The Development of a Forest Nursery and its Problems.

By F.S. Newman.

In discussing the problems encountered in the development of a forest nursery, it is well to keep in mind that factors of establishment play a major part in the subsequent methods of procedure in nursery practice. For what may be applicable to one nursery may not be at all suitable for another, on account of a diversity of reasons, such as climatic, site and soil differences. It is therefore intended to deal with nursery problems in a general manner, with an occasional reference to specific management.

There is at present a decided inclination toward the establishment of large private nurseries by those actively engaged in the lumbering industry, and it may not be amiss to deliberate upon the factors which determine the location and subsequent arrangement of a forest nursery.

Location of a Forest Nursery.

The choice of location is primarily governed by the use to which a nursery is to be put. If the project is a private one, the productive area should be situated as closely as possible to that section where permanent planting is to be done. On the other hand, if the intention is to initiate a public or government nursery, the choice of a central position, with due regard to transportation facilities for the serving of a large district, must essentially be foremost.

The next consideration in the choice of location is regulated by soil and site. These two factors of establishment require a preliminary survey of that district in which it is desired to locate. Heavy clay land is unsuitable for nursery purposes. It is expensive to work, tardy in the spring, bad in wet weather, aggravates drought damage, and seedlings grown upon it are most susceptible to frost heaving. Highly acid, extremely light sand land, lacking in humus, does not recommend itself, but in spite of this, is preferable to heavy clay soils. The best type of soil, and that which meets the requirements for growing the greatest variety of species, is a deep sandy loam.

Although the price of good nursery land is high, it is ultimately cheaper to choose a good soil, since fertilizing, and the time lost in building up sterile soil to that stage of fertility requisite to the successful production of planting stock, entails an expenditure greatly in excess of that amount which would buy No. 1 farm land. This fact may be emphasized by tabulating

figures taken from the fertilizing and yield records of two compartments at the Norfolk Forest Nursery, and comparing the results obtained from soils differing in fertility by a wide margin. (See Table 1).

Expenditure for fertilizers on Lot 10 amounts to over \$150.00 or \$75.00 per acre. This land was purchased at \$15.00 per acre and it may therefore be readily seen that between the years 1921 and 1926 an investment of \$90.00 per acre was necessary to build up a cheap light soil, suitable for the production of nursery stock. The better soil of Lot 30 was less exacting in its requirements and produced more nursery stock within the same period. When consideration is given to the time necessary to bring up poor soil to a productive stage, and the accrued interest on capital invested, it does not appear to be good business to be too parsimonious in the choice of a nursery site.

Where possible the site chosen should be favorable for producing a wide range of species, unless, of course, the desire is to grow specific planting stock. Such factors as slope, aspect and surroundings are worthy of consideration, and the question of a permanent water supply for the inevitable irrigation of the nursery, is of initial importance.

Arrangement of Nursery.

The arrangement of a nursery will depend upon its permanency. If a large acreage has been procured for the production of seedling stock for an indefinite period, decided plans may be made to facilitate systematic handling. Residences and executive buildings should be so erected as to be convenient, yet at the same time not to usurp an excessive area of the best nursery ground. It naturally follows that main roads be laid out. These should be of good width - 18' to 24' - for, as they will likely be bordered by hedges, ample space is required to accommodate the lateral development of tree growth.

Nursery compartments may be of any desired size, but preferably not less than two acres in area, and should be arranged to lie at right angles to the main roads. Compartments may be either square or rectangular, but should all be of the same size, as this will systematize the maintaining of records regarding rotation of crops, fertilizing and yield. The designation of compartments in the field is important, and may be done by painting numbers on strong posts, placed at regular intervals along the main roadways.

If the nursery site is exposed, windbreaks should be established to bound the compartments and afford protection to the productive area. Where cultivation is provided, windbreaks grow rapidly, and within an incredibly short period present a real obstruction to the wind. This is important to the nursery, as evaporation is minimized, while perhaps a greater asset lies in the fact that winter browning of conifers is greatly reduced.

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The writer has in mind a 25 acre field of white cedar, red and white pine transplants which were badly browned during the winter of 1925. Several thousand white cedar were killed outright as a result of this injury. This area was recently acquired and as yet the windbreaks have not attained a sufficient height to be effective. No winter injury was observed on the older compartments where adequate protection by means of windbreaks had been afforded.

