INTRODUCTION

Although the responsiveness of lodgepole pine to fertilization has been well documented (Weetman et al. 1985; Brockley 1989), very little fertilizer response information has been collected for other coniferous species in the interior of British Columbia. Foliar nutrient concentration data collected from various species and locations indicate that severe to very severe nitrogen deficiencies are common in interior forests. Although the supplies of other essential nutrients may be adequate to balance native supplies of nitrogen, they may sometimes be inadequate to sustain or enhance growth response following nitrogen fertilization. Also, certain site preparation practices (e.g., prescribed burning and windrowing) have apparently exacerbated nutritional problems in many interior spruce plantations (Ballard and Hawkes 1989).

To verify the nutrient deficiencies that have been tentatively identified in many interior forests, trees yielding a “deficient” foliar nutrient concentration must be shown to respond favorably to the application of the supposedly deficient nutrient. In 1987, Dr. Gordon Weetman of the University of British Columbia and Kathie Swift, a graduate student in silviculture, initiated a 2-year FRDA project to investigate this topic.

The objectives of this project were:

1. to establish a number of forest fertilizer “screening” trials to document specific nutrient deficiencies affecting the growth of young interior spruce, interior Douglas-fir, and western larch stands, and so refine deficiency diagnoses;

2. to estimate the relative responsiveness of these species to various fertilizer treatments; and

3. to identify specific nutrients to be included in future conventional, fixed-area plot trials.

Ten fertilizer trials (4 Fd; 4 Lw; 2 Sx) were established in the southern Interior during the first year of the study. In 1988, 17 trials (12 Sx; 5 Fd) were established in the north-central Interior. In almost all cases, the interior spruce and Douglas-fir trials were established in 15- to 20-year-old plantations. Of the western larch stands, one was established in a 15-year-old plantation and three were established in natural, thinned stands (one 8-year-old stand and two 40-year-old stands).

METHODS

Because so little is known about the nutrition and fertilization response potential of these species, screening trials were thought to be the most appropriate way of beginning fertilization research. Fertilizer screening trials using various “single-tree” or “microplot” designs have been used with considerable success in rapidly identifying nutrient deficiencies and evaluating the response potential of lodgepole pine in the British Columbia Interior. Preliminary growth response data, recording increases in needle weight and shifts in foliar concentration of added and non-added nutrients, can be obtained within one year of treatment. Previous studies have shown a strong positive correlation between first-year needle weight response and subsequent stemwood response. Efficient screening trials are easy and inexpensive to establish and, therefore, enable a large number of stands to be tested over a short period.

Sixty microplots (6 treatments x 10 replications/treatment) were systematically located within each stand. Factorial combinations of N (0, 100, and 200 kg N/ha as ammonium nitrate) and a “complete mix” fertilizer (0 and 1170 kg/ha) were randomly assigned to treatment plots. At 1170 kg/ha of fertilizer applied, the amounts of nutrients contained in the “complete mix” were as follows (kg/ha): P - 100; K - 102; Ca - 129; Mg - 51; S - 50; Fe - 9; Zn - 3.5; Mn - 3.7; Cu - 1.5; B - 1.5; Mo - 1.0. Fertilizer was applied by hand to a 6-m radius surrounding a dominant “plot centre” tree. The outer edges of adjacent treatment plots were separated by a distance of at least 6 m. Two trees per plot — the “centre” tree and an adjacent “off-centre” tree — were identified for subsequent foliar sampling. In 1988, all trials were fertilized in the spring, before bud break. However, because of earlier flush of western larch and Douglas-fir, many trees had flushed and shoots had partially elongated before the fertilizer was applied in 1987.

At the end of the first growing season following treatment, the current year’s needles were collected from the two trees per plot. The foliage from the “centre” and “off-centre” trees were bulked together to produce 60 foliage samples per stand. For two of the larch stands, foliage was also differentiated on the basis of shoot type (long vs. short shoots) and branch position (current, 1-year-old, and 2-year-old wood). The dry weight of needles (g/1000 needles) that were produced in the first year after fertilization was measured and recorded for each treatment plot. In 1987, the 60 foliage samples were bulked to produce five composite samples per treatment (i.e., 30 samples per installation); in 1988, the samples were bulked to produce two composite samples per treatment (i.e., 12 samples per installation). All composite samples were analyzed for N, P, K, Ca, Mg, total S, sulphate-S, Mn, Cu, Zn, B, total Fe, and active Fe.

RESULTS AND DISCUSSION

Fertilization had very little effect on the weight of needles formed during the first growing season after treatment in the trials established in 1987. The application of fertilizer after new growth had flushed probably accounts largely for lack of
first-year response. Reliable estimates of the fertilization response potential of these trials will have to wait until stem radial increment is measured after 4 years. Conversely, fertilization had a highly significant effect on first-year needle weight in the Douglas-fir and interior spruce trials established in 1988.

