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Fuelwood Production Utilizing *Pinus eldarica* and Sewage Sludge Fertilizer

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ABSTRACT

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The response of *P. eldarica* to soil amendments and irrigation regimes was evaluated. Treatments included 67 t ha^{-1}* sewage sludge, 67 t ha^{-1} steer manure, 84 kg ha^{-1} 21—0—0 inorganic fertilizer and control. Plots were flood irrigated to a depth of 5 cm and irrigation treatments were applied at 7-, 14- or 21-day intervals. Sewage sludge increased growth response, while height growth decreased as irrigation frequency increased. Results indicate that sludge fertilized *P. eldarica* plantations could provide needed fuelwood resources for mitigating the energy crisis in many arid and semiarid regions.

INTRODUCTION

Pinus eldarica Medw. which is native to only a small, low mountain and semidesert area near Tbilisi, Georgia, Transcaucasia, USSR, is drought tolerant and adaptable to arid environments in southwestern United States (Fisher and Widmoyer, 1978). Las Cruces, New Mexico is located at latitude 32 N and longitude 107 W and at an elevation of 1158 m. The mean annual rainfall is 200 mm, occurring mainly in late summer. The area has 200 frost-free days and a temperature range of −23°C to 41°C. Soil pH ranges from 7.4 to 8.4 (Bulloch and Neher, 1980). These edaphic and climatic conditions are within the range of those reported for *P. eldarica* (Little, 1983; Servertoka, 1975).

Climates similar to southern New Mexico's are common around the world, and many of these areas lack the economic resources to provide fossil fuel for heating and cooking needs. Trees and shrubs can be grown to meet the fuelwood requirements of less developed countries. Areas with the most critical fuelwood shortages are the villages and small cities

*Metric tons are used throughout the text.

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of developing countries. Population growth and influxes of people have accelerated the destruction of surrounding vegetation.

Wood shortages in arid zones lead to environmental degradation and, ultimately, desertification. While high population density poses many problems, it also generates large volumes of potentially valuable sewage sludge. Sewage sludge, combined with an adapted, fast-growing fuelwood species could contribute needed energy and, at the same time, retard or reverse the adverse affects of destructive land use practices.

Fuelwood plantations could be established by combining *P. eldarica* with the soil amending and fertilizing qualities of sewage sludge. Studies at New Mexico State University (NMSU) have further quantified the growing requirements for *P. eldarica.* Fisher et al. (1984) measured mean yield per tree of 0.04 m^3 at five years after planting. The stocking level was 2470 trees ha^{-1} and the mean yield was 18 m^3 ha^{-1} y^{-1}. Trees were grown under a mean annual precipitation of 200 mm, plus 380 to 500 mm of supplemental irrigation water. *Pinus eldarica* height averaged almost 6 m at the end of the sixth growing season from seed (Fisher et al., 1984). Similar growth has been observed in many plantings throughout southern New Mexico.

On the basis of soil moisture depletion studies, White and Fisher (pers. comm.) concluded that rapid growth of *P. eldarica* can be maintained at a consumptive use of 800 mm y^{-1}. Considering the ambient rainfall, supplemental water of 600 mm y^{-1} would be needed to maintain near optimum growth in southern New Mexico. Seedlings appear to tolerate salinity. Manuchia (personal communication) found that *P. eldarica* can be grown hydroponically at 6000 ppm total dissolved salts. The ability to supplement annual rainfall with irrigations of moderately brackish water would facilitate the establishment and maintenance of *Pinus eldarica* fuelwood plantations in arid areas with a supply of saline water.

Sewage sludge and composted sludge are attractive alternatives to inorganic fertilizer because their properties benefit both soil and plant management. Compared to inorganic fertilizers, organic amendments are less expensive, more readily available and offer a wider range of soil amending properties. The disadvantages of sewage sludge are that it requires coordination of resources, may be more labor intensive and may be socially unacceptable.

Sewage sludge and composted sludge improve the nutrient level and physical condition of soils. Berry and Marx (1980) reported increased levels of organic matter following an application of 125 m^3 ha^{-1} of sewage sludge to a disturbed borrow pit site. In a two-year study reported by Pagliai et al. (1981), total porosity and soil aggregate stability increased with the addition of sewage sludge or sludge-compost mixture. Epstein (1975) reported a 11% to 18% increase in stable soil aggregates as a result of adding 5% (by dry weight) sewage sludge. Mays et al. (1973) reported an increase in moisture-holding capacity and a decrease in bulk density and compression strength for soils receiving 80 t ha^{-1} to 143 t ha^{-1} of sewage sludge plus municipal refuse compost. He also reported increases in pH, organic matter, K, Ca, Mg and Zn.

Lunt (1955) measured a 5% increase in the moisture-holding capacity of soils treated with 90 t ha^{-1} dried sewage sludge and a 13% increase with a sludge—woodchips mixture (Lunt, 1959). McCaslin and O'Connor (1982) reported that gamma-irradiated sewage sludge increased soil moisture-holding capacity, nutrient exchange and absorption. Their treatments improved micronutrient availability on alkaline soils without causing a build-up of toxic heavy metals.

