The Saline Soil Syndrome and its Effect on Bare-root Production in Two Rocky Mountain Area Nurseries[1]

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Abstract.--The saline soil syndrome is a complex nutritional disorder affecting conifer seedling growth at Mt. Sopris and Albuquerque Nurseries. This disease appears to be related to reduced uptake and utilization of plant nutrients in saline, calcareous soils. Treatment consists of proper fertilization and promoting leaching of saline soils.

INTRODUCTION

There has been a chronic problem in the production of coniferous tree seedlings at Mt. Sopris Nursery, and the same symptoms are becoming evident at the newly developed Albuquerque Nursery. The problem appears in areas of salty soil where salt crusts are present on affected soils and on the roots of diseased seedlings.

Because most coniferous tree nurseries are located on slightly acid soils, many nurserymen are not familiar with alkaline soil problems. However, after several years of working on this problem, we have discovered that it is neither unique nor new as it has been encountered in the production of agricultural and fruit tree crops on salty soils also.

Although the terms are used synonymously, there is a technical distinction between saline and alkaline soils. Saline soils are characterized by high levels of calcium and magnesium salts and relatively low concentrations of sodium salts in contrast to alkaline soils which are dominated by sodium. Calcareous soils are the same as saline in that calcium is the prevalent salt.

HISTORY OF THE PROBLEM

Early photographs of the first tree crops at Mt. Sopris Nursery show areas of irregular seedling growth. Stunted, chlorotic seedlings were distributed randomly among patches of normal appearing stock. The problem is reflected in nursery inventories also. The inventory of shippable seedlings has been chronically lower than the nursery's estimates. In 1977 an entire nursery block of ponderosa pine seedlings exhibited this stunting pattern during the 2-0 year after a perfectly normal appearing 1-0 season, which necessarily caused a drastic reduction in nursery inventories.

Past nurserymen were aware of some connection between the salty soils and the diseased seedlings. In particular, a soil condition known as the "ditch effect" has been evident since the first tree seedlings were raised. The phenomenon refers to band-shaped growth patterns extending diagonally across the nursery beds. These bands correspond directly to the location of old irrigation ditches that served to irrigate pastureland that the nursery was developed from. Cover crops such as rye exhibited dark green growth in these bands, whereas coniferous seedlings remained stunted and chlorotic.

SYMPTOMS AND SPECIES AFFECTED

The diseased seedlings exhibit a predictable set of symptoms, and all coniferous seedlings raised at Mt. Sopris are affected, including: ponderosa pine (Pinus ponderosa), lodgepole pine (Pinus contorta), Engelmann spruce (Picea engelmannii), Douglas-fir (Pseudotsuga menziesii), and white fir (Abies concolor). Lodgepole pine is most sensitive to this problem and Engelmann spruce is most acutely affected because of its small size during the first year.

Symptoms include chlorosis of new foliage, tip burn of needles, the characteristic mosaic growth pattern, stunting, and eventual death of

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Table 1.--Soil Chemical Analyses at Mt. Sopris and Albuquerque Nurseries[1]

FACTOR	SOIL CONCENTRATIONS				RECOMMENDED LEVEL
	MT. SOPRIS		ALBUQUERQUE		
	Avg.	Range	Avg.	Range	
Reaction (pH)	6.0	5.0-7.3	8.2	6.1-8.8	5.5-6.5
Phosphorus (ppm)	93	70-149	66	17-155	150
Calcium (ppm)	2689	1,798-6,174	9,977	1,170-48,578	1,000

[1]Performed by Dr. Al Leaf, Syracuse University. 1978.

severely affected seedlings. These symptoms are relatively consistent among the various coniferous seedlings.

SOIL AND SEEDLING FOLIAGE CHEMICAL ANALYSES

A complete battery of soil tests were collected from Mt. Sopris and Albuquerque Nurseries in 1978 and tested at Syracuse University. The test results revealed some interesting trends at both nurseries (Table 1). Soil pH at Mt. Sopris Nursery is at an optimum 6.0, although the soils range up to 7.3. The Albuquerque pH levels average 8.2, far exceeding the recommended range of 5.5-6.5, with some samples reaching pH 8.8. Soil phosphorus levels at both Mt. Sopris and Albuquerque are lower than recommended, whereas calcium levels are excessively high. In fact, soil calcium levels range from almost twice to over 48 times the recommended level.

