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Bruns, Paul E.

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Cultural Practices, Fertilizing and Foliar Analysis of Balsam Fir Christmas Trees

by

Paul E. Bruns, Professor of Forest Resources

NEW HAMPSHIRE
AGRICULTURAL EXPERIMENT STATION
DURHAM, NEW HAMPSHIRE

COVER PHOTOGRAPH: *Balsam fir fertilized with low level ammonium nitrate in the spring of 1966. Note response in 1967 leader growth and development of internodal branches. Near Joe's Pond, Vermont, on Growers' Plots. Photo taken June 3, 1968.*

SUMMARY:

An initial shearing in the spring to shape a heretofore uncultured balsam fir Christmas tree followed by spring clipping in subsequent years (to develop greater numbers of lateral tips) was the cultural sequence that made for best improvement in overall grade. Leader control if needed is best accomplished with spring tip pruning with a 90° cut favored. Trees were 4 to 5 feet in height at the beginning of the three year experiment.

Spring applications of a complete (N-P-K) fertilizer in ratio .23-.27-.26 lbs. elemental nutrient applied per tree, or a nitrogen fertilizer contributing .23 lbs elemental nitrogen per tree, result in marked color improvement that maintains itself over a two year period. Growth improvement also follows, with evidence that rapid leader growth is compensated for by more vigorous internodal bud and branch development. The number of internodal buds per inch of leader growth was maintained with increased leader growth. Fertilizing is therefore a method of reducing the rotation period as well as improving the color characteristics of balsam fir.

Efforts to correlate foliar chemical analyses with soil analyses for a variety of nutrients were unsuccessful. However, foliar analysis results are presented in tables indicating the variation encountered for typical healthly young balsam fir trees when samples were collected in the fall. The season of sampling, age of needles, and vertical location of samples on a tree are important variables affecting the results of chemical analyses.

INTRODUCTION:

The following work describes the results of a study of balsam fir Christmas tree culture developed in 1963 with initial field work undertaken in 1964, and continued through 1966.

The purpose initially was to test some alternatives that would improve tree form, color, and ultimately the grade of both wild and plantation grown trees of this species in northern New England.

The experiment, entitled "A Study of Cultural Practices for Balsam Fir Christmas Tree Production" was financed through McIntire-Stennis funds and the New Hampshire Agricultural Experiment Station and designated as Project MS-I of the Station.

The author, who was project leader, acknowledges the work of David R. Noyes, Forester, who was associated with the earlier stages of the project, and the field and office assistance of Harry Berquist and of numerous former students, in particular John B. Cote and Donald A. Wilson. The cooperation, understanding and patience of the members of the New Hampshire-Vermont Christmas Tree Growers Association is appreciated. Gratitude is expressed to Willard E. Urban, Jr., Station Statistician, for his part in setting up the statistical design and in following through on most of the statistical analysis. Dorothy Josselyn and Henry A. Davis of the Analytical Services Laboratory, and Clarence L. Grant of the Center for Industrial and Institutional Development accomplished the soil and foliar analyses.

This manuscript is in three parts. Part I deals with the "Main Plots", a study of cultural practices primarily at three northern New Hampshire locations on lands of commercial Christmas tree growers. Part II is called the "Growers' Plots", and analyses the findings after application of a variety of fertilizers at ten locations in New Hampshire and Vermont. Part III presents results of foliar analyses of balsam fir Christmas trees.

Part I. MAIN PLOTS

This section reports on applications of various combinations of cultural practices known to govern the form of young balsam fir to be marketed as Christmas trees. The primary objective of treatment was to test alternatives in both leader and lateral branch growth control, in attempts to produce a more saleable tree. The trees used in the study were native balsam fir, initially averaging four feet in height, in both natural (volunteer) and planted stands at three locations in New Hampshire (Coos, Grafton and Merrimack counties). At each location 225 trees were treated employing a factorial arrangement of 9 leader treatments x 5 lateral treatments, followed in 1966 with 5 fertilizer treatments. The work was initiated in the spring of 1964 with annual measurements terminated in the fall of 1966. Both lateral and terminal treatments were imposed in the spring and the fall. Thus there was a complex interaction of three general categories of treatments (leader treatment; lateral treatment; and fertilizer), replicated at the three locations in a randomized block design.

A. Explanation of Treatments

The treatments applied included most that appeared promising from informal field experimentation and local practice such as tip pruning to control terminal length to forestall "spindly" tree appearance. This experiment did not, however, test basal pruning to slow terminal growth because of the small size of the trees. Spring treatments were applied in late June or early July (during succulent growth) while fall treatments were applied in September or October after growth had "hardened off". Treatments are summarized as follows:

Terminal treatments
- Tip prune, both at 45° and at 90°, either in the spring or fall.
  - Maleic hydrazide (a growth inhibitor), either spring or fall.
  - Root prune, either spring or fall.
- Control (no treatment).

Lateral treatments
- Clip, either spring or fall.
- Shear, either spring or fall.
- Control.

Fertilizer application (delayed until the spring of the third year)
- Nitrogen = N
- Phosphorus = P
- Potassium = K
- Complete = NPK
- Control.

In order to interpret and apply results, a few definitions of terms and explanation of treatment techniques are needed. Figure 1, a schematic diagram for denoting annual growth of a balsam fir tree should assist in this explanation.

Terminal treatment of which tip pruning was one treatment, consisted of shortening the current leader growth by cutting it back to near the point where lateral branches (the topmost whorl of branches) meet the leader when these laterals are bent up to meet the leader. The leader was cut off about ¼ inch above an internodal bud at or near this point. The 90° cut was made perpendicular to the stem axis, and the 45° cut at that angle to the axis. Such terminal treatment is based on the premise that reduced internodal length would result in an increased tree density, as the lateral whorls would then be less widely spaced. Cutting angles and season of application were expected to have an effect on subsequent terminal bud development. Since random selection of trees was the rule, a few trees having short terminals did not require and therefore did not receive a tip pruning.

Maleic hydrazide is a chemical that was applied to a terminal bud either in the spring or the fall, in a 0.1 percent water solution. It was hoped that maleic hydrazide would inhibit leader growth by altering hormone balance without adversely affecting tree form.

Another terminal treatment, root pruning, was done through four cuts into the soil outward from the tree stem, two thirds of the distance to the crown drip line. Each cut was made straight into the ground to the full depth (12 inches) of a No. 2 round pointed shovel blade. The intent is to reduce terminal growth by reducing the root area of a tree.

Lateral treatments consisted of clipping and shearing lateral branches and were intended (as were terminal treatments) to be applied annually either in spring or fall. Clipping was originally interpreted to be removal of the primary lateral-terminal growth that had been added to the tree branches during the previous year (see Figure 1). Clipping was confined to one year old wood in the 1964 first annual treatment and performed on the entire tree except for the top or current year's whorl. The practice was intended to produce a fuller tree by having the lateral-lateral growth contribute more "tips" to the periphery of the tree (refer to Figure 1). In theory, for every "lateral tip" which is cut off (clipped) there should be two lateral-laterals producing tips the following growing season. (Results indicate that this happened to a large degree). In applying the treatments, whenever secondary lateral-terminal growth contributed to filling in the outer surface of the crown, it was also removed.

In practice, clippings subsequent to the initial 1964 treatment were changed in that only bud clusters on primary lateral terminals were removed and wood was left intact. This variation for 1965 and 1966 resulted in trees of fuller appearance and accomplished the purpose in clipping.

