RESPONSE OF WESTERN HEMLOCK AND SITKA SPRUCE TO FERTILIZATION IN SOUTHEASTERN ALASKA

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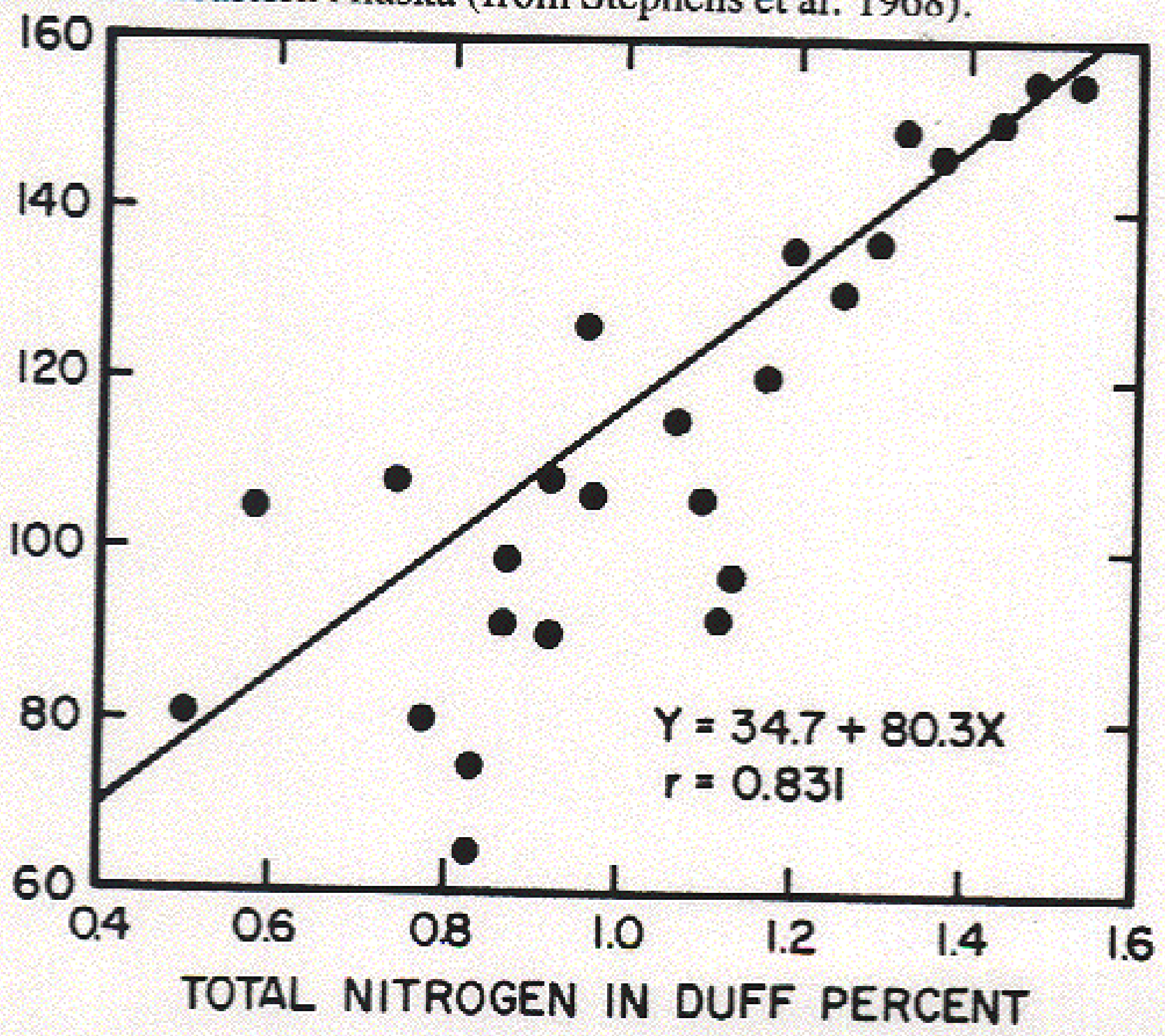
ABSTRACT

In Alaska about 5400 acres (2200 hectares) of young western hemlock and Sitka spruce have been fertilized with urea. One investigation showed that spruce increased height and diameter growth over a four-year period. Response of hemlock could not be evaluated because of shoot dieback. Foliar nitrogen levels increased and foliar color changed the year following fertilization, but changes did not persist. Neither large-scale fertilization nor response studies are currently being done. Interest in treatments to improve tree growth now center on thinning. Information of tree-soil nutrition is needed before advances in forest fertilization can be made.

