MAINTAINING SOIL FERTILITY IN FOREST NURSERIES IN THE PRAIRIE PROVINCES

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ABSTRACT

The six largest forest nurseries in the prairie provinces occupy a total of 358 ha and together produce 34 million bare-root seedlings annually. Soil properties vary. Most have a suitable texture and organic matter content, but most also have unsuitably high pH and salinity. Soil fertility is maintained through the application of amendments such as green manure, sphagnum peat, sand, sulfur, and sulfuric acid as well as fertilizers. It is suggested that more intensive monitoring of the seedling production system be pursued in future in order to compensate as much as possible for variation in stock quality due to weather.

INTRODUCTION

Of the six major forest nurseries in the prairie provinces, two (Pine Ridge and Oliver) are located in Alberta, three (Prince Albert, Big River, and Indian Head) are located in Saskatchewan, and one (Pineland) is located in Manitoba. Although they are distributed in a northwest-southeast band across the provinces (1600 km from Pine Ridge in the northwest to Pineland in the southeast), their climate is similar. Mean annual precipitation ranges from 375 mm at Pineland to 470 mm at Oliver in the northwest (Table 1). There is even less variation in the length of the frost-free period: Pine Ridge is lowest with 106 days[1] and Indian Head is highest with 130 days.

SIZE AND PRODUCTION OF NURSERIES

The nurseries differ widely in size and production (Table 2). In total, they currently use 358 ha to produce 34 million bare-root seedlings which, with the exception of Oliver and Indian Head, is comprised of conifers entirely. Pine Ridge produces lodgepole pine and white spruce, Prince Albert and Big River produce jack pine and white spruce, and Pineland produces jack pine, white spruce, red pine, and Scots pine. The *raison d'etre* of Oliver and Indian Head is to produce stock for shelterbelt and recreational plantings and as such produce deciduous trees and shrubs (e.g., elm, willow, poplar, caragana, etc.) predominantly but lesser amounts of Colorado spruce, white spruce, and Scots pine. Because of wider spacing requirements for deciduous stock, both nurseries have relatively large areas in current use compared to the number of seedlings produced.

1 The nursery is only 3 years old, and this value represents the mean length recorded during 1978-80.

Table 1. Mean annual precipitation and length of frost-free period at selected prairie nurseries

Nursery	Province	Mean annual precipitation mm	Frost-free period days
Pine Ridge	Alberta	415	106
Oliver	Alberta	470	122
Prince Albert	Saskatchewan	390	112
Big River	Saskatchewan	400	110
Indian Head	Saskatchewan	380	130
Pineland	Manitoba	375	115

Table 2. Currently producing area and annual bare-root seedling production in selected prairie nurseries

Nursery	Province	Area currently used ha*	Production millions	Conifers as fraction of production %
Pine Ridge	Alberta	73	10.0	100
Oliver	Alberta	65	3.2	30
Prince Albert	Saskatchewan	61	8.0	100
Big River	Saskatchewan	13	4.0	100
Indian Head	Saskatchewan	142	6.0	7
Pineland	Manitoba	4	2.5	100
Total		358	33.7	

* 1 hectare = 2.5 acres.

SOIL CHARACTERISTICS

Soil characteristics at the nurseries vary throughout the region (Table 3), and certain chemical characteristics are closely associated with texture. Pineland is sandy, Pine Ridge and Prince Albert are loamy sand, Big River and Indian Head are sandy loam, and Oliver is mostly clay. Available water capacity (AWC)[2] varied from 8.5% at Pine Ridge to 26.5% at Big River and was related to the amount of silt-sized particles in the soil. Thus although Big River and Indian Head are nominally similar in soil texture (sandy loam), their percentages of silt are 31% and 18%, respectively, and this is reflected in the AWC. Soil pH is acceptable at Pine Ridge only; the level at all other nurseries is too high. (Recommended standards are given in Table 5.) Moreover, while calcareous subsoil exists in parts of these nurseries, free carbonate is present in the surface soil at Indian Head.

Electrical conductivity (EC) is a measure of total salinity, and only Pineland nursery is sufficiently low in soluble salts to be of no concern. Calcium and magnesium are the predominant water-soluble cations at all nurseries except Oliver, where sodium predominates. Among water-soluble anions, sulfate is present in highest concentration at all nurseries, particularly Prince Albert and Oliver (60 and 450 ppm, respectively). Chloride level at Indian Head (75 ppm) is about twice the concentration at other nurseries. Organic matter content is similar at all nurseries except at Indian Head, where the level is approximately one-half that of the others.