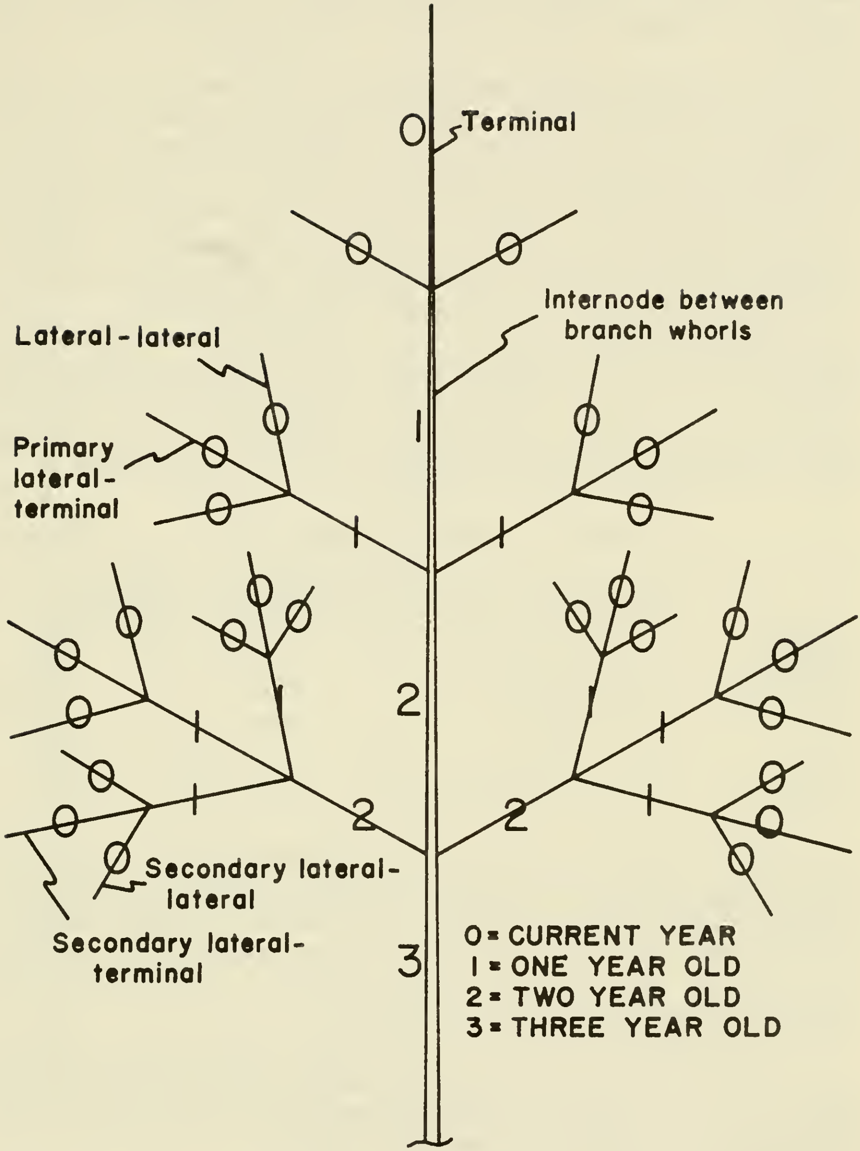

Figure 1. Branching terminology and code for denoting annual growth.

Shearing shapes a tree by cutting two years of lateral-terminal growth from each branch which has at least three years of growth on it. For example, in the schematic diagram (Figure 1), only N and N-1 primary lateral-terminal growth would be sheared from whorl N-3 during the year N, and the younger whorls above left untouched (older whorls below would be sheared as was the N-3 whorl).

It was originally thought that shearing two years growth from available primary lateral terminals would be followed annually. However, the effect of shearing the first year was analogous to the commercial practice of "shaping" a tree the first time, obtaining a more symmetrical form. It became apparent that a similar treatment in a subsequent year was not needed, and in fact would leave a tree looking decimated. Therefore, beginning in the spring of 1965, shearing assumed a form similar to the original definition of clipping; that is, primary lateral terminals were cut to the base of the previous year's growth.

Fertilizer was applied around a tree in a circular band extending 8 inches from the stem out to the "drip line" of the crown. N,P, and K applications were computed as "moderate" levels based on known experience and resulted in roughly equivalent weights for each element. The N-P-K or "complete" fertilizer was a total composite. The amount applied per tree is indicated in Table 1.

Main Plots – Fertilizer Dosages

Element	Composition and Percent of Element	Total Fertilizer Weight per tree: Pounds	Grams	Elemental Equivalent: Pounds	Grams
Nitrogen	NH_4NO_3–35.5% N	.4	182	.14	65
Phosphorus	Superphosphate–19% P_2O_5	.8	364	.15	69
Potassium	KCl–61% K_2O	.25	114	.15	69
Complete	Combination of above	1.45	660	.44	203

Annual measurements and observations of treatment trees included total height change, number of "good" or usable whorls from the standpoint of developing a Christmas tree, numbers of lateral tips in the top three whorls (in the 0, -1 and -2 years with 1963 being zero, with measurement of tips developed in new whorls thereafter), number of branches which developed in the new whorls, internodal lengths and crown diameter.

An overall grading of the tree as a Christmas tree was also made on a scale from 1 (very poor) to 7 (excellent) at the beginning and end of the experiment. Needle color of each tree was recorded (Munsell system) at these times, but was not a criterion in arriving at tree grade in this study.

Data were analysed by use of analysis of variance (see Table 2). In the heading, the table also contains the objective and partially subjective criteria used in evaluating the various cultural practices at the end of the three year study. When the terms "significant" or "significantly" are used in this writing, they are used in the statistical sense on the 0.05 level.

Table 2. Statistical Analysis Among the Main Plots by Analysis of Variance

Source of Variation	d. f.	Crown Symmetry	Crown Density	Crown Taper	Change in Grade	Change in Inter-nodal Branch Rating	Change in Munsell Hue	Change in Munsell Value	Change in Munsell Chroma	Change in Inter-nodal Length	Change in Inter-nodal Length 64-65	Change in Lateral Tips	Change in Whorl Branches
Area	2												
Fertilizer	4						*	*	*				
(Lateral Treatment)	(4)												
Control vs. Treatment	1								*			*	
Method	1	*		*								—	
Season	1	*	*	*	*							—	
M * S	1											*	
(Terminal Treatment)	(8)												
Control vs. Treatment	1									*			
Method	3	—	*	—	—					—	—		—
Season	1	—		—	—					—	—		—
M * S	3	*		*	*					*	*		*
F * L	16												
F * T	32												
L * T	32												
F * L * T	128												
Residual	448												

* = statistically significant at the 0.05 level
— = inappropriate to test because of interaction

B. Results of Cultural Practices Study—Main Plots

The overall result of cultural practices on a Christmas tree is expressed in a change in tree grade, which is a relatively subjective criterion. What is the reaction of the beholder to the tree? At the beginning of the study the trees were graded on a scale ranging from 6 (excellent) to 1 (very poor) and a grade comparison made three years later. The Appendix explains the grading system, which took into account the components of crown symmetry, crown density and crown taper in arriving at the tree grade. Color was not included in the grading. However, tree color was not significantly affected by terminal or lateral treatments, but rather by fertilizer application.Treatment effect on tree form was also evaluated by recording a three year change in a subjective internodal branch rating, also on a 6 to 1 rating scale.

