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PRILL, RICHARD
CONE INDUCTION ON WESTERN LARCH SEED TREES
CDEH c. 1 ma Main........
December 7, 1990

Ministry of Forests,
Silviculture Branch,
3rd Floor, 31 Bastion Square,
Victoria, B.C.
V8W 3E7

Attention: Mei Ching Tsoi

Dear Mei:

Attached is the report on Silviculture Trial SX8760-10, Cone Induction on Western Larch Seed Trees.

Yours truly,

[Signature]

R. P. W. R., P. F.
Silviculture Planner
Boundary Forest District

RP/sm

Enclosure
CONE INDUCTION

ON

WESTERN LARCH SEED TREES

by

Richard Prill
Pupil #234
ABSTRACT

Western larch (Larix occidentalis Nutt.) is a valuable commercial tree species in the southern interior. Regenerating this species is difficult, where natural regeneration is the reforestation method, because larch is a poor and sporadic seed producer in the West Kootenays. It is therefore, paramount that an artificial means of inducing cone and seed production be found. Inducing cone crops in larch has the additional benefits of reducing the regeneration delay, thereby reducing the rotation period and ensuring the desired species mix on a particular site is achieved.

In this trial, five treatments were tested against a control. These treatments included using a powersaw to girdle 90 year old larch trees, and girdling in association with urea and nitrate fertilizer. The treatments also include using each fertilizer in isolation.

The trial found that girdling alone and nitrate with girdling produced results 242 and 278% respectively greater than the control. In addition the cost to produce each cone, over and above that of the control is $0.46 for girdling alone and $0.48 for nitrate with girdling. Girdling alone also appears to be the most practical treatment.

Finally, the trial concludes that if the sole object of a treatment is to produce cones, girdling alone is the most appropriate. However if there is concern about the growth vigour of the larch trees, then the treatment of choice should be nitrate with girdling.
TABLE OF CONTENTS

I Introduction 6

II Study Area 9
   A. Location
   B. Site of History
   C. Topography
   D. Soils

III Project Design 14
   A) Treatments
   B) Methodology
   C) Timing

IV Monitoring 16
   A. Visual Inspections
   B. Cone Sampling

V Cone Maturation 21
   A) Harvesting
   B) Treatment Results

VI Discussion 25
VII Conclusion 29

VIII Literature Cited 32

IX Appendix I Results of Power Saw Girdling 34

X Appendix II Cost Benefit Analysis 37

XI Appendix III Statistical Analysis 38
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Graph/Item</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graph #1 Rotation Length = Culmination Age</td>
<td>7</td>
</tr>
<tr>
<td>Graph #2 Rot. Age = Culmination Age + Regen Delay</td>
<td>7</td>
</tr>
<tr>
<td>Site Map</td>
<td>10</td>
</tr>
<tr>
<td>Site Photos</td>
<td>11</td>
</tr>
<tr>
<td>Table #1 Visual Monitoring Results</td>
<td>18</td>
</tr>
<tr>
<td>Table #2 One Way ANOVA... Derive Error Term</td>
<td>19</td>
</tr>
<tr>
<td>Graph #3 Visual Monitoring Results</td>
<td>22</td>
</tr>
<tr>
<td>Graph #4 Production vs. Cost</td>
<td>23</td>
</tr>
<tr>
<td>Table #3 The Cost of Producing Extra Cones</td>
<td>24</td>
</tr>
</tbody>
</table>
INTRODUCTION

Western Larch, \textit{(Larix occidentalis Nutt.)}, is an important tree species in the IDF and ICHA ecosystems, because of its high value and resistance to decay. Larch is also well suited to selective and seed tree silvicultural systems, because it is wind firm. Larch and Douglas-fir, \textit{(Pseudotsuga menziesii Mirb.,Franco)} are the primary species in these types of silviculture systems in the Boundary Forest District. Therefore the amount and quality of seed produced by larch leave trees is important, as the seed rain will help to restock the area and determine the next crop.

Larch, in the west Kootenays, is a sporadic and unreliable producer of cone and seed crops. Normally seed crops are produced in five to ten year intervals. Therefore, an induction method which improves the production of cones and seeds is desirable. In addition, the method of cone induction must be reliable, cost effective and practical.

