Exponential Fertilization and Nutrient Loading of Forest Planting Stock

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This workshop presentation will introduce a new concept of steady-state nutrient preconditioning for forest planting stock that results in enhanced growth and nutrition of seedlings after field planting. The conditoning process involves two fertilization techniques which are novel to nursery culture: exponential fertilization and nutrient loading. When transplanted from a high fertility environment of the nursery to a low fertility condition of the field, seedlings often experience nutritional stress because of limited nutrient supply and slow regeneration of the root system that restrict exploitation and absorbtion of soil nutrients. This stress may contribute to early growth check and plantation failure. Special cultural regimes that precondition seedlings for outplanting can reduce the severity of planting check.

Traditional fertilization regimes that prepare seedlings for the outplanting environment commonly consist of intensive supplementing of plant nutrient requirements during the active growing season in the nursery, which is followed by reduced fertilization after bud set to expose the trees to nutrient stress during dormancy. The period of reduced fertilization is supposed to ensure sufficient hardening of the seedling before planting. Typically, these regimes follow "constant feed" fertilization schedules that are characterized by declining tissue nutrient concentrations in the plants as the growing season progresses, because tree nutrient reserves are diluted by increasing growth with time. These regimes reflect non steady-state nutrient conditions since decreasing tissue nutrient concentrations indicate that nutrient supply or plant uptake of nutrients was unable to keep up with dry matter production causing nutrient dilution. Studies have shown that severe nutrient dilution in planting stock may negatively influence early outplanting performance.

The goal of steady-state nutrient preconditioning is to rear seedlings at stable or constant nutrient concentrations that reflect matching growth and nutrient uptake of seedlings during nursery culture, thus countering internal nutrient dilution. This goal can be achieved by employing fertilization schedules that deliver nutrients at exponentially increasing rates that are synchronized with the exponential growth and nutrient demand of young seedlings, thus inducing steady-state nutrient conditions. Another goal of steady-state nutrient preconditoning is to ensure that seedlings accumulate ample nutrient reserves during nursery production that serve as a readily available source of nutrients for growth after field planting. This is achieved by high-dose exponential fertilization (or exponential nutrient loading) which induces a progressive build up of nutrients in the crop as steady-state luxury consumption. Consequently loaded seedlings are of similar size as conventionally fertilized seedlings, but contain much higher nutrient reserves. These reserves can be remobilized under nutrient stress for retranslocation to current growth.

Steady-state nutrient culture of seedlings also corresponds better with the outplanting environment, since stable internal nutrient accumulation in the greenhouse phase conforms with steady-state nutrient uptake of natural exponentially growing vegetation in the field. Exponential nutrient delivery to container-restricted root systems also better simulates nutrient flux reached by expanding roots in a field soil with constant nutrient availability. Combined with nutrient loading, the higher nutrient reserves and improved nutrient balance in seedlings contribute to enhanced stress resistance and increased growth performance. Our studies have demonstrated that exponentially loaded seedlings grow faster and take up more nutrients in the field, and suppress weeds more effectively than conventionally fertilized seedlings. The implementation of exponential fertilization and nutrient loading practices in relation to the production of containerized tree seedling stock will be dicussed. More information on our findings is available in the references listed below.

References

Imo, M and V.R. Timmer. 1992. Nitrogen uptake of mesquite seedlings at conventional and exponential fertilization schedules. Soil Sci. Soc. Am. J. 56:927-934.

Imo, M. and V.R. Timmer. 1992. Growth, nutrient allocation and water relations of mesquite *(Prosopis chilensis)* seedlings under differing fertilization schedules. For. Ecol. Manage. 55:279-294.

Imo, M. and V.R. Timmer. 1997. Vector diagnosis of nutrient dynamics in mesquite seedlings. Forest Sci. 43:268-273.

Malik, V.S. and V.R. Timmer. 1995. Interaction of nutrient loaded black spruce seedlings with neighbouring vegetation in greenhouse environments. Can J. For. Res. 25:1017-1023.

Malik, V.S. and V.R. Timmer. 1996. Growth, nutrient dynamics and inter-specific competition of nutrient loaded black spruce seedlings on a boreal mixedwood site. Can. J. For. Res. 26:1651-59.

McAlister, J.A. and V.R. Timmer. 1997. Nutrient enrichment of white spruce seedlings during nursery culture and initial plantation establishment. Tree Physiology (in press).

Miller, B. D. and V.R. Timmer. 1994. Steady-state nutrition of Pinus resinosa seedlings: response to nutrient loading , irrigation and hardening regimes. Tree Physiology 14:1327-38.

Miller, B.D. and V.R. Timmer. 1997. Nutrient dynamics and carbon partitioning in nutrient loaded Picea mariana seedlings during hardening.. Scan. J. For. Res. 12:122-129.

Quoreshi, A.M. and V.R. Timmer. 1996. Exponential fertilization improves nutrition and ectomychorhizal development of black spruce seedlings.

Annual Meeting, Soil Sci. Soc. Am., Indianapolis, IN. Agron Abstr. 1996: 299.

Timmer, V.R. 1997. Exponential nutrient loading: a new fertilization technique to improve seedling outplanting performance on competitive sites. New Forests 13:279-299.

Timmer, V.R. and A. Aidelbaum. 1996. Manual for exponential nutrient loading of seedlings to improve outplanting performance on competitive forest sites. Nat. Res. Can., Canadian Forest Service-Saulte Ste. Marie, ON. NODA/NFP Tech. Rep. TR 25. 21 pp.

Timmer, V.R. and A.D. Munson. 1991. Site-specific growth and nutrient uptake of planted Picea mariana in the Ontario Clay Belt. IV. Nitrogen loading response. Can. J. For. Res. 21:1058-1065

Timmer, V.R. and B. D. Miller. 1991. Effects of contrasting fertilization and irrigation regimes on biomass, nutrients, and water relations of container grown red pine seedlings. New Forests 5:335-348.

Timmer, V.R., Armstrong, G. and B.D. Miller. 1991. Steady-state nutrient preconditioning and early outplanting performance of containerized black spruce seedlings. Can. J. For. Res. 21:585-594.

Timmer, V.R. and Armstrong, G. 1987. Growth and nutrition of containerized Pinus resinosa at exponentially increasing nutrient additions. Can. J. For. Res. 17:644-647.