Nutrient amendments to balled and burlapped Colorado spruce (*Picea pungens* Engelm.) affect tree growth after transplanting

Jennifer Van Wagoner, John E. Lloyd, Robert Tripepi, Deborah Page-Dumroese and Stephen Cook
University of Idaho
Moscow, Idaho

Introduction

Growth of transplanted trees has primarily focused on fertilization practices used in the nursery (Cabrera and Devereaux 1999, Lloyd et al. 2006), planting (Gilman 2004), or post-planting (reviewed in Struve 2002). Balled and burlapped (B&B) trees are field grown, dug and then the soil ball is wrapped in burlap. During the time between harvest and planting, trees are stored by wholesale or retail nurserymen, at garden centers, or by landscape contractors. During storage, tree root balls are buried in organic mulch beds to protect them from desiccation and temperature extremes.

Mulch used in B&B storage beds can have a carbon (C) to nitrogen (N) ratio higher than 100:1 (Lloyd et al. 2002). The high C:N ratio of the mulch beds likely limits the amount of nitrogen available to B&B stock. In environments with C:N ratios above 30:1, net mineralization of N is reduced from microbial immobilization (Kaye and Hart 1997, Lloyd et al. 2002). Decreased C:N ratios generally supports greater N mineralization (Kaye and Hart 1997, Lloyd et al. 2002). Future tree growth may be reduced as a result of this period of limited N availability.

Generally, a one year lag takes place when N is taken up by trees and vegetative growth responds (reviewed in Struve 2002). Therefore, while B&B trees are stored in mulch beds they are using stored N taken up before extraction from the field. By placing B&B trees in a nutrient immobilizing media before transplanting, nutrient reserves may be reduced, hence reducing tree growth after transplanting. Fertilizer applications to trees has been shown to compensate for the immobilization of N by microbes (Lloyd et al. 2002).

While a long accepted idea is that adequate fertilization can enhance plant resistance to insect damage, current research indicates that fertilization frequently increases the amount of insect damage (Herms 2002). Douglas-fir tussock moth (Orgyia psuedotsugata) larvae, defoliator pests on Colorado spruce, especially in urban areas (Brooks et al. 1978), are suggested to have increased survival and insect weights when feeding on N fertilized trees (Brooks et al. 1978). Fertilized trees in several studies produced lower concentrations of phenolic defensive compounds than non-treated controls (Herms and Mattson 1992, Glynn et al. 2003), which may also lead to less insect damage on trees.

Fertilization can alter B&B tree establishment and growth by influencing insect infestations, photosynthesis, and growth. Therefore, the objectives of this study were to evaluate the effects of nutrient treatments applied to B&B Colorado Spruce while in a mulch storage bed on plant growth, gas exchange, terpene production and insect growth after transplanting into a managed landscape. The goal was to determine if better quality trees for transplant can be produced by amending with nutrients while they are in storage.

Materials and Methods

Treatments

Sixty Colorado spruce (Picea pungens Engelm.), field grown were dug, balled and burlapped and transported from Hash Tree Farm, Princeton, Idaho to the University of Idaho Plant Science Farm in Moscow, Idaho in April of 2003. Of the 60 trees, 12 trees for each treatment were randomly selected to receive one of four nutrient amendments and twelve trees, randomly selected, were stored in pine mulch and did not receive any nutrient amendments and were used as a control. The treatments were 1) even distribution of 114.2 g Osmocote® fertilizer (15N-3.9P-10K) around the tops of the root balls, 2) insertion of one Ross® Gro-Stake® (10N-4.3P-8.3K) evergreen fertilizer spike into the tops of each root balls, 3) injection of one-half cartridge Ross® Root Feeder® (10N-5.2P-10K) evergreen fertilizer into the root ball at four points, 4) a 1:1 EKO Compost:pine bark mixture (by volume) surrounding the root balls.

Trees were removed from mulch storage bed and planted on a north-facing slope on the Moscow Campus of the University of Idaho the year following treatment (April 2004).