The benefits of an effective induction method would be ensuring a good population of regenerating larch, reducing the regeneration delay thereby putting the ground back into production quicker and reducing the rotation period. Graph #1 shows rotation period and culmination are the same when there is no regeneration delay. In Graph #2, however, the rotation period equals culmination age plus a ten year regeneration delay. The M.A.I. at culmination for graph #1 (no regeneration delay) is 2.16 m$^3$/ha/yr whereas for Graph #2 it is 1.92 m$^3$/ha/yr.

In addition the rotation period for Graph #1 is 80 years whereas it is
90 for Graph #2. Therefore a reduction in regen delay is very beneficial.

**GRAPH 1**

**ROTATION LENGTH = CULMINATION AGE**

*site index 25*

---

**Volume**

---

**Age**

---

**M.A.I.**

---

- Volume/Age (m³/ha)
- M.A.I. (m³/ha/yr)

---

**Culmination Values**

vol: 172.9  age: 80  m.a.i.: 2.16

---

*by Richard Prill*

---

**GRAPH 2**

**ROT. AGE = CULMINATION AGE + REGEN DELAY**

*site index 25*

---

**Volume**

---

**Age**

---

**M.A.I.**

---

- VOLUME/AGE (m³/ha)
- M.A.I. (m³/ha/yr)

---

**Culmination Values**

vol: 172.9  age: 90  m.a.i.: 1.92

---

*by Richard Prill*

---

*From Yield Prediction System, Version III Inventory Branch M.O.F.*

A reliable cone induction method which would ultimately reduce the regeneration delay and rotation period is very desirable because it would raise M.A.I. over the rotation period by 0.24 m3/yr. Therefore a method of cone and seed induction which improves the production of cones and seeds is an important addition to the intensive management of naturally regenerating stands.

There is evidence to suggest that fertilization, and girdling and combinations of fertilization and girdling effectively stimulate flowering and seed production (Puritch 1977; Smith 1985). Graham (1985) also found girdling to be effective in a 70 year old western larch stand and suggested fertilizer would also be effective in stimulating cone production. Our study was conducted to determine if these same results would be obtained in the West Kootenays.

The three methods tested in this trial are:

i) Girdling: Cuts were made through the bark and phloem stopping at the xylem.

ii) Fertilizer: Urea and nitrate applied at rates of 800kg/ha. This concentration was intended to be toxic to the trees, thereby producing a "shock" response (ie. flowering in the trees).

iii) Girdling and Fertilizer in combination: The third treatment included a combination of each fertilizer used separately and girdling.
II Study Area

A. Location

The trial area is located in the Boundary Forest District of the Nelson Forest Region. The site is located at the junction of the Burrell Creek and Tenderloin Forest Service roads approximately 70 kms north of Grand Forks, (see map).

B. Site History

The original stand had a Douglas-fir, Larch and Lodgepole pine (Pinus contorta var. latifolia Engelm) species composition. The mean age of the stand was 90 years and the average height was 24m. The stand was harvested as a seed tree clear-cut by Pope & Talbot Ltd. of Grand Forks in 1983. Harvesting was conducted under Forest license A18969 on cutting permit 53 (see photos following). The trial was conducted on cut block 3, which is approximately 8 ha in size and had a volume of approximately 240 m³ per hectare. Harvesting was conducted in the spring and summer using hand falling techniques and rubber tired skidders. The skidding created sufficient ground disturbance to provide adequate seedbed for natural regeneration.
C. **Topography**

The topography is rolling with slopes of 0 to 40% throughout the block. The block is positioned on the lower slope at approximately 950m a.s.l. with a south westerly aspect (Trerise 1981).

