Raw Paper Mill Sludge in A Rooting Medium for Deciduous Woody Cuttings

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Abstract. Stem cuttings of seven deciduous landscape shrubs {silky dogwood (*Cornus amomum* Mill.), coralberry (*Symphoricarpos orbiculatus* Moench), Peegee hydrangea (*Hydrangea paniculata* Siebold, 'Grandiflora'), Bridal-wreath spirea [*Spiraea ×vanhoutteii* (C. Briot) Zab.], spirea (*Spiraea ×bumalda* Burv. 'Goldmound'), fragrant viburnum (*Viburnum farreri* Stearn), and weigela [*Weigela florida* (Bunge) A. DC. 'Variegata Nana']} were rooted under mist in 100% perlite (no sludge) medium or in mixtures of 10%, 20%, 30%, 40%, 50%, or 60% (v/v) of raw paper mill sludge and perlite. There was a large linear reduction in percent rooting of viburnum (from 80% to 21% with 0% and 60% sludge, respectively) in response to increasing level of sludge. The mean root count per cutting also was significantly decreased, from 14 to 5. However, the length of longest root was unaffected. In contrast, all the other species ranked good to excellent in rooting, regardless of the level of sludge. Differences, if any, in rooting performance were not of practical significance.

The pulp and paper industry generates large quantities of effluent wastes (3% to 5% total solids content, dry-weight basis) that typically are processed and dewatered into raw sludge (30% to 40% total solids) to facilitate handling and disposal (Bellamy et al., 1995). In North America, ≈10 million tons of raw sludge are discarded annually (K.L. Bellamy, personal communication). In many areas, the traditional disposal of paper mill sludges in landfills has become prohibitively expensive. Hence, there is a greater need for alternative and more environmentally friendly approaches to disposal or reuse of this waste.

Since the 1950s, researchers have been assessing the use of paper mill effluents and sludges in land reclamation (Hoitink and Watson, 1982; National Council of the Paper Industry for Air and Stream Improvement, 1959), forestry (Brockway, 1983; Clear Lake, 1993; Henry, 1991), and agriculture (Bellamy et al., 1990, 1995; Dolar et al., 1972). In Ontario, raw paper mill sludge is relatively free of chemical contaminants and is used primarily as an amendment rather than a fertilizer because of its low mineral nutrient and high organic matter content, primarily cellu-

lose (Bellamy et al., 1995). These properties make this sludge suitable for improving the physical properties of plant growing media.

Raw paper mill sludge was effective as an amendment to container media for the production of a wide range of nursery crops (Chong and Cline, 1993, 1994; Cline and Chong, 1991). However, media with more than one-third raw sludge by volume depressed growth due to decreasing availability of N and other nutrients (Chong and Cline, 1994; Cline and Chong, 1991).

The objective of this study was to investigate the rooting of cuttings of seven deciduous woody landscape species under outdoor mist using perlite amended with up to 60% raw paper mill sludge.

Materials and Methods

Cuttings were rooted from seven deciduous woody landscape shrubs: silky dogwood, coralberry, Peegee hydrangea, Bridal-wreath spirea, 'Goldmound' spirea, fragrant viburnum, and 'Variegata Nana' weigela.

Current-season, terminal stem cuttings of each species were collected between 21 June and 5 July 1994. Following collection, cuttings were placed in black polyethylene bags and kept overnight at 1 to 2 °C. The next day, cuttings were trimmed to a length of 6 to 8 cm and the basal 1 cm of each was dipped for 5 s in 0.5% indole-3-butyric acid (IBA) dissolved in Turbo Power –40 °C car windshield washer fluid [47.5% methanol plus small (unspecified) amounts of detergents and dyes; Rechochem, Montreal, Que.], a new alternative and inexpensive IBA solvent (Chong and Hamersma, 1995). Cuttings were then inserted in 50 × 35 × 10-cm-deep flats filled with 100% perlite (no sludge) medium, or perlite with 10%, 20%, 30%, 40%, 50%, or 60% (v/v) raw

paper mill sludge (QUNO Corp., Thorold, Ont.). The characteristics of this sludge were described by Chong and Cline (1993). Before being mixed with perlite, the sludge was passed through a portable soil shredder, resulting in irregular-sized particles with lengths of 0.5 to 1.5 cm.

