (*Liriodendron tulipifera* L.)] were grown under standard nursery cultural regimes at the Indiana Department of Natural Resources' Vallonia Nursery during 2001. Following lifting, seedlings were cold-stored at 2° C until delivered to the field planting site. The outplanting site for this study was located at the Southeastern Purdue Agricultural Center (SEPAC) in southeastern Indiana (39°01'N, 85°35'W). The site was formerly in agricultural production and was tilled prior to planting.

The CRF examined in this study was Osmocote® Exact Lo-Start 15N-9P-10K plus minors. Nutrients in this CRF are encapsulated within multiple layers of a polymeric resin, which acts to slow the dissolution rate of nutrients into the soil solution. This CRF was designed by the manufacturer to release over 90% of its nutrients within 16 to 18 months following application, assuming a soil temperature of 21° C at position of fertilizer placement. At this longevity rating, we assumed that seedlings would receive enhanced nutrition for two growing seasons since fertilizer release during the winter months should be slowed. To estimate rates of nutrient release, we placed 75 g CRF within PVC rings covered in nylon. These were buried at the approximate depth of fertilizer placement (30 cm) and excavated periodically during the experiment (8 sampling intervals × 5 replications). The excavated fertilizer was dried at 70° C for 48 hr and re-weighed.

Seedlings were planted on either 2002 April 10 (three blocks) or 2002 April 24 (remaining three blocks) using a tractor-hauled coulter with trencher and packing wheels. Fertilizer was applied at six rates (0, 15, 30, 45, 60, and 75 g per seedling) using a modified funnel system installed onto the machine planter (Fig. 1). For ease of application, rates were converted to volume estimates from lab trials prior to planting. For each seedling, the appropriate CRF rate treatment was measured by volume and applied into the planting trench (approximately 30 cm depth) through the funnel system. The 75 g per seedling rate encompassed a length of about 15 cm along the trench. Seedlings were planted directly over fertilizer with roots extending to just above the fertilizer layer. Herbicide applications were made prior to and following planting, and weed competition was minimal throughout the first growing season.

Seedlings were measured for initial height and root collar diameter on 2002 April 29 and 30. In early May 2002, an electric deer fence was installed around the perimeter of the study and maintained for the duration of the experiment. Seedlings were re-measured in November 2002 for height, diameter, and incidence of shoot dieback when terminal bud died with a lateral bud becoming the new leading shoot.

Figure 1.—Modified funnel system on machine planter for fertilizer application.

The study was established as a randomized complete block design with six blocks and factorial treatments (3 species × 6 CRF rates). Environmental conditions differed among blocks but conditions were relatively homogenous within blocks. Within a block, each of the 18 treatments was randomly assigned to a row in which 20 seedlings representing a treatment combination were planted. The sampling unit was each individual seedling and the experimental unit used for data analysis was the mean value of the 20 seedlings within a row for each treatment. Data were analyzed using analysis of variance (ANOVA). When significant ($P \leq 0.05$) effects were detected in the ANOVA, Fisher's Protected Least Significant Difference test was used to identify differences among treatments ($\alpha = 0.05$).

RESULTS

Fertilization (averaged over species) affected both seedling height ($P = 0.0019$) and diameter ($P = 0.0002$) growth during the first growing season. Fertilizer effects on first-year growth did not vary among species, as indicated by the lack of a significant species × fertilizer rate interaction for both height ($P = 0.3358$) and diameter ($P = 0.6188$) growth. Height growth was increased by 52% as compared to the control at the 60 g per seedling fertilizer rate (Fig. 2). The 60 g per seedling rate was also the most effective rate for diameter growth, with a 37% increase as compared to the control (Fig. 3). For both height and diameter growth, mean values increased along the continuum in fertilizer rate from 0 to 60 g, until decreasing at 75 g (Figs. 2 and 3). Fertilization had no significant effect on survival ($P = 0.3594$) with all treatments resulting in ≥ 91% survival or on the incidence of terminal bud dieback ($P = 0.3387$).

