MONITORING OF STOCK BY NURSERYMEN

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MONITORING SOIL MOISTURE

There is more than one way to measure or monitor soil moisture. Before deciding on the system to be used, a nurseryman should decide what he hopes to accomplish by applying water to his seedlings. In my estimation, there are two extremes to which one may go. First you may decide that your watering practice will be only a band-aid approach to periods of dry weather; under this system you will only apply water to prevent trees from dying of drought. At the other end of the scale one could decide to add water in an attempt to keep his trees optimally supplied with moisture all during the growing season regardless of rainfall distribution.

In the first instance, the old nursery statement that "you can keep trees alive during a drought but you can't keep them growing" is true. Under the second regime you will be able to keep the seedlings growing.

At Orono, during the last thirty years, we have evolved from the "prevent dying" philosophy to the point where we now are attempting to keep seedlings growing in an environment where they will always have an optimum moisture supply.

Over the years our moisture monitoring techniques have changed, as have the aims of our irrigation programme.

At first our monitoring technique simply consisted of taking Wisconsin soil auger cores and visually assessing moisture conditions. Where we were only attempting to prevent death by drought, this was fairly simple; one could watch the moisture content drop and the only decision that had to be made was when to start watering so that death was prevented.

During the late 1940's, under Mr. G.M. Linton, the then Superintendent at Orono, we began using the Thornthwaite "Calculation of Evapotranspiration" in order to estimate the available moisture in the soil. (Thornthwaite, C.W., 1948).

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For those not familiar with this system, Thornthwaite developed a formula based on temperature, rainfall and daylength to estimate the daily water loss from the soil for evaporation and transpiration. This was a great improvement over the soil auger method and allowed us to maintain an estimated soil moisture content much higher than we had been doing in the past.

However, Thornthwaite's calculation, which is surprisingly accurate over a full growing season, had built in drawbacks when one was estimating irrigation requirements on a day to day basis. The formula does not take into account cloudiness, humidity or wind. Over the full growing season you receive periods of sun and cloud, low and high humidity and calm and windy days, and these tended to average out. On the day to day basis of calculation, if you run into a period of no cloud, low humidity and high winds, as is usual in time of drought, the formula tends to underestimate the evapotranspiration and you do not apply enough irrigation water. Conversely, if you go through a period of high humidity, low winds and cloudy conditions the formula tends to over-estimate water loss and you over irrigate.

I like to define irrigation as "the application of a measured amount of water to correct a known soil moisture deficiency". This definition implies that you must be able to monitor soil moisture conditions and at some predetermined point add a given quantity of water to the soil to return it to another predetermined level of moisture.

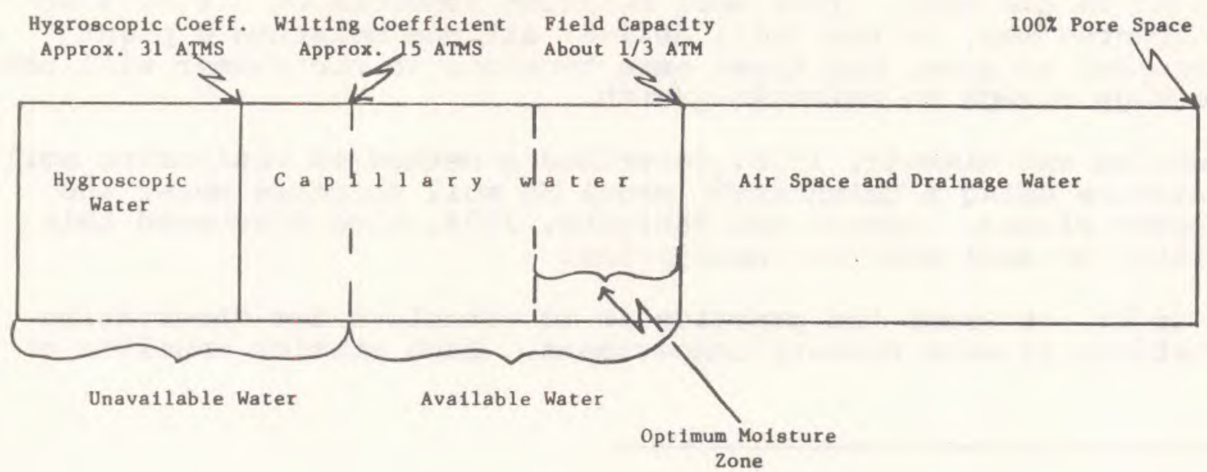

FIGURE No. 1

Diagrammatically, our soil could be represented by the diagram in Figure 1. Quite often, when thinking of soil moisture available to plants, we feel that this consists of the water from field capacity to wilting point. This is true if all we intend to do is to keep the plants alive. If we intend to keep the plants growing, this is another story.