D. **Soils**

The soil is a shallow (1.0-1.5m) sandy loam with 5 to 10% exposed rock. They are generally well drained with small microsites in both hydric and xeric moisture regimes. The site is located in the lower Columbia-Kootenay, moist, southern interior, Cedar- Hemlock (ICHa) biogeoclimatic subzone tending toward mesic and subhygric soil moisture regimes and a mesotrophic nutrient regime. This represents a moderately productive site with an expected mean annual increment of 2.2 m$^3$/ha.
III  Project Design

A. Treatments

Sixty Larch trees that demonstrated desirable phenotypes were randomly selected from the seed trees left after logging. Each treatment was randomly applied to 10 trees, scattered throughout the block. Care was taken to reduce the possibility of results modified by microsite differences. The six treatments were:

i) Control

ii) Urea nitrogen (Urea)

iii) Ammonium nitrate (nitrate)

iv) Girdling

v) Urea and girdling

vi) Nitrate and girdling

In addition, the selected trees are located at least 20m apart, so as to prevent treatments overlapping. Each tree selected demonstrated similar height, age and crown characteristics. The larch had an average age of 90 years, height of 24.0 meters, and d.b.h. of 30.7 cm.
B. Methodology

The treatment groups are detailed as follows:

i) Control: These trees were selected to have no treatment applied. The trees in the control became a baseline against which the other treatments were compared.

ii) Girdling: These trees were girdled using a powersaw. The girdles were applied through the bark and phloem and cambial layers, stopping at the xylem, using two partial circumferal girdles, one on each side of the tree. Cuts were oriented north/south, each not exceeding 3/4 of the circumference. In addition, the girdles were offset 30 cm apart, the lower girdle being positioned at a height of one meter above the germination point.

iii) Urea: The selected trees were treated with standard agricultural Urea nitrogen, (46-0-0) fertilizer. The fertilizer was applied at a rate of 800Kg/ha. The Urea was distributed evenly within a 3m radius around the bole approximating the "dripline" of the crown.

iv) Nitrate: The selected trees were treated with standard agricultural Ammonium nitrate (34-0-0) fertilizer, applied at a rate of 800Kg/ha. The nitrate was distributed evenly within a 3m radius around the bole approximating the "drip line" of the crown.
v) Girdling and Urea: The selected trees were treated using a combination of the girdling and urea treatments detailed earlier.

vi) Girdling and nitrate: The selected trees were treated using a combination of the girdling and nitrate treatments detailed earlier.

C Timing

The timing of the treatment is thought to be as critical as the treatment itself. Each treatment must be initiated at the proper stage in bud development in order to be effective (Puritch 1978). For girdling, Ebell (1971) found the treatment must coincide with the period of bud initiation and differentiation. Generally, this is approximately one month prior to vegetative bud break. For fertilization, the nutrients must also be applied at the time of bud differentiation. This will, apparently, stimulate the development of reproductive buds (Puritch 1977). In our trial, application of the various treatments took place in early April. This was estimated to be the period of bud differentiation and approximately three to four weeks prior to flushing.

IV Monitoring

Periodic monitoring of the cone crop began in June, 1988 to assess the progress of the trial.
A. Visual Inspections

Using binoculars and a spotting scope, each tree was examined initially for indication of success or failure of the various treatments. The early survey indicated that enough cones had been produced to proceed with the trial. Later, a more detailed random survey of the 29 trees was undertaken. On each tree, a branch having the heaviest indication of new cones in each of the top, middle and lower crown was surveyed and recorded. The survey indicated the urea only treatment did not stimulate cone production above that of the control. Whereas, each of the other treatments did produce cones above that of the control.

(see table #1)
Table I
Visual Monitoring Results

<table>
<thead>
<tr>
<th>Treatment</th>
<th># of trees sampled</th>
<th>Cones per branch</th>
<th>% of Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>7</td>
<td>12.6</td>
<td>100</td>
</tr>
<tr>
<td>Girdling</td>
<td>4</td>
<td>30.5</td>
<td>242</td>
</tr>
<tr>
<td>Nitrate</td>
<td>5</td>
<td>24.2</td>
<td>192</td>
</tr>
<tr>
<td>Urea</td>
<td>4</td>
<td>10.5</td>
<td>83</td>
</tr>
<tr>
<td>U + G</td>
<td>4</td>
<td>21.8</td>
<td>173</td>
</tr>
<tr>
<td>N + G</td>
<td>5</td>
<td>35.0</td>
<td>278</td>
</tr>
</tbody>
</table>

Expt Mean 29 22.4 178

Only 29 of 60 trees were given visual cone counts. Had all 60 trees been surveyed, similar results would most likely be obtained at a higher confidence level (personal correspondence with Lorne Ebell, Research Branch, Ministry of Forests).
Table #1 shows that nitrate with girdling and girdling alone produce similar results. They both produce over 200% more cones than that of the control. After running the data through an analysis of variance, table #2 shows there is a 0.077 probability of the treatment not being statistically different. Thus there is a 92.3% probability that the treatment results are different from the control.