Components which are used to judge tree form on a quantitative basis are internodal length, branches per whorl, and lateral tips. Terminal treatments affected internodal length. Changes in internodal length can be looked at for evaluation of these treatments. A terminal treatment that is successful in shortening internodes that are too long may not be a desirable cultural practice if there are fewer branches in the subsequent year's whorl, or if it results in fewer lateral tips, or in poorer internodal bud development.

Lateral treatments had a direct effect on the components of tree grade. One quantitative measure that is fundamental to tree grade is the number of lateral tips. The changes brought about by treatments were significant. At this point, the effects of terminal, lateral and fertilizer application will be separated to some extent, but in actuality they are interrelated.

1. Terminal Treatments

It is obvious that a physical cutting back of a terminal by tip pruning would be effective in controlling leader growth, but the root pruning and spring maleic hydrazide treatment was also effective. Fall application of maleic hydrazide was not effective.

As a basis for this judgment, the internodal lengths (representing height growth) for the 1961-63 years were subtracted from those of the 1964-66 years. For the effective treatments, then, some of the side effects need to be examined.

During preliminary work to the experiment it was suspected that fall tip pruning might reduce the number of branches counted in the new whorl following pruning. Statistical analysis was made of the whorl branch changes with terminal treatments in the experiment. In this, the number of branches in the 1964-66 whorls were compared to the numbers in the pre-treatment 1961-63 years for individual trees in each treatment. The results were conclusive in that:

a. root pruning and fall maleic hydrazide did not differ much from the control tree performances. Whorl branching about held its own in this group.

b. other spring treatments tended to reduce whorl branching with a drop off of one to two branches total over the three year period, with spring maleic hydrazide performing most poorly in this group.

c. fall tip pruning cannot be recommended because of a marked drop off of four branches over a three year period as against the control.

Change of grade with terminal treatment when compared to the control trees developed as follows:

a. fall tip pruned trees and trees root pruned either spring and fall did not grade out as well as the control trees.

b. trees tip pruned 45° in the spring performed as well as control trees and those tip pruned 90° in the spring showed a significant improvement over control in grade change.

c. maleic hydrazide fall treatment showed somewhat of an improvement over control but this is meaningless when it is recalled that this treatment affected neither terminal growth nor whorl branching. Maleic hydrazide spring treatment matched the control trees in grade change.

When the components of overall grade are examined, it is of interest to note that fall tip pruned trees scored well in crown density but more than lost this gain in symmetry and taper. The reason for a good density rating with relative reduction in whorl branching is not explained, since the internodal length reduction was not different from the other effective treatments. The density would logically be expected to be caused by increased internodal branching or in foliage characteristics such as number and length of needles. The change in internodal branch rating was recorded in the experiment, but no treatment significance was shown.

In summary, if terminal control is applied, tip pruning in the spring with the 90° cut is favored. In Section II or Growers' Plots, more is said on terminal control in conjunction with fertilizer application. After reviewing the results on this related experiment a suggestion is made that perhaps terminal control can be dispensed with, at least as a routine measure, when fertilizer application is a standard practice. Fertilizer as recommended should improve internodal bud formation and internodal branching, allowing excellent form even with long internodes.

2. Lateral Treatments

It is important in the application of results of the lateral control work to understand how shearing and clipping were interpreted and applied in this experiment (Section A).

Both fall and spring treatments as applied were highly effective in increasing the numbers of lateral tips and thereby developing a fuller Christmas tree. The basis for comparing treatments was the increase in number of growing tips in what were the top three whorls in 1963 and the 1964-66 whorls combining, in other words, the changes in number of tips in the whorls dating from 1961 through 1966.

In the 3 year period, the control trees increased by 16.1 tips per tree. Treatments added the following tips: spring shearing, 42.2; fall clipping 37.5; spring clipping 35.9; and fall shearing 33.5. Among the lateral treatments, the most effective treatment used was therefore spring shearing. There was no significant difference in the experiment between spring and fall clippings or spring clipping and fall shearing.

In grade change, trees with spring lateral treatments developed significant improvement over those treated in the fall. Whether overall grade or its components (symmetry, density or taper) were examined, spring treated trees rated higher than control (with one exception—spring shearing, in the symmetry rating), and the fall lateral treatment trees no better and mostly lower than the control.

Spring clipped trees showed greater grade improvement over spring sheared trees in crown symmetry and crown taper but the result in overall grade improvement was not significantly different between the two treatments. Perhaps the lack of differentiation is caused in part by the experimental method. In the experiment, the first year shearing was applied to a tree whether it needed the shearing or not, as long as the random selection indicated that shearing was the technique to use on that tree. The general results suggest that if a tree needs an initial shearing to improve its form, this should be done in the spring, and that subsequent spring clipping will prove effective in producing a tree of quality form.

3. Fertilizer Treatment

The effect of fertilizers on growth are indicated by the associated Growers' Plots experiment described in Section II of this publication. Cultural work had been underway for two years on the Main Plots when a limited number of fertilizers were applied (quantities listed in Table 1) in the spring of the third year so as to test the effect on tree color. The color was recorded by use of Munsell color charts in the fall of 1966. Significant changes favorable in relation to what is desirable for commercial Christmas tree culture did occur in hue, value and chroma.

Hue notation indicates where the color stands within the spectrum of red, yellow, green, blue and purple. Complete (NPK) and nitrogen (N) fertilizing resulted in a significant hue change toward the blue range in trees so treated, compared to control trees and trees treated with potassium (K) and phosphorus (P). The latter showed no significant difference in hue.

Chroma, which is the purity or intensity of a color, or departure from neutral, was significantly higher in the control trees, and those treated with K and P. The NPK and N trees showed less color intensity (more neutral shades). The approach toward gray is not considered a disadvantage in balsam fir Christmas trees, provided the hue moves toward blue and the value moves toward the darker part of the range.

Value is the relative lightness or darkness of a color. The NPK and N group of trees possessed the darkest value (an improvement for balsam fir Christmas tree purposes). The K and P treated trees were in a middle group with the control trees in the lightest of the three significantly different groups.

The overall conclusion supports the more detailed findings of the Growers' Plots work; namely, that fertilizing with complete (NPK) or nitrogen (N) fertilizer brings significant improvement in tree color in the year in which it is applied when applied in dosages as suggested. The dosages on the Main Plots, incidentally, were intermediate in volume between the two levels used in the Growers' Plots (Table 1 lists each dosage as .15 pounds elemental nutrient or .44 pounds for the NPK combination). The trees averaged between six and seven feet in total height at the time of fertilizing.

Part II. GROWERS' PLOT

In the spring of 1966, tests on the effect of a variety of fertilizers on balsam fir Christmas tree characteristics were made with the cooperation of commerical growers, members of the New Hampshire-Vermont Christmas Tree Association. The trees averaged four and one-half feet in height when the experiment was initiated. These trees grew in both natural (volunteer) and plantation stands at ten separate locations in northern New Hampshire and Vermont. Most applications were made in late May with a few delayed until early June. Twenty-eight trees were selected at random for treatment at each of the ten locations, herein called "plots". There were also two control trees selected at random at each location for a total of thirty trees per plot.

The purpose of the experimentation was to develop some judgments as to the practical effects of individual fertilizers, applied in varying quantity, on some of the tree characteristics influencing balsam fir's desirability as a Christmas tree.

A. Explanation of Treatments

Fertilizer treatments were applied at low and high levels of application for each of seven elements or combination of elements. The elements, their codes and the levels are as follows:

N = nitrogen as ammonium nitrate (33.5%N). Low level, 0.3 lbs. (0.10 lbs. elemental N) per tree. High level, 0.7 lbs. (0.23 lbs elemental N).

P = phosphorus as superphosphate which is 19% P_2O_5. Low level 0.6 lbs. (0.11 lbs. elemental P), per tree. High level, 1.4 lbs. (0.27 lbs. elemental P).

K = potassium as muriate of potash which is 61% K_2O. Low level 0.195 lbs. (0.12 lbs. elemental K) per tree. High level 0.42 lbs. (0.26 lbs. elemental K).

Ca = calcium as agricultural limestone which is 50% CaO. Low level, 0.45 lbs. (0.22 lbs. elemental Ca) per tree. High level 1.05 lbs. (0.52 lbs. elemental Ca).

Mg = magnesium as magnesium sulfate which is 16% MgO. Low level, 0.375 lbs. (0.06 lbs. elemental Mg) per tree. High level, 0.875 lbs. (0.14 lbs. elemental Mg).

S = sulphur as powdered sulphur which is 95% S. Low level, 0.45 lbs. (0.43 lbs. elemental S) per tree. High level 1.05 lbs. (1.00 lbs. elemental S).

Comp. = complete, or NPK applied at a composite treatment of the individual rates for N, P and K stated above. The low level application was 0.10, 0.11, and 0.12 lbs. of elemental N, P and K, respectively. The high level was 0.23, 0.26 and 0.22 lbs. of elemental N, P and K, respectively.

In the complete (NPK) treatment the low or high level was applied by separately measuring out the appropriate weights of ammonium nitrate, superphosphate and muriate of potash for N, P and K. Since elemental N, P and K ratio in the Comp. are roughly equivalent to a 10-10-10 complete commercial mix, a 10-10-10 with these ingredients would yield an approximate low level by application of 1.1 lbs. per tree, and a high level with 2.5 lbs. per tree. If mixed from individual NPK fertilizers as utilized here, an approximate 10-10-10 ratio is achieved by a respective 3-6-2 individual fertilizer weight distribution.

A given treatment, such as N low, was applied to two randomly selected trees on each of the ten plots. Thus each of seven fertilizers accounted for four trees (two at the low, and two at the high level). With two control trees per plot, the total was 300 trees on the ten locations or plots.

The levels as given can be translated to pounds per acre depending on the number of trees to the acre. An acre (about 208.7 feet on a side) covers 43,560 square feet. An 8 x 8 spacing, for example, demands 64 square feet a tree or allows 680 trees per acre. The low level N application in the experiment under these circumstances amounts to 204 lbs. of ammonium nitrate per acre for trees of this size class. For Comp. low application rate averages almost 1.1 lb. per tree and for Comp. high 2.52 lbs. per tree, or 745 and 1,714 lbs. per acre, respectively, on this tree size and spacing basis.

Trees four to five feet in height have a foliage or green tissue mass that differs from those of other size classes, and rates of fertilizer application should consider such variation. Commercially, over acreages of managed stands, the fertilizer would perhaps be applied between the rows, and more "loss" might result than in the experiment. In the experiment the fertilizer was measured and applied under the tree by hand, moving all around the tree with the bulk deposited under the tree's "drip line" where the feeder roots are concentrated. Cooperating growers tried to keep the fertilizer at least eight inches away from the stem or trunk of the tree itself.

The tree characteristics measured and analysed included:

a. leader growth change
b. internodal bud and internodal branch development
c. foliage color characteristics

These measurements were made both in 1966, and for most characteristics in 1967 to judge the effect of an initial fertilizer treatment over a two year time span.

Rapid leader growth would be of great benefit in the economics of Christmas tree production provided there were no sacrifice in full tree form. Increased leader growth results in a taller tree in fewer years, in effect shortening the Christmas tree rotation. Unfortunately, if there is no filling in of the long spaces between annual whorls through internodal budding and subsequent internodal branching, trees with rapidly growing leaders can appear sparse or "spindly", and as a result, cultural practices such as root pruning and tip pruning of the leaders are resorted to in order to produce a "full" tree. The ideal Christmas tree, from a management standpoint, results by maintaining both rapid leader growth and good internodal branch development, thus producing a "full" tree in the shortest possible time.

B. Results of Treatments

1. Leader Growth Change

During the year prior to fertilizing, leaders on control trees grew an average of 8.96 inches (1965). This increased to 10.69 inches in 1966 and 12.60 inches in 1967. Increase in leader growth on unfertilized trees of this size is to be expected under normal weather conditions probably as a function of age. Control trees therefore accelerated leader growth 1.73 inches in 1966 and 3.64 inches in 1967, as compared to 1965. Comparisons were made of the effect of various fertilizers on growth acceleration with the control as a standard. Some growth acceleration over the 1965 experience took place in all cases, regardless of treatment. An overview of the result can best be gained by reference to Figure 2.

First year results indicated that there were significant[1] treatment effects on mean leader growth acceleration. Among some of the greater accelerators were low levels of N and both levels of complete (NPK) compared to N high and treatments such as Ca low, Mg high, P low and S low that were producing less leader growth acceleration.

In 1967, the effect of fertilizer treatments on leader growth were consistent with results observed in 1966. In addition, the trees receiving complete (NPK) treatments (both levels) and N low were significantly greater in leader growth than the control trees. Some of the treatments were experiencing a holdover in negative leader growth effect as compared to the control trees. When 1967 growth was compared to that of 1966, five treatments had a significantly lower gain over their own 1966 base as compared to the control trees. These treatments were N high, P low, K high, Ca high and S high.

Overall conclusions are that complete (NPK) fertilizers and low levels of nitrogen accelerate leader growth; that results in this respect are more pronounced in the second year, particularly with the complete treatment. Some fertilizers reduce leader growth–high levels of N fall in this category.

2. Internodal Bud and Branch Development

The greater the number of branches developing between whorls (the internodal length on the main stem) the better the tree form. The interrelationships among three variables concerned with internodal branching are what really determine the overall effect on tree form. These variables are the

[1] "Significant" is used to mean statistically significant at the 0.05 level. Analysis of variance was the statistical method initially employed. Pre-planned orthogonal tests with one degree of freedom were then used to test the difference among individual treatments.