Total nitrogen (N) at Oliver nursery (0.14%) is twice the level at other nurseries and this gives it the lowest carbon:nitrogen ratio (9.6) of the six nurseries. The next higher C/N ratio is at the Indian Head nursery (11.6), but the remainder vary between 15 and 20. A low C/N ratio (e.g., less than 12:1) indicates that less nitrogen will be immobilized during breakdown of soil organic matter and therefore more of it will be available to plants through nitrification. Nitrate nitrogen (NO_3-N) is a measure of readily available nitrogen in the soil. Pine Ridge and Big River contain greatest amounts (81-83 kg/ha), whereas Pineland is least (19 kg/ha). The phosphorous[3] level at Indian Head (240 kg/ha) was more than 2-4 times the concentration determined in other soils. Oliver and Indian Head are highest in ammonium acetate-extractable potassium (995 and 1494 kg/ha) and reflect the naturally high K levels in medium and fine-textured prairie soils. Overall, Pineland soils are lowest in fertility, which is due undoubtedly to the sand texture. Cation exchange capacity (CEC) reflects texture as well as organic matter content. At Oliver, CEC is two to three times that at the other nurseries and is due to the high clay content (70%) of this soil.

MAINTENANCE OF SOIL FERTILITY

Organic Amendments

The maintenance of soil fertility in prairie forest nurseries is through application of green manure, peat, sand, sulfur, and sulfuric acid and, of course, fertilizers (Table 4).

2 *Available water capacity is the difference between soil moisture content at 0.1 bar* tension and soil moisture content at 15 bars tension.

3 *Determined by extraction with 0.5 M sodium bicarbonate and development of color* with ascorbic acid.

Table 3. Summary of soil characteristics at selected tree nurseries in the prairie provinces

Nursery	Province	Texture	AWC[1] %	pH	EC[2] mS/cm	OM[3] %	Total N %	NO_3-N kg/ha	P kg/ha	K kg/ha	CEC[4] meq/100 g
Pine Ridge	Alberta	LS	8.5	5.3	0.92	6.0	0.23	83	87	390	12.34
Oliver	Alberta	C	24.9	6.5	1.48	6.8	0.41	36	53	995	44.22
Prince Albert	Saskatchewan	LS	21.6	6.8	1.65	6.5	0.22	42	91	306	20.96
Big River	Saskatchewan	SL	26.5	6.3	1.27	6.1	0.19	81	74	293	17.62
Indian Head	Saskatchewan	SL	16.8	7.9	1.30	3.4	0.17	58	240	1494	15.29
Pineland	Manitoba	S	16.1	6.7	0.34	5.6	0.16	19	98	136	15.84

[1] AWC = available water capacity.

[2] EC = electrical conductivity.

[3] OM = organic matter.

[4] CEC = cation exchange capacity.

Table 4. Amendments used in soil fertility program

Nursery	Province	Amendments				
		Green manure	Peat	Sand	Sulfur	Fertilizer
Pine Ridge	Alberta	X	X		X	X
Oliver	Alberta	X	X	X		X
Prince Albert	Saskatchewan	X	X		X	X
Big River	Saskatchewan	X	X		X	X
Indian Head	Saskatchewan	X				X
Pineland	Manitoba		X		X	X

The objectives of green manuring and the application of peat are to maintain an adequate level of organic matter (approximately 5%), since organic matter adds fiber, improves tilth, and most important in coarse-textured soils) increases cation exchange capacity and available water capacity. At Pine Ridge, green manuring consists of plowing under fall rye and faba bean, whereas at Oliver, Prince Albert, and Big River, fall rye and oats are used. At Indian Head, the crops used are crested wheatgrass, alfalfa, and oats. No green manure is used at Pineland nursery. Peat is a common source of organic matter at all nurseries in the region; it is generally spread to a thickness of 5-10 cm and plowed into the soil during preparation of the seedbed. Because of its relative accessibility and low cost at most prairie nurseries, it is anticipated that peat will continue to play a significant role in their management. At Indian Head, laboratory studies to determine the breakdown rate of peat have shown that 40% of the original peat remains in the soil after 4 years. Such studies at other nurseries would be helpful in utilizing this organic amendment more judiciously. At Pineland nursery, sawdust has been used as a substitute for peat, and although it was an effective source of organic matter, nitrogen chlorosis developed in succeeding crops of seedlings unless extra nitrogen was applied to compensate for that assimilated by microorganisms.

