Are Differences in Formulations of Fertilizers for Use at Planting Important?

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Abstract

Fertilization at planting is carried out quite widely in British Columbia, Washington and Oregon, but the benefits are not precisely known. Examples of no response or adverse effects are not infrequent. In the few instances where they have been compared, fertilizers of different compositions and release rates show little difference other than that attributable to N content. Reasons to expect responses to P on some sites, and the need to apply sufficient P to obtain a response are discussed. Ways to improve fertilization at planting are examined.

Introduction

Reforestation sites that previously carried forest have sufficient nutrients available to sustain slow growth of a newly planted crop. Sometimes they may have quite high levels of nutrients for a short time as a result of harvesting disturbance of the environment. However, additional nutrients are often found to increase growth of newly planted trees. This has been recognised for a long time, and fertilization at planting is not new. The value of adding P fertilizers at planting of Sitka spruce in Scotland has been known since the beginning of this century (McIntosh 1980). Nine g urea formaldehyde resin pellets were tested on Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) and Sitka spruce *(Picea sitchensis* (Bong.) Carr.) before 1960 (Austin and Strand 1960), and subsequently on 8 species in four eastern Provinces of Canada by 1965 (Swan 1965). Some large responses (height increases of 40%) were reported by Austin and Strand (1960), but responses in eastern Canada were less or non-existent.

Fertilization at planting continues on a large scale (McLeod *et al.* 1992, Anon. 1995, Chambers and Smestad 1995, Dunsworth and Arnott 1995, Simpson and Vyse 1995, Roth and Newton 1996, Terry 1997). Fertilization at planting seems to increase growth, on average, in British Columbia (Anon. 1995). However, the procedure is not an exact science, with reduced survival (McLeod *et al.* 1992, Anon. 1995) and unpredictable growth response or lack of response (Munson *et al.* 1993, Anon. 1995, Simpson and Vyse 1995, Roth and Newton 1996) occurring. Formulation of fertilizer, amount of fertilizer, and placement of fertilizer are matters of debate. Competing fertilizer vendors recommend fertilizers of different formulations and release rates.

Control of competing vegetation around the planted seedling is widely recognised as important for ensuring improved establishment and growth of artificial regeneration (Cellier and Stephens 1980, Nambiar and Zed 1980, Tiarks and Haywood 1986, Roth and Newton 1996), but it is not always carried out in the Pacific Northwest. Positive responses to fertilization at planting may occur more uniformly with vegetation control.

Tests of Different Formulations

In an operational experiment conducted by MacMillan Bloedel four fertilizers were tested at planting of Douglas-fir, western hemlock *(Tsuga heterophylla* (Raf.) Sarg.) and western red cedar *(Thuja plicata* Dorm) at two sites (Sandford and Andersen 1997). All the fertilizers used in this experiment (Table 1) had slow release rates as follows: Nutricote, release of 80% of N (as NO_3 and NH_4) over 360 days at 25°C (Arnott and Burdett 1988); Osmocote, 14-16 month longevity, with N as urea, NO_3 and NH_4; Gromax tea bag, majority of the N "prill that delays release for first month or later after planting", mainly as urea; Briquettes contained isobutylidene diurea, an N source which is only slightly soluble in water with a release rate dependent on particle size (Benzian 1967). Thus the amounts of fertilizer were different, with different proportions of N P K, and different forms of N.

Seedling growth during the first year was substantially increased by fertilizer treatments, as indicated by the stem volume growth of the Douglas-fir (Table 1). Without further consideration, it would be possible to conclude that the Osmocote was the most suitable fertilizer, and much superior to Gromax tea bags and briquettes. By considering the growth responses to the amount of each nutrient supplied a different conclusion was reached. On each site, increase in stem volume was strongly related to the amount of N supplied (Figure 1), but unrelated to the amounts of P and K supplied. It seemed that on these two sites, in the coastal western hemlock zone of eastern Vancouver Island, neither formulation nor release rate had any effect on response. Only the total amount of N, and site affected the outcome.

Table 1. Details of fertilizers applied at planting and first year volume growth of Douglas-fir container seedlings planted on two sites (Sandford and Andersen 1997).

