Growth and Drought Tolerance of Viburnum plicatum var. tomentosum ‘Mariesii’ in Pine Bark-amended Soil

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Abstract. Container-grown Viburnum plicatum Thunb. var. tomentosum (Thunb.) Miq. ‘Mariesii’ were planted in unamended planting holes, tilled plots, and tilled plots amended with aged pine bark. A 36-day drought was initiated 108 days after planting. Amending induced N deficiencies, reduced shoot growth, and increased root growth. Plants harvested from tilled and planting-hole plots at drought initiation had 63% and 68% more dry weight, respectively, than plants from amended plots. Between 8 and 19 days after drought (DAD) initiation, plants from tilled plots maintained higher relative leaf water content (RLWC) than plants from planting holes. Plants in amended plots maintained higher RLWC than both other treatments between 7 and 33 DAD. Amended and tilled treatments had higher relative leaf expansion rates (RLERs) than the planting-hole treatment 8, 11, 13, and 15 DAD. As the drought lengthened, plants in amended plots maintained higher RLERs than plants in tilled plots. While plants in pine bark-amended plots were more drought tolerant than those in tilled plots, it is unclear if increased drought tolerance was caused by the improved rooting environment or N deficiency.

Compacted soils on landscape sites limit the survival and growth of newly planted woody plants (Foil and Ralston, 1967; Zisