Late-Season Fertilization of Nursery Stock

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Regulating seedling nutrient content through fertilization is a key component of nursery culture for both bareroot and container stock. Typically, fertilizers are applied early in the growing season to fuel active shoot growth. Then, fertilization (especially nitrogen) is reduced or stopped to induce budset and promote development of cold hardiness, usually during July through September depending on species, seed source, and stocktype specifications. However, a significant amount of root and stem growth can still occur late in the growing season as long as temperatures remain within favorable ranges. This increase in biomass late in the growing season can lead to nutrient dilution within the plant unless more nutrients are supplied through fertilization. If nutrient concentrations drop below the adequate range, there may be inadequate reserves for vigorous growth following outplanting. However, many growers are concerned about the traditional belief that fertilizing too late in the season will cause budbreak, stimulate additional shoot growth, or delay or reduce cold hardiness.

To prevent nutrient dilution, some nurseries apply late-season fertilizers after shoot growth has ceased (Figure 1A). Because seedlings are actively growing roots well into the fall, there is great potential to increase seedling nutrient content with fertilization. Nutrient loading is a relatively recent cultural practice in which late-season fertilization is used to increase seedling nutrient reserves with the objective of promoting additional growth after outplanting. Nutrient concentration in nursery plants follows a classic uptake curve and nutrient loading is the uptake of nutrients beyond the adequate range, but not so much that toxicity is reached (Figure 1B). This enhanced internal nutrient reserve is thought to increase root egress and promote

