Fertilization Affects Growth and Incidence of Grey Mold on Container-Grown Giant Sequoia

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Different formulations of commercial soluble fertilizers were tested on container seedlings of giant sequoia (Sequoiadendron giganteum *(Lindl) Buchholz). The 28-14-14 formulation, followed by the 10-52-10, 35-5-10, and 8-20-30 formulations, resulted in seedlings with adequate dimensions (height of 26 cm and collar diameter of 7 mm). As far as grey mold caused by* Botrytis cinerea *Pers. ex Fr. was concerned, 0-15-40 and 8-20-30 formulations produced seedlings in excellent sanitary state. In the container nursery conditions of the Association Foret-Cellulose (AFOCEL) experiment station, from now on, giant sequoia seedlings will be provided with the 28-14-14 formulation from May to July and then with the 8-20-30 formulations from August to September, in order to obtain seedlings with desirable growth characteristics and disease resistance.* Tree Planters' Notes 44(2):68-72; 1993.

In producing vigorous container seedlings of giant sequoia *(Sequoiadendron giganteum* (Lindl) Buchholz) for outplanting, there are two main difficulties. After 7 months of growth, it is hard to obtain a majority of seedlings above the minimum height of 15 cm. Grey mold, caused by *Botrytis cinerea* Pers. ex Fr., damages giant sequoia seedlings throughout the growing season. More than 30% of seedling production at the Association Foret-Cellulose (AFOCEL) nursery has been at times affected by grey mold.

Controlled-release fertilizers supply major and minor nutrients in the growing medium but meet seedlings' needs only during the first several months. At the beginning of the growing season, if temperatures are very high, nutrients can be released in excess compared to seedlings' needs, causing "burning," whereas, later in the season, nutrients are liable to be insufficient. Therefore, it becomes necessary to add fertilizer, and watering is the most commonly used method of applying fertilizer in France. To obtain a balanced fertilization, formulations used must contain major nutrients (N, P, K) as well as minor nutrients (Lemaire *et al.* 1989).

Botrytis is a facultative parasite, living either as a saprophyte on decaying organic matter or as a parasite on living tissue. Moreover, it is a polyphagous pathogen and can be found on a great number of plants, ranging from shrubs to cut flowers and trees. It is also ubiquitous, growing everywhere from greenhouses to the natural environment when conditions are favorable. Two environmental factors favor its spread-high relative humidity (> 98%) and warm air temperature (15 to 20 /C) (Lamarque 1979). Consequently, rainy and mild springs and autumns promote favorable environmental conditions for *Botrytis* proliferation. Chemical control of this fungus involves protective treatments using both systemic and contact fungicides alternatively at low concentration (2 parts to 1,000 parts water), as well as treatments with systemic fungicides at high concentrations (4 parts to 1,000 parts water) (James and Woo 1984). However, although sensitive fungus strains disappear, resist ant fungus strains spread, thus making this control method difficult or even ineffective (Gillman and James 1980).

Botrytis is principally found in vineyards in France, and prophylactic management strategies against *Botrytis* in woody plant nurseries can draw inspiration from wine-growing practices:

1. Growing density is low; as soon as seedling twigs touch each other, growing density is reduced from 250 seedlings/m^2 (25/foot^2) to 125 seedlings/m^2 (12.5/foot^2).
2. Diseased twigs or seedlings are systematically destroyed.
3. Seedlings are transported from greenhouse to outside as early as possible because a prolonged stay in greenhouse favors abundant tender and succulent shoots, which are less resistant to spore germination (Peterson et al. 1988).

4. Low-nitrogen fertilizer (Bourdier 1986) is used to minimize foliage development.

In the experimental nursery of AFOCEL station in Malissard, we tested various formulations of commercial soluble fertilizers during the growing season to find a fertilizer that would enable us to produce container-grown giant sequoias of sufficient height that were also relatively disease free.