	Fertilizer		N	P	K	Volume growth cm^3	
Treatment	Analysis	g/tree		g/tree		Site 1	Site 2
Nutricote	16-10-10	28	4.5	1.2	2.3	8.85	3.02
Osmocote	22-4-6	28	6.2	0.5	1.4	8.86	4.23
Gromax	21-7-14	10	2.1	0.3	1.2	4.67	2.69
Briquette	9-9-4	17	1.5	0.7	0.6	6.57	2.62
Control		0	0	0	0	2.56	1.95

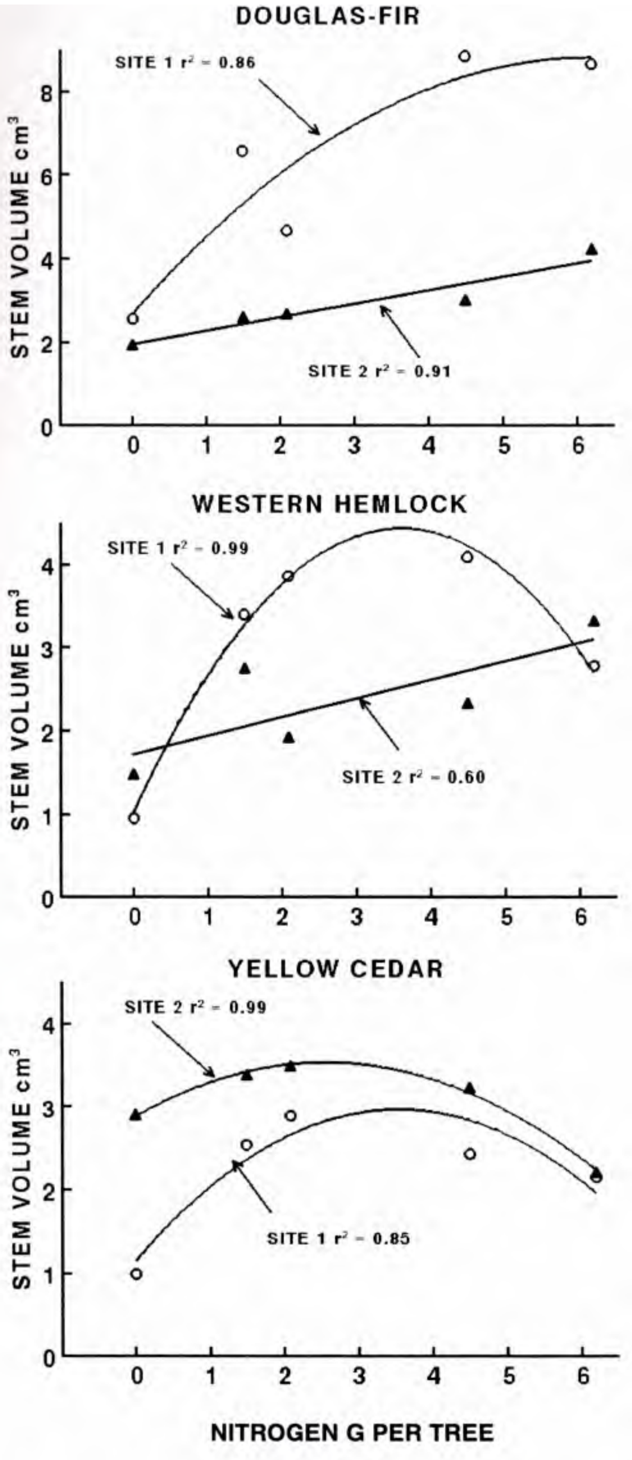

Figure 1. Stem volumes for three species one year after fertilization at planting with Nutricote, Osmocote, Growmax and IBDU briquettes, plotted by site and amount of N supplied per tree. r^2 must exceed 0.86 to be significant at $p \leq 0.05$. (Data of Sandford and Andersen 1997).

The lack of fertilizer formulation effect on growth response to fertilizers applied at planting has been shown previously in well replicated experiments in which Agriform, diammonium phosphate, ammonium sulphate, and sulphur coated urea were tested (van den Driessche 1988). There was also no evidence that of five Gromax formulations, used over several years in B.C., one was any better than the others (Anon. 1995).