As the plants extract water from a soil at field capacity, it takes only about 1/3 of an atmosphere of tension to move the water into the plant roots. However as soil moisture is used, the amount of tension that has to be applied to move it, increases rapidly. Long before you reach wilting point, the plant will not be able to extract water fast enough from the soil to be able to maintain a good degree of growth and plant growth slows down. This slowing down of growth is due to at least two factors. Firstly, as extraction pressure increases, less and less moisture and dissolved nutrients are taken in by the roots, hence photosynthesis and the synthesis of proteins are slowed down. Secondly, as the plant is put under moisture stress, to preserve the moisture within the plant, the stomata close down to reduce water loss. This closing down of the stomata reduces the intake of CO_2 and photosynthesis and proteins synthesis are further reduced. The time of the season also has an effect on how high a soil moisture tension can be tolerated by the tree and still produce a good rate of growth.

The rate of transpiration (90% or better of water taken in by a tree is lost in transpiration) is directly proportional to air temperature, up to a certain "cardinal" point. Thus a plant, exposed to high temperature during mid-summer, has to receive more water from the soil than it will when temperatures are lower later in the fall. Thus soil moisture tensions of 3,4 or 5 atmospheres may, in the fall, deliver all the moisture a plant required to grow, but these same tensions in mid-summer will not be high enough to maintain growth.

Bunting and Kimmett, 1972, described a method of monitoring soil moisture using a Delmhorst[2/] Model KS soil moisture meter and gypsum blocks. Armson and Sadreika, 1974, also discussed this method of soil moisture monitoring.

Briefly, at Orono the practice is to establish two observation stations in each nursery compartment. Each station consists of

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2/ Delmhorst Instrument Co., 607 Cedar St., Boonton, N.J. 07005 two gypsum blocks, one set at about three inches and the other about **six** inches in the soil. The gypsum block, once placed in the soil, takes on the same moisture content as the soil surrounding it. Since the electrical resistance of the block varies with its moisture content, connecting the block to the moisture meter and noting the reading gives an estimate of the moisture content of the soil.

At Orono, irrigation applications are scheduled by the readings of the three inch block. The six inch block is used to ensure that sufficient moisture is applied that it reaches the **six** inch layer thus preventing the development of a dry layer of soil under the seedbeds.

Irrigations are applied when the reading from the three inch layer reaches 100 on the Delmhorst scale or about 0.8 bars of tension. Twenty-five millimeters of irrigation water will result in meter readings of 180, field capacity for our soil.

This maintenance of high moisture content in the soil was found to increase the size of conifer seedlings for all parameters measured by McClain and Armson, 1975, and by McClain, 1973.

In these tests where four levels of fertility and three moisture regimes were maintained, I think it is fair to say that, as the moisture regimes increased the differences between fertility regimes tended to disappear. Thus the maintenance of soil moisture at low levels of tension optimizes seedling growth. The Delmhorst moisture meter is the best method we, at Orono, have found to monitor this condition.

MONITORING SEEDLING GROWTH

Introduction

Since 1970, Orono Nursery has been trying to monitor the growth of seedlings in the nursery compartments. The reason is to assist nursery staff in assessing the development of stock over the growing season so that we will end up with a product of given attributes at the end of the season, year after year. (i.e. a 2-0 white spruce seedling of 2.25-2.50 gm).

We find that it is fairly easy to remember what stock of the desired size looked like at the end of the growing season. However, when the question is asked during mid season, "will this stock make the desirable size by the end of the season?" one is never quite sure of the answer. You continue on in faith applying water, fertilizer etc. as you have in the past in the hope