Foliar Elements

Percent N in the Colorado spruce foliage was sampled yearly through the experiment. Current year's foliage was collected from the trees on July 20, 2004 and July 22, 2005. Needles coffee grinder for 30-40 seconds. Foliage from the grinder was pulverized into a fine powder in a rotating ball mill. The fine powder was sent to Midwest Laboratories, Omaha, Nebraska for analysis of foliar N.

Colorado spruce trees in the mulch holding bed. Trees were held for one year after application of nutrient amendments.

Photosynthesis

Photosynthesis measurements were taken in June, July and August of 2004 and 2005. A Li-Cor 6400 portable gas exchange analyzer with a conifer chamber attachment was used to measure the net photosynthesis. The measurements were taken between 9:00 a.m. and 12:00 p.m. in full sun (PAR average = 1300) over a two day period.

Growth Measurements

Growth measurements consisted of leader height (cm), branch length (cm) and trunk diameter (cm). Growth measurements were taken October 2004 and 2005 after terminal buds had set.

Height growth was determined by measuring the terminal leader branch from the top down to the last bud scar. Branch length was determined by averaging the measurements from a total of 12 randomly selected branches distributed throughout all sides and heights in the trees canopy. Branch length was measured from the tip of the branch back to the last bud scar.

Insect Growth on Colorado Spruce Needles

During 2004, current year's foliage was used to examine treatment impacts on insect weight gain. Douglas-fir tussock moths (Orgyia psuedotsugata) egg masses were collected near Stanley, Idaho (44.211oN, 114.945oW). Larvae were reared on commercial diet (Bio-Serv Inc, Frenchtown, NJ) in a growth chamber. Once caterpillars were identified as being 3rd instars they were weighed and placed in groups of ten in petri plates containing current year's foliage with water saturated plaster of paris to keep humid both the foliage and the insects. Petri plates were placed back in the growth chamber for 10 days. Foliage was replaced every 2-3 days. After the 10-day feeding period, the larvae were weighed and the weight gain was analyzed between treatments.

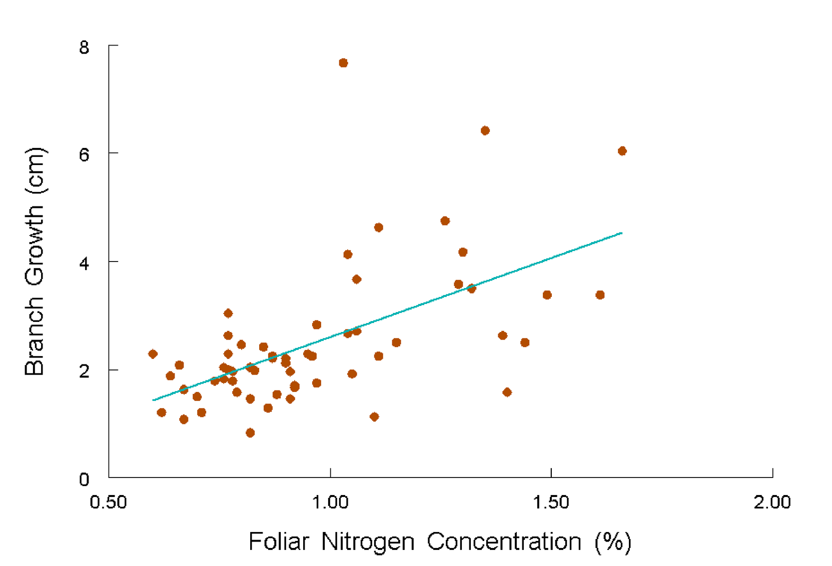

Figure 3. Relationship of terminal branch growth and percent nitrogen in foliage of Colorado spruce (*Picea pungens* Engelm.) in 2004 (F = 28.31, P value < 0.0001, r2 = 0.328).

