PREPARATION AND USE OF A NUTRIENT SOLUTION FOR CULTURING SEEDLINGS OF LODGEPOLE PINE AND WHITE SPRUCE (WITH SELECTED BIBLIOGRAPHY)

by

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NORTHERN FOREST RESEARCH CENTRE

EDMONTON, ALBERTA

INFORMATION REPORT NOR-X-1

CANADIAN FORESTRY SERVICE

DEPARTMENT OF THE ENVIRONMENT

JULY, 1971

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TABLE OF CONTENTS

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ABSTRACT

After a brief literature review, a nutrient solution is described giving good growth of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and white spruce (*Picea glauca* (Moench) Voss var. *albertiana* (S. Brown) Sarg.). Detailed instructions are given for preparation of the solution, together with a discussion of its practical use, an irrigation schedule, and a consideration of rooting substrata. A selected bibliography follows.

INTRODUCTION

There is a need for artificial culture of tree seedlings on defined mineral salts for experimental purposes. In addition, recent developments in methods of regeneration call for rearing of large numbers of small seedlings upon relatively non-nutritive substrata. For both of these applications, simple instructions for preparation and use of a suitable nutrient solution are desirable.

Although there are many reports of studies on nutrient requirements of a broad range of tree species (see Bibliography), generally, they do not give instructions for preparation and practical use of solutions. The nutrients are commonly stated in parts per million or milliequivalents of elements rather than in grams of salts per litre or gallon. Seldom are practical hints given regarding problems likely to be encountered in the use of solutions.

Depending in part on the range tested and the methods used, different investigators have obtained results that differ widely in concentrations of the important elements. Table 1 gives the ranges of concentrations of these elements that have given good growth of several coniferous species under normal temperature, moisture, light and rooting volume. Reports of good growth at very low levels of N or P generally describe conditions of growth including replenishment of nutrients by irrigation with solutions several times daily. Other conditions of rearing will, of course, effect growth responses outside these ranges.

Table 1. Major elements and their concentrations (ppm) that give good growth of coniferous seedlings. (Source: literature reports of nutrition studies; see Bibliography.

Element	Concentration (parts per million)
N	25-250
P	1-200
K	50-500
Mg	15-90

Within the ranges of concentrations shown, increasing the proportion of nitrogen or the concentrations of all elements generally increases the growth of shoots, especially foliage, and increases the shoot-to-root ratio. Small changes in concentration, within the ranges shown, generally make only small differences in growth responses when nutrients are continually replenished and rooting volume is large, but might be important during practical use when irrigation is performed only every few days.

COMPOSITION OF THE NUTRIENT SOLUTION

Table 2 shows the concentrations of major elements giving good balanced growth in detailed studies of nutrient requirements of Alberta lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.), and white spruce, (Picea glauca (Moench) Voss var. albertiana (S. Brown) Sarg.). Studies were conducted for 84 days in sand and in peat cultures with large rooting volume, at 70 F and 18 hr. photo-period, with daily excess irrigation with nutrient solutions. Complete details will be published separately.

Table 2. Nutrients suitable for Alberta lodgepole pine and white spruce in large rooting volume and daily nutrient exchange.

Element	Concentrations tested (ppm)	Concentration found best for: lodgepole pine	white spruce
N	28,112,224,448	112	112
P	16,31,62,124	31	31
K	156,312	156	156
Mg	6,24,48,96	48	48
Shoot/root ratio (by weight)		2.1	3.0
Total weight of seedling (mg)		500	200

Note: Ca at 80 ppm and S at about 150 ppm (varying) and micronutrients were present in all test solutions.

Within the ranges of concentrations studied, differences in growth response were generally quite small. They followed the tendency of increased shoot growth with increased nitrogen and increased root growth with increased phosphorus.

In addition to the major elements discussed above, several other elements (micronutrients) are required in trace amounts. Little is known about the limits of these tree seedlings' requirements for micronutrients, but there is no doubt that an adequate supply for satisfactory growth is provided by the concentrations given in the following instructions for preparation. These are, in parts per million, B-0.4, Fe-0.56, Mn-0.22, Zn-0.05, Cu-0.02, Mo-0.01.