Table 2

One way ANOVA Treatment Effects on Cone Production, using all Sampled Trees to Derive Error Term.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F. Value</th>
<th>Pr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>5</td>
<td>2548.834</td>
<td>509.766</td>
<td>2.31</td>
<td>0.0772</td>
</tr>
<tr>
<td>Error</td>
<td>23</td>
<td>5076.407</td>
<td>220.713</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected total</td>
<td>28</td>
<td>7625.241</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix III shows the calculation of the standard error of the mean. At plus or minus 2 standard deviations there is a 95% probability that both the nitrate with girdling and girdling alone produce results significantly different from the control. Therefore these two treatments effectively produce the desired results.

B. Cone Sampling

In August, the cone crop was monitored by clipping, using a .22 calibre rifle to shoot off selected branches and dissecting cones to determine crop viability. In addition the cones provided a measure of maturity of the seed in order to organize the picking of the crop. All the trial trees were to be felled and each tree picked and bagged separately. This would allow accurate counting of cones and viable seeds by tree and treatment by the seed extraction plant.

Unfortunately, after four days of clipping branches and dissecting cones, the indicated cone crop was very poor. The trial was abandoned at this point as the crop wasn't pickable both from a practical and financial point of view. All trees in the control and treatment had few viable cones suggesting it was a poor cone crop year.
Each cone clipped was dissected and filled seeds were counted. Many cones were vacant of any seeds in the cross-section. Cones that had seed, had only one or two. Many of the cones exhibited evidence of a cone axis and seed predator, possibly *Henricus* sp.

Discussions with Barry Jaquish, R.P.F., Research Scientist, Kalamalka Research Station in Vernon, suggest that cool, wet weather during the pollination period caused the poor crop. The cool, wet weather inhibited the growth of pollen tubes thus preventing fertilization of many of the seeds.

V CONE MATURATION

A. **Harvesting**

The cone crop was not picked because of the low seed viability. The trial was, therefore, abandoned at this point. The trial was not a total loss, however, as some conclusions may be drawn from observations made during the trial. These observations will be discussed in the next section.

B. **Treatment Results**

i) Reliability

As stated earlier, nitrate with girdling and girdling alone significantly affect cone production. Graph #3, Visual Monitoring Results shows that nitrate with girdling produced the most cones (35.0 cones/tree) closely followed by girdling at 30.5 cones/tree. These results are well above that of the control and also the mean. Again, referring to Graph #3 using ± one standard
error for each treatment, the variability of the various treatments can be seen. The greater variation with the nitrate only indicates that the nitrate treatment could be further refined whereas girdling was close to optimal.

Graph #3

VISUAL MONITORING RESULTS

NUMBER OF CONES PER TREE

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean</th>
<th>Control</th>
<th>Girdling</th>
<th>Nitrate</th>
<th>Urea</th>
<th>Urea + Girdling</th>
<th>Nitrate + Girdling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

These results are consistent with the findings of Puritch (1977). He indicates that the nitrate form of nitrogen fertilizer is effective in producing cones. He goes on to indicate girdling also enhances cone crops.
ii) Cost Effectiveness

A cost per unit analysis is necessary to determine the treatment which produces the best results at the least cost. The cost of each treatment per tree was calculated using the parameters detailed in Appendix II.

The cost to treat each tree was then divided by the number of cones produced, arriving at a cost/cone. The results, as indicated in Graph #4, Production vs Costs, shows nitrate, girdling and nitrate with girdling as being significantly less expensive than the rest. Girdling only at $0.27 produces the most cones at least cost, followed closely by nitrate with girdling at $0.31 and nitrate only $0.43. Therefore, girdling only appears the most cost effective treatment method.