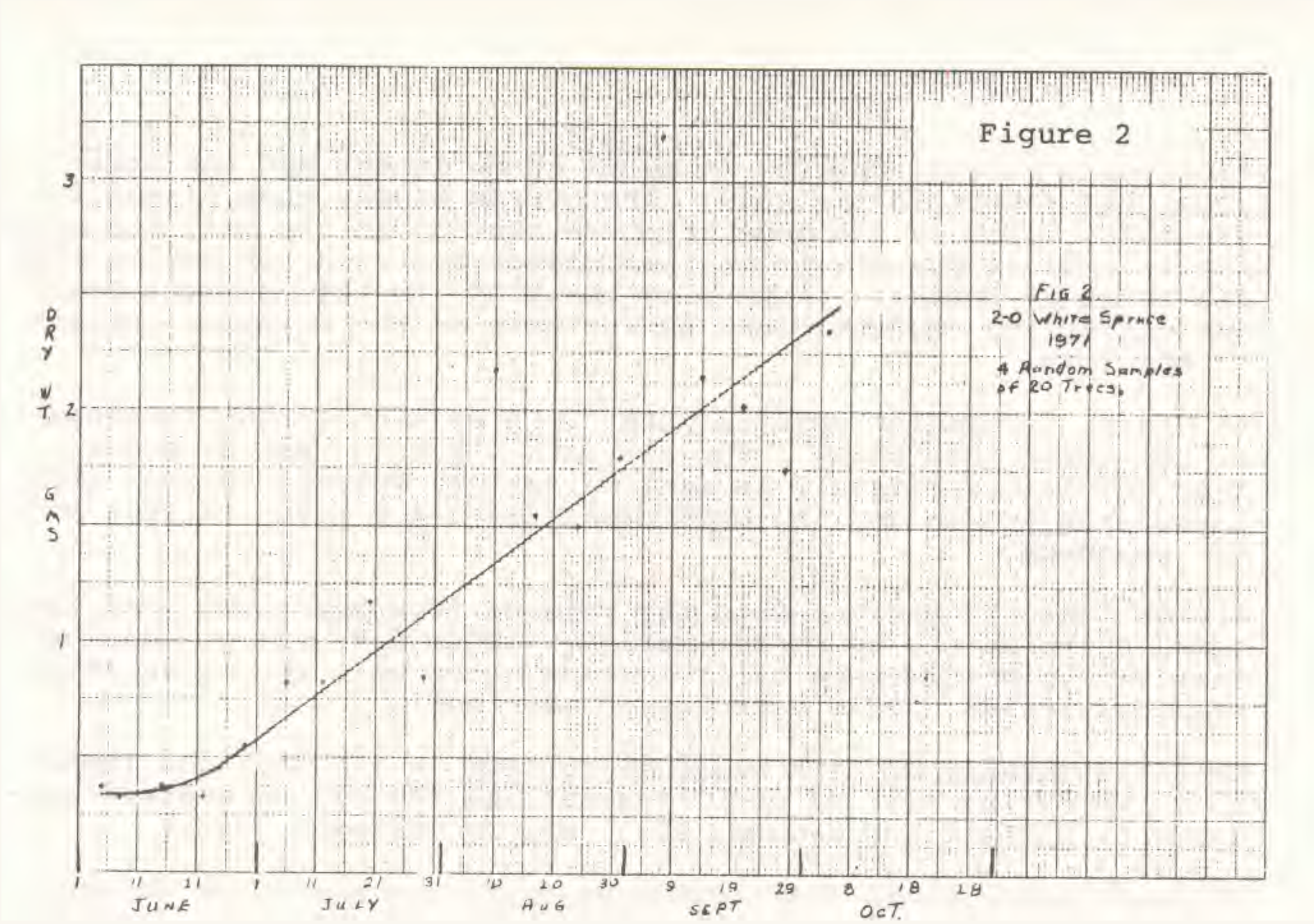


Figure 2

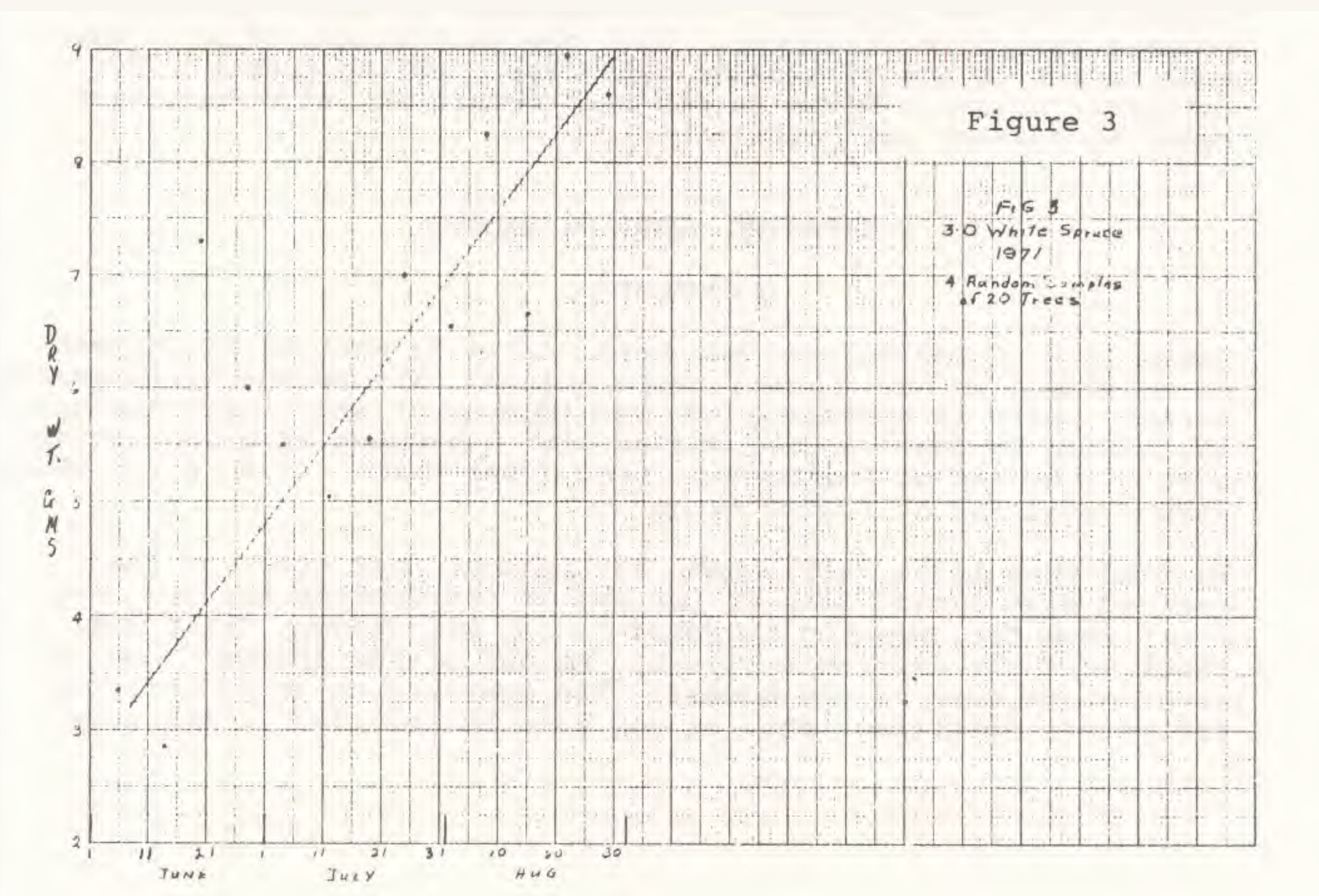


Figure 3

that your results will be consistent year after year.