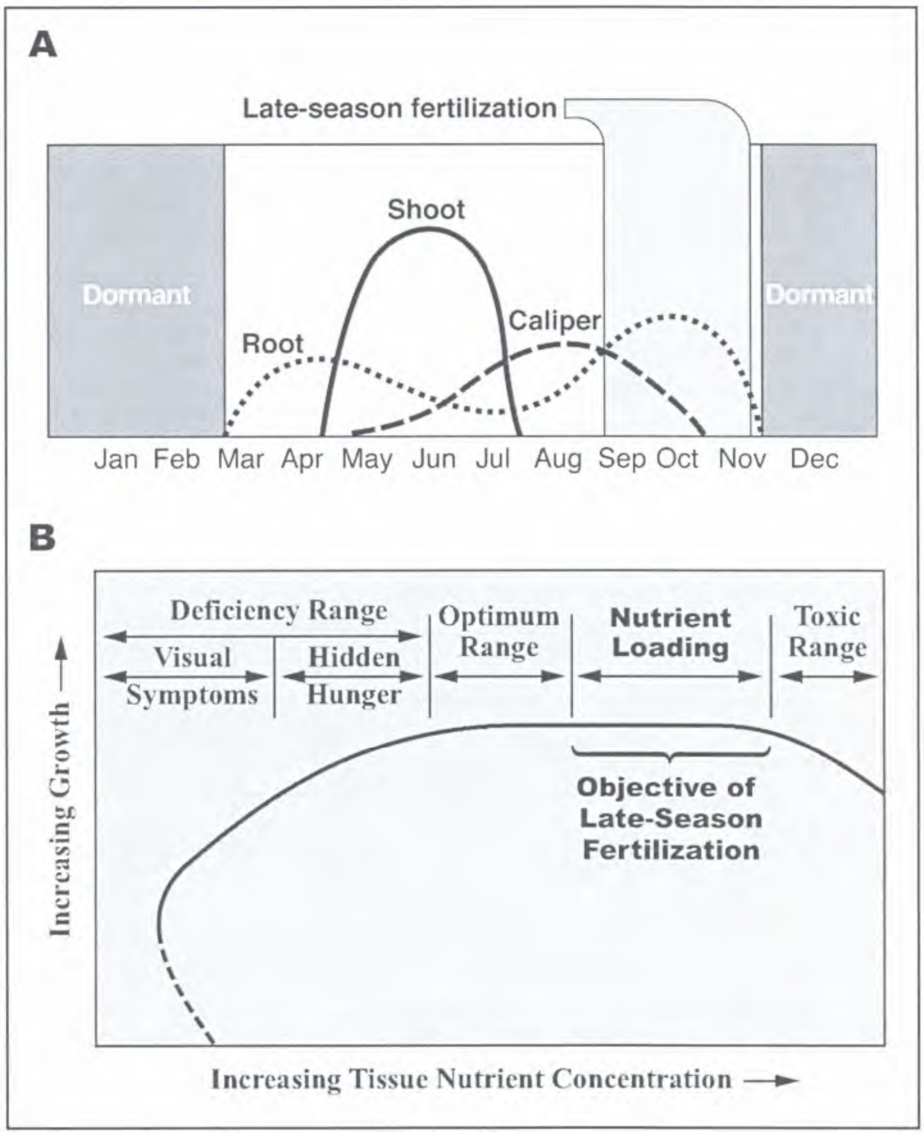

Figure 1 – Late season fertilization is applied after shoot growth has ceased (A) with the objective of "loading" the plants with extra mineral nutrients (B) to promote better growth after outplanting. (B, modified from Chapman 1967).

faster shoot growth immediately following outplanting. Nutrient loading is promoted to improve seedling field performance, especially on nutrient-poor sites or sites with heavy competition (Timmer 1997).

Numerous research studies on late season fertilization have been conducted, and results have been variable to say the least (Table 1). One explanation for this variation is that studies have been done on different crops,

Table 1 - Summary of research studies on with late-season fertilization of conifer seedlings

Source	Stocktype	Type and Rate of fertilizer	Application timing	Effects on nursery stock
Benzian and others (1974)	Bareroot	NH_4NO_3+$CaCO_3$ or K_2SO_4 at 62 or 125 lb/ac	Early September	Increased foliar nitrogen (N) concentrations; earlier budbreak; increased growth of spruce but reduced survival of fir
Birchler and others (2001)	Bareroot	NH_4NO_3+K_2SO_4 or $(NH_4)_2SO_4$+KCL at 0 to 285 lb N and K/ac	September to November	Increased foliar N; root growth potential and cold hardiness unaffected; earlier budbreak; no effect on outplanting performance
Boivin and others (2002)	Container	Soluble 20-20-20 NPK at 6 or 12 mg N per seedling	During hardening period	N, P and K uptake increased up to 164, 70 and 32%, respectively; greater biomass; lower shoot-to-root ratio
Boivin and others (2004)	Container	Soluble 20-20-20 NPK at 0 to 48 mg N / seedling	9 weeks after bud set	Increased N uptake and growth after outplanting; reduced survival at the highest rate
Hinesley and Maki (1980)	Bareroot	Macronutrient fertilizers at 150 N lb/ac	Late October	Increased seedling size and foliar nutrient concentrations
Irwin and others (1998)	Bareroot	NH_4NO_3 at 51 lb N/ac applied 0 to 3 times	November to December	Increased N concentration with no change in morphology; increased first-year field height and survival
Islam and others (2009)	Bareroot	NH_4NO_3 at 0 to 80 lb N/ac	Mid-September	Increased shoot height, bud size, number of needle primordia, N concentration, and cold hardiness
Montville and others (1996)	Container	foliar fertilization (27-15-12) at 324 to 972 ppm	Twice weekly during budset	Increased stem diameter, bud length, shoot biomass, and N concentration
South and Donald (2002)	Bareroot	0, 134 lb/ac N, 134 lb/ac of N + 134 lb/ac of P, or 134 lb/ac of K	Early October	Increased N concentration with no effect on morphology; variable effects after outplanting
Sung and others (1997)	Bareroot	NH_4NO_3 at 0 to 36 lb/ac	Mid-September	Fewer culls at high rate; increased first order lateral roots and dry weights
van den Driessche (1985)	Bareroot	Macronutrient fertilizers at 0 to 71 lb N/ac	July to October	Increased N concentration and new roots; higher relative growth rate in sand culture but not in artificial soil; earlier budbreak
VanderSchaaf and McNabb (2004)	Bareroot	NH_4NO_3 at 0 to 178 lb N /ac	January	Increased N concentration; no effect on morphology; greater growth after outplanting
Williams and South (1992)	Container	$(NH_4)_2HPO_4$ at 0 to 180 lb N/ac	September to November	Fertilization did not delay the progression of the bud dormancy cycle; temporary effects on cell division