Results and Discussion

Foliar Elements

Foliar N collected during July 2004, the first summer after transplanting, was significantly different for trees receiving various nutrient amendment treatments (Figure 1). The compost-treated trees had the highest foliar N (1.29%), followed by the fertilizer spike-treated trees (1.05%). Osmocote® and Root Feeder® treatments were similar to the unfertilized control. Differences in foliar N were absent the second season after transplant, indicating that trees had acclimated to planting site conditions and were no longer relying on nutrient reserves from the storage treatments. This result is consistent with previous studies that have documented a one year time interval between when N is acquired and when a growth response is observed (reviewed by Stuve 2002).

Growth

Height growth of the terminal leaders was similar among trees receiving storage treatment or the control for 2004. However, significant differences were observed in 2005. Leader height growth during 2005, the second season after transplant, was highest for EKO compost-treated trees (Table 1). Fertilizer spike-treated trees had less height growth than EKO compost-treated trees, but grew more than the Osmocote®-treated, Root Feeder®-treated, and control trees (Table 1).

Table 1. Effect of nutrient amendment treatments and control on height growth of the main leader of transplanted B&B Colorado spruce. Measurements were taken October 15th 2004 and in October 19th 2005.

	2004	2005
Fertilization	Height Increase	Height Increase
Treatments	cm	cm
Control	10.6[x]	21.9 c [z]
Osmocote®	13.3	27.1 c
Fertilizer Spike	14.0	36.8 b
Root Feeder®	11.4	22.9 c
EKO Compost	16.6	46.1 a

[x]No significant differences in 2004 (Model F = 1.20, P value = 0.3072)

[z]Means within a column followed by the same letter are similar (p < 0.05; n = 12)

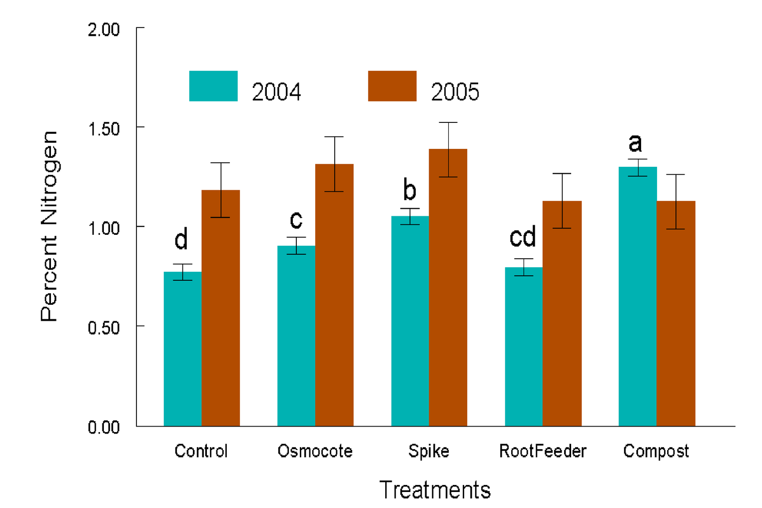

Figure 1. Percent nitrogen (± standard error) in the current year's foliage of B&B Colorado spruce (*Picea pungens* Engelm.) sampled July 20, 2004 (F = 14.59, P value < 0.0001) and July 22, 2005 (F = 0.90, P value = 0.4809). Means within 2004 with the same letter are similar (P value < 0.05; n = 12).