In addition to the improved physical properties associated with the use of sewage sludge and sludge-compost, these materials also provide essential plant nutrients. Sludge and sludge-compost are capable of meeting plant N, P and K needs, as well as essential Fe and Zn (Table 1). McCaslin and O'Connor (1982) reported that sludge compared favorably with inorganic fertilizer in improving sorghum yield.

TABLE 1

Macro-nutrient analyses of sewage sludge and sludge-compost soil amendments

Organic amendment	Nutrient (% dry wt.)			Source
	N	P	K	
Sludge	2.0	1.0	0.05	Berry and Marx, 1980
Sludge	1 – 6	1 – 6	<1.5	Clevenger et al., 1984
Sludge—woodchips	0.9	0.7	0.2	Gouin, 1977
Sludge—compost	1.2	0.2	0.8	Mays et al., 1973
Sludge	1.9	2.4	n/a[a]	McCaslin and O'Connor, 1982

[a]n/a: not analysed.

MATERIALS AND METHODS

A fertilizer/irrigation study of *Pinus eldarica* was conducted from 1983 to 1984 at the NMSU Fabian Garcia Horticulture Farm in Las Cruces, NM. A split-plot randomized complete block design with four replications was used to determine seedling response to four fertilization treatments applied to subplots and three irrigation levels applied to main plots separated by 0.5 m irrigation borders. Seedlings grown in 150-cm^3 containers to a height of about 30 cm were planted May 12, 1983. Trees were spaced 0.75 m apart within eight-tree rows spaced 1.5 m apart within basins. On June 16 and 17, 1983 plots received one of the following treatments: 67 t ha^{-1} dry sewage sludge, 67 t ha^{-1} steer manure, 84 kg ha^{-1} ammonium sulfate or no fertilizer (control). Organic amendments were roto-tilled to a depth of 10 cm. All basins were irrigated with 8 cm of water on May 6 and 27, 1983. Thereafter, basins were irrigated at 7-, 14- or 21-day intervals.

Classified in the Brazito series, soils within the experimental area were formed in mixed alluvium and are deep and well drained (Bulloch and Neher, 1980). Soils within the top 40 cm consist of brown, very fine loam. The underlying material is very pale brown sand to a depth of 150 cm. Soil pH was 7.6 and organic matter was 1.5%. Contents of NO_3-N, PO_4 and K were 1.9 ppm, 5.3 ppm and 46.5 ppm, respectively. Sludge obtained from the Las Cruces municipal sewage treatment plant contained the elemental levels reported in Table 2. Steer manure contained, on a dry-weight basis, 4% N, 0.6% P and 2% K.

Tree heights and ground level diameters were recorded October 1983, December 1983 and October 1984. Tree fresh weights were determined at the last measurement date. Height and stem diameter relative growth rates (*RGR*) were calculated as follows:

$$RGR = \frac{M_2 - M_1}{M_1} \cdot \frac{1}{T_2 - T_1}$$

where M_1 is the measurement at the beginning of the growing period, M_2 is the measurement at the end of the growing period, and T_2 is the time of final measurements and T_1 is the time of initial measurement.

TABLE 2

Chemical analysis of Las Cruces sewage sludge as determined by the Soil and Water Testing Laboratory, New Mexico State University

Element	Sewage sludge content
Total N	3.90%
$NaHCO_3$-extractable P	810 ppm
P	1.4%
K	0.61%
Mg	0.39%
Ca	2.52%
Na	0.21%
Co	9 ppm
Cu	273 ppm
Fe	10,329 ppm
Mn	2,008 ppm
Mo	2,257 ppm
Zn	1,003 ppm
Ag	127 ppm
Cd	199 ppm
Cr	197 ppm
Ni	174 ppm
Pb	297 ppm

RESULTS

Tree height after two years was significantly smaller for higher irrigation frequencies (Fig. 1). Ground line diameter was not significantly affected by irrigation treatment.

Height and above ground biomass after two years were improved by fertilization with 67 t ha^{-1} of sewage sludge (Table 3). In contrast, seedlings fertilized with manure (67 t ha^{-1}) or 21—0—0 were not as tall as those in control plots. Stem basal diameter growth increased by the sludge treatment, but was not affected under the other fertilizers.