Inorganic Amendments

Sand has been used at Oliver and Indian Head to modify the fine-textured soil in the seedbeds. On the whole, this method of modifying texture has been impractical because of the large amount of sand required. Moreover, at Indian Head its use on coniferous species was discontinued because the sand supply was a source of calcium carbonate. Elemental sulfur is used to acidify the soils and thus reduce their pH to levels that are more suitable for conifers. Sulfur is recommended for this role because, although it is slow-acting (up to 2 years), it is recognized that coarse- and medium-textured soils generally have a low buffering capacity and therefore slow pH changes are preferable. The usual recommendation for S is 550-1100 kg/ha. At Pine Ridge and Prince Albert, soil pH is reduced to suitable levels through acidification of the irrigation water with sulfuric acid. The water is reduced from its initial pH of about 8.0 to pH **5.5** or 6.0. The acid is injected automatically into the irrigation system following monitoring of the initial pH.

Fertilizers

Without exception, the nurseries use fertilizers to maintain soil fertility. At Pine Ridge, most of it is applied as a solution via injection into the irrigation system, and the amount added through the season is based on accumulated degree-days. The liquid fertilizer applied is 28-10-22. Solid fertilizer as either ammonium sulfate (21-0-0) or urea (46-0-0) is used to supplement this when irrigation is inappropriate. The other nurseries use solid fertilizers exclusively, the only difference among them being the type and amount of fertilizer. For example, Oliver uses 46-0-0, monoammonium phosphate (11-480), and potash (0-0-62), whereas Prince Albert and Big River apply ammonium nitrate (340-0), 21-0-0, 11-48-0, and 0-0-62. Pineland, on the other hand, uses ammonium phosphate (16-20-0), 34-0-0, ordinary superphosphate (0-20-0), and potassium sulfate (0-0-50). For its conifers, Indian Head applies only nitrogen (30 kg/ha as 34-0-0) since phosphorus and potassium levels are already adequate (Table 3). The total amount of fertilizer applied depends on the age of the crop, but basically phosphorus and potassium are applied and mixed into the seedbed prior to seeding, while nitrogen is top-dressed in multiple (3-5) applications during the growing season to achieve the prescribed levels (Table 5). In the case of nitrogen, 56, 112, and 112 kg/ha may be required for 1-0, 2-0, and 3-0 stock, respectively.

Table 5. Recommended standards for forest nursery soils in the prairie provinces

Texture	LS-SL
pH	5.5
EC	<0.75 mS/cm
OM	5 %
NO_3-N	56-112 kg/ha
P	45-90 kg/ha
K	280 kg/ha

The type of fertilizer is selected on the basis of local conditions, availability of material, and demonstrated effect. For example, it was found at Indian Head that Colorado spruce and Scots pine grew equally well when nitrogen was supplied as either ammonium or nitrate. At Prince Albert it was found that, whereas jack pine benefited equally from either source of nitrogen, white spruce favored the ammonium form. As a result of the alkalinity of most of the soils, 21-0-0 and/or 16-20-0 are recommended because of their high residual acidity. They help to lower soil pH to the recommended level (Table 5). If, on the other hand, adjustment of soil pH is not desired, then 34-0-0 is used. Local conditions also dictate the choice of the potassium fertilizer. Where salinity is a potential problem, 0-0-50 is preferable to 0-0-62 because of the lower salt index of the former material.

RECOMMENDED STANDARDS

The recommended standards (Table 5) are intended as guidelines for the nurseries. Site selection initially may influence all the listed characteristics, but

unsuitable texture will definitely have profound consequences on the entire nursery as a viable operation. Whereas the other characteristics can be manipulated with relative ease, textural changes are often impractical and uneconomical because of seedling costs. While these standards are recommended (based on plot experiments), each nurseryman is urged to determine the specific requirements for stock of prescribed quality at his particular location. Production of bare-root stock is subject to numerous vagaries of the weather. Whenever possible, the reproducible aspects of the operation should be maintained and strengthened.

CONCLUSIONS

1. Different soil characteristics at prairie forest nurseries have resulted in different approaches to maintenance of soil fertility. Each nurseryman should be familiar with the limitations of his particular situation and take appropriate steps to deal with these problems specifically.

2. More 'maintenance' studies are needed. The Indian Head study on the breakdown of peat should be pursued at other locations, since it would enable a more efficient use of this resource. The long-term effect of sulfate (from elemental sulfur and sulfuric acid) should be monitored. Also, where facilities permit, integration of foliar analysis into the nursery should be considered.

3. More judicious use of fertilizers and irrigation would undoubtedly increase efficiency of the nurseries generally. With desired standards of nursery stock already in mind, manipulation of these inputs should be done (while monitoring nutrient leaching) to see how the stock is affected. On the prairies, however, input of heat units will remain a critical determinant of crop quality.

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