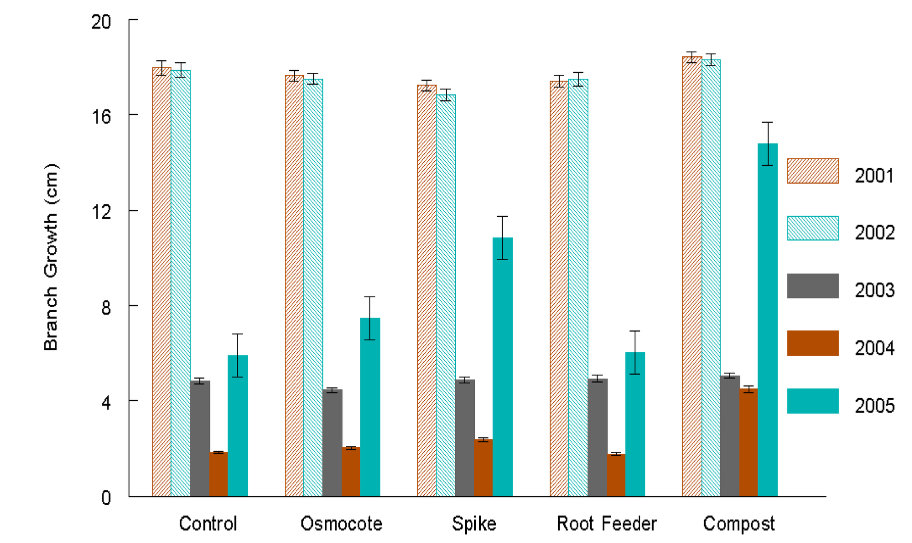

Figure 2. Effect of nutrient amendment treatments and control on branch growth (± standard error) of B&B Colorado spruce while grown in the field (2001, F = 0.81, P value = 0.5318; 2002, F = 0.99 P value = 0.4381), in storage (2003, F = 0.74, P value = 0.5746) and after transplanting (2004, F = 21.47, P value < 0.0001; 2005, F = 16.55, P value < 0.0001).

Growth of branches of trees receiving the EKO compost treatment was almost twice as much as in all other treatments (Figure 2). Branch growth for all the treatments increased in 2005, the second summer after transplanting, but the trends between treatments and control were similar to the prior growing season. EKO compost-treated trees again had the highest branch growth, although the difference between the compost and the fertilizer spike treatment's branch growth was reduced. Branch growth increased with increased foliar nitrogen concentrations (Figure 3). Increased branch growth of trees that have been fertilized prior to transplanting is reported in previous nursery fertilization studies (Lloyd et al. 2006). For Colorado spruce, high concentrations of soil nutrients and favorable soil conditions lead to increased shoot growth (Erhart and Hartl 2003). The increase in tree height in 2005 and the continued increase in branch growth from 2004 and 2005 support the contention that N acquired in previous seasons, as was described by foliar nitrogen concentration in 2004, is stored and utilized the next season for growth processes.

Two years after transplanting, the Colorado spruce still had lower branch growth than branch growth prior to being removed from the field (Figure 2). This result water and mineral uptake and hence lead to greater growth of these trees. Watson (1985) suggests that increased root growth may minimize the severity and duration of transplant shock.

Photosynthesis

Photosynthesis rates during the first three months after transplanting showed significant differences between treatments each month (June through August 2004) (Table 2). Trees that received the EKO compost treatment consistently had higher photosynthetic rates than the Root Feeder® -treated and control trees during that first growing season. All three months in 2004 showed similar results, but the differences between treatments were reduced by August. In June, the EKO compost-treated trees had a photosynthetic rate 17% higher than the controls, and in August, EKO compost-treated trees' photosynthetic rate was 15% higher than the control trees.

Table 2. Effect of nutrient amendment treatments and control on net rate of photosynthesis of transplanted B&B Colorado spruce (*Picea pungens* Engelm.) for 2004.

	June 2004[a]	July 2004[b]	August 2004[c]
Fertilization		A_{max}	
treatments		($\mu mol \cdot m^{-2} \cdot s^{-1}$)	
Control	16.07 c[z]	14.88 bc	11.76 bc
Osmocote®	17.05 bc	16.35 ab	13.31 ab
Fertilizer Spike	18.04 ab	16.55 a	12.81 abc
Root Feeder®	15.35 c	14.66 c	11.07 c
EKO Compost	19.40 a	17.82 a	13.87 a

[a]F = 6.47, P value = 0.0016
[b]F = 3.91, P value = 0.0168
[c]F = 3.05, P value = 0.0407
[z]Means within a column followed by the same letter are similar (p < 0.05; n = 12).

Photosynthetic rate among storage nutrient amendment treatments was similar during the second summer (June through August 2005) after transplanting. Again, trees apparently adjusted to their new environment one year post transplanting.