Cuttings of each species were arranged in separate randomized complete-block designs with four replications and 14 cuttings per plot. Flats of cuttings were held under lath (50% shade) in outdoor frames provided with intermittent mist between 0600 and 2000 hr every 4 min for 8 s. The rooting period for each species was as follows (days): 'Goldmound' spirea, 20; Peegee hydrangea, 26; coralberry and silky dogwood, 27; Bridal-wreath spirea and 'Variegata Nana' weigela, 28; and fragrant viburnum, 29. Rooting performance was assessed by mean percent rooting of cuttings with one or more roots longer than 1 mm, number of roots per rooted cutting, and length of the longest root per cutting. Transformations of the data (arcsin for percent rooting; log for root count and root length), analyzed separately by species, were carried out, but were deemed unnecessary. As a result, each nontransformed rooting response was regressed on percent paper mill sludge.

At the start of the experiment, three air-dried samples of each rooting medium were analyzed for bulk density, air pore space, water pore space (freely draining), and total pore space (air + water pore space) at 10-cm suction (depth of flat) (Ontario Ministry of Agriculture, Food and Rural Affairs, 1994; Warncke, 1980). Electrical conductivity (EC) and pH also were determined at the start and end (5 Aug.) of the experiments using 1 medium : 2 water (v/v) extracts.

Results and Discussion

Percent rooting. Regression analysis indicated substantial reduction (linear relationship) in percent rooting of viburnum in response to increasing level of raw sludge in the medium (Fig. 1). There was a small but statistically significant decreasing trend in percent rooting of Bridal-wreath spirea (linear relationship) and weigela (curvilinear relationship) with increasing levels of sludge (Fig. 1). However, sludge percentage had no significant effect on mean percent rooting (in parentheses) of coralberry (100), dogwood (88), hydrangea (97), or 'Goldmound' spirea (98).

Root count. Increasing the percentage of sludge resulted in a curvilinear increase in weigela root count (calculated maximum of 18 roots with 20% sludge), relatively large linear reductions for Bridal-wreath spirea and viburnum, and a smaller linear reduction in coralberry (Fig. 2). Root count of dogwood was unaffected. At the time of rooting evaluation, there were many roots on hydrangea and 'Goldmound' spirea cuttings in all treatments and counts were not taken.

Root length. In contrast to decreasing trends in percent rooting (three species, Fig. 1) and root count (four species, Fig. 2), sludge percentage resulted in relatively large and small

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Fig. 1. Significant ($P \leq 0.05$) percent rooting response of deciduous shrub taxa to increasing paper mill sludge percentage in the rooting medium. Equations: weigela, $Y = 98 + 0.16X - 0.0045X^2$ ($r^2 = 0.47$); Bridal-wreath spirea, $Y = 97 - 0.21X$ ($r^2 = 0.24$); viburnum, $Y = 80 - 0.84X$ ($r^2 = 0.49$).

Fig. 2. Significant ($P \leq 0.05$) root count response of deciduous shrub taxa to increasing paper mill sludge percentage in the rooting medium. Equations: coralberry, $Y = 26 - 0.084X$ ($r^2 = 0.64$); weigela, $Y = 17 + 0.130X - 0.0034X^2$ ($r^2 = 0.32$); Bridal-wreath spirea, $Y = 25 - 0.23X$ ($r^2 = 0.82$); viburnum, $Y = 14 - 0.15X$ ($r^2 = 0.44$).

positive curvilinear trends in root length (Fig. 3) of coralberry (calculated maximum of 12 cm with 50% sludge) and Bridal-wreath spirea (maximum of 3 cm with 25% sludge), respectively. There were small linear increases in longest root length of dogwood, hydrangea, and 'Goldmound' spirea cuttings. Mean root lengths (in brackets) of weigela (6.0 cm) and viburnum (2.8 cm) were unaffected.