When applied singly, N and the “complete mix” fertilizer had little effect on needle weight. Combined applications, however, resulted in a relatively large response. This interaction effect is clearly shown in Figure 1. These results indicate that although N deficiencies undoubtedly hinder the growth of these two species in the Interior, growth response following N fertilization may be poor unless other nutrients are added in conjunction with N. In other words, although supplies of certain non-added nutrients may be adequate to balance native supplies of N, they may be inadequate to sustain or enhance growth following N fertilization.

Which nutrients in the “complete mix” fertilizer are responsible for the increased needle weight response cannot be stated conclusively. However, examination of foliar nutrient concentration data may provide certain hypotheses that can be tested in future research trials. For example, Figure 2 clearly illustrates the effects of the various fertilizer treatments on first-year foliar nitrogen:sulphur mass ratio. Trees within plots which received only N exhibited nitrogen:sulphur ratios far greater than the “critical” value (14.6) suggested by Ballard and Carter (1989). The sulphur contained in the “complete mix” fertilizer (50 kg S/ha) was apparently sufficient to maintain a more favourable nitrogen:sulphur balance.

Examination of foliar sulphate sulphur data provides further evidence of inadequate S nutrition in the 1988 trials. Because any S above that required to balance the N in protein formation is accumulated in the foliage as inorganic sulphate sulphur, foliar sulphate sulphur may be a more sensitive indicator of a tree’s S status than is total S. In this study, the almost complete exhaustion of foliar sulphate sulphur reserves following fertilization with N alone (Figure 3) indicates that fertilized trees may have been unable to use the added N effectively during the first year following treatment. By elevating foliar sulphate sulphur levels, S additions may have increased both N use and needle weight. Previous studies have indicated that N fertilization may induce S deficiencies in lodgepole pine (Brockley 1989, 1990).

![Figure 1](image1.png)

**FIGURE 1.** The effect of individual and combined applications of nitrogen and “complete mix” fertilizer on the mean dry weight of needles (g/1000 needles) produced in the first growing season after fertilization (relative to control = 100). For each species and treatment, values represent the mean of all trials (n=12 for Sx; n=5 for Fd).

![Figure 2](image2.png)

**FIGURE 2.** The effect of individual and combined applications of nitrogen and “complete mix” fertilizer on mean foliar nitrogen:sulphur mass ratio one growing season after fertilization. For each species and treatment, values represent the mean of all trials (n=12 for Sx; n=5 for Fd).

![Figure 3](image3.png)

**FIGURE 3.** The effect of individual and combined applications of nitrogen and “complete mix” fertilizer on mean foliar sulphate sulphur concentration one growing season after fertilization. For each species and treatment, values represent the mean of all trials (n=12 for Sx; n=5 for Fd).

Although inadequate S nutrition is a likely cause of the observed N x “complete mix” interaction illustrated in Figure 1, other possible nutritional problems cannot be ruled out. As shown in Figure 4, interior spruce foliar K concentrations were strongly diluted in the first year following fertilization, especially in the nitrogen-only treatments. However, the dilution K levels remained higher than suggested “critical” values when relative values were converted to an absolute scale.
Systematic testing of the K requirements of interior spruce is required so that current deficiency diagnosis criteria can be confirmed or rejected.

\[ \text{Relative needle weight} \]
\[
\begin{array}{c|c|c|c|c|c}
\hline
\text{Relative K concentration} & 70 & 80 & 90 & 100 & 120 & 140 \\
\text{Relative K content} & 70 & 80 & 90 & 100 & 120 & 140 \\
\hline
\end{array}
\]

\text{Figure 4. The effect of individual and combined applications of nitrogen and "complete mix" fertilizer on interior spruce needle dry mass and foliar K nutrient status (relative to control = 100) one growing season after fertilization. Plotted values are means of all installations (n=12).}

CONCLUSIONS

Initial response data from these screening trials indicate that many young spruce and Douglas-fir plantations in the British Columbia Interior may have a requirement for N plus other nutrients. These trials will be remeasured after 4 years to test whether the N x "complete mix" interactions documented in the first year affect subsequent radial stem growth response.

Future research trials will be specifically designed to test the nutrient deficiencies that have been implied in these screening trials (e.g., S and K). Once isolated, the deficient nutrients will be tested with N in conventional, fixed-area plot trials.

Large-scale operational fertilization of interior spruce, Douglas-fir, and western larch stands is not recommended until the nutrition and fertilization response potential of these species is more fully understood.

REFERENCES