Another study found similar results of gas exchange being affected by pre-planting N fertilization the first year following treatment but were unaffected the second year (Lloyd et al. 2006). Unlike shoot growth, photosynthesis is only moderately affected by increased N (Herms and Mattson 1992). The rate of photosynthesis in the spruce was unrelated to N concentration within the foliage (F = 3.31, P value = 0.0741). Because photosynthetic rate was unrelated to foliar N, other factors may be involved in the nutrient amendment treatments that affected photosynthesis. Another factor such as water uptake, which was excluded from this study, might have influenced photosynthetic rates. As mentioned previously, EKO compost-treated trees appeared to have more new roots outside the burlap of the original root ball. The EKO compost:pine mulch adhered to the roots outside the burlap and remained on the roots when planted. Perhaps there was increased water-holding capacity of the EKO compost:pine mulch mixture in the storage beds increased root growth and water uptake, which in turn increased the photosynthesis. Increases in water availability, controlled using irrigation treatments, can have significant affects on trees one to five years after the irrigation has been stopped (Gilman 2001, Gilman et al. 2003, Lloyd et al. 2006).

Trees were transplanted on the Moscow campus of the University of Idaho April 2004.

Insect Growth on Colorado Spruce Needles

Douglas-fir tussock moth (DFTM) weight gain of third instars was similar when fed spruce foliage from any tree receiving the nutrient amendment treatments and control (Model F = 1.76, P value = 0.0802). Despite being statistically similar, larval weight gain of insects on needles from EKO compost-treated trees increased 1.5 times that of the insects fed foliage from Root Feeder®-treated trees and control trees (mean larval weight gain from EKO compost-treated trees = 61.6 mg, Root Feeder® -treated trees = 29.4 mg, control trees = 29.4 mg). Weight gain of insects feeding on Osmocote®-treated trees and fertilizer spike-treated trees were also less than the weight gain of insects feeding on EKO compost-treated trees (mean larval weight gain from Osmocote®-treated trees = 36.5 mg, fertilizer spike-treated trees = 39.8 mg). Insect growth was significantly correlated with foliar N concentration (Figure 4). Herbivores, such as DFTM, acquire their needed N from plants and compensate for poor N concentrations in foliage by eating more foliage (Mattson 1980). Therefore, insect growth is regulated by the amount of N they can accumulate (Mattson 1980). Many studies have found increased N in plants to be beneficial for herbivore insect growth, although for conifers the results have been mixed (reviewed in Herms 2002).

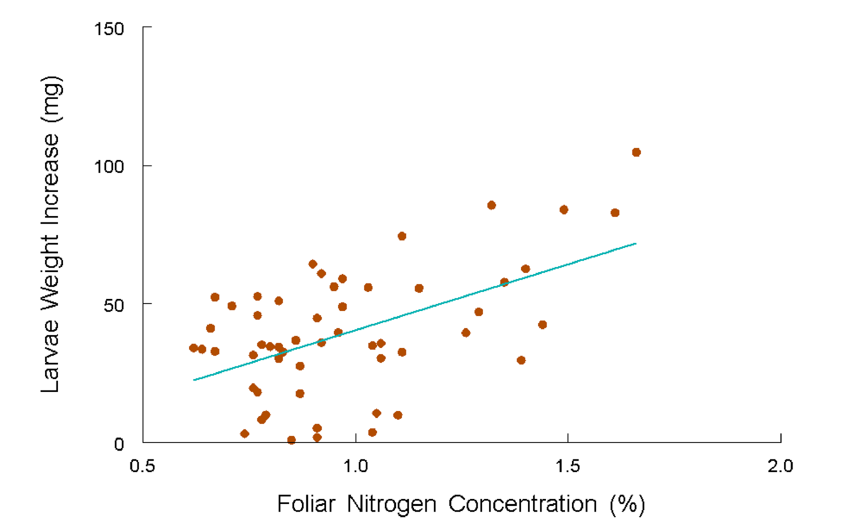

Figure 4. Relationship between Douglas-fir tussock moth (*Orgyia psuedotsugata*) weight gain on Colorado spruce (*Picea pungens* Engelm.) foliage from nutrient amendment treatments and control trees and percent nitrogen in foliage in 2004 (F = 20.17, P value < 0.0001, r2 = 0.279).