Graph #4

![Graph showing production vs cost for different treatments](image-url)
However, a better way to look at cost effectiveness is to determine the incremented cost per cone produced over and above that of the control. Table #3, The Cost of Producing Extra Cones, shows similar results as compared to Graph #4 except that nitrate only no longer compares favorably to nitrate with girdling and girdling only.

**TABLE 3**
The Cost of Producing Extra Cones.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Cones/Tree</th>
<th>Cost/Tree</th>
<th>Cost/Cone</th>
<th># Extra Cones</th>
<th>Cost/Extra Cone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>12.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girdling</td>
<td>30.5</td>
<td>$8.38</td>
<td>$0.27</td>
<td>17.9</td>
<td>$0.46</td>
</tr>
<tr>
<td>Nitrate</td>
<td>24.2</td>
<td>10.46</td>
<td>0.43</td>
<td>11.6</td>
<td>0.90</td>
</tr>
<tr>
<td>Urea</td>
<td>10.5</td>
<td>10.44</td>
<td>0.99</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>U &amp; G</td>
<td>21.8</td>
<td>10.82</td>
<td>0.50</td>
<td>9.2</td>
<td>1.18</td>
</tr>
<tr>
<td>N &amp; G</td>
<td>35.0</td>
<td>10.84</td>
<td>0.31</td>
<td>22.4</td>
<td>0.48</td>
</tr>
</tbody>
</table>

# Extra Cones = Average cones per treatment tree / average cones per tree tree control

Cost per Extra Cone = Cost per tree / extra cones per tree

The girdling only treatment produces the least expensive extra cone, closely followed by nitrate with girdling.
iii) Practicality

Girdling seems to be the most practical, assuming girdling alone and nitrate with girdling are the two treatment options. The girdling treatment requires only one "tool", the powersaw. Whereas, the nitrate with girdling treatment requires the powersaw and fertilizer. The second treatment requires either two trips to the treatment site, one to girdle, the other to deliver the fertilizer, or two workers because a worker can not carry a power saw and a bag of fertilizer.

However, if a swede saw were used instead of a powersaw, the nitrate with girdling option would be more attractive. A swede saw is considerably smaller and lighter and would be able to be handled adequately by one person with the nitrate. This is, of course, assuming a wound created by a swede saw would interrupt the transfer of nutrients from the crown to the roots sufficiently to produce the desired response.

VI DISCUSSION

Each method of cone induction acts in one or more ways to induce cones. For example:
i) Girdling: in Puritch (1977) suggests translocation of nutrients from the crown to the roots is impeded by the girdle. The nutrients are prevented from moving down the stem via the phloem and accumulate in the crown. In addition, nutrients transferred from the roots to the crown will also accumulate in the crown. Both these processes act to cause an increase in the nutrients in the crown. This abnormal increase is linked to enhancing the formation of cones. Both Ebell (1971) and Puritch (1977) go on to suggest that the concentration of nutrients may be a consequence rather than a cause of flowering. The flowering is a result of or increase in, amino acids, such as arginine. Puritch (1977) indicates that arginine increases in concentration in cone producing trees. It follows then that girdling increases the concentration of arginine. Another theory, (Ross and Pharis 1985) suggest girdling causes a shock or stress response which triggers the production of cones by diverting assimilates normally associated with rapid shoot elongation to reproductive bud development. Girdling acts in one, or more likely, a combination of the above ways to stimulate a flowering response.

ii) Fertilizer: The excessive amounts of fertilizer should produce a shock response and flowering. Flowering seems linked to excessive amounts of the nitrogen metabolite, amino acids and arginine absorbed and processed by the roots and transported up the xylem into the crown (Ebell and McMullen 1970). This shock
response also forces the tree to divert nutrients from the production of
Puritch (1977) feels that excessive levels of fertilizer, particularly nitrate, causes or produces excessive amounts of nutrients in the crown. These high levels of nutrients then trigger a flowering response by the tree.