Growing Regimes

Seeds came from a natural stand of the center of the native distributional range of giant sequoia in the United States, from a region called Black Mountain in southern California near Randsburg (36/ N and 118/ W), between 1,170 m (3,838 feet) and 2,070 m (6,791 feet).

On February 1, 1990, seeds were stratified for 6 weeks in moist cold at 4 /C in the AFOCEL station's cold chamber. On March 15, 1990, seeds were set out in small trays (15 X 40 cm, or 0.5 X 1.3 foot) filled with a 1:1 (vol/vol) mixture of peat moss and pine bark. They were watered with a fungicide solution-oxyquinoleine (Cryptonol)-at 0.2%) and placed under a tent made of a transparent plastic sheet at 20 /C in the glass-covered greenhouse.

Seedlings were transplanted when cotyledons were horizontal and the first bud was visible (April 1990) into bottomless Fertiss containers. These 250-cm3 tube-like containers (5.5 X 11 cm, or 2.1 X 4.3 inches) are made of nonwoven synthetic material that roots can penetrate (figure 1). They were filled with a 1:1 mixture of peat moss and pine bark. Containers were set up in bottom less AFOCEL-Stamp trays (40 X 60 cm, or 1.3 X 1.9 feet) made of plastic, each containing 60 Fertiss containers side by side.

Once transplanted, young seedlings stayed under a tent in the greenhouse. The tent was removed when roots penetrated the nonwoven walls. During this period, water was supplied by subirrigation through a wadded cloth, and protective fungicides at low concentration (2 parts to 1,000 parts water) such as benomyl (Benlate), thiophanate-methyl (Pelt44), dichlofluanide (Euparene), iprodione (Royal), and procymidone (Sumisclex) were applied alternatively once a week. Seedling growing density was reduced from 250/m2 (25/foot2) to 125/mz (12.5/foot2) as soon as first twigs touched each

Figure *1-Seedlings of giant sequoia transplanted into bot tomless containers of nonwoven synthetic material (Fertiss) in the greenhouse.*

Container seedlings, still in AFOCEL-Stamp trays, were carried to an outside growing area at the be ginning of July 1990. Daily irrigation by sprinkling was done on an as-needed basis. Fungicide treat meats were completely stopped at that time.

Experimental Design

On July 4, 1990, we used a randomized complete block design with 2 blocks. There were 30 trees in each treatment block combination. We tested 5 for mutations of concentrated soluble fertilizers made commercially by Plant-Prod (Fertil France Company).

Control
35-05-10
00-15-40
OS-20-30
10-52-10
28-14-14

Fertilizers were applied by watering (6 liters of solution composed of 5 parts fertilizer to 1,000 parts water per 30 seedlings). Treatments were identified by N-P-K balance: for instance, 28-14-14 meant the fertilizer whose N-P-K balance was 28-14-14.

Applications took place after morning sprinkling until saturation with a watering can. Fertilization was initiated on July 5, 1990, after seedlings were carried to the outside growing area. Fertilizers were applied once a week until August 30, 1990, for a total of 9 applications. Overall quantities of nutrients applied per seedling at the end of the 9 applications were calculated according to fertilizer compositions given by Plant-Prod (table 1).

Measurements

Four traits were measured: height from soil level to tip of the terminal bud in centimeters on July 3, 1990 (initial measurement) and September 4, 1990 (final measurement); root collar diameter in millimeters on September 4, 1990; and a rating for amount of disease on October 22, 1990. Seedlings received a rating of **1** if they were disease-free or **2** if they had *Botrytis* symptoms (typical brownish necrosis).

Analysis of variance for the two factors was performed on all collected data according to general linear models procedure based on Fisher's method and tables (Dagnelie 1970). Differences among means were evaluated using the test of additivity from Tukey and Kramer (Dagnelie 1970), designed specifically for comparisons based on the studentized range.