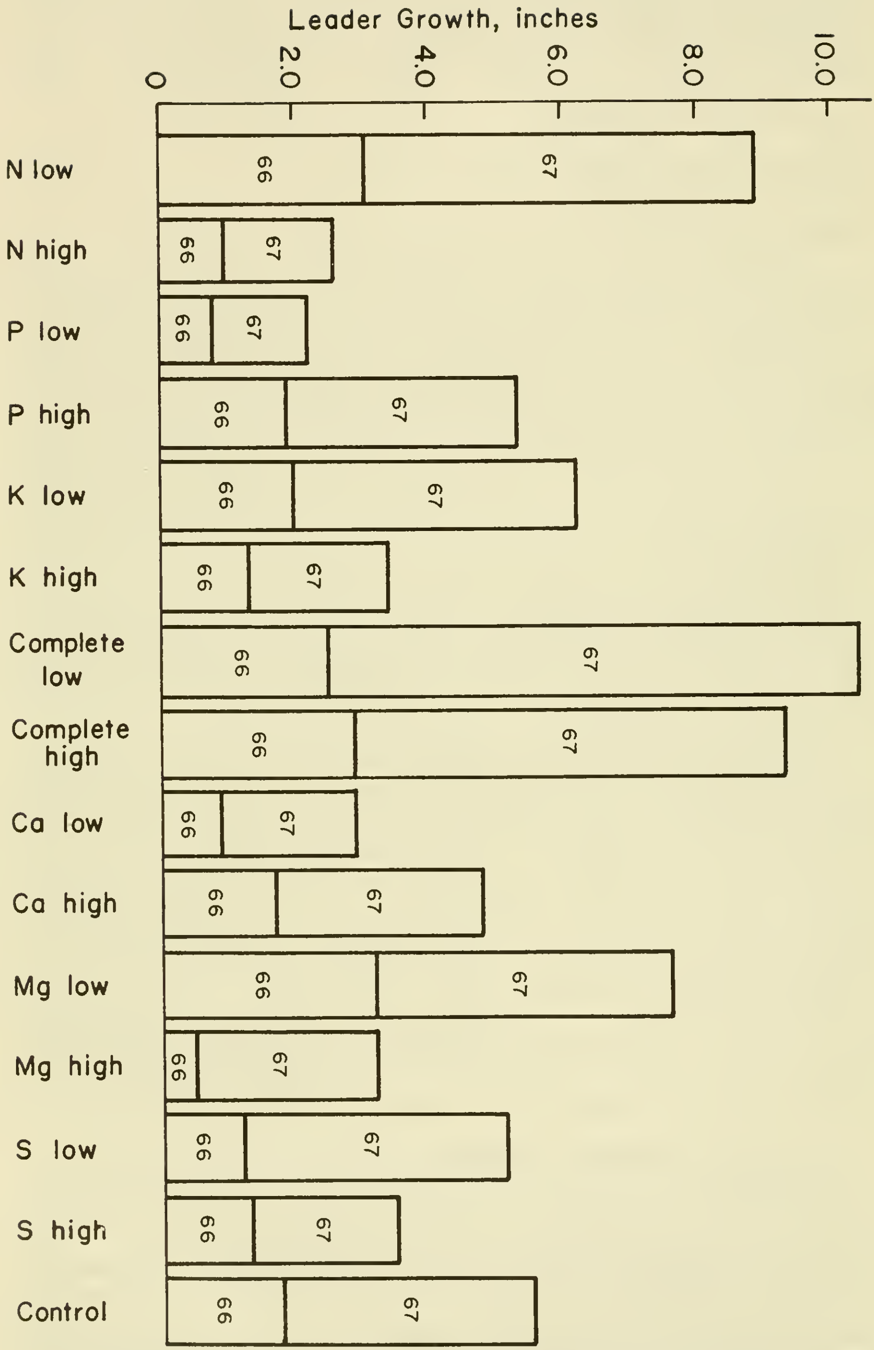

Figure 2. Leader growth acceleration, 1966 and 1967 as compared to no fertilizer year 1965, Growers' Plots, for all treatment and control.

Table 3. Statistical Analysis of the Growers' Plots by Analysis of Variance

Source of Variation	d.f.	1967 Leader Growth	1967 Internodal Buds	Leader Growth Change 1966-65	Leader Growth Change 1967-65	Leader Growth Change 1967-66	Internodal Bud Change 1966-65	Internodal Bud Change 1967-65	Internodal Bud Change 1966-65	Munsell Hue Change 1966-65	Munsell Value Change 1966-65	Munsell Chroma Change 1966-65	Visual Color Grading Change 1967-66
Block	9	*	*	*	*	*	*	*	*	*	*		*
Treatment	14	*	*	*	*	*	*	*	*		*		*
Residual	126												

* = statistically significant at the 0.05 level

Table 4. Comparison of Leader Growth, Internodal Bud and Branch Development Among Selected Treatments and Control, Growers' Study

Treatment	1965 Leader Growth Inches	1965 Inter-nodal Buds	1965 Branches Developed	1966 Leader Growth Inches	1966 Inter-nodal Buds	1966 Branches Developed
Control	9.0	11.45	10.90	10.7	11.40	9.60
N low	9.6	11.65	11.55	12.7	13.75	13.10
N high	9.2	11.50	11.22	10.3	13.00	10.61
Comp. low	8.5	10.20	9.10	10.8	13.50	11.95
Comp. high	9.7	13.42	12.26	12.4	16.10	13.89

Treatment	1967 Leader Growth Inches	1967 Inter-nodal Buds	1967 Branches Developed
Control	12.6	16.25	No data
N low	15.4	22.40	No data
N high	11.4	19.28	No data
Comp. low	16.3	30.40	No data
Comp. high	16.2	30.26	No data

number of internodal buds formed, the length of the internode on which these are located, and the number of buds that actually develop into branches coming out from the internode.

The data does not support a change in branch numbers developing from internodal buds as a result of fertilizer application. A developed branch to bud ratio on the 300 balsam fir trees in 1965 growth prior to fertilizing was .92, and .85-.90 is a reasonable working range and expectation as to actual initial branch development. Fertilized trees did not show any marked variation from this in 1966—a drop to .86, but then the twenty control trees were .84 during that period also.

The data on internodal bud development were tested as to the effect of treatment on internodal bud change. The treatments did cause significant changes for 1967 and 1966 as against 1965 in internodal bud formation. There was a significant increase in the number of internodal buds produced in 1966 as a result of the application of Comp. low and high, and N low. In 1967, N low did not maintain a significant difference although complete (NPK) fertilizers did significantly increase bud development. The conclusion is that Comp. low and high fertilizers were effective in spurring bud formation.

Since it was previously established that complete (NPK) and N low fertilizer accelerated leader growth, some kind of relationship between leader growth (or length of internode) and the internodal bud needs to be established. Ten internodal buds are more than six, but if they are spread over twice the internodal length, the tree form is not improved. This relationship can be measured and evaluated by a ratio. The ratio is the number of internodal buds developed per inch of leader growth, or buds per inch on the internode. 1965 data prior to fertilizer application indicate that balsam fir developed an average of 12.05 internodal buds, from which 11.12 branches were produced, on an average 1965 leader growth of 9.25 inches—a bud per inch of internode ratio of 1.30. This ratio was maintained for the two years after fertilizer treatments during which accelerated leader growth took place, (ratio 1.47), a point of major practical importance. Since the complete (NPK) fertilizers do the job of developing internodal buds and maintain this ratio in the second year (Table 4) there is strong argument for growers to consider fertilizing with low levels of complete fertilizers and to be less concerned with long leaders. Internodal budding and subsequent branching should offset the leader growth in producing a tree of good form. The results are presented in greater detail in Table 4.

In the statistical analysis of data the complete fertilizers and N low effected a significant first year positive change in internodal branching compared to the control. When 1967 internodal bud formation was compared to that of 1966 and 1965, the improvement in performance was significantly greater for the complete (NPK) fertilizers than that of the control, indicating a carryover in treatment effect into the second year after treatment.