Although judicious consideration is imperative in connection with the location and arrangement of a forest nursery, the real problems of development are encountered in the actual work of producing nursery stock in the most economical manner.

Propagating hardwood species is relatively simple, but the growing of coniferous planting material is attended by many dangers, and it is only by providing ideal conditions that optimum results are obtained.

Soil.

One of the prime requisites of successful seedling development is a proper conception of the soil. The atmosphere supplies the climatic conditions, which are, of course, not within the control of man. The soil, however, is a vital part of the plant environment, for it is not only a limiting factor in seedling production, but it is to a large extent controllable. In so far as it fails to supply the necessary constituents, it limits tree growth and is a medium in which unhealthy stock, susceptible to disease, may be expected to be developed. If we can increase the amount of available plant nutrients in the soil, we can effect a condition that will materially decrease the per cent of loss in the early life of the seedlings, since a virile, healthy soil will produce vigorous seedlings which are better able to stand up against other unfavorable conditions that may occur.

Adequate drainage is the first essential in soil improvement. A soil containing more than its optimum amount of water is a cold, poorly aerated soil and is liable to cause root rot. A point to remember when laying tile throughout the nursery area is that all tile joints should be cemented in the vicinity of permanent trees, hedges or positions where such future plantings are likely to be made. A detailed survey of all tile lines, and in fact of any underground water mains, should be made and recorded, as this provision will save considerable labour and expense at some future date when adjustments may have to be effected.

The second essential in soil management is maintenance of organic matter. All soils are composed of two classes of materials, mineral matter and organic matter. Organic matter is necessary in order that the mineral material may become a soil, and that it may provide an efficient growing medium. The physical condition of the soil depends largely on the presence of organic matter and the chemical changes are effected almost entirely by its decay. In connection with the development of

nursery stock, those standard compartments which are allotted to the growing of seedlings only, must receive a greater amount of applied organic matter than the transplant compartments, since the growing of several million trees on a couple of acres creates a tremendous drain upon the soil. With the exception of scotch and jack pine, coniferous seedlings are developed two years in seed beds. At the end of the second year, or the following spring when they are removed, a green manure crop of soy beans is sown, after which decomposed manure at the rate of 30 tons per acre is applied as top dressing. As a fertilizer, ordinary barnyard manure cannot be excelled, and may be spoken of as the natural return to the soil of the constituents taken from it. Soy beans sown for green manure on the seed bed compartments are chosen because they rank high in organic matter, the seed is fairly cheap, and on account of the possibility of obtaining heavy growth between the middle of June and the end of August, it works in conveniently with the 2 - 1 rotation.

A comparison with other cover crops indicates that the use of soy beans may be safely recommended within a favourable climatic region.

Table No. 2 shows the relative value of an acre of different sorts of cover crops ploughed under.

Rye and vetch are usually sown together and give consistent results as a green manure crop. This crop is of value for fall seeding on lighter areas that are subject to soil erosion.

It is advisable to apply lime at the rate of 1 - 1½ tons per acre once in every three years. Most sandy soils are inclined to be acid. An acid soil, like a water-logged one, is not a healthy environment, and even though nutrients are supplied in the form of fertilizers in liberal quantities, the plant's feeding capacity will be limited by its environment.

To sum up them, good soil management for the most profitable returns from fertilizers demands first, adequate drainage, and secondly, where the soil needs it, the application of lime. Considerable space has been allotted to the question of soil management, but the writer wishes to emphasize that no problem in the development of a forest nursery is of greater importance than the close study of the soil, especially on those compartments assigned to seedling production.

To what extent fertilizers shall be applied to transplant compartments will depend upon the initial degree of fertility present in the soil. At the Norfolk Forestry Station, one instance that may be cited, proved conclusively that an application of 20 tons per acre of ordinary barnyard manure increased the fertility of this soil to such an extent that it was possible to send out material for permanent planting at two years of age instead of at three years of age as formerly. The cost of manure, plus labour of applying, averages \$2.00 per ton. Thus

an expenditure of \$40.00 per acre for fertilizing saved one year's cultivation of nursery stock which in this specific case comprised 160,000 jack pine. It costs .40¢ a thousand to cultivate this species throughout one growing season, and it may therefore be computed that an outlay of \$40.00 on fertilizing effected a net saving of \$24.00 per acre for that one yield alone.