In 1971 we decided to plot growth curves of our developing seedlings, using dry weight as the parameter to assess seedling development. Samples from four randomly selected places in each of our nursery compartments were chosen each week and twenty seedlings from across the bed were selected (total 80) to be measured for stem caliper, height and dry weight.

Average dry weights from week to week fluctuated widely. At the end of the season it was relatively easy to draw a curve (Figures 2 and 3) representing how you felt the seedlings developed, but on a week to week basis the data were not able to tell you if your seedlings were developing faster or slower than you planned.

It is obvious that seedlings do not develop in this erratic manner over the season. Our problem was that the sample was so small that we were not getting an average dry weight for the compartment. It was apparent that we required a much larger sample. However, the destructive sampling for dry weight is a lengthy process with the capacity of the drying ovens being the bottleneck. It was decided that we would have to look for another parameter to measure, hopefully one that could be taken as a non-destructive sample.

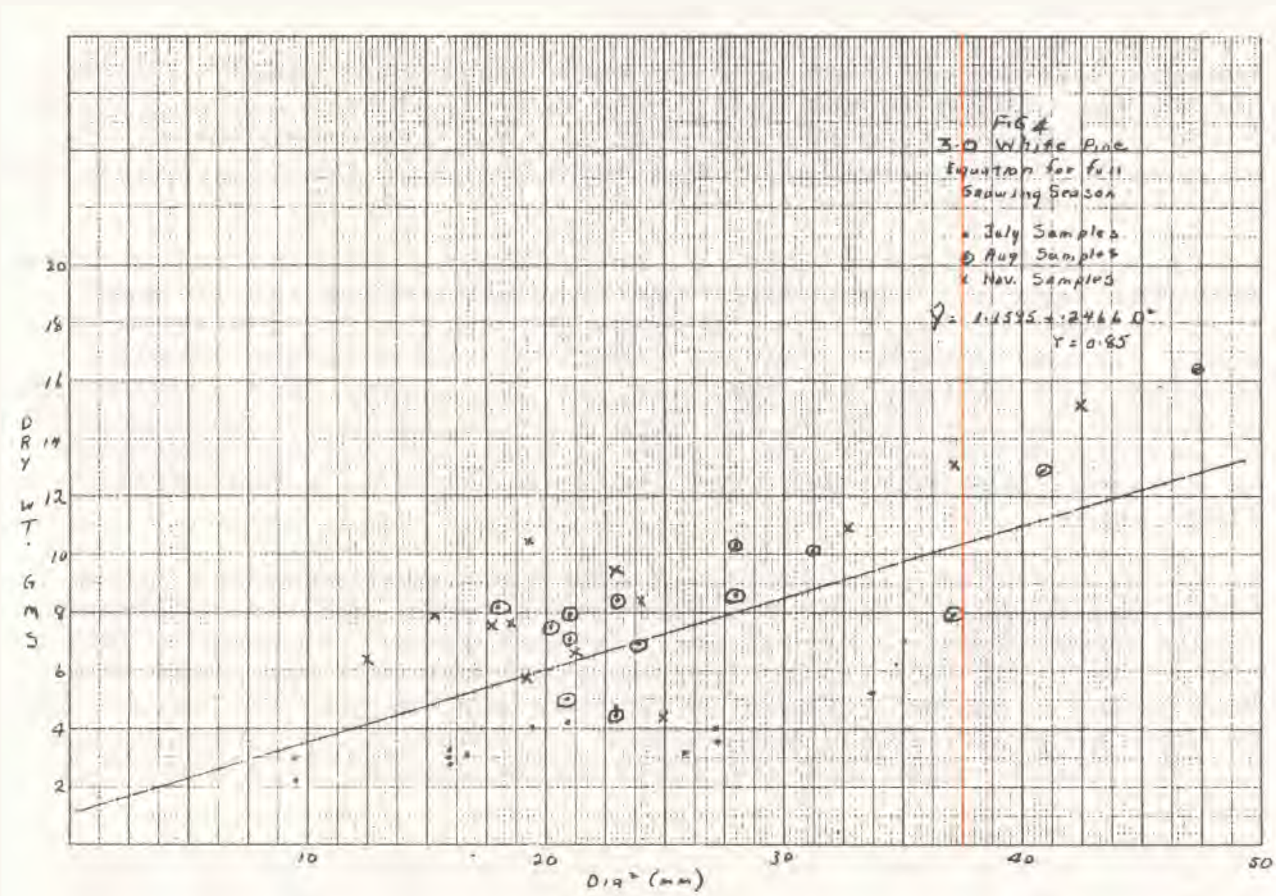
In going over the literature, it was found that Armson & Smith in 1966, had found a linear relationship between seedling diameter squared and seedling dry weight for Jack Pine. It was decided to see if we could develop regression equations for our major species using diameter squared to express dry weight. If this could be done we would have a method that would allow us to take relatively large numbers of non-destructive samples in a short period of time.

