sponses when applied to ‘Hino-crimson’ azalea as the 4E formulation at about one-half the amount of active material.

**Literature Cited**


**Abstract.** Effects of Cd accumulation on dry weight accumulation and acetylene reduction (N₂ fixation) of 1-year Alnus glutinosa (L.) Gaertn. exposed to 0, 1, 2, 4, or 8 ppm Cd as CdCl₂·2½ H₂O were determined. After 6 months of greenhouse sand culture, significant amounts of Cd accumulated in the nodules and roots, but not in shoot tissues. There were no significant differences on root, nodule, or shoot dry matter accumulation or on C₂H₂ reduction (N₂ fixation) due to CdCl₂ treatments.

Sewage sludge can be used safely and successfully as a strip mine spoil amendment (3, 11-13). The use of waste sewage sludge provides an ecologically sound method of disposal (12) and aids site amelioration and successful revegetation of strip-mined land (8, 11, 12). Irrigation of municipal sewage effluent and liquid-digested sludge has helped to relieve low pH conditions and raise the exchangeable base contents of acid mine spoils (3).

Application of municipal sewage sludges and effluents can be a means of entry of Cd and other heavy metals into agricultural lands and the food chain (2). Sludges differ greatly in their heavy metal content depending on the nature and degree of industrial activity. Cadmium concentrations from 1 to 1500 ppm have been reported for dry sludge (9).

Various patterns of Cd accumulation and tolerance have been reported for several vegetable and forage species grown in soil amended with Cd-enriched sludge (1, 2). Foliar accumulation of Cd was found in forages grown on sludge-amended mine spoil; however, no plant toxicity symptoms were evident (8). Cadmium has also been shown to accumulate in soils and vegetation around coal-burning power plants (5). Growth reduction in silver maple (Acer saccharum L.) has been correlated with increasing media Cd levels (6).

Soil treatments from 50 to 1000 ppm CdCl₂ markedly stimulated N₂ fixation by the soil-borne bacteria Azotobacer chroocuccum (10). After 8 months, almost all applied rates of Cd reduced N₂ fixation activity. Application of Cd and other trace elements inhibited nitrogenification, causing accumulation of ammonium-N in soil (7).

Cadmium additions severely reduced N₂ fixation and photosynthesis in soybean (Glycine max (L.) Merr.). Application at seeding emergence had a greater effect than treatment 30 days after emergence (4). Uptake and translocation of Cd by Phaseolus vulgaris L. was slow, with greater accumulation in roots than in nodules. Nodulation was impaired, but little Cd accumulated in shoots (14).

The purpose of this study was to determine the effect of Cd on the growth and N₂ fixation by Alnus glutinosa (L.) Gaertn., a species frequently in strip-mine reclamation. Nodulated, dormant 1-year-old A. glutinosa seedlings were planted during April in 12.7-cm plastic pots lined with a polyethylene bag and filled with 2400 g of white quartz sand. The plants were pruned to a uniform height after planting and grown in the glasshouse. Treatments of 0, 1, 2, 4, or 8 ppm Cd as CdCl₂·2½ H₂O were applied in 300 ml of deionized water shortly after planting. Treatments were randomized and replicated four times.

Plants were watered with deionized water and fertilized periodically with half-strength, minus-N Hoagland solution. The drainage from individual pots was collected in plastic cups and recirculated through the sand.

After 6 months of growth, the plants were harvested and acetylene reduction assays were performed on the nodules. All nodules from a single plant were excised, washed, blotted, placed in a 250-ml volumetric flask and scaled with a rubber serum stopper. Twelve milliliters of air was replaced with commercial grade acetylene. After a 1-hr incubation at 24°C, three 0.1-ml samples were withdrawn and analyzed by gas chromatography. Fresh weight of the nodules was determined immediately following analysis. Foliage, stems, [Graph or table data]

**Fig. 1.** Cadmium concentration in root and nodule tissue of A. glutinosa grown in sand culture with various levels of CdCl₂. Correlation coefficients (r) were 0.972 for root [Y = 20.8 + 30.7(X)] and 0.997 for nodule [Y = 2.65 + 14.65(X)] tissue.
roots, and nodules were dried at 70°C for 5 days and weighed. All tissues were ground separately through a 20-mesh screen and wet-washed using sulfuric acid and hydrogen peroxide. The digest was analyzed for Cd containing no Cd, wet-ashed with the same procedure. Analysis of variance, mean separations, and linear regression analysis were performed on all data.

Cadmium concentration in the root (r = 0.972) and nodule (r = 0.994) tissues of A. glutinosa increased linearly with treatment additions (Fig. 1). There was no Cd found in either the stem or foliage, however. Cadmium concentrations were also lower in stems than roots of dry bean (14) and differential tissue accumulation of Cd has been reported in tobacco (Nicotiana sp.) (15), vegetable, and forage species (1, 2).

After 6 months of exposure to different Cd levels there were no effects on growth or acetylene reduction (N2 fixation) (Table 1). This response has not been reported in other Cd studies with woody plants.

Significant growth reduction was reported in silver maple grown in a similar system, but plants were exposed to Cd starting at germination (6). Growth and N2 fixation of A. glutinosa may have been affected more than noted if exposed to the heavy metal from germination. In soybean, greater reductions in growth, photosynthesis, and N2 fixation occurred when Cd was applied at seedling emergence than if added 30 days later (4). Nitrogen fixation of dry bean was not affected greatly by Cd treatment (14).

Cadmium appeared to have no short-term effect on the growth or N2fixation capabilities of a 1-year-old seedling of A. glutinosa even though appreciable amounts accumulated in the root and nodule tissue. Long-term effects of Cd on species used in reclamation warrants further investigation.

**Table 1.** Mean nodule, root and shoot dry weights (g) of Alnus glutinosa grown at various levels of CdCl2 in sand culture.

<table>
<thead>
<tr>
<th>Cd (ppm)</th>
<th>Nodules (g)</th>
<th>Roots (g)</th>
<th>Shoots (g)</th>
<th>mmol C2H4/g per hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.370</td>
<td>18.8</td>
<td>22.6</td>
<td>39.0</td>
</tr>
<tr>
<td>1</td>
<td>0.370</td>
<td>18.8</td>
<td>17.9</td>
<td>29.3</td>
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<tr>
<td>2</td>
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<td>4</td>
<td>0.395</td>
<td>20.0</td>
<td>21.3</td>
<td>23.9</td>
</tr>
<tr>
<td>8</td>
<td>0.351</td>
<td>24.9</td>
<td>17.9</td>
<td>39.5</td>
</tr>
<tr>
<td>r</td>
<td>NS</td>
<td>NS</td>
<td>0.96*</td>
<td>NS</td>
</tr>
</tbody>
</table>

*Correlation coefficient.