Disease.

Disease factors in the development of coniferous seedlings supply one of the greatest impediments and problems with which the nurseryman has to contend. Root rot may be avoided by intelligent soil management, but in spite of the fact that a healthy soil provides an environment in which parasitic fungi are least likely to be effective, there is always the danger of excessive loss from this source, especially during a spell of unfavourable climatic conditions. The action of parasitic fungi is generally termed damping off. Fungi of the genera Pythium and Fusarium are given credit for damage sustained by seedlings shortly after germination has taken place. Within a period of from three to six weeks, greatest loss is observed, and it is during this time that 90% of the losses to nursery stock occur.

Control measures that may be adopted in an effort to overcome injury from damping off relate to the following:-

- (a) Cultural methods.
- (b) Soil sterilization.

Soil management is a cultural method, and as stated before, is of paramount importance in preventing damping off. The use of subsoil for covering the seed after sowing is another cultural method. Parasitic fungi prevail in the top soil, hence by surrounding seed with subsoil a medium comparatively free of disease factors is provided. An experiment in this connection was carried out in 1922, but was attended with variable results. (See Table 3.)

As will be seen, the use of subsoil recommends itself only in the case of red pine. Subsequent experiments have, however, not shown this to be so conclusively the case, and after four years, the writer does not consider the use of subsoil commendable except as a covering for seed sown on heavier soils where there is a liability of a hard compact crust forming prior to germination.

Late fall, or early spring seeding effects early germination, and produces seedlings well advanced before the seasonal period when damping off is most prevalent. Recorded observation during the past seven years indicates that the greatest loss from damping off occurs between the 5th and 30th of June. It follows, therefore, that if early germination be obtained, the liability of loss during the June period is minimized. The problem as to what results might be obtained from seeding in late June, in order that germination would occur just about the end of the damping off period, was tested out in 1926. The results obtained from this experiment are significant when compared with the losses sustained

from seed-beds which were sown in the fall of 1925. (See Table 4).

Although it is true that seedlings obtained from this late sowing were not as large as those developed from late fall or early spring seeding, they were well lignified and had developed their winter buds by the end of the growing season. It may, however, be well to repeat this experiment before admitting that the 1926 results are conclusive.

Soil sterilization on a large scale should only be attempted when it has been proven that results warrant the equipment and expenditure of application that is entailed. Experiments in the use of fungicides with special reference to H_2SO_4 , and a mercuric compound called Uspulun, indicate that the former is of value as a general disinfectant against damping off. Results of these experiments are herewith submitted.

One quarter of a pound of Uspulun dissolved in $9\frac{1}{2}$ gallons of H_2O applied once in the fall of 1925 and once in the early spring of 1926 to a surface of 110 square feet appears to be of little value. In fact, its effect upon growth was adverse. Seedling development seemed to be retarded, and a distinctly off-colour of foliage indicated those beds which were treated. (See Table 5).

It is evident, therefore, that those beds which were treated sustained a heavier loss than the untreated ones, due perhaps to the sickly condition of the seedlings, apparently caused by the solution. Uspulun is a compound of organic mercury, and is one of the most recent developments in the field of plant disease control. Many things are claimed for it, but it is still in the experimental stage, and in abeyance of future trials no definite conclusions are conceded as to its effectiveness as a fungicide.

Apart from its value in preventing damping off, sulphuric acid is supposed to be very efficacious in keeping down weeds. The significance of this is evident to any nurseryman. In the sulphuric acid treatment of seed-beds, a solution of $1/8$ fluid ounce of acid to one pint of water, per square foot should be applied directly after the seed has been covered. One application is considered sufficient. (See Table 6).

The total seedling injury due to causes other than damping off amounts to 85, or a loss of 7.34%. One hundred and seventy-four seedlings died from damping off, resulting in a loss of 15.02%. Comparing the seedling mortality of treated beds with that sustained by untreated or check beds, we find that from 15% to 25% more seedlings are destroyed as a result of parasitic disease in those beds to which acid was not applied.

The problems of combating loss in the early life of seedlings must not however be considered to the exclusion of losses which occur to transplant stock, for it is futile to produce a

fine lot of seed-bed material which may be subsequently destroyed. Loss factors in connection with transplants are not as formidable, nor so difficult to control, as obtains in seedling development. Pathological activity responsible for excessive mortality during the seed-bed period is practically innocuous to two and three year old transplants.