Turning to broadleaf species, first year unpublished results (van den Driessche and Brown 1996) from an experiment with slow release and soluble fertilizers applied to two hybrid poplar *(Populus trichocarpa x deltoides)* have shown similar lack of difference. Two slow release fertilizers and two soluble fertilizers (Table 2) were dibbled into holes at 15 cm from the cuttings to supply 0, 13.5 or 27 g N in a factorial experiment replicated in 8 blocks.

Height, stem diameter, and volume showed a significant linear effect of fertilizer level, and clone 2 showed significantly greater response than clone 1, but it was not possible to show a significant effect between fertilizers. The mean stem volumes of the highly soluble STND seem a little lower than the other three fertilizers, so a "type II error" may be involved here (Figure 2). However, it was noticeable how the leaf N and P concentrations of poplars sampled in September, receiving STND and DAP were generally higher than in leaves of those receiving the slow releasing fertilizers (Figure 2). There is no reason to prefer one fertilizer over another based on first year results.

Table 2. Fertilizers applied at planting of hybrid poplar to supply 0, 13.5 and 27 g N per cutting.

Fertilizer	Abbreviation	Analysis	Release
Agroblen Tablets	AGF	15-9-9-3 Mg	24 months
Osmocote Poly-S	OSPS	19-7-11	8-9 months
Growers Standard	STND	15-30-15	Soluble
Diammonium phosphate	DAP	21-55-0	Soluble

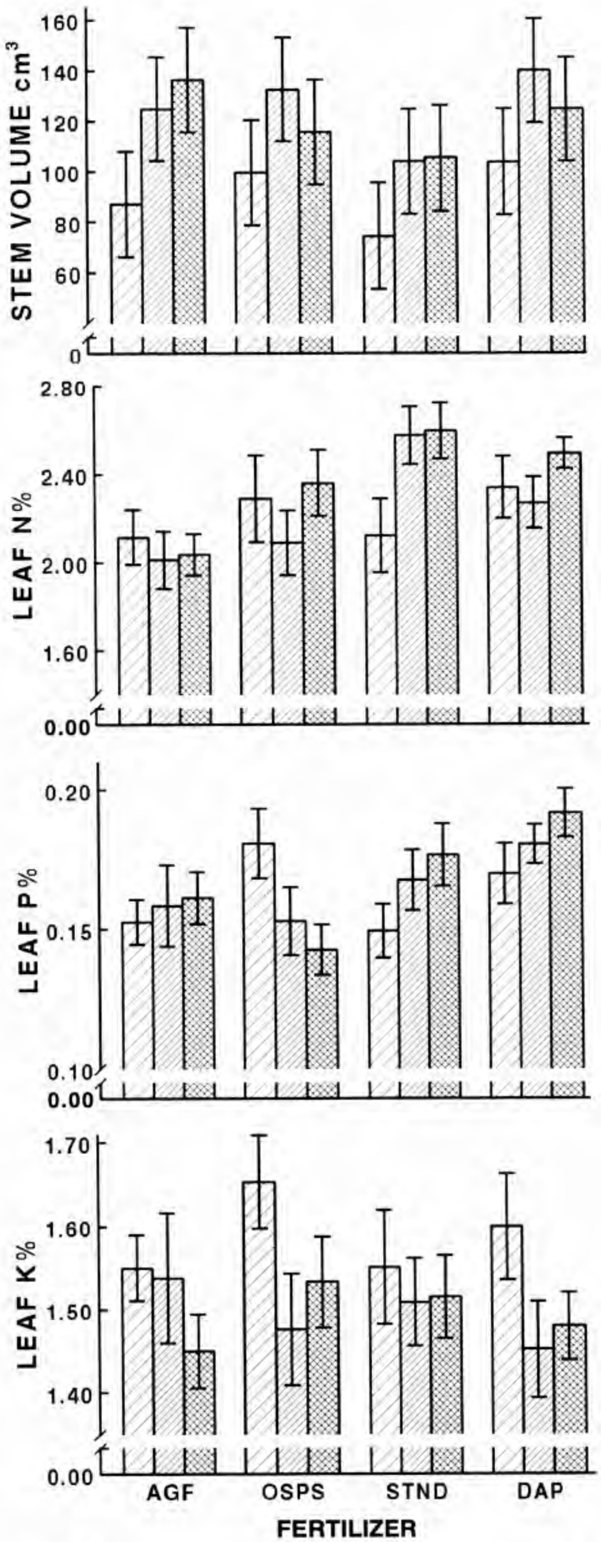

*Figure 2. Stem volume and leaf N, P and K concentrations of hybrid poplar (*Populus trichocarpa x deltoides*) one year after receiving two slow release fertilizers (AGF and OSPS) and two soluble fertilizers (STND and DAP) at planting. Fertilizer details are given in Table 2.*