INTRODUCTION

Interest in forest fertilization in southeastern Alaska dates back to the 1960's when soil scientists began soil and soil-site surveys in the region. Soils of southeastern Alaska are typically shallow, wet, and overlain with 4–12 in. (10–30 cm) or more of organic matter. Most tree roots are found in the organic layer and in the first few inches of soil. Ten inches (25 cm) of mineral soil over bedrock appears to be sufficient for maximum tree growth (Heilman and Gass 1974). Good growth is often maintained with much less mineral soil.

Figure 1. Relation of site index to total (Kjeldahl) N content of duff layers in southeastern Alaska (from Stephens et al. 1968).



Nutrient analyses of the organic layers and mineral soil show that most nutrients are stored in the organic layers; base saturation percentages and exchangeable bases are low in mineral horizons. Most of the forested soils are Spodosols and, regardless of parent material, these soils have markedly similar mineral horizons (Gass and Heilman 1967, Heilman and Gass 1974).

FOREST FERTILIZATION IN ALASKA

Stephens et al. (1968) found total (Kjeldahl) N content of the organic layer to be highly correlated with site index (Figure 1); but significant correlations could not be found between site index and extractable P, K, Ca, or Mg. These findings led in 1967 to the installation of small fertilizer plots at several locations. Early results showed significant growth increases from added N (Johnson 1970), which in turn prompted the USDA Forest Service to test large-scale aerial applications of urea in young stands of hemlock/spruce. Four projects were undertaken in the late 1960's and early 1970's, mostly to gain experience in methods, costs, and logistics of large-scale applications in remote areas (Johnson 1970, Bowkett 1969). All areas were fertilized by helicopter with urea prills (46% N by weight) at the rate of 400 lb urea/acre (448 kg/ha; Table 1).

Table 1. Aerial applications of urea (prills) on young stands of hemlock/spruce in southeastern Alaska.

Yr of application	Location	Area (acres)	Age (yr) of regeneration at time of application
1969	Thomas Bay	1500	6–10
1970	Mitkof Island	1500	5–10
1971	Prince of Wales Island	1500	6–10
1972	Kosciusko Island	930	15

THOMAS BAY STUDY

Only at Thomas Bay did we study the effects of aerial fertilization on foliar nutrient levels of western hemlock and Sitka spruce and height and diameter growth of individual spruce (Farr et al. 1977). Response of western hemlock on both fertilized and unfertilized areas could not be measured because of severe shoot damage to hemlock from infection caused by the fungus *Sirococcus strobilinus*. Later investigation by Wicker et al. (1978) indicated some tendency for fertilizer application to favor the fungus, but results were inconclusive.

The fertilized units at Thomas Bay are located on a glacial-outwash plain where site index of hemlock and spruce averages about 70 ft (21 m) on a 50-yr base. Soils are Spodosols and Entisols that developed after glacial retreat, and they tend to be excessively well-drained, coarse sands and coarse sandy loams. These soils do not have thixotropic properties common to most well-developed soils in southeastern Alaska because of their low levels of incorporated iron and humus.

The area was fertilized in May 1969. Costs, including fertilizer, helicopter application, and administration, averaged $39/acre ($96/ha). At the time of fertilization, hemlock and spruce regeneration averaged 5–8 ft (1.5–2 m) in height and all areas were stocked with 3000–6000 trees/acre (7400–14 800/ha). Because trees were small, we analyzed height and diameter growth of individual trees instead of basal area or volume response on an area basis. Transects were run through fertilized and unfertilized units in the fall of 1969, and dominant or codominant hemlock and spruce were selected as permanent sample trees at 1-chain (20-m) intervals.