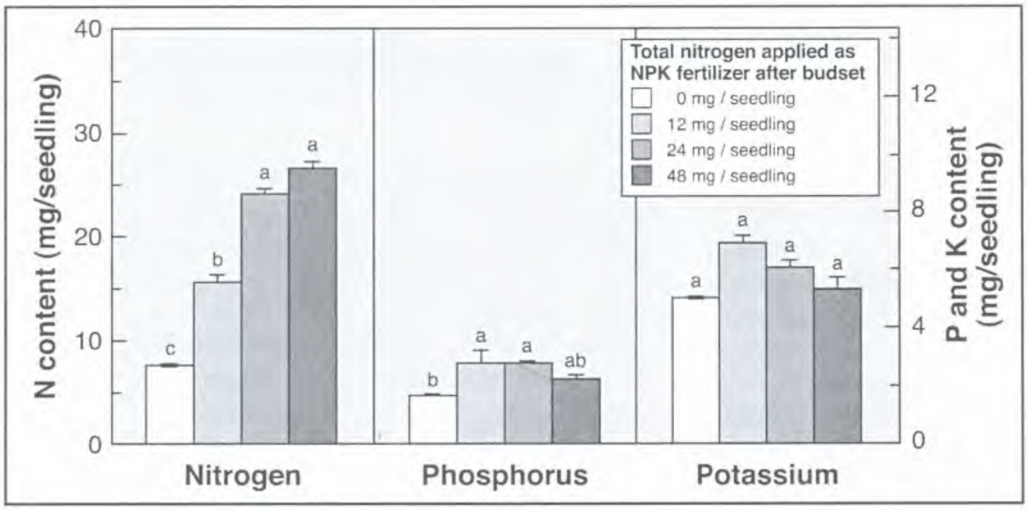

Figure 2 – When black spruce (Picea mariana) seedlings were loaded with NPK fertilizer, nitrogen showed the greatest increase. For each nutrient, bars with the same letter are not statistically different ($\alpha \leq 0.05$). Adapted from Boivin and others (2004).

with different fertilizers, at different rates, and applied at different times. Therefore, it is impossible to generalize about the effects of late season fertilization on your particular crop. However, one consistent finding is that late season fertilization greatly increases seedling nutrient concentrations, especially nitrogen (Figure 2). The effects of late season fertilization on seedling morphology, physiology, and subsequent growth after outplanting are also variable, but two out of three studies report some type of positive response. In some cases, seedling size increased in the nursery (Boivin and Timmer 2002; Hinesly and Maki 1980; Islam and others 2009; Montville and others 1996; Sung and others 1997) but no additional growth was measured in other studies (Boivin and others 2004; Irwin and others 1988; South and Donald 2002; VanderSchaaf and McNabb 2004). Late season fertilization can affect budbreak the following year; several studies report that budbreak was earlier in the following season for nutrient-loaded seedling compared to control seedlings (Benzian and Freeman 1974; Birchler and others 2001; van den Driessche 1985). After outplanting, growth of seedlings with increased nutrient reserves was found to be greater in some cases (Benzian and Freeman 1974; Boivin and others 2004; Hinesley and Maki 1980; Irwin and others 1988; South and Donald 2002; van den Driessche 1985; VanderSchaaf and McNabb 2004) but was unaffected in others (Benzian and Freeman 1974; Birchler and others 2001; South and Donald 2002; van den Driessche 1985). In a few cases, very high fertilization rates resulted in reduced survival after outplanting (Benzian and Freeman 1974; Boivin and others 2004; South and Donald 2002) indicating the need to avoid excessive nutrient loading into the toxic range (Figure 1B).

Late season fertilizer applications must be carefully scheduled to avoid negative effect on phenology. By applying fertilizers after plants have been exposed to cold nights, the chances of stimulating Lammas growth will be lessened. One of the biggest concerns about late season fertilization is that it would decrease cold hardiness. One study found that cold hardiness is unaffected by properly applied, late-season fertilization (Birchler and others 2001) and, in fact, the development of cold hardiness can actually be impaired if plant nutrient concentrations are too low.

Summary

Late-season fertilization has potential for improving seedling quality and outplanting success but nurseries should conduct trials on fertilizer formulations and rates in order to develop an optimum treatment for a specific crop. Monitor mineral nutrient uptake through seedling nutrient analysis to ensure that fertilization treatments are effective, and prevent overfertilization which can reduce plant quality and accelerate nutrient runoff.

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