3. Effect of Fertilizers on Needle Color

The investigators relied on field comparisons of needle color using

Munsell color charts to record colors. The Munsell system classifies any existing color on the basis of three attributes: hue, value and chroma, as was previously explained in Section I describing the work on the Main Plots. To summarize:

Hue in Christmas trees is the location of needle color in relation to yellow on one end of the scale and blue on the other. Balsam needles tend to fall in the 5 GY (a yellow-green 50-50 mix) or 7.5 GY slot, somewhat more toward the green category. A move toward the blue range in hue was considered a color improvement in this study.

Value in color indicates its lightness, and a decrease in value scale or darkening of the color was considered an improvement.

Chroma in a color is its purity or intensity. It is also described as its strength, or departure from neutral. It was pointed out Section 1, an approach toward gray (less pure of intense) might not detract from the appearance of a Christmas tree if the hue and value characteristics are pleasing. A lower reading in chroma indicates more gray.

A numerical code was developed for computer analysis of color changes The use of the Munsell system allowed a more objective approach to color rating, but there are weaknesses in matching colors in the field. It soon became apparent that it is easier to be aware of color differences in the field just by looking at trees than it is to locate the obvious difference on the color charts. In other words, the charts are not as "sensitive" or discriminating among small differences in color as is the eye. Also, changes in lighting with time of day and season affected the reaction of the observers. Finally, the reaction of one observer may differ from that of another. With these limitations admitted, the chart system was the only objective way available to rate color.

Hue is probably the most fundamental color characteristic related to Christmas tree quality. Hue changes that developed during 1966 cannot be said to be definitely due to treatment, but changes were discernible under the rating system employed. There was a measured movement toward the blue range through application of Comp. low, Comp. high, P low, N low and K low. An orthogonal test between control trees and individual treatments indicated significant differences between Comp. low and control trees with an improvement in tree color toward blue. The Mg low treatment resulted in a significant shift in tree color toward yellow.

Value changes (lightening or darkening) are significantly affected by the fertilizer treatments. Comp. low treatment was again excellent, darkening the needles. N low also recorded a significant improvement over the control. N high and Comp. high darkened color but not as positively as Comp. low and N low. Needles were significantly lightened by both levels of magnesium fertilizers.

Chroma changes were recorded but results were inconclusive. The treatment that showed the greatest departure from control was Comp. low with a significant shift toward the gray.

In the fall of 1967, when plots were remeasured, the observers compared 1967 with the 1966 needle color. The analyses just presented were the first year changes, results of 1966 relative to those of 1965. The second year comparison was a simple visual rating scheme, subjectively judging if the 1967 color appeared poorer, the same or better than the 1966 foliage (this was to give an indication of "hold-over" on color change into the second fall after first year spring fertilizing). The comparison made it clear that the 1967 foliage of N and complete (NPK) treated trees had regressed to a significantly "poorer" visual reaction, whereas the control and other treatment trees had not changed significantly from their 1966 appearance. The color change was not sufficiently great as to justify fertilizing every year. Another conclusion was that the color had started to "regress" nearer to 1965 with both high and low levels of N and complete (NPK) fertilizers. Holdover in color improvement during the second year by heavier fertilizer application was not substantiated in the Growers' experiment.

C. Conclusions of Growers' Plots

The results of the Growers' experiment argues strongly for use of complete (NPK) fertilizer to shorten rotations of balsam fir Christmas trees and still produce trees of comparable form. Fertilizers if applied in late May or early June in northern New England will result in marked tree color improvement for early fall harvest. It is believed that fertilizers should be applied at low levels[1] and *not* be done on an annual basis. Application every other year would appear maximum, with further study needed to see whether this can be extended without significant fall-off in growth rate.

The commercial grower can refer to data on the soils encountered in the Growers' Plots, presented in Table 5, and compare it to that on his own lands. He should also relate the size of his particular trees to those in the study in adjusting fertilizer dosages. The efficiency of his method of application (the fertilizer reaching tree roots) as compared to the hand method employed in the experiment is another major consideration before determining the poundage of fertilizer to apply in any specific situation.

To relate fertilizing practice with nutrient uptake, the foliar analyses of control trees on the Growers' Plots making up part of Section III on Foliar Analysis was conducted.

Part III. FOLIAR ANALYSIS OF BALSAM FIR

A. Growers Plots

During the development of this study the potential of foliar analysis as a means of pinpointing nutritional deficiencies in balsam fir Christmas trees prompted preliminary work in this field. The work was limited to chemical analysis of foliage of some of the control trees in the Growers' study and on the Main plots, and of selected trees at other locations. All foliar analyses were

[1] Previously, low level complete (NPK) or Comp. low was defined as 0.10 lbs of elemental nitrogen, 0.11 lbs of elemental phosphorus and 0.12 lbs of elemental potassium per 4 to 5 foot balsam fir tree, or 1.1 lbs of a 10-10-10 NPK fertilizer per tree.

Table 5. Foliar Analysis – Growers Plots

Plot No.	Location County & State	Soil Type	Aspect	K %	Ca %	Mg %	P %	N %	Fe ppm	Mn ppm	Zn ppm	Moisture %	Ash %
1	Coos, N. H.	Berkshire loam	N slope	0.96	0.66	0.06	0.22	1.02	44	1500	54	95.52	3.78
2	Coos, N. H.	Colebrook gravelly fine sandy loam	W slope	0.85	0.68	0.11	0.15	1.69	37	391	58	94.92	3.49
3	Essex, Vt.	Blanford loam	S slope	0.77	0.54	0.12	0.31	1.83	56	260	64	95.56	3.14
4	Essex, Vt.	Cabot Ridgebury loam	NE slope	0.60	0.37	0.12	0.10	1.01	35	383	32	95.46	2.12
5	Grafton, N. H.	Canaan stony sandy loam	W slope	0.75	0.89	0.05	0.21	1.32	40	369	71	94.19	3.98
6	Caledonia, Vt.	Glover series, sandy loam and ledge	S slope	1.02	0.62	0.10	0.25	1.61	56	1200	69	95.48	3.90
7	Lamoille, Vt.	Woodbridge loam	S slope	0.88	0.60	0.12	0.15	1.31	45	1890	50	95.48	3.30
8	Coos, N. H.	Colebrook fine sandy loam	Lowland bog	0.64	0.44	0.08	0.15	1.76	51	1010	55	95.15	2.68
9	Coos, N. H.	Peru stony loam	W slope	0.90	0.69	0.08	0.21	2.09	59	892	69	95.22	3.74
10	Coos, N. H.	Lyman loam smooth phase	SE slope	0.76	0.59	0.13	0.22	1.43	32	336	67	94.37	3.17
			Average =	0.81	0.61	0.10	0.20	1.51	45.5	823	59	95.14	3.33

Code: K = potassium; Ca = calcium; Mg = magnesium; P = phosphorus; N = nitrogen; ppm = parts per million of; Fe = iron; Mn = manganese; Zn = zinc limited to unfertilized trees. The principal objective was to compare or correlate the results for control trees on individual Growers' Plots with the soil analysis for those plots. A second objective was to try to establish some standards of nutrient levels in healthy balsam fir within the geographic area of this study. Such standards, stated in percentages or in parts per million for the major soil elements, could help to identify the nature of a nutritional deficiency in sickly trees.

The general methods employed in both soil and foliar analyses in the study are presented in the appendix.

The results of chemical foliar analysis of control trees on the Growers' plots is presented in Table 5, and can be compared with the soil analysis for the same plots in Table 6. Samples of foliage were taken in late September 1966, confined to current year's growth, and were a mix from various whorls of the control trees sampled on the plot.