PREPARATION OF THE STOCKS OF NUTRIENT SOLUTIONS

It is important to use chemicals of the exact formulae given. Other compounds could supply the essential elements equally well, but they would be in different proportions and the weights needed would have to be re-calculated. Furthermore, use of different compounds could lead to problems of insolubility in the stock solutions.

The components are divided into two stock solutions to separate materials that, together, would precipitate at the concentrations in the stock solutions. Therefore, when making the feed solution, one must add the stock solutions to the whole volume one at a time, and not mixed before dilution.

The two stock solutions together contain all the essential elements at concentrations 250 times the concentrations desired in the feed solution.

Solution 1:

Chemical Name	Formula	Quantity
Distilled water	H_2O	2 litres
Sulfuric acid (1%)	H_2SO_4	5 ml
Ammonium chloride	NH_4C_1	107.0 grams
Potassium sulfate	K_2SO_4	87.0 g
Potassium phosphate, dibasic	K_2HPO_4	87.0 g
Boric acid	H_3BO_3	1.126 g
Molybdenum trioxide	MoO_3	0.007 g

Solution 2:

Chemical Name	Formula	Quantity
Distilled water	H_2O	2 litres
Calcium nitrate	$Ca(NO_3)_2.4H_2O$	236.0 grams
Magnesium chloride	$MgCl_2.6H_2O$	203.0 g
Manganous chloride	$MnCl_2$	0.5 g
Zinc chloride	$ZnCl_2$	0.05 g
Cupric chloride	$CuCl_2.2H_2O$	0.025 g
Ferric chloride*	$FeCl_3.6H_2O$	1.35 g

*If available, a chelated form of iron, such as ferric EDTA or sodium ferric-ED-di-(o-hydroxyphenylacetate) may be used, at about the same quantity. An iron chelate is less likely than ferric ions to precipitate upon small changes in the pH of the solution. However, ferric ion (from ferric chloride) is completely satisfactory for seedlings grown on most substrates except highly alkaline ones.

Once prepared, the two stock solutions must be stored in a refrigerator, because they can support growth of micro-organisms. This also applies to unused feed solution. If stored at room temperatures, fungi, or algae, or both, would soon grow. These organisms would alter the nutrient concentrations and can very easily clog pipes, valves, sprinklers, and other application equipment.

PREPARATION OF FEED SOLUTION

The concentration of feed solutions described below will produce balanced seedlings where the rooting volume is adequate. As a general guide, rooting volume should be at least equal to the volume of air that will be occupied by the foliage when growth is complete for the purpose at hand. For other considerations, see the following section.

The feed solution is prepared by adding one part of each stock solution to 250 parts of water, or according to the following Table 3:

Table 3. Preparation of feed solution for conditions of low evapotranspiration.*

To water, add	Stock Solution 1	Stock Solution 2
1 litre	4 ml	4 ml
1 imp gal	18 ml (2/3 fl oz)	18 ml (2/3 fl oz)
1 US gal	14 ml (1/2 fl oz)	14 ml (1/2 fl oz)
5 imp gal	3 1/3 fl oz	3 1/3 fl oz
5 US gal	2 1/2 fl oz	2 1/2 fl oz

*In conditions of high evapotranspiration, use half as much stock solutions and irrigate to slight excess more frequently.

The water used for making up the feed solution or for supplementary irrigation must be soft water with neutral or slightly acidic pH (5 to 7). Hard or alkaline water may cause some of the nutrient elements to precipitate and will certainly alter the nutrient balance.

Feed solution may be made up directly in the vessel (watering can or storage tank) used to apply it. The prepared solution should be used up completely within a day or so, to avoid growth of micro-organisms in it. Small amounts may be stored in the refrigerator.

ROUTINE USE OF THE NUTRIENT SOLUTION

This nutrient solution may be applied simply by watering-can when used on a small scale. For large-scale operations, the concentrated stock solutions can be introduced by appropriate metering devices into an automatic irrigation system. In any system, it is desirable to permit the irrigation water to warm up to room temperature, to avoid thermal shock to the seedlings. The quantity applied should be a slight excess, to ensure that there is a degree of flushing and the solution remaining is the desired concentration. A typical irrigation schedule for fast growth is given in Table 4.