There is, however, one important problem in transplant culture which concerns itself with the choice of planting season. This has a direct bearing upon the ultimate success of developing nursery stock to that size and age requisite for permanent planting. Autumn versus spring transplanting from seed-beds to nursery lines has been the subject of much discussion and argument. Doubt-

less there is more time available in the fall for this work, but probable injury from winter-browning and positive loss from frost-heaving in early spring, establishes a conclusive basis for reasoning that spring transplanting is the safer method to adopt. This assertion is verified by records which indicate that extreme transplant losses are a direct sequence of fall transplanting. (See Table 7).

Stock.

The question of what tree species shall be propagated is quite simple and depends upon whether the requirements are general or specific. Government nurseries endeavour to produce at least all indigenous species, while private enterprises are more directly concerned with developing definite sorts or groups of species to meet their individual needs.

It is quite another matter to foretell, even approximately, how much seed to sow, or how many seed-beds to put in, to meet a certain demand, which in itself may fluctuate from year to year. There is, however, a more or less consistent call for certain species, and in order to arrive at a decision as to how much seed must be sown to provide nursery stock to supply this demand, a system of recording seed sown, losses and net yields must be maintained annually. Superior judgment, guided by reference to these records, will avert over-production of certain species, and will, moreover, prevent under-production of nursery stock that is required in large quantities. (See Table 8).

These are but a few of the more prominent problems which confront the forester in his vocation of developing a forest nursery. There are innumerable details of an exacting nature that demand constant supervision, and although of apparent single insignificance, they exert a collective influence toward the general achievement of results.

Well conceived working plans and detailed records are of fundamental importance in matters of reference. The maintenance of an hourly cost system, aside from providing first-hand information regarding classified expenditure, is indispensable in suggesting alternative methods of management.

The all embracing problem of nursery development may be summarized as the production of the greatest quantity of first quality transplants in the most economical manner.

TABLE 1

COMPARATIVE YIELD FROM TWO COMPARTMENTS RELATIVE TO FERTILIZERS APPLIED AND SOIL CHARACTERISTICS

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(2 acre) Compartment No. 10	Date	Fertilizers Applied					No. of Trans- plants Grown	(2 acre) Compartment No. 30	Date	Fertilizers Applied					No. of Trans- plants Grown
		Manure Tons	Lime Tons	Dried Blood Pounds	Acid Phos- phate Pounds	Sulphate of Ammonia Pounds				Manure Tons	Lime Tons	Dried Blood Pounds	Acid Phos- phate Pounds	Sulphate of Ammonia Pounds	
Very Light Sandy Soil	1921	9	.....	.....	.....	.....	.....	Deep Sandy Loam Soil	1921	.....	.....	.....	.....	.....	112,000
	1922	Rye and Vetch, Green Manure Crop							1922	Soy Beans, Green Manure Crop					
	1923	15	2	300	800	200	.....		1923	.....	.....	.....	.....	.....	100,000
	1924	20	.....	.....	.....	.....	.....		1924	5	.....	.....	.....	.....	90,000
	1925	27	Soy Beans, Green Manure Crop						1925	23	2	185	870	150	.....
	1926	.....	.....	.....	.....	.....	190,000		1926	.....	.....	.....	.....	.....	298,000
	Totals	71	2	300	800	200	190,000		Totals	28	2	185	870	150	600,000

TABLE 2

SHOWING THE RELATIVE VALUE OF AN ACRE OF DIFFERENT SORTS OF COVER CROPS PLOWED UNDER

Crop	Nitrogen Pounds	Phosphoric Acid Pounds	Potash Pounds	Cost of Seed Per cwt.	Amount of Seed Sown per acre	Cost of Seeding One acre
Over.....	49.06	11.61	63.55	\$50.00	12 Pounds with 1½ Bus. Oats	\$6.00 90) \$6.90
Cow Peas.....	61.9	15.45	77.20	9.00	2 Bus.	10.80
Rye.....	24.07	11.4	39.0	1.50	1½ Bus.	1.35
Soy Beans.....	152.29	27.38	100.89	5.00	2 Bus.	6.00
Vetch.....	121.2	27.2	85.5	8.00	2 Pecks	2.40