There was little correlation between soil nutrient level and foliar content of selected elements. Direct comparison of the quantitative results in Tables 5 and 6 is supplemented by Table 7 presenting a relative comparison of nutrient level in both soil and foliage either numerically or in symbol. Trees on soils relatively high in nitrogen content may show relatively low, average, or high level of foliar nitrogen. A correlation between soil nitrogen and organic matter present may logically be expected but was not statistically significant in these data. A positive correlation may exist between foliar phosphorus and soil reserve phosphorus but with the limited data at hand from the Growers' Plots this is conjectural.

B. Canterbury, New Hampshire Late June Foliar Analyses

Foliar analyses were made of 16 healthy balsam fir growing in Canterbury, New Hampshire (north of Concord and the southernmost of the numerous locations in the work with balsam fir). This was one of the "Main" plot locations. Here comparisons were made between current (1965) needles and one year old (1964) needles on the same tree (Table 7). The table also contains the previously presented results of September samplings on the Growers' Plots, for comparative purposes. The area of June samplings is removed geographically from those of September samplings but the data nevertheless suggests that the time of year could have a large influence on results obtained from foliar analysis. At Canterbury, the primary nutrients NPK (nitrogen, phosphorus and potassium) were present in greater amount in current as against one year old needles, with this trend reversed in other nutrients. The differences between current and one year old foliage proved to be significant.

Further work was done at Canterbury, again with June gathered foliar samples, confirming the previous point and indicating in addition that in relatively "green" trees the NPK percentages may be somewhat greater in the tops as against the base of trees (Table 8). No data from fall samplings is available to support this point. It would nevertheless appear well to standardize foliar samplings not only as to (1) age of foliage and (2) time during the growing season but also as to (3) the vertical portion of the tree crown sampled.

Table 6. Soil Analysis – Growers' Plots

Plot No.	Location County & State	Soil Type	Aspect	Bulk Density	% Dry Matter	Organic Matter %	P #/A	Reserve P #/A	K #/A	Ca #/A	Mg #/A	N #/A	pH
				SOIL ANALYSIS									
1	Coos, N. H.	Berkshire loam	N slope	1.00	98.34	7.62	2	36	1016	196	6406	4880	4.9
2	Coos, N. H.	Colebrook gravelly fine sandy loam	W slope	1.02	98.46	6.24	Trace	5	1524	326	6846	3140	5.1
3	Essex, Vt.	Blanford loam	S slope	1.12	98.57	5.96	3	60	1968	266	5944	4220	5.2
4	Essex, Vt.	Cabot Ridgebury loam	NE slope	0.97	97.81	6.80	2	9	3476	232	10388	3080	5.0
5	Grafton, N. H.	Canaan stony sandy loam	W slope	1.11	98.50	6.14	2	76	994	266	3918	3800	5.7
6	Caledonia, Vt.	Glover series, sandy loam and ledge	S slope	0.99	97.95	7.25	2	23	1756	162	11618	4160	5.1
7	Lamoille, Vt.	Woodbridge loam	S slope	1.10	98.75	5.02	2	19	284	168	2836	2680	4.9
8	Coos, N. H.	Colebrook fine sandy loam	Lowland bog	0.85	97.30	9.87	1	8	268	198	3598	3800	4.8
9	Coos, N. H.	Peru stony loam	W slope	1.08	98.50	6.34	1	9	304	232	2396	2640	4.9
10	Coos, N. H.	Lyman loam smooth phase	SE slope	0.99	98.42	8.85	2	33	2032	250	10852	5820	4.9
			Average =	1.02	98.26	7.01	1.7	27.8	1362	230	6480	3822	5.05

Code:
#/A = lbs. per acre
P = phosphorus
K = potassium
Ca = calcium
Mg = magnesium
N = nitrogen
pH = is a measure of relative acidity or alkalinity, these soils being acidic (pH 7.0 is neutral).
Bulk density is explained in the Appendix.

Table 7. Comparisons of Soil Characteristics and Foliar Content, Growers' Plots, as Shown by Chemical Foliar and Soil Analysis of Unfertilized Control Trees

Plot No.	Nitrogen		Organic Matter, %	Phosphorus		Reserve P per acre	Potassium		Calcium		Magnesium		Bulk Density
	Foliar	Soil		Foliar	Soil		Foliar	Soil	Foliar	Soil	Foliar	Soil	
1	L	H	H	A	A	A	H	A	A	L	L	A	A
2	A	L	L	L	L	L	A	A	A	H	A	A	A
3	H	A	L	H	H	H	A	H	L	H	H	A	H
4	L	L	A	L	A	L	L	H	L	A	H	H	L
5	L	A	L	A	A	H	A	A	H	H	L	L	H
6	A	A	A	H	A	A	H	H	A	L	A	H	A
7	L	L	L	L	A	A	H	L	A	L	H	L	H
8	H	A	H	L	L	L	L	L	L	L	A	L	L
9	H	L	L	A	L	L	H	L	A	A	A	L	H
10	A	H	H	A	A	A	A	H	A	A	H	H	A

H = relatively high
A = average and
L = relative low by comparison in the ten plot series

Table 8. Foliar Analysis Comparisons of Canterbury, N. H. Grown Balsam Fir of Current, One and Two Year Old Foliage From Top and Base of Trees. Basis – 4 Trees (2 "Green", 2 "Yellow")

June 22, 1965 samples

		Green			Yellow	
	K	N	P	K	N	P
	%	%	%	%	%	%
1965 Top	.80	1.35	.21	.78	1.26	.21
Base	.70	1.40	.19	.76	1.27	.21
1964 Top	.38	1.21	.12	.39	1.03	.11
Base	.29	1.17	.10	.41	1.03	.11
1963 Top	.32	1.15	.11	.29	.97	.08
Base	.23	1.12	.09	.32	.98	.09

			Green					Yellow		
	Ca	Mg	Fe	Mn	Zn	Ca	Mg	Fe	Mn	Zn
	%	%	ppm	ppm	ppm	%	%	ppm	ppm	ppm
1965 Top	.35	.10	.21	287	44	.40	.09	.21	263	37
Base	.39	.10	.19	295	48	.34	.09	.21	238	40
1964 Top	.81	.09	.12	644	93	.73	.08	.11	675	199
Base	.91	.10	.10	951	108	.85	.09	.11	665	70
1963 Top	.99	.08	.11	788	107	1.12	.09	.08	915	83
Base	1.12	.10	.09	1040	129	1.23	.09	.09	775	172

C. Comparisons Between "Light" and "Dark" Trees

There was an attempt to discover whether foliar analysis could point up a measurable difference between "dark", or green trees, as against "light", or more yellowish green trees on individual plantations, both groups appearing healthy and commercially acceptable but with the market advantage to the former group.

Three locations (all in Coos County, northern New Hampshire) contributed five dark and five light trees to the sampling for a total of thirty trees. A soil sample was also taken at the tree. An additional pair, one light and one dark tree, was sampled at a fourth location in the same general area.

By Munsell color chart, the trees on the locations compared approximately as follows:

	Dark	Light
Location I	7.5 GY 4/6	7.5 GY 5/6
Location II	7.5 GY 4/5	7.5 GY 4.5/6
Location III	7.5 GY 4.5/6	5 GY 5/8
Location IV	7.5 GY 4/6	5 GY 5/6

This would indicate among the first three locations with five samples in each classification, that Location II offered relatively little visual difference between the categories. The averages were computed for the dark and light categories and presented in Table 9.