Response to the sludge treatment appears to last through two growing seasons for the diameter growth, but only one year for the height growth (Table 3). Stem basal diameter *RGR* with the sludge treatment was greater than with other treatments both years (Table 3). This is consistent with other fertilizer studies in which diameter and biomass growth were more sensitive than height to amendments (Will, 1977). While height is no longer

TABLE 3

Growth and leaf tissue nutrient responses to organic and inorganic amendments

Response	Treatment			
	Sludge 67 t ha^{-1}	Manure 67 t ha^{-1}	$(NH_4)_2SO_4$ 84 kg ha^{-1}	Control
Final ht. (cm)	100.6 A[a]	88.6 B	87.9 B	92.7 BC
Ht. RGR[b] (cm cm^{-1} y^{-1})				
10/83—12/83	0.62	0.43	0.45	0.47
12/83—10/84	2.32	2.19	2.17	2.31
Final GLD (mm)[c]	26.9 A	22.8 B	22.2 B	23.8 B
GLD RGR (mm mm^{-1} y^{-1})				
10/83—12/83	1.53	1.33	1.25	1.21
12/83—10/84	2.55	2.55	2.20	2.39
Biomass (kg f.w./tree)	1.04 A	0.77 B	0.79 B	0.78 B
Total nutrients (g/tree)				
N	17.9	13.6	14.0	14.3
P	1.7	1.2	1.3	1.2
K	9.4	6.6	7.1	7.1

[a]Means within the same row, followed by the same letter do not differ significantly at $P = 0.05$.
[b]RGR: relative growth rate, as defined in the text.
[c]GLD: ground line diameter.

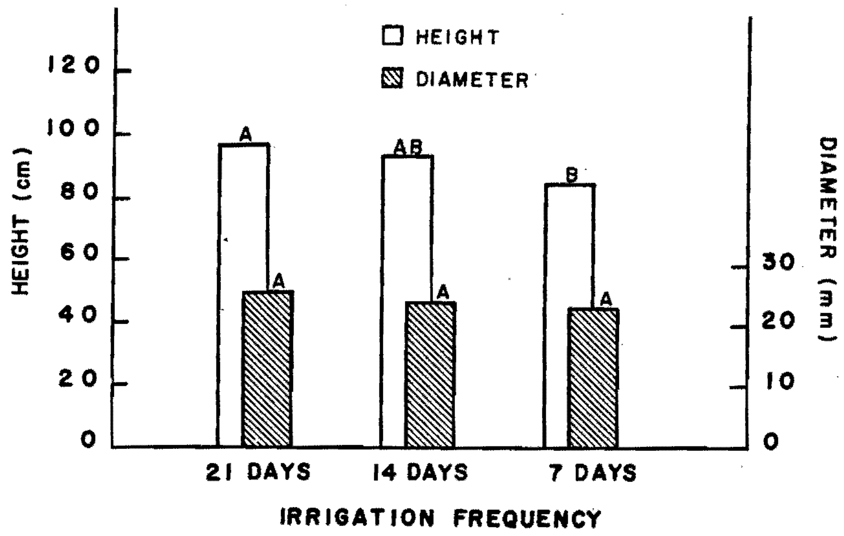

Fig. 1. Final height and diameter of two-year old *P. eldarica* by irrigation frequency. Treatments with the same letter did not differ significantly at $P = 0.05$.

responsive to the applied sludge, it is possible diameter will continue to respond.

DISCUSSION AND CONCLUSIONS

Part of the sludge response may be indirect because nutrient reserves stored in the foliage may result in continued response to sludge. Trees in the sludge treatment had higher contents of nitrogen, phosphorus and potassium (Table 3). Nutrient concentrations were not different among the treatments, but total content was different, reflecting a total biomass response to sludge.

The negative irrigation response found in this study may be the result of overwatering. Based on White and Fisher's (pers. comm.) recent data for *P. eldarica*'s consumptive use, all but the lowest frequency irrigation received too much water. Main plots irrigated at 7-day intervals were watered 59 times over the course of the study compared to 23 times for the 21-day interval treatment. The combined rainfall and irrigation for the lowest irrigation frequency was 740 mm per growing season, which is comparable to the reported 800 mm y^{-1} optimum. The remaining irrigation treatments exceeded the optimum and excessive watering may have impaired root functioning or leached soluble nutrients below the active rooting zone of *P. eldarica* decreasing total biomass production.

The economic value of this fertilizer response has not been determined. Although the response in this study has been significant, it may not be economically justified. The social advantage of disposing of sludge may make the program feasible. In addition, multiple applications may improve the response. Furthermore, the additional organic matter may increase the moisture holding capacity on the site, resulting in additional growth.

Based on the adaptability of *Pinus eldarica* and availability of sewage sludge, it appears feasible to establish fuelwood plantations in regions similar to those described. Assuming an area could meet the edaphic and climatic conditions necessary to support *Pinus eldarica*, the next step would be to secure the cooperation of the village to acquire sewage sludge. Sludge could be composted or treated in some manner to ensure safe handling.

Dalmat et al. (1982) reported a co-composting system that combines raw sewage sludge with biodegradable refuse to produce a soil amendment high in nutrients and organic matter. Available labor could be used to clear vegetation from the proposed planting size and to construct water catchments. Seedlings could be produced in inexpensive containers and planted into the plantation. Planting should be scheduled to take advantage of favorable seasonal climatic conditions marked by average precipitation and cool temperatures. Once established, the plantation must be managed to ensure orderly and appropriate harvesting of the fuelwood crop.

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