Table *1-Overall quantities of nutrients per gram of N-P-K fertilizer at the end of 9 applications*

Treatment (N-P-I()	Nitrogen (g)	Phosphorus lg)	Potassium Cg)	Total lg)
Control	0	0	0	0
35-05-10	3.15	0.45	0.9	4.5
00-15-40	0	1.35	3.6	4.95
08-20-30	0.72	1.8	2.7	5.22
10-52-10	0.9	4.68	0.9	6.48
28-14-14	2.52	1.26	1.26	5.04

Results

On July 3, 1990, mean heights of different treatments were not significantly different (table 2). This first measurement ensured that the initial seedling population was homogeneous. The treatments had significant differences for height when measured on September 4, 1990. The treatment producing the tallest seedlings was treatment 28-14-14. Block effects were non-significant. There were also significant differences in height growth. The best treatment was 28-14-14, which produced excellent growth. Treatments 10-52-10, 35-5-10, and 8-20-30 produced superior growth as well. The treatment producing the largest diameter seedlings was 28-14-14 followed by 8-20-30 and 10-52-10

Overall differences among treatments were significant.

For percentage of disease-free seedlings, all treat ments exceeded control but differences among treatments were not always significant. Only 0-15-40 and 8-20-30 formulations showed signifi cantly higher percentages than the other 4

Table *2-Effects* of six *fertilizer treatments on container seedlings* of *giant sequoia grown in Valence, France*

Treatment (N-P-K)	Height (cm) 7/10/90	Height (cm) 9/4/90	Growth	Root collar diameter (mm) 9/4/90	% Disease-free seedlings 10/22/90
Control	13.4 a	15.5 d	2.15 c	4.9 be	70 b
35-05-10	13.3 a	20 be	6.7 b	5.7 be	98 b
00-15-40	15.7 a	18.1 cd	2.4 c	5.9 b	100 a
08-20-30	14.4 a	19.7 cd	5.3 be	6.3 ab	100 a
10-52-10	15.1 a	22.4 ab	7.3 ab	6.1 ab	95 b
28-14-14	15.6 a	26.4 a	10.8 a	6.9 a	95 b
Average	14.5	20.3	5.7	5.9	93

Values in columns with no letters in common differ significantly.

One of the two most concentrated nitrogen formulations (28-14-14) produced the tallest seedlings (26 cm height and 7mm collar diameter). The relatively unexpected response of treatment 35-5-10

might be due to the low phosphorus and potassium contents of the fertilizer. Formulations 10-52-10, 8-20-30, and 0-15-40 also exceeded the control (figures 2 and 3). This experiment confirms nitrogen as the major element that has the highest control on the vegetative growth, provided that the other nutrients are present in enough quantities.

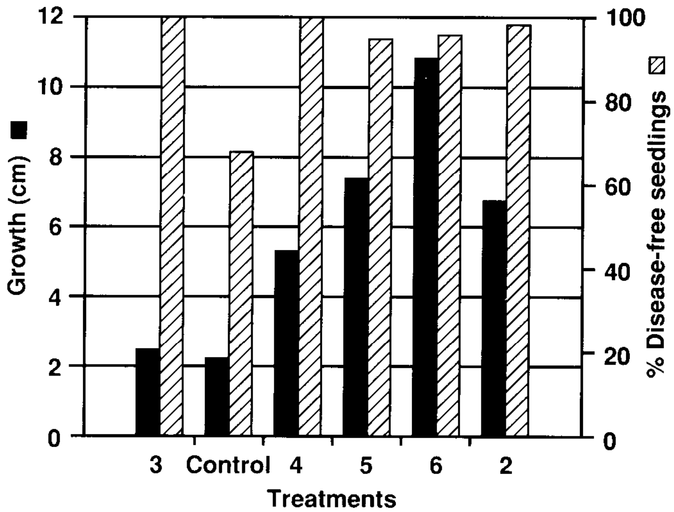

Figure *2-Fertilizer treatment effects on seedling growth and percentage of discase-free seedlings of giant sequoia ranked according to increasing N contents in the fertilizer (treatment 2 = 35-5-10, 3 = 0-15-40, 4 = 8-20-30, 5 = 10-52-10, 6 = 28-14-14 N-P-K).*