Upon statistical analysis, the apparent differences in the tabular presentation between nitrogen percentages in dark as against light foliage proved significant for Locations I and III but not for Location II. This was anticipated in view of what was already indicated as to the relatively subtle difference in color in Location II, with light trees approaching the color of dark trees at Location III.

As in the Growers' Plots analysis, an attempt to correlate foliar content and soil sample content for specific nutrients failed. There were no apparent correlations when the dark and light groupings for Locations I, II, or III were compared. Table 10 is the soil data summary which can be compared with the chemical foliar summary in Table 9. Although group, rather than tree by tree results are in the tables, analyses by individual tree also produced no hint of consistent relationships.

D. "Standard" for typical balsam, fir, fall sampling in northern New Hampshire and Vermont

The preliminary work on chemical foliar analysis makes available the data presented within Table 11 as an indication of what may be expected with typical balsam fir of marketable Christmas tree size. The data used to develop Table 11 was obtained from 52 trees sampled between September 29 and November 9th during 1965. It is expected that some of these trees were growing under conditions of less than ideal nutrient availability and were deficient in some nutrients, as the ranges encountered would suggest. Nevertheless, although some trees were rated relatively "light" or "yellowish green" within their plantation or

Table 9. Comparison Between "Dark" and "Light" Foliage Trees On Locations In Coos County, New Hampshire Samplings, Early November

	Dry Matter %	Ash %	K %	Ca %	Mg %	P %	N %	Fe ppm	Mn ppm	Z ppm
Location I										
Dark	96.23	3.65	.79	.69	.05	.22	1.93	52	1916	66
Light	96.63	3.58	.81	.74	.05	.21	1.69	51	1413	57
Location II										
Dark	96.56	2.69	.59	.54	.10	.18	1.57	40	517	35
Light	96.53	2.79	.63	.58	.11	.17	1.49	33	508	40
Location III										
Dark	96.61	3.26	.65	.62	.12	.19	1.65	42	499	52
Light	96.65	2.86	.59	.61	.13	.17	1.18	32	334	44
*Location IV										
Dark	95.86	3.16	.61	.76	.12	.16	1.84	49	484	46
Light	96.34	2.66	.43	.64	.16	.14	1.16	35	341	49

*One sample of each, rather than five in average.

Table 10. Soil Comparisons At "Dark" and "Light" Foliage Trees On Three Locations In Coos County, New Hampshire
Early November

		Organic Matter %	K #/A	Ca #/A	Mg # /A	P #/A	P Reserve P #/A	N #/A
Location I	Dark	8.64	1623	253	6755	4.6	52	5440
	Light	8.47	1530	270	6686	4.2	49	5280
Location II	Dark	12.47	824	329	3246	3.2	18	7440
	Light	12.66	797	301	3044	2.6	14	7400
Location III	Dark	10.76	558	361	2307	1.2	8	6240
	Light	10.32	583	446	2909	.2	6	5800

growing site, (specifically, some needle colors matched 5 GY 5/6 and 5 GY 5/8 in the Munsell chart) they appeared to be vigorous and typical of commercial quality Christmas trees.

Two out of every three such trees may be expected to fall within the one standard deviation range in Table 11 (or 21 out of 22 within two times the deviation presented).

This indicates considerable variability in healthy trees in any one nutrient characteristic rather than a rigidity, and also suggests a lack of rigidity in nutrient demand.

Despite this flexibility in healthy trees it is hoped that in any one instance the preliminary standards will prove of value in the use of foliar analysis to pinpoint nutrient deficiency.

IV. Appendix

A. Bulk density

Bulk density (referred to in Table 4 and the studies) is also called volume weight, or apparent specific gravity. It is the ratio between the dry weight of a given volume of undisturbed soil and the weight of an equal volume of water. The volume measured includes pore space. (Note-specific gravity itself is a similar ratio but pore space is not included). Very compact soils have high volume weights (less pore space contributes to this). Mineral soil material free of organic matter develops very little variation in specific gravity, therefore the amount of organic matter in the soil is reflected in lowered bulk density. Generally, rocks and sand in soil favor high values (Lutz and Chandler, Forest Soils, John Wiley & Sons Inc., 1946).

B. Tree Grade for the Main Plots

Christmas tree grading measures appeal-looks. The overall appeal of a particular tree is determined by varying combinations of many minute characteristics which are not obvious at first glance. These characteristics are grouped into three classes, major features:

1. **Crown Symmetry**
   a. Even length of branches at a particular node.
   b. Branches of proportional length at successive nodes.
   c. Full whorls (branches evenly spaced around the bole at each node).
   d. Stemform (straight, bent, crooked, multi-leaders, etc.)
2. **Crown Density**
   a. Branches per node
   b. Internodal length
   c. Internodal branching
   d. Foliage characteristics (number and length of needles).

Table 11. Averages In Chemical Foliar Analyses of Typical Commercial Quality Balsam Fir Christmas Trees In Northern New Hampshire and Vermont

Basis: 52 Trees, Fall Sampling From September 29 to November 9

Nitrogen, per cent	1.50	Iron, p.p.m.	43
standard deviation	±.42	standard deviation	±10
range	1.01–2.09	range	25–66
Phosphorus, percent	.19	Manganese, p.p.m.	831
standard deviation	±.04	standard deviation	±590
range	.10–.31	range	181–2320
Potassium, percent	.72	Zinc, p.p.m.	53
standard deviation	±.14	standard deviation	±13
range	.43–1.02	range	29–73
Calcium, percent	.62	Moisture, %	95.98
standard deviation	±.12	standard deviation	±.81
range	.37–.96	range	94.19–97.14
Magnesium, percent	.10	Ash, %	3.13
standard deviation	±.03	standard deviation	±.65
range	.04–.16	range	2.12–3.98

To grade a tree, each of the three major features is carefully evaluated and the whole tree is scored excellent, very good, good, fair, poor, or very poor; 6 through 1 respectively. Internodal branching is then rated separately to indicate the degree to which it contributes to the overall grade. The same 6 through 1 ratings are used.

For a particular tree to be graded excellent, it must score excellent in each major feature. However, to score excellent in a single major feature does not necessitate an excellent score in all contributing characteristics. For example, a tree with many branches at each node and short internodes may have a very low degree of internodal branching and still score excellent for crown density. Due to the short internolar and many branches per node, this tree doesn't need a high degree of internodal branching for a full appealing crown.

Another example, might be a tree scored good for crown density, even though it has 12-inch internodal, 4 branches per node and healthy long needles if the lack of internodal branching leaves naked spaces between the branches of each node. Color is not included in the above grading system.

C. Methods of Analyses

Nitrogen foliar and soil analyses were made with the Kjeldahl method from the Association of Official Agricultural Chemists.

Phosphorus foliar analysis by the molydate blue method as described by H. Hill, Central Experimental Farm, Ottawa, Canada. Soil phosphorus and reserve phosphorus procedures as outlined by Vermont Soil Test, based in part on Bray and Kutz procedure as adapted by Jackson, M.L., Soil Chemical Analysis (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1958), p. 160.

Calcium, magnesium, iron mangenese and zinc analyses were made by use of atomic absorption spectrophotometer.

Potassium foliar and soil analyses employed the flame emission spectrograph.