Nitrogen and Phosphorus Fertilizer Proportions

Judging from the above observations, response seems to be essentially independent of fertilizer formulation. The reason why the formulation (NPK composition) of the fertilizer has no detectable effect on growth response could be because of the small amount of P and K supplied per seedling.

Phosphorus

World wide, P is the most commonly applied nutrient at planting (van den Driessche 1991). In the southeastern U.S., 40 to 50 kg of P ha I are applied to poorly drained soils of the lower coastal plain for establishment of loblolly pine *(Pinus taeda* L.). In New Zealand the standard application rate of P to radiata pine seedlings *(Pinus radiata* D. Don) is 17 g per tree (Ballard 1978). This amounts to 195 g of superphosphate (0-20-0, SP) or 87 g of triple superphosphate (0-45-0, TSP) per tree. In Australia the rates vary from 4 to 35g of P per tree at, or shortly after, planting (Birk 1994).

Application of substantial amounts of P fertilizer in the Pacific Northwest would not be justified without some likelihood of response. Ancient forest soil is usually low in P (Rackham 1995), and P is probably continuously lost from forest soils, possibly in combination with dissolved organic carbon (Donald *et al.* 1993). Conifers are adapted to low supplies of P through mycorrhizal habit and slow growth. However, newly planted trees do not immediately have the benefit of well established mycorrhizal association, and nowadays we do not tolerate slow growth. Furthermore, there is evidence that responses to P fertilization can be obtained in the Pacific Northwest. Responses to P on forest soils from coastal Washington have been shown for Douglas-fir, and western hemlock (Heilman and Ekuan 1980a,b, Radwan 1992, Porada and Zasoski 1987).

On Vancouver Island increasing levels of TSP applied to 2-0 Douglas-fir seedlings resulted in a linear increase in survival over a range of P levels up to 28.8 g per tree, but had no effect on growth (van den Driessche 1988). On northern Vancouver Island young Sitka spruce showed response to 50 kg P ha ^{1}, and western hemlock and red cedar to 100 kg P ha' when applied to a deep mor-humus podzol (Weetman *at al.* 1989a,b).

Bearing in mind the ability of some soils to render P unavailable, the amounts of elemental P supplied per tree have to be in the 5 to 15 g range, rather than the 0.5 to 1.5 g range. Even higher rates may be beneficial in some instances. Responses of hybrid poplar to 200 kg P ha ^{1} (equivalent to 182 g P per cutting) have been obtained on a windrowed site of eastern Vancouver Island (van den Driessche and Brown 1996).

Critical values at which P fertilization is essential have been developed for the southeastern U.S. pine forests, and are less than 5 mg P soil (dilute acid fluoride extraction) and less than 0.11% P in pine foliage (Allen and

Ballard 1982). Responses of Douglas-fir and western hemlock to P fertilization in pot experiments have been obtained when the mineral soil exchangeable P was 1 to 8 mg kg', and needle concentrations were between 0.06 and 0.14% P (Heilman and Ekuan 1980a,b, Radwan 1992).

Nitrogen

Most fertilizers applied at the time of planting contain N, except perhaps in regions where P is expected to be the main limiting element. Even here, if the P deficiency is corrected, response to N is then obtained and therefore applied. However, N may not have only beneficial effects. It can cause root damage and mortality when supplied in a soluble form. In New Zealand, application of 60 g of urea per seedling 15 cm from the base of the tree caused 10-15% mortality, whereas this was reduced by using urea formaldehyde or sulphur coated urea (Ballard 1978). When N fertilizers were applied to Douglas-fir at planting mortality increased in order: diammonium phosphate<sulphur coated urea< urea formaldehyde<ammonium sulphate (van den Driessche 1988).