Conclusion

Nutrient amendment treatments used in the mulch storage beds had significant effects on tree growth the following two years after planting in an irrigated landscape (3 years after fertilization in storage). Compost added to the mulch storage bed resulted in significantly more branch elongation the first and second year after planting and higher height growth of the terminal leader the second year after planting. In addition to the increased foliar N in the EKO compost-treated trees found in 2004, increased growth may also have been influenced by the larger root systems that were observed outside the burlap of the initial root ball when transplanting. Increased Colorado spruce growth by the EKO compost-treated trees may be less important in a non-irrigated landscape where nutrient uptake might be limited due to lack of available water. Further investigation of nutrient amendment treatments on trees stored in mulch storage beds transplanted to non-irrigated environments may be helpful asfor producing quality specimen conifers for all landscapes. not all consumers will maintain the trees with regular irrigation after planting.

Literature Cited

Brooks, M.H., R.W. Stark and R.W. Campbell (Editors). 1978. The Douglas-fir Tussock Moth: A Synthesis. Forest Service Science and Education Agency Technical Bulletin 1585.

Cabrera, R.I. and D.R. Devereaux. 1999. Crape myrtle post-transplant growth as affected by nitrogen nutrition during nursery production. Journal of the American Society for Horticultural Science 124:94-98.

Erhart, E. and W. Hartl. 2003. Mulching with compost improves growth of blue spruce in Christmas tree plantations. European Journal of Soil Biology 39:149-156.

Gilman E.F. 2001. Effect of nursery production method, irrigation, and inoculation with mycorrhizae-forming fungi on establishment of *Quercus virginiana*. Journal of Arboriculture 27:30-39.

Gilman, E.F. 2004. Effects of amendments, soil additives, and irrigation on tree survival and growth. Journal of Arboriculture 30:301-310.

Gilman, E.F., J. Grabosky, A. Stodola and M.D. Marshall. 2003. Irrigation and container type impact red maple (*Acer rubrum* L.) 5 years after landscape planting. Journal of Arboriculture 29:231-236.

Glynn, C., D.A. Herms, M. Egawa, R. Hansen and W.J. Mattson. 2003. Effects of nutrient availability on biomass allocation as well as constitutive and rapid induced herbivore resistance in poplar. Oikos 101:385-397.

Herms, D.A. 2002. Effects of fertilization on insect resistance of woody ornamental plants: Reassessing an entrenched paradigm. Environmental Entomology 31:923-933.

Herms, D.A. and W.J. Mattson. 1992. The dilemma of plants to grow or defend. Quarterly Review of Biology. 67:283-335.

Kaye, J.P. and S.C. Hart. 1997. Competition for nitrogen between plants and soil microorganisms. Trends in Ecological Evolution 12:139-142.

Lloyd, J.E., D.A. Herms, B.R. Stinner and H.A.J. Hoitnik. 2002. Comparing composted yard trimmings and ground wood as mulches. BioCycle 43(9):52-69.

Lloyd, J.E., D.A. Herms, M.A. Rose and J. Van Wagoner. 2006. Fertilization rate and irrigation scheduling in the nursery influence growth, insect performance, and stress tolerance of 'Sutyzam' crabapple in the landscape. HortScience 41:442-445.

Mattson, W.J. Jr. 1980. Herbivory in relation to plant nitrogen content. Annual review of Ecological Systems 11:119-161.

Struve, D.K. 2002. A review of shade tree nitrogen fertilization research in the United States. Journal of Arboriculture 28:252-263.

Watson, G.A. 1985. Tree size affects root regeneration and top growth after transplanting. Journal of Arboriculture 11:37-40.