Chemical analysis of seedling foliage showed some definite differences in the nutritional composition of normal appearing (Good) and diseased (Poor) seedlings (Table 2). Phosphorus was lower in the poor seedlings in both Engelmann spruce and ponderosa pine, although calcium and other macronutrients were higher in those seedlings. There was considerable difference in the micronutrient concentrations between the two types of seedlings, especially for manganese, iron, and zinc. Manganese had much lower levels in the poor seedlings compared to iron and zinc, which are higher in the poor class of seedlings. These higher levels may reflect a nutrient accumulation condition in which the diseased seedlings uptake the micronutrients but cannot utilize them because they are not in the proper chelated form.

SALINE SOIL SYNDROM

Based upon years of observation, chemical analyses of soil and foliage, and considerable searching of literature, I have formed the following hypothesis to explain the malaise affecting seedlings at Mt. Sopris and Albuquerque Nurseries and have dubbed it the saline soil syndrome.

The saline soil syndrome is a nutritional disorder related to a chemical imbalance in the soil. It is actually a complex of two previously described nutritional conditions: limeinduced chlorosis and phosphorus deficiency.

Lime-induced or iron chlorosis is a nutritional disease that is well described in literature (Russell, 1973) and is quite common in many crops and ornamentals growing on alkaline or calcareous soils. Iron chlorosis is actually a complex condition because the disease may be complicated by an imbalance of iron, manganese, and zinc in combination with adverse soil conditions (Tisdale and Nelson, 1975).

Table 2.--Seedling foliage samples. Fall 1978 Mt. Sopris Nursery.[1]

	2-0 PONDEROSA PINE		2-0 ENGELMANN SPRUCE	
NUTRIENT	GOOD	POOR	GOOD	POOR
%				
Nitrogen	1.75	1.73	2.47	2.04
Phosphorus	0.16	0.10	0.22	0.16
Potassium	0.78	1.07	0.53	0.73
Calcium	0.67	1.13	2.09	3.79
Magnesium	0.14	0.14	0.24	0.46
PPM				
Manganese	370	60	330	190
Iron	281	391	323	3967
Zinc	18	325	118	265
Copper	4	5	14	20

[1]Performed by Dr. Al Leaf, Syracuse Univ., New York.

Phosphorus availability is severely curtailed in saline, calcareous soils because calcium can chemically fix phosphate into a form unavailable to plants (Tisdale and Nelson, 1975) The resultant phosphorus deficiency is an induced condition because phosphorus is present in the soil but unavailable because of the abundance of calcium. Phosphorus fertilization is often not effective because only 5-10% of the added phosphate is ever available to the crop in a normal soil (Russell, 1973); in a calcareous soil, phosphate fertilizers would be even less effective.

The saline soil syndrome, therefore, is a nutrient availability problem caused by excessive soil calcium. Saline soils are almost always a result of water-deposited salts combined with poor soil drainage and high evapotranspiration rates (U.S. Salinity Lab, 1969).

Mt. Sopris and Albuquerque Nurseries are both located in semi-arid climates and have saline water sources. Mt. Sopris obtains water from irrigation wells and ditches supplied by the Roaring Fork River (Table 3). Both waters are classified as Medium Salinity with a Low Sodium Hazard. Water of this quality is suitable for the irrigation of most crops if adequate drainage occurs (U.S. Salinity Lab, 1969).
Without drainage through the soil profile, salts are deposited when soil water is evaporated from the soil surface. The resultant salty soil crust can be damaging to germinating seeds and young succulent seedlings.

Past cultural practices such as rototilling seedbeds have destroyed soil structure and caused the development of impermeable plow-pans in Mt. Sopris Nursery soils. Soil water percolation is restricted above these layers resulting in a perched water table. This impeded drainage along with the high evapotranspiration rates characteristic of semi-arid climates has lead to high salt accumulations in nursery soils. The "ditch effect" mentioned earlier is most likely a result of years of accumulated salt deposition along the old irrigation ditches.