Total height, current year's growth, and annual height growth for the 3 yr before fertilization were recorded; and foliage samples were collected from each tree. Height growth was measured each fall through 1974, and additional foliage samples were collected in 1972, 1973, and 1974. In 1973, five growing seasons after fertilization, additional sample spruce trees were felled and sectioned so diameter development could be measured. Diameter growth of fertilized and unfertilized spruce were compared at a height of 2 ft (0.6 m) above the root collar because many of the sample trees had not reached breast height at the time of fertilization.

RESULTS AT THOMAS BAY

Height growth of fertilized Sitka spruce increased 20%–25% during 1970, the second year after fertilization. No difference was detected the first year. By the fourth year there were no significant differences in height growth of fertilized and unfertilized trees when adjusted for tree size.

Diameter response was about 25%–30% during the second and third year following fertilization. Response appeared to decline after that and by the end of the fifth year there were indications that differences in growth rates were no longer significant. Analysis of foliage samples collected in the fall of the year fertilizer was applied showed that fertilized spruce and hemlock quickly picked up N. The N content in fertilized spruce averaged 2.43%—about double that in unfertilized spruce; N content in hemlock averaged 2.28%—about 66% higher than in unfertilized hemlock. There was no evidence that the addition of N affected levels of other nutrients. After four growing season, concentrations of N in fertilized spruce and hemlock had dropped off to levels about equal to those in unfertilized trees (Farr et al. 1977).

Levels of K were quite low in all samples, averaging 0.46% in 1969 and 0.58% in 1972. This is considerably below levels normally found in healthy Sitka spruce in England (Binns et al. 1970, Binns and Atterson 1967).

Color of foliage changed noticeably the first growing season after fertilization. This color difference was not only apparent in live trees but carried over into dried and ground needle samples. We compared color of dried sample material against standard Munsell color charts for hue, value, and chroma and found that the color of fertilized trees was greener, about equally dark, and more intense than unfertilized trees. This difference in color, however, was not apparent after the first year.

To summarize the Thomas Bay study, we found after 5 yr that the fertilized trees were about 2 ft (0.6 m) taller and 0.5 in. (1.3 cm) larger in diameter than they would have been had they not been fertilized. Although there were immediate results in terms of stand appearance and growth response, the fertilizer did not produce long-lasting results; and the area still had 3000–6000 trees/acre (7400–14 800/ha). This level of stocking is typical in southeast Alaska where most naturally seeded stands are overstocked.

Use of fertilization has been proposed as a possible substitute for precommercial thinning. Application of fertilizer, it has been argued, could increase growth of trees in the upper diameter classes relatively more than growth of trees in the lower diameter classes, thus hastening competition and natural thinning. From our field trials, we have no data to test this hypothesis. Our work with dominant and codominant trees of various sizes, however, showed a consistent increase in height growth across all height classes.

FOLIAR ANALYSIS

Foliar analysis was done on a limited basis in connection with the study at Thomas Bay and more recently for unfertilized trees on the Maybeso Experimental Forest.[1] In both cases we looked at correlations between height growth and nutrient concentrations. Results were not at all consistent. Variables found significant for one plot or area were often insignificant

1. Harris, A. S., and Wilbur A. Farr. Foliar analysis of western hemlock and Sitka spruce on good and poor sites on the Maybeso Experimental Forest, Southeast Alaska. Unpublished manuscript, USDA Forest Service, Juneau, Alaska.

for others. Spruce regularly gave more consistent results than did hemlock. Height growth of hemlock was seldom related to any nutrient.

Comparison of nutrient levels of spruce with those commonly found in pole-sized stands of spruce in England suggests that available N and perhaps K may be in short supply for optimum growth of spruce in Alaska (Table 2). The same could be true for hemlock, but available information summarized by van den Driessche (1976) shows a wide range of nutrient values.

At present we know very little about tree-soil nutrient relations in southeastern Alaska. Considerable work will be needed before enough will be known to guide the forest manager in the efficient use of fertilizer in the forest.