iii) Girdling and Fertilizer in combination: We were looking for both treatment effects componding on each other to produce a flowering response. The combined treatments, in theory at least, should magnify the response of the tree and produce flowers. The girdle would prevent any nutrients from flowing down the stem through the ploem, causing a nutrient build-up in the crown. The byproducts of fertilization would be transported up the xylem, accumulating in the crown. This massive build-up of nutrients along with the shock response of the girdle and fertilization, should cause the massive build-up of nutrients, carbohydrates, arginine, etc. All these semm linked to the differentiation process of reproductive bud development (Ebell and McMullen 1970). It was expected that the combination of treatments was expected to result in a flowering response.
As mentioned earlier, there are vast numbers of cone induction trials using girdling and or fertilization, on various conifers. Many of the trials undertaken in British Columbia and the Pacific Northwest have been on Douglas-fir. Puritch (1977) provides an excellent summary of trials on Douglas-fir and a variety of other species. Generally, Puritch suggests fertilization with nitrate and girdling are successful in inducing cone crops. He does, however, infer that fertilization is the most acceptable means of inducing cone crops. This is due to its added advantage of enhancing tree growth and vigour. Ebell (1971), in a girdling trial on three double stemmed Douglas-fir found girdling did reduce the diameter and height growth by approximately 10% over ten years, although he observed no foliage or other visual symptoms of adverse effects.

In our trial, the significance of tree vigour and growth was not assessed. However, Appendix I shows the extent of healing on the powersaw cuts for each treatment. The nitrate with girdling cuts were greater than 90% healed compared to only 72% healed for the girdling only.
Ebell (1971) found that girdling produced cone numbers up to 7.4 times that of control stems. This compared to results obtained with nitrogen fertilizers in other trials.

Graham (1985) also found girdling to be effective in stimulating cone production in a 70 year old larch stand. Puritch (1977) lists three girdling studies involving Japanese (L. leptolepis) and European (L. decidua) larch. In these studies, girdling seems to increase flowering.

Some examples involving fertilizer trials include Ebell (1971), who suggests that the nitrate form of nitrogen fertilizer is the only effective fertilizer for stimulation of cone production in Douglas-fir. Ross and Pharis (1988) also suggests that fertilization is an effective means of cone stimulation. Smith (1985) used both nitrate and urea forms of nitrogen fertilizer in a study in New Brunswick involving black spruce (Picea mariana (Mill) B.S.P.). He found that nitrate increased both male and female flowers, whereas urea did not. This confirms Ebell's (1971) findings that nitrate is the only effective form of nitrogen fertilizer useful in stimulating cone production. Urea, in our trial, also was ineffective in producing cones.

VII CONCLUSIONS

The objectives of this trial were to investigate the reliability, cost effectiveness and practicality of three methods of artificial
cone induction in larch. The methods included girdling, two forms of nitrogen fertilizer (urea and nitrate) and girdling used in conjunction with

The trial virtually failed to produce viable cones. This may have been a result of a poor cone year because the control trees also did not produce cones. Discussions with B. Jaquish, R.P.F. from the Kalamalka Research Station suggested cool, damp weather during pollination may have caused this. However, the conclusions of this report are drawn from visual observations of new cones, on randomly selected trees in conjunction with reference material.

In this trial, we used a powersaw to girdle the trees. Appendix I shows pictures of the extent of wounding and healing of the powersaw cuts. Although some cuts were severe, there was significant healing. The trees treated with nitrate and girdling healed the best, with an average 90.8% of the wound healed. These results were followed by girdling only at 72% and urea and girdling at 62.5%.

The results obtained in this trial indicate that nitrate with girdling and girdling alone produce reliable results. According to the one way ANOVA in Appendix III, these two treatments will produce the desired results 95% of the time. In short, both treatments are effective in producing cones. Further trials with nitrate only, perhaps at different concentrations, may indicate it also is an effective technique.
Table #3 shows an excellent way to view cost effectiveness, by looking at the cost to produce each cone over and above that produced in the control. Table 3 shows similar results to Graph #4 except that nitrate only no longer compares favourably to nitrate with girdling and girdling alone. The table clearly shows girdling at $0.46 per extra cone as the most cost effective treatment closely followed by nitrate with girdling at $0.48 per extra cone. Therefore, girdling alone is the most cost effective treatment.