When examining species independently of fertilizer treatment (i.e., averaged over fertilizer rates), there were significant differences among species for both first-year seedling height ($P < 0.0001$) and diameter ($P < 0.0001$) growth. For height growth the ranking was white ash > yellow-poplar > black walnut (Fig. 2), while for diameter growth the ranking was yellow-poplar > white ash > black walnut (Fig. 3). There were differences in survival ($P < 0.0001$) among species, with yellow-poplar having significantly lower survival (85%) than either white ash (100%) or black walnut (97%). There were also differences in incidence of terminal bud dieback among species ($P < 0.0001$), with black walnut having a significantly greater percentage of trees with dieback (22%) than either white ash (10%) or yellow-poplar (13%).

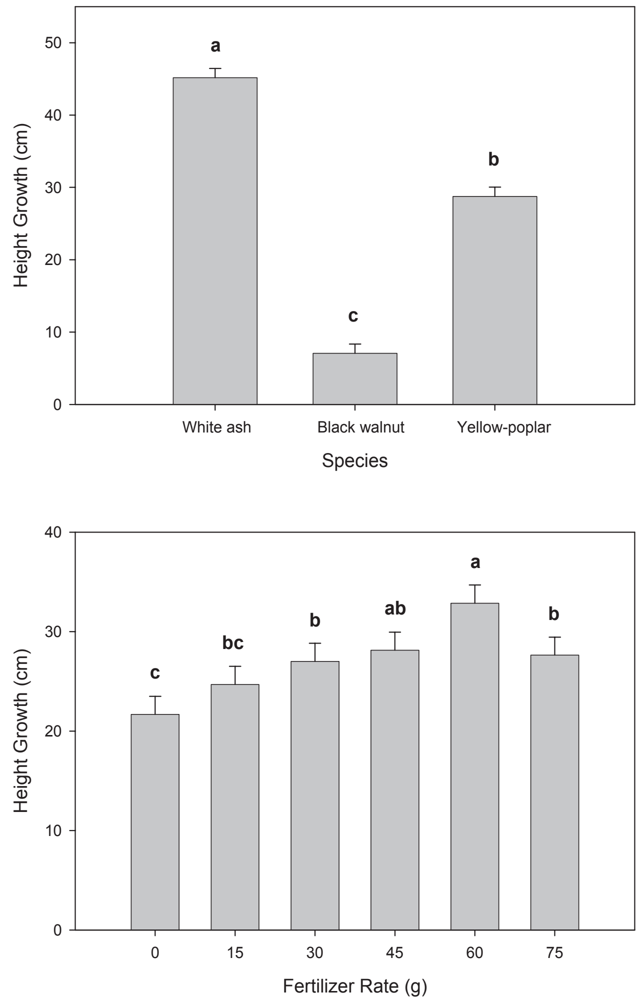

Figure 2.—First-year height growth for species ($P < 0.0001$) and fertilizer rate ($P = 0.0019$). Species × rate was non-significant ($P = 0.3358$). For either species or fertilizer rate treatments, similar letter groupings did not differ significantly at $\alpha = 0.05$.

Analysis of changes in residual fertilizer weight indicated that fertilizer weight decreased to 68% of the original weight by the end of the first growing season. Approximately 33% of fertilizer weight (primarily comprised of residual polymer prill materials) typically remains at the end of the designated release period with polymer-coated CRF (Jacobs and others 2003a). Thus, we expect that additional fertilizer nutrients should still be available for plant uptake during the second growing season.

DISCUSSION

Application of CRF at plantation establishment clearly accelerated first-year seedling growth of