When N fertilizer is applied at the same time as P fertilizer, P uptake by conifer seedlings may be decreased (Teng and Timmer 1995). The effect is attributed to rizosphere acidification by N fertilizer resulting in direct Al toxicity to roots and also inactivation of P as aluminophosphate. Increased P supply overcomes the negative effect of N on P uptake.

Nitrogen can also promote competing vegetation, which often responds much more rapidly to applied fertilizer than the tree seedling. The result is that other site resources, such as water, non-fertilizer nutrients and light, may become less available to the seedling (Ballard 1984, Tiarks and Hayward 1986). This type of effect apparently accounted for the reduced growth of Douglas-fir receiving urea broadcast at planting in plots without weed control (Roth and Newton 1996). The reason for the failure of trees on weed controlled plots to respond was attributed to possible adverse effects of urea fertilizer.

Urea is the most widely used fertilizer in forestry, in the Pacific Northwest because of its high N content and cheapness. It is not necessarily the best, and has been little used in Sweden for stand fertilization since the 1960s because ammonium nitrate was found to give significantly better growth (Dangerfield and Brix 1979). Established stands of Douglas-fir have also responded better to AN than to urea (Harrington and Miller 1979, Barclay and Brix 1984).

Recovery of Nutrients from Fertilizers

A seedling of 1 to 2 g dry weight might take up 20 to 40 mg N and 3 to 6 mg P, if its dry weight doubled during the season after planting. It seems surprising that fertilizer applications of perhaps 5 g of N and 15 g P may be necessary to ensure that this occurs. The reason seems to be that these nutrients are rapidly rendered unavailable to the planted tree and uptake efficiency is low. Four-year old conifer trees can have efficiencies between 2% and 5% in the absence of vegetation control (Table 3). These trees had been allowed to develop a root system for four years, and it is possible that newly planted trees, attempting to establish a root system, would have lower efficiencies. Uptake efficiencies from urea are at least as low because of volatilization, leaching, denitrification, and immobilization (Morrison and Foster 1977).

Based on above ground harvest, uptake efficiency of P was as high as 3.3% for three-year old *Pinus radiata* three years after fertilization at planting (Ballard 1978). Higher efficiencies are obtained when older plantations are fertilized (Ballard 1984).

Table 3. Efficiency (as % of applied ^{15}N recovered) of N uptake from ammonium sulphate fertilizer applied at 200 kg N ha^{-1} to four-year old conifer trees (Chang *et al.* 1996).

Weed treatment	Species		
	Western red Cedar	Western hemlock	Sitka spruce
Untreated	4.1%	2.0	4.9
Weed control	7.7	17.8	10.3

Release Rates

Uptake of fertilizer N by trees is seasonal and brief (Nambiar and Bowen 1986, Mead and Preston 1994). Many of the slow release fertilizers do not release fertilizer for more than a growing season, and so the nutrient concentrations they provide are no higher than are available from soluble fertilizers. They could even be less effective if the main uptake occurs with the flush of root growth in spring, but they release fertilizer steadily over the whole growing season. On the other hand, fertilizers which release nutrients over two or three years should theoretically be advantageous (Ballard 1984).

Conclusions

Differences between formulations of fertilizers currently applied at planting are relatively unimportant, but changes outlined below might lead to more effective formulation.

- Fertilizer applied at planting is most successful if placed into the ground 5 to 15 cm from the seedling because root damage is minimised, and larger amounts of fertilizer can be used. Larger amounts of fertilizer provide a longer lasting core of available nutrient.
- The need for large amounts of fertilizer is also supported by low uptake efficiencies of N and P.
- Responses to P fertilization at planting can be expected on some sites, but only if P is applied at higher levels than heretofore.
- Identification of soils responsive to P should be attempted by analysing mineral soil for available P.
- Control of vegetation around the planted seedling is likely to increase response to fertilization at planting.
- The advantages between different types of slow release fertilizers, or of slow release compared to soluble fertilizers are not clear. Multiple year release fertilizers might be advantageous.
- Different N sources may give different results and should be tested.
- An effective way of developing fertilizers for application at planting might be to study the effects of nutrient source, amount, placement, and season of uptake on total uptake using isotopically labelled fertilizers.

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