Table 3.--Irrigation water quality at Mt. Sopris Nursery during the 1975 growing season.[1]

GENERAL INDEXES	UNITS	YEARLY AVG.		COMPARATIVE VALUES	REFERENCE
		WELL	RIVER		
pH	Logarithmic Units	7.7	7.8	6.9 - 8.3	(Armson & Sadreika 1974)
Electrical Conductivity (E.C.)	mcmhos/cm	483	421	250-750=Medium Salinity Hazard	(U.S. Salinity Lab., 1969)
Sodium Adsorption Ratio (S.A.R.)	None	0.3	0.4	0-10=Low Sodium Hazard	(U.S. Salinity Lab., 1969)
Specific Ions					
Sodium	mg/l	12	14	1-13	(Armson & Sadreika 1974)
Calcium	mg/l	75	64	4-55	(Armson & Sadreika 1974)
Magnesium	mg/l	15	12	2-22	(Armson & Sadreika 1974)
Boron	mg/l	.08	.05	0.3-1.25=Satisfactory for Sensitive Crops	(U.S. Salinity Lab.,1969)
Sulfate	mg/l	68	86	5-130	(Armson & Sadreika 1974)

[1]Analyses performed by Agricultural Consultants Laboratory, Brighton, Colorado.

THERAPEUTIC MEASURES

The saline soil syndrome can be alleviated by two separate but interdependent courses of action:

Correct Nutrient Imbalance Caused By Excess Calcium

The phosphorus fixation problem can be ameliorated by phosphorus fertilizer applied at the proper rate, in the proper location, and at the proper time. Phosphate ions are immobile in the soil profile so we are incorporating concentrated superphosphate fertilizer (0-46-0) into the seedbed prior to planting. This technique will render the phosphorus available to young seedlings which are most apt to be affected by salt concentrations in the surface soil layer. Developing seedlings also have a great demand for phosphate in their rapidly expanding tissue.

Ammonium phosphate fertilizer (18-46-0) is being applied monthly during the growing season as a top dressing and then cultivated into the seedbed. This fertilizer has been shown to be readily available because the ammonium ion appears to stimulate phosphorus uptake (Tisdale and Nelson, 1975). Monthly fertilizer applications should offset calcium fixation by providing a regular resupplying of phosphorus.

Organic forms of phosphorus such as "Milorganite" fertilizer (6-2-0) are being used in late-season and preplanting applications because organic fertilizers are slow in releasing nutrients and organic phosphorus is not as subject to calcium fixation (Tisdale and Nelson, 1975).

The critical micronutrients such as iron, zinc, and manganese are being applied as a foliar spray twice during the growing season. Presently, we are using "THIS" brand fertilizer which is a mixture of 1% iron, 1% manganese, and 1% zinc in an organically chelated form. If these micronutrients are absorbed through the seedling foliage, they can circumvent the calcium fixation problem. They can also be taken up through the root system where the chelation increases their availability under saline conditions.

Flaked sulfur applications are continuing during the fallow year to promote optimum soil pH levels.

Accelerate Leaching of Excess Calcium Salts

The fallow year between rotations of seedlings is being used to improve the physical condition of nursery soils and encourage rapid percolation of saline irrigation water.

Sawdust is applied at a rate of 250 cubic yards per acre, because organic matter inhibits calcium fixation of nutrients and also encourages water infiltration and drainage. Urea fertilizer (46-0-0) is added to accelerate breakdown of the sawdust and improve the carbon/ nitrogen ratio in the soil.

Soils are also deep-ripped and rock-picked to a depth of 12 inches after the sawdust application. This procedure breaks up the impervious plow-pan and incorporates sawdust into this layer to retard their further development. The incorporation of organic matter into the soil profile should increase porosity and result in better water drainage and air exchange.

The existing "Skinner" irrigation system is being replaced with a "Rainbird" type system to provide better water coverage and infiltration.

CONCLUSIONS

The saline soil syndrome is a complex nutrient availability problem that is not completely understood. Calcium appears +o be the operative factor rather than soil pH, because this salt can chemically fix available phosphorus, iron, manganese, and zinc.

The problem can be rectified by proper fertilization and correcting soil physical properties to insure adequate drainage. Fertilizers must be in a form that is resistant to calcium fixation. They must be applied at the proper rate and time and incorperated into the soil.

Saline, calcareous soils were originally formed as a result of water deposition so they can be corrected by improving soil infiltration, percolation and drainage. Addition of organic matter will inhibit calcium fixation as well as improve soil porosity.

Saline soils are extremely variable and therefore solutions developed for Mt. Sopris Nursery may not be directly applicable to other nurseries such as Albuquerque, although the general techniques should be the same.

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