In 1973, samples were taken from our three major species, white pine, (Pinus strobus L.), red pine, (Pinus resinosa, Ait.) and white spruce (Picea glauca (Moench) Voss.) These samples consisting of 15 to 20 individuals were taken at weekly intervals from June 6 to November 28. Individual measurements for height, diameter and dry weight were obtained for each tree.

During the winter of 1973-74 regression equations for our three species and two age classes (2-0 & 3-0) were developed. While 1-0 measurements had been secured it was found that the diameters of this age class were so small that our calipers were not able to measure real differences.

Our first attempt at developing a regression equation consisted of pooling the 2-0 and 3-0 data for the full growing season.

When the data, upon which the equation was based, were plotted against the calculated regression line it was apparent that this equation tended to overestimate the weight of 2-0 seedlings and underestimate the 3-0 seedlings, particularly at the larger diameters.



Our second attempt consisted of developing an equation for each species and age class over one full growing season. However, once again, when the data were plotted against the equation line (Figure 4) it was found that the equation tended to overestimate the dry weight of diameters taken early in the growing season and underestimate those taken late in the season.

In our third attempt, we decided to develop an equation for each species and age class by month. Thus we developed one equation for 2-0 white spruce for May, one for June and so forth. Data for each of these equations were collected about mid month and it was planned to use the equation for calculating the dry weight of samples taken during that month. This approach immediately presented a problem in that the regression equation was calculated on the individual dry weights and diameters collected at one time in a month. This numbered only 50 to 80 individual trees and it was felt this was too few observations on which to base a regression equation, yet it was not possible to find time to put more samples through the drying ovens. To get around this problem it was decided to set up a ledger (Figure 5) to accumulate the data on a year to year basis. This will increase the accuracy of the equation as additional observations are gathered in subsequent years. As new samples are taken each year, they are added to the previous totals and a new equation is developed following the instructions in Elementary Statistical Methods for Foresters, U.S. Dept. of Agriculture Handbook 317, pages 51-55.

Figure 5

X = D² mm
Y = Dry wt. gms.

2-0 White Spruce — July

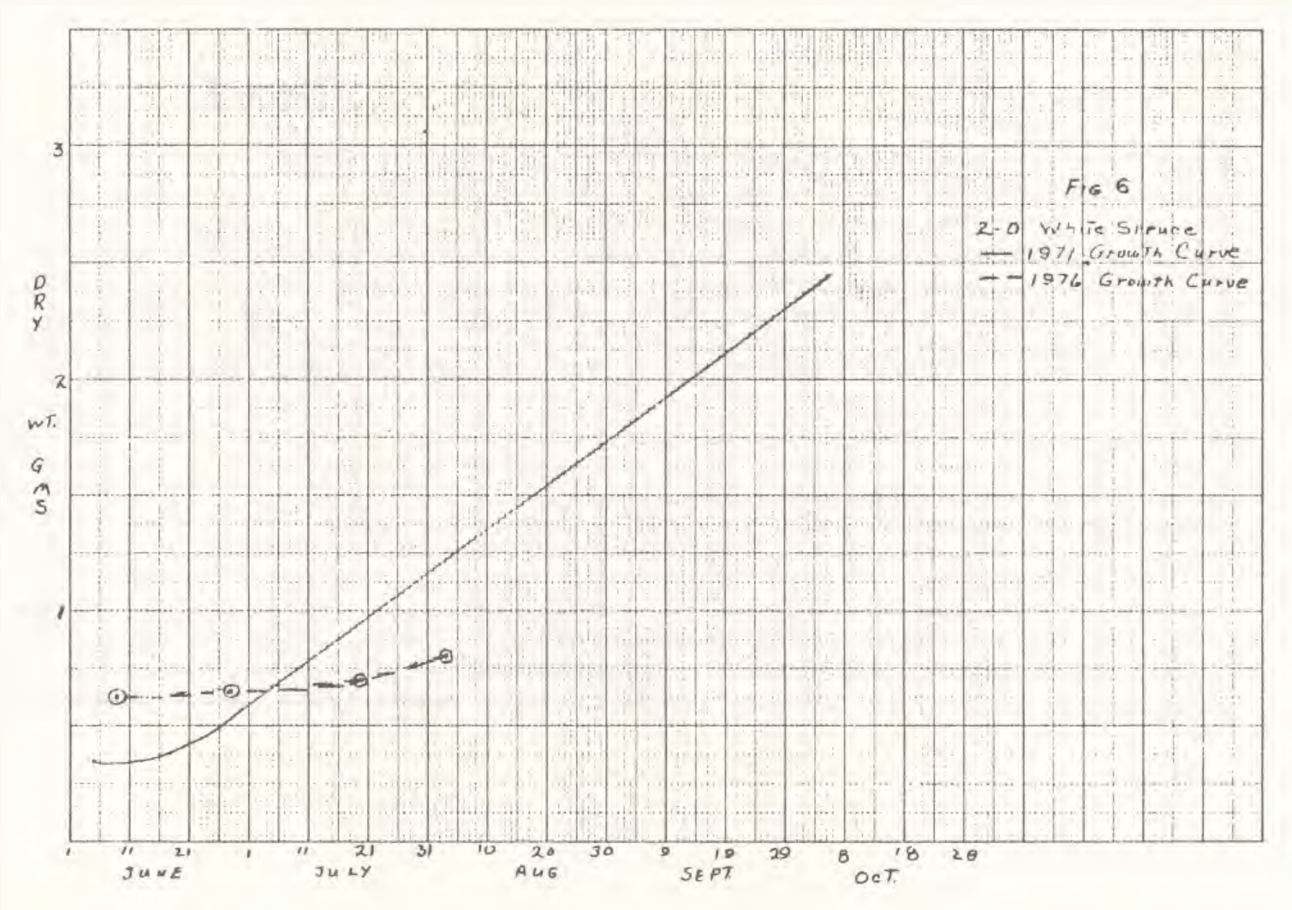
Date	No. Trees	ΣX	ΣX²	ΣY	ΣY²	ΣXY	Regression	r
1974	80	395.53	2,625.7792	61.90	67.5732	414.5353	$\hat{Y} = -.0267 + .1619D^2$	.95
1975	40	252.70	2,065.0414	35.77	41.9695	291.0615	$\hat{Y} = 0.0168 + 0.1399D^2$	.95
1976	50	280.4484	1243.9873	57.95	86.0689	378.9766	$\hat{Y} = 0.2167 + 0.1680D^2$	.69
	170	927.4774	6,584.8099	155.62	196.4120	1084.5734	$\hat{Y} = 0.0481 + 0.1540D^2$	.83