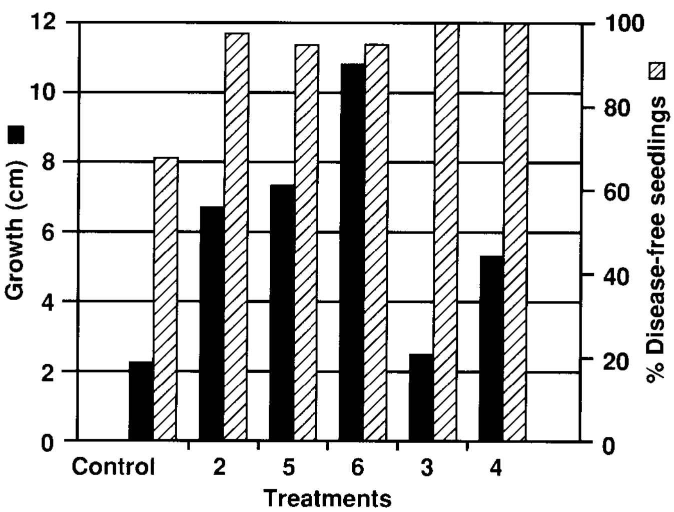

Figure *3-Fertilizer treatment effects on seedling growth and percentage disease-free seedlings of giant sequoia ranked according to increasing K content in the fertilizer (treatment 2 = 35-5-10, 3 = 0-15-40, 4 = 8-20-30, 5 = 10-52-10, 6 = 28-14-14 N-P-K).*

Discussion

As far as *Botrytis* damages are concerned, we recorded slightly different trends. July and August 1990 were particularly dry and hot months and therefore unfavorable to *Botrytis;* on the other

and therefore favorable to this fungus. In July and August, all seedlings were healthy, but during September and October, some lots were covered with brownish necrosis typical of the disease. All formulations appeared to give good protection from *Botrytis* damage. Therefore, seedling resistance to *Botrytis* seemed to be related to the quantity of mineral elements available, with a tendency toward good results with less nitrogen and more potassium.

If effects of nutrient nature and quantity on growth have long been investigated, it is not the case for their effects on disease resistance; literature dealing with this subject is scarce and contradictory: facing a given fertilization, each species reacts differently in interaction with each disease, which

may be either favored or unfavored. According to Podger and Wardlaw (1990), even seasonal or ephemeral nutrient deficiencies contribute to spring needle-cast affecting Monterey pine *(Pinus radiata* D. Don.). On the other side, Patila and Uotila

Scleroderris canker can be associated with increased growth due to fertilization. A rich manure favors *Botrytis* on vineyards, but has the opposite effect on giant sequoia seedlings; keeping giant sequoia seedlings growing thanks to a suitable fertilization seems an effective practice against *Botrytis.* Grape vine as a "frugal" plant seems to bear far better with a low-nitrogen fertilization regime compared to giant sequoia, a "greedy" plant, which grows better under higher nitrogen regimes. Indeed, the control in this study shows more disease than other treatments.

Other work (Lepp and Edwards 1984) demonstrates an inhibitory role for iron in the germination of spores from *Botrytis cinerea* on tomato. Potassium, which plays an important role on osmotic pressure regulation in cells, could reinforce natural cell barriers towards *Botrytis* and explain better results towards disease resistance with more potassium and less nitrogen (Lafon et al. 1988)

Conclusion

In our growing conditions, the 28-14-14 formulation produces tallest seedlings, whereas the 8-20-30 formulation gives better disease protection. The difference between 95% disease-free seedlings (28-14-14) and 100% disease-free seedlings (8-20-30), although small, may possibly appear important in mild and rainy years. That is why providing

seedlings with the 28-14-14 formulation from May to July and then the 8-20-30 formulation from August to September should give the best compromise

between seedlings of target growth and disease characteristics. Our conclusions are obviously provisional and need to be confirmed by other similar and complementary experiments.

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