For small-scale laboratory or experimental use, exactly known quantities of nutrients may be applied by pipette.

Where seedlings are grown for extended periods, it becomes necessary to increase frequency of irrigation with nutrients as the seedlings increase in size.

In all applications, however, two important factors might arise: the nutrients might become concentrated to toxic levels through evaporation

Table 4. Nutrient irrigation schedule suitable for lodgepole pine and white spruce under conditions of fast growth: temperature 60 to 70°F, light intensity over 1000 ft-candles, photoperiod 18 hours.

Day	Week	
0	0	Sow seed, water, and cover; check periodically and water when needed.
14	2	Emergence generally almost complete. Thin or fill-in as needed.
21	3	Water.
28	4	Water.
35	5	Apply first nutrient irrigation; water as needed between applications.
42	6	Irrigate with nutrient solution.
49	7	Irrigate with nutrient solution.
56	8	Irrigate with nutrient solution.
63	9	Irrigate with nutrient solution.
67	9½	Irrigate with nutrient solution. (Seedlings larger and entering phase of rapid growth, so require more frequent irrigation).
70	10	Irrigate with nutrient solution.
74	10½	Irrigate with nutrient solution.
77	11	Irrigate with nutrient solution.
81	11½	Irrigate with nutrient solution.
84	12	Irrigate with nutrient solution. (Remove seedlings to cold frames or reduce temperatures to 50°F if they are intended for field planting).
88	12½	Irrigate with nutrient solution.
91	13	Irrigate with nutrient solution.
95	13½	Irrigate with nutrient solution.
98	14	Irrigate with nutrient solution.
102	14½	Irrigate with nutrient solution.
105	15	Irrigate with nutrient solution.
109	15½	Irrigate with nutrient solution.
112	16	Irrigate with nutrient solution. (Seedlings ready for field planting.)

of the water, or the nutrients might be leached or diluted to deficiency levels by supplementary irrigation. Proper control of nutrient concentrations in the rooting zone of the seedlings depends upon planned irrigation.

If seedlings are in a hot, dry, or windy atmosphere, subject to high transpiration and evaporation losses, it might be necessary to irrigate with water between applications of nutrient solution, say every other day or three times a week. In extreme situations, it may be desirable to use a higher dilution in preparation of the feed solution,: say 1 or 2 ml per litre instead of 4.

In a humid atmosphere, where evaporation losses are small, it would be necessary to keep supplementary irrigation to a minimum. Excess moisture may lead to stunting of growth in lodgepole pine; or to disease problems in any species.

In case of either toxic concentration or deficiency of nutrients the first symptom is usually a yellowing (chlorosis) of new needles. Positive diagnosis may be made on the basis of the conductivity of the rooting medium. Whether a toxic concentration or a deficiency is responsible may be decided rapidly by considering the evapotranspiration conditions, and irrigation can be adjusted.

CONSIDERATIONS ON ROOTING SUBSTRATE COMPOSITION

In the laboratory, seedlings may be grown on vermiculite, sand, peat, or other substrata. Perlite should not be used unless it is first leached with warm, dilute hydrochloric acid to remove excess aluminum, present in the tetrahedral silica structure. A feed solution with a pH lower than about 5 will gradually leach aluminum from untreated perlite possibly leading to toxic accumulation in the plants.

For large scale use where seedlings are intended for planting in the field, a substrate with nutrient holding capacity is desirable. A peat-loam mixture is suitable, and good results have been obtained with peat alone.

Incorporation of a slow-release fertilizer should be carefully considered. Many types of "slow-release" fertilizer in fact release all their nutrients within 8 to 10 weeks, and will no longer be available if the seedlings are planted beyond that age. Furthermore the gradual leaching of fertilizer during the rearing stage of the seedlings can lead to toxic concentrations of nutrients if a nutrient solution is applied. Toxic concentration can result also if the dosage of slow-release fertilizer is not carefully controlled. In any case, incorporation of additional nutrients in the rooting medium reduces the control over nutrient availability that is possible when applying nutrients solely by irrigation.

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