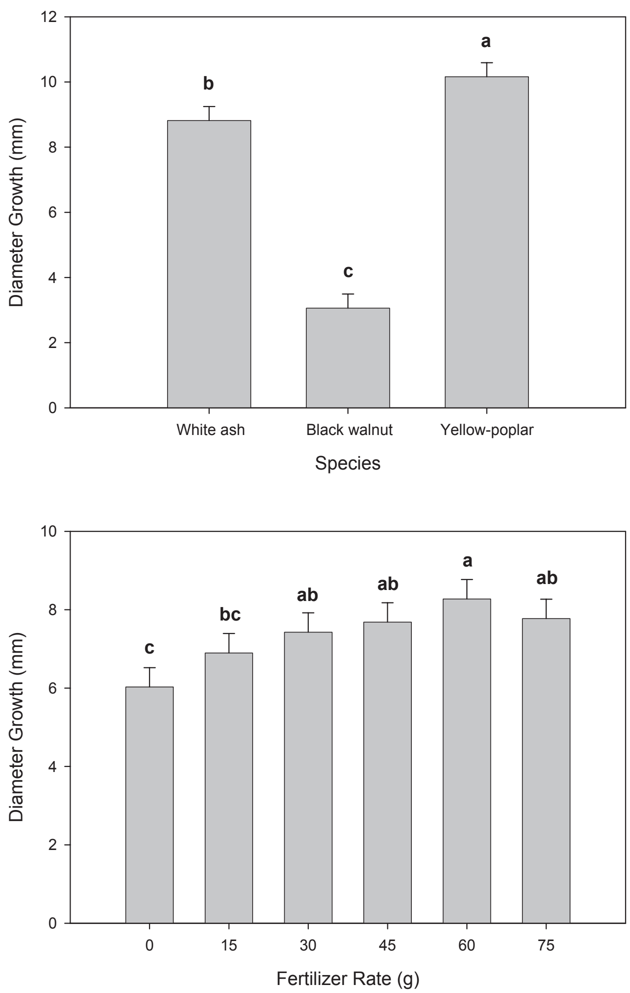

Figure 3.—First-year diameter growth for species ($P < 0.0001$) and fertilizer rate ($P = 0.0002$). Species × rate was non-significant ($P = 0.6188$). For either species or fertilizer rate treatments, similar letter groupings did not differ significantly at $\alpha = 0.05$.

each of these three hardwood species. Regardless of species, fertilization at 60 g per seedling increased height growth by 52% and diameter growth by 37% compared to controls without CRF fertilizer applications (Figs. 2 and 3). Although we know of no published observations examining use of CRF at the time of planting with hardwood species, similar results have been reported for conifer species. After two growing seasons, total height was increased by 42% in Douglas-fir (*Pesudotsuga menzeiseii* (Mirb.) Franco) (Carlson and Preisig 1981) and 27% in western hemlock (*Tsuga heterophylla* Raf. Sarg.) seedlings with application of 21 g of Osmocote CRF at time of planting. Incorporation of Osmocote 18N-5P-12K into the growing media of container seedlings at 30 kg per m^3 resulted in a doubling of stem volume compared to controls after three growing seasons (Nursery Technology Cooperative 2001).

These results suggest that CRF may offer a means to enhance initial plantation growth of hardwood seedlings, which may act to improve the establishment and early productivity of hardwood afforestation plantings. Hardwood plantations have historically been relatively difficult to establish, with a high degree of variability in success. A random survey of 88 recently-established (ages 1 to 5) plantations throughout Indiana indicated that seedling survival averaged approximately 65%, with the majority of mortality occurring the first year following planting (Jacobs and others in press). This survival rate contrasts dramatically with operational conifer tree plantations in the Pacific Northwest and the southeastern United Steas where plantation survival is routinely above 90%.

The majority of hardwood plantation failures in the eastern United States are attributed to vegetative competition and damage from animal browse incurred during the first 1 or 2 years after planting (see citations in Jacobs and others in press). Application of CRF at planting may provide hardwood seedlings with a means to rapidly accelerate over the level of browse and competing vegetation, allowing seedlings to reach a free-to-grow status in a shorter time frame. It should be noted, however, that weed control on this site was excellent and is likely a necessary prerequisite for attaining positive seedling response from any fertilizer application. Although this study was not intended to provide a financial assessment of incorporating CRF technology into forest tree plantation establishment, we estimate the cost of 60 g (the most effective rate per seedling in this study) of this CRF at approximately $0.20 - $0.30 per seedling.

Estimates of fertilizer release in our study indicated that approximately 50% of nutrients had actually released from CRF prills during the first growing season, suggesting that additional nutrients may be available for plant uptake during the second growing season. Additionally, growth of seedlings is largely dependent on the re-translocation of nutrients from stored reserves (Salifu and Timmer 2003). The increased growth of fertilized seedlings compared to seedlings in the control treatment was likely associated with greater nutrient uptake, and implies that enhanced levels of nutrients were also stored by fertilized seedlings which may act to fuel growth during the second season. We expect to conduct long-term monitoring of this plantation to assess whether the growth responses observed during the first year continue to be maintained over time.

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