Potential disadvantages of using waste sludge in plant culture are the presence of undesirable chemicals; excess total salts; toxicities, deficiencies, or fixation of nutrients, particularly N (Cline and Chong, 1991). Woody landscape plants typically exhibit large differences in rooting responses among species (Dirr and Heuser, 1987). Except for the combined effects of the large reduction in percent rooting (slope -0.84 , Fig. 1) and root count (slope -0.15 , Fig. 2) of viburnum with increasing sludge, the reduction in percent rooting or root count in the other species was small or insufficient by itself to be of practical significance. Furthermore, such reductions may have been offset for some species by root length increases.

Pore space varied little and fell within acceptable and narrow ranges, between the no sludge and 60% sludge-amended media (total, 60% vs. 59%; air, 38% vs. 38%; water, 22% vs. 21%, respectively) and seemed unlikely to affect rooting response. However, the bulk densities, while also within acceptable ranges (Swanson, 1994), increased with increasing level of sludge (0.184 to 0.303 $\text{g}\cdot\text{cm}^{-3}$ in 0% and 60% sludge), as did final medium pH (6.1 to 7.9 in 0% and 60% sludge). These factors could have influenced rooting response to some degree (Locklear et al., 1983; Swanson, 1994). Initial pH (6.1 and 6.7 in 0% and 60% sludge; variable among other treatments, 6.2 to 6.9) was apparently unrelated to sludge proportion.

Although raw paper mill sludges vary widely in chemical composition (Bellamy et al., 1990, 1995), the batch used in this study contained only small quantities of nutrients [$\text{mg}\cdot\text{liter}^{-1}$, mean of three samples, saturated medium extraction procedure (Warncke, 1980)]: $\text{NO}_3\text{-N}$, 47; P, 13; K, 41; Ca, 78; Mg, 21; Cl, 106; Fe, 0.4; Zn, 0.8; Mn, <0.1; Cu, <0.1. Initial values of EC, 0 (no sludge) to 0.2 $\text{dS}\cdot\text{m}^{-1}$ (60% sludge), a measure of total soluble salts content at the start, were below critical levels to cause injury to cuttings (Hartmann and Kester, 1983). Furthermore, corresponding final EC values were even lower (0 to ≤ 0.1 $\text{dS}\cdot\text{m}^{-1}$), indicating leaching of salts from the sludge-amended medium during rooting.

In earlier propagation studies (unpublished results) conducted in fog-humidified, double-layer, polyethylene-covered greenhouse compartments, we observed progressively decreasing rooting in cuttings of a wide range of evergreen landscape taxa in response to increasing levels of raw sludge (0% to 100% by volume) in the rooting medium. The medium became more hardened and shrunken, and the surface more "crusted," with the increasing percentage of sludge. This condition was apparently induced by the bottom heat and seemed

Fig. 3. Significant ($P \leq 0.05$) root length response of deciduous shrub taxa to increasing paper mill sludge percentage in the rooting medium. Equations: coralberry, $Y = 8.1 + 0.16X - 0.0017X^2$ ($r^2 = 0.53$); dogwood, $Y = 5.8 + 0.018X$ ($r^2 = 0.32$); hydrangea, $Y = 3.5 + 0.016X$ ($r^2 = 0.35$); 'Goldmound' spirea, $Y = 3.8 + 0.010X$ ($r^2 = 0.36$); Bridal-wreath spirea, $Y = 2.4 + 0.047X - 0.00098X^2$ ($r^2 = 0.58$).

to have restricted water penetration and/or air exchange in the medium. Cuttings of some taxa, nevertheless, rooted fairly to acceptably well with sludge present in amounts $\leq 30\%$ by volume.

In this study under mist, the sludge-amended rooting medium remained friable and normal in appearance. Rooting in six of the seven species was good to excellent over all levels of sludge. These results demonstrate that raw paper mill sludge in amounts up to 60% by volume in the rooting medium can be an effective amendment for rooting under mist.

As an organic waste product that may be obtained, where available, at little or no cost, raw paper mill sludge could be more widely

used by nursery propagators as an inexpensive rooting medium amendment.

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