FERTILIZATION AND WATER QUALITY

Effects of fertilization on streamwaters were studied at Falls Creek on Mitkof Island, where Meehan et al. (1975) found an initial short-term increase in ammonia-N in one stream, apparently from fertilizer inadvertently falling directly into it, not from runoff. The concentration never exceeded 1.28 mg/litre, a concentration well below that considered toxic to aquatic life. Concentration of nitrate-N in both streams remained higher than normal during a 1-yr sampling period but never exceeded 2.36 mg/litre, far below the upper limits for human consumption defined as 10 mg N/litre.

PRESENT SITUATION

Since 1972 there has been no aerial fertilization in Alaska. Lack of funds is one reason, plus the realization that basic information is needed on soil properties, species requirements, and responses to fertilization before additional expenditures are justified.

On the management level, the interest in increasing fiber yield, which in the late 1960's centered on fertilization, has now shifted to precommercial thinning. On the research level, program direction has also changed with efforts now directed toward thinning. This reflects current thinking on priorities for allocating limited research dollars. As mentioned previously, our hemlock/spruce stands are typically very dense. Stands regenerate naturally, and stocking levels of 3000 to 6000 or more stems per acre (7400–14 800/ha) are common. We know that fertilization may stimulate growth for a few years, but we would still be faced with greatly overstocked stands. We believe that fertilization alone is not a suitable substitute for early thinning. We also suspect from initial thinning tests that early stocking control will result in longer lasting positive gains in production of usable wood fiber.

Additional gains probably could be made through fertilization in conjunction with thinning. If fertilization is done in Alaska in the future, it will most likely be done in thinned stands. Questions of the economics of fertilization in the face of an uncertain energy supply and rampant inflation are troubling to say the least, but even more troubling is our lack of

Table 2. Means and ranges of nutrient concentrations in good and poor growth of Sitka spruce and western hemlock in England and in the Maybeso Experimental Forest, Hollis, Alaska.

Species	Percentage ovendry weight					Source
	N	P	K	Ca	Mg	
Sitka spruce						
Good growth	1.59 (1.19–1.93)	0.22 (0.19–0.34)	1.27 (0.81–1.67)	0.35 (0.25–0.55)	0.14 (0.07–0.20)	Binns *et al.* 1970
	1.47 (1.07–1.76)	1.24 (0.18–0.33)	1.15 (0.68–1.58)	0.24 (0.15–0.40)	0.12 (0.09–0.16)	Binns & Atterson 1967
	1.38 (1.05–1.66)	0.22 (0.13–0.32)	0.80 (0.55–1.35)	0.31 (0.13–0.56)	0.09 (0.06–0.15)	a
Poor growth	1.09 (0.86–1.34)	0.16 (0.09–0.27)	0.88 (0.52–1.15)	0.43 (0.36–0.59)	0.14 (0.08–0.25)	Binns *et al.* 1970
	0.95 (0.72–1.27)	0.16 (0.08–0.19)	0.69 (0.30–0.89)	0.28 (0.21–0.37)	0.10 (0.08–0.12)	Binns & Atterson 1967
	0.88 (0.69–1.12)	0.15 (0.10–0.21)	0.65 (0.42–0.92)	0.31 (0.14–0.50)	0.07 (0.03–0.10)	a
Western hemlock						
Good growth	1.47	0.16	0.77	0.39	0.16	van den Driessche 1976
	1.28 (1.00–1.48)	0.28 (0.18–0.34)	0.68 (0.26–0.94)	0.20 (0.09–0.34)	0.13 (0.09–0.17)	a
Poor growth	0.83 (0.60–1.02)	0.18 (0.09–0.40)	0.62 (0.40–0.82)	0.17 (0.08–0.28)	0.09 (0.07–0.14)	a

[a]Data from the Maybeso experimental Forest, Hollis, Alaska; on file at the USDA Forest Service, Juneau, Alaska.

understanding of the basic nutritional requirements of hemlock and spruce and their response to fertilization on a variety of sites. Until this knowledge is acquired, additional field application will doubtless be of limited value.

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