As mentioned earlier, girdling only is also the most practical. However, substituting a swede saw for the power saw will make nitrate with girdling a little more practical.

Finally, girdling seems to be the most reliable, cost effective and practical method of inducting cones. Therefore, the author recommends girdling alone as the treatment of choice for inducing cone crops in larch.

Further study in cone induction on western larch seed trees could involve varying the method and severity of girdling, the application rates of the fertilizer and the timing of the treatments. A multi-year study may also indicate if the induction method used have a delayed cone production response.
Literature Cited

Can. J.Bot. 49:453-466

Can. J. Forest Res. 2,327.338


Rep. INT-203 pp. 166-170


APPENDIX I

Results of Power Saw Girdling

The following table shows the extent of healing on the powersaw cuts for each treatment.

HEALING OF GIRDLING WOUNDS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>% Healed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girdling</td>
<td>72.5%</td>
</tr>
<tr>
<td>U &amp; G</td>
<td>62.5%</td>
</tr>
<tr>
<td>N &amp; G</td>
<td>90.8%</td>
</tr>
</tbody>
</table>

Photos of a selection of cuts showing the extent of healing are the following pages.
TYPICAL SIRDLE
APPENDIX II

COST BENEFIT ANALYSIS

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>COST PER TREE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girdling</td>
<td>8.38</td>
</tr>
<tr>
<td>Nitrate</td>
<td>10.46</td>
</tr>
<tr>
<td>Urea</td>
<td>10.44</td>
</tr>
<tr>
<td>U &amp; G</td>
<td>10.82</td>
</tr>
<tr>
<td>N &amp; G</td>
<td>10.84</td>
</tr>
</tbody>
</table>

The results are obtained from the following data:

Labour @ $100.00/day (10 hr. day) - 50 trees = $8.00/tree

N: (5 bags x $9.85/bag)/ 20 trees = $2.46/tree

U: (3.8 bags x $12.85/bag)/ 20 teees = $2.44/tree

Power saw - .25 hours x $1.50 per hour (1)(2) = $.38/tree

(1) From Forest Service Equipment Rental Rates (88/04 B.C.)

(2) Assuming each tree takes 15 min. to complete treatment.
APPENDIX III

<table>
<thead>
<tr>
<th>Sample</th>
<th>Stand. Error of Mean</th>
<th>-Sx</th>
<th>+Sx</th>
<th>-2Sx</th>
<th>+2Sx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>7</td>
<td>12.57</td>
<td>7.25</td>
<td>± 2.74</td>
<td>9.83</td>
</tr>
<tr>
<td>Nitrate</td>
<td>5</td>
<td>24.20</td>
<td>24.83</td>
<td>± 11.10</td>
<td>13.10</td>
</tr>
<tr>
<td>Girdling</td>
<td>4</td>
<td>30.50</td>
<td>12.50</td>
<td>± 6.25</td>
<td>24.25</td>
</tr>
<tr>
<td>Urea</td>
<td>4</td>
<td>10.50</td>
<td>3.78</td>
<td>± 1.89</td>
<td>8.61</td>
</tr>
<tr>
<td>N &amp; G</td>
<td>5</td>
<td>35.00</td>
<td>18.72</td>
<td>± 8.37</td>
<td>26.62</td>
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<tr>
<td>U &amp; G</td>
<td>4</td>
<td>21.75</td>
<td>13.60</td>
<td>± 6.80</td>
<td>14.95</td>
</tr>
</tbody>
</table>

Courtesy Lorne Ebell

N.B. Treatments are compared with the untreated control, not with the experimental mean.

\[ x \pm 2S \] x will enclose 95% of the points on a distribution curve of samples about a mean. Therefore, if these points on the distribution curve for the two treatments do not overlap, the treatments may be taken to be statistically significantly different as indicated by * above. The girdling results seem to overlap, however this is most likely due to the low number of trees sampled, had all trees been sampled it is highly likely that it would not overlap (personal correspondence with Lorne Ebell, Research Branch, M.O.F. Victoria).