TABLE 3
EFFECT OF THE USE OF SUB-SOIL IN SEEDING

Species	Average Loss with Sub-soil		No Sub-soil	Remarks
	Over and Under Seed	Over Seed Only		
White Pine.....	10%	9%	7 %	Based on counts made on fifteen beds of each species.
Red Pine.....	18%	28%	34 %	
Scotch Pine.....	5%	15%	7.6%	
Jack Pine.....	20%	18%	17.8%	

TABLE 4
PERCENTAGE LOSS OF RED PINE WITH REFERENCE TO TIME OF SEEDING

Species	Seed Sown	Seed Germinated	Percentage Loss	Remarks
Red Pine.....	Nov. 4th, 1925	May 17th, 1926	33%	Based on counts made on fifteen seed beds.
Red Pine.....	June 5th, 1926	June 19th, 1926	21%	

TABLE 5
USPULON TREATMENT FOR THE PREVENTION OF DAMPING-OFF

Species	Percentage of Loss		Remarks
	Beds Treated	Beds Not Treated	
Red Pine.....	43.4 %	30.42%	Based on the treatment of twelve beds.
White Spruce.....	28.77%	19.65%	

TABLE 6
SULPHURIC ACID TREATMENT FOR THE PREVENTION OF DAMPING OFF

Count	Date counts were made 1926	No. of Healthy Seedlings	Loss							Total Germination
			Mechanical	Birds, etc.	Insects	Sun Scorch	Root Rot	Damping Off	Total	
	June 5	682	3	22				12	37	719
	" 14	937		6				61	67	1041
	" 21	974						48	48	1126
	" 29	964	14	4	2			17	37	1153
	July 6	947	4					15	19	1155
	" 13	925	7	3				13	23	1156
	" 20	909	2	2	8			6	18	1158
	" 27	900	2	2	3			2	9	1158
	Aug. 3	899		1					1	1158
		899	32	40	13			174	259	1158

[6 Strips]

Based on counts made on two beds of Red Pine

[Factor 120]

TABLE 7

RELATIVE RESULTS OBTAINED FROM FALL AND SPRING TRANSPLANTING

Species	Spring Transplanting, 1926			Fall Transplanting, 1923		
	No. of Trees Set Out	Final Yield of Permanent Planting Stock	Percent. Yield	No. of Trees Set Out	Final Yield of Permanent Planting Stock	Percent. Yield
White Pine.....	880,000	618,000	77.1	1,035,000	730,000	70.5
Red Pine.....	770,000	695,000	90.3	475,000	280,000	58.9
Scotch Pine.....	573,000	525,000	91.6	425,000	286,000	67.3
Jack Pine.....	780,000	650,000	84.6	1,444,000	1,040,000	72.0
White Spruce.....	490,000	420,000	85.7	110,000	90,000	81.8
For. Spruce.....	390,000	355,000	89.9	215,000	143,000	66.5

TABLE 8

1925 SEEDING RECORD SHOWING SEEDLING PRODUCTION IN TERMS OF PERCENTAGE. (BEDS 110 SQUARE FEET.) YIELD PER LB. OF SEED SOWN

Species	Collected	Origin	Germination Test	Sown	Germinated	No. of Beds Sown	Amount of Seed Sown per Bed	Total Seed Sown	Average Yield per Bed	Total Yield	Yield per Pound Seed	No. of Clean Seed per lb. (Our count)	Percent. Yield per lb. of Seed Sown
White Pine...	1924	Simcoe Co.	84%	Nov. 6	May 14	335	18 ozs.	502½ lbs.	9,430	3,159,050	8,380	32,800	25.5%
Red Pine....	1924	Simcoe Co.	79%	Nov. 12	May 16	360	12 ozs.	315 lbs.	9,030	3,250,800	12,040	58,000	20.7%
Scotch Pine...	1923	Norfolk Co.	90%	Nov. 12	May 10	136	10 ozs.	97½ lbs.	17,380	2,363,680	27,800	67,200	40.3%
Jack Pine....	1923	Norfolk Co.	91%	Nov. 13	May 12	45	8 ozs.	28½ lbs.	36,800	1,656,000	73,600	130,000	56.6%
White Spruce	1924	Simcoe Co.	52%	Nov. 21	May 15	45	14 ozs.	45 lbs.	23,280	1,047,600	26,460	370,000	7.1%