Estimating Dry Weight

In measuring diameters of a block of seedlings in order to estimate dry weight, the following procedure is followed at Orono.

For a block of seedlings which occupy 3,000 lineal feet of bed or more, 100 sample areas are systematically chosen by dividing the total bed length by 100. For 4,000 lineal feet of bed (4,000 100 = 40 feet) you place a sample every 40 feet.

Our sample frame is a two square foot frame 44" (our bed width) X 6.55". The idea is to select ten seedlings, systematically, from within this two square foot frame for measurement. To do this we use last year's inventory to calculate the average seedling density per square foot. If the average density is 25 trees per square foot, on the average your two square foot frame should contain 50 trees. Hence every fifth tree is measured for stem caliper. Some samples will have less than ten trees and others will have more, but the overall average should be about 10 per frame.



For areas that have less than 3,000 lineal feet of bed, a sample as described before is taken every thirty feet.

Our sampling is done over the summer by two University students. Sampling is done every two weeks; on the average it takes about three to three and one half hours to take the measurements in 2-0 stock and four to five hours to do a 3-0 compartment.

Once the measurements have been taken the average diameter is obtained and simply plugged into the appropriate regression equation to estimate the dry weight.

The estimates are then plotted on a graph (Figure 6) that contains an idealized growth curve and comparisons can be made as to how the sampled trees are doing when compared to the predicted development. Thus nursery staff should be able to juggle fertilizer applications and/or water in order to slow down or speed up development of the seedlings, as is required, to produce a product of given size at the end of the production cycle.

TEST PLANTINGS

Any nurseryman who has been in the business for very long has no doubt posed various questions to himself about what would happen if 2 The answers to these questions, whether they be regarding the effect on seedling size of seedbed density, levels of a fertilizer, effectiveness of weedspray or whatever, may come from research scientists in various institutions with which the nurseryman has contact. However the most convincing answer will come when the nurseryman sets out to answer these questions himself, since his answers will be based on the conditions prevailing on his nursery, soil type, nutrient regime, moisture regime and climatic conditions.

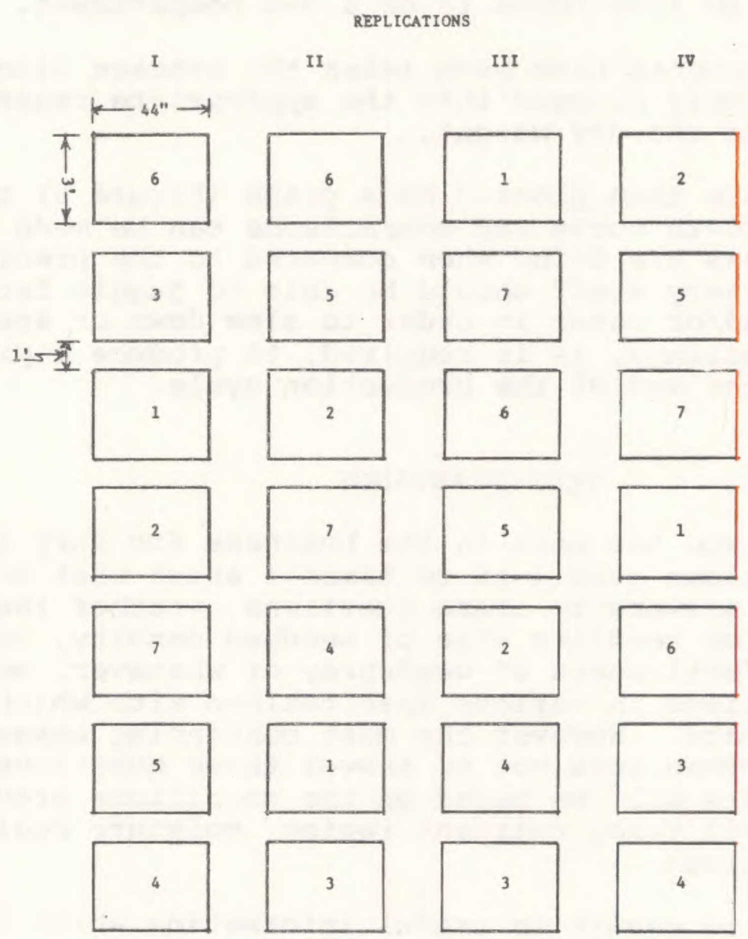
If the test is to result in useful information which the tester may use and also pass on to others, then certain steps have to be followed in setting it up. Briefly these are:

1. Formulate the question the experiment will answer
2. Design the experiment
3. Service and measure the experiment
4. Compilation of data and report

<u>1.</u> <u>Formulate the question the experiment will answer,</u> i.e. what effect will increasing amounts of nitrogen top dressings have on the size of white pine seedlings?

<u>2.</u> <u>Designing the experiment</u> - All experimental work is subject

Figure 7



2-0 W. Pine Nitrogen Trials

1 - 0 lbs EL N/Ac
2 - 10 " " " "
3 - 20 " " " "
4 - 40 " " " "
5 - 80 " " " "
6 - 160 " " " "
7 - 320 " " " "

to experimental error, (the measure of variation due to chance causes). It is the reduction of this error with which the experimenter is concerned in designing his experiments, for it is only by keeping experimental error small that treatment effects can be shown to be significantly different.

Experimental error can be decreased in two ways- a) By increased control of the factors that may effect the error. In our previous example this includes control of density of beds, control of soil moisture levels, laying out the experiment in as uniform a soil type as possible, etc. b) By increasing the size of the plots so that more individuals are measured, or by increasing the number of replications (the number of times the treatments are repeated). Increasing the size of the plots or number of individuals measured is of value only up to a certain point. When the unit becomes too large, increase in differences due to uncontrollable factors may negate any gain in precision. The most practical way to reduce experimental error is to increase the number of replications of the treatments.

In practice we have found in working with tests in seedbeds that plot sizes of 3 foot lengths with 1 foot buffer zones between plots are satisfactory and either four or five replications, with the plots located at random within the replications, are adequate.

In designing the experiment one must also decide how many treatments are required. In our example for white pine we believe in going from the ridiculous to the sublime. In other words, we have a range of application rates from where we feel we will get no results to levels of fertilizer which we feel will be too heavy. In an actual test with 2-0 white pine at Orono we decided on seven application rates.

Level No.	Total Elemental Nitrogen (lb/ac)
1	0
2	10
3	20
4	40
5	80
6	160
7	320

The applications were made in five equal quantities over the growing season from April to September (Bunting, 1974). Our design for this appears in Figure 7. This type of design is known as a randomized block design. It is one of the simplest experimental designs and one that has so far proven quite adequate for all our tests at Orono.

Figure 8

2+0 Results				
Fertility Level	Elemental N lb/ac	Height cm	Dry Weight gm	Stem Caliper mm
1	0	8.38 a	0.70 a	1.7 a
2	10	8.85 ab	0.79 a	1.8 a
3	20	8.78 ab	0.69 a	1.7 a
4	40	9.30 b	0.88 a	1.8 a
5	80	9.98 c	1.22 b	2.1 b
6	160	10.72 d	1.53 c	2.4 c
7	320	11.22 d	1.88 d	2.6
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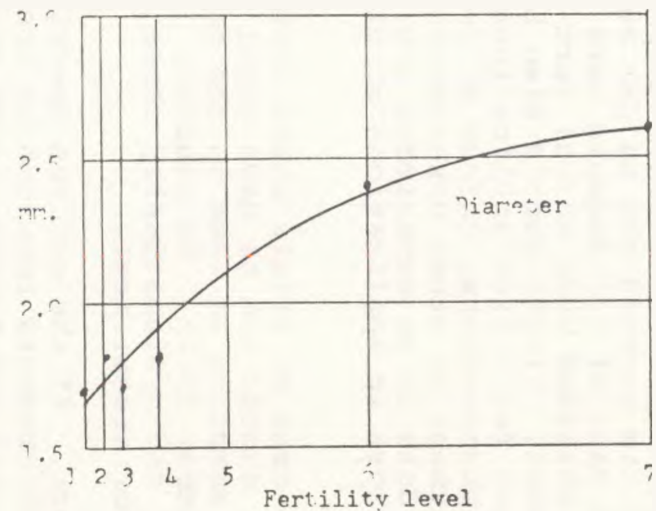
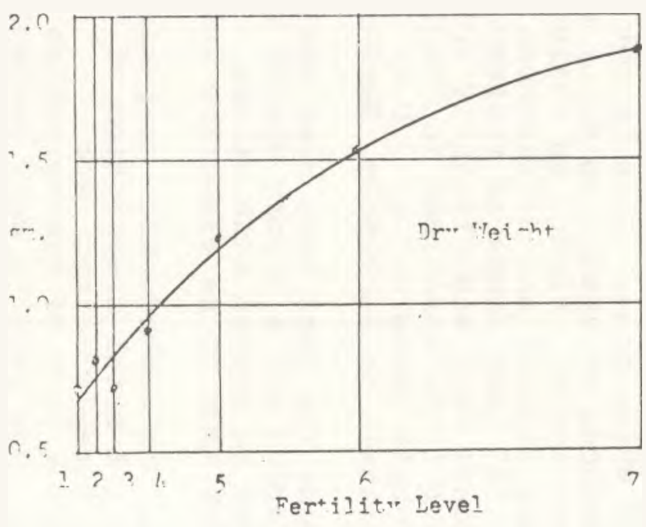
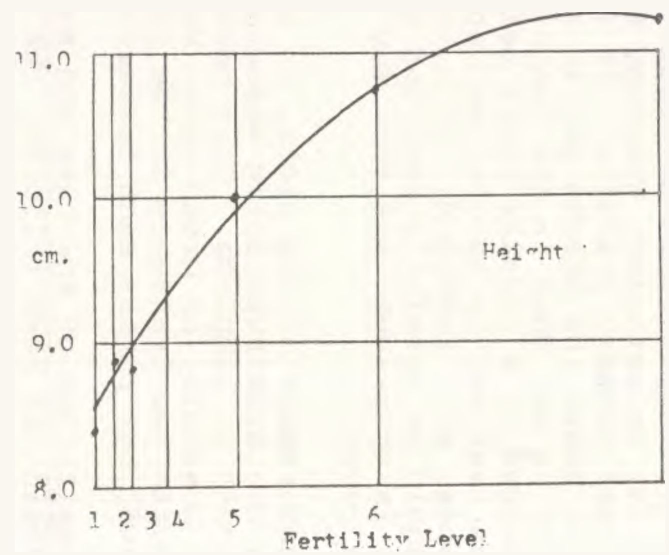
*** Significant'at 0.1% level

Measurements followed by the same letters do not vary significantly.

Figure 9
2 +0
Growth Curve







3. Servicing and measuring the experiment. Plans must be laid for someone to service the experiment over the summer, in this case to apply the fertilizer. At Orono we attempt to place all our experiments in production compartments so that care, as far as watering, weeding, etc. is carried out as per our normal nursery practice. In the case of our example here it also meant the blocks had to be shielded when normal fertilizing was done in the compartment. Visits should also be planned on a regular basis between fertilizer applications so the test may be watched and any observations, colour differences, etc. recorded. Each treatment or other observation should be carefully recorded by date in an experiment log. It is very important that any errors in applications should be recorded.

   Measurement of the plots, in the case of trials where growth is the attribute being measured, should not be made until growth is complete. This means sampling as late in the fall as possible, at Orono about November 15-20. We randomly locate two transects in the plot and systematically chose 25 seedlings across each transect for measurement.

4. Compilation of the Data and Report. If the outline described herein has been followed, the measurements recorded by treatment and replication can now be analyzed to see if the various treatments did in fact have a significant effect on the growth of white pine. This is not the time or the place to discuss methods of analyzing data, suffice it to say so far we use two tests. First, an analysis of Variance determines if there are significant differences between the treatments and second, a "t" test compares treatment means to determine which treatments vary significantly (Figure 8 and 9). These two tests are fully described in "Experimental Design and Analysis in Forest Research" by J.N.R. Jeffers, published by Almquist and Wiksell in Stockholm, Sweden.

   Once the data have been analyzed, your conclusions can be formed and a report should be written so that your experience may be shared with others. For most reports the form does not have to be elaborate but should contain the following:

   1. An introduction outlining the objectives of the test.
   2. A brief description of the type of design used, number of replications, etc.
   3. A list of the variables to be assessed.
   4. How results were accomplished. This section would also include any errors or omissions in planned treatments.
   5. Results of Experiment - a full discussion of results of test.

6. Tabular summary of results.
7. Conclusions.

LITERATURE CITATIONS

1. Armson, K.A. Smith, V.G. 1966. Dry weight diameter relationships for Jack pine seedlings. Forest Science, 12(3) pp 365-366.

2. Armson, K.A. Sadreika, V. 1974. Forest tree nursery soil management and related practices pp 62-67 O.M.N.R.

3. Bunting, W.R. Kimmett, C.R. 1972. Measurement of soil moisture in irrigation practices. Nursery Notes No. 31, June 1972, 16p O.M.N.R.

4. Bunting, W.R. 1974. Response of white pine to nitrogen, Nursery Notes No. 36, March 1974, 10p O.M.N.R.

5. McLain, K.M. 1973. Growth response of some conifer seedlings to regimes of soil moisture and fertility under greenhouse and nursery conditions,M.Sc.F. Thesis, University of Toronto.

6. McLain, K.M. Armson, K.A. 1975. Growth response of pine and spruce seedlings to regimes of soil moisture and fertility. Soil Science of America Proceedings 39(1) pp 140-144.

7. Thornthwaite, C.W. 1948. An approach towards a rational classification of climate. Geographical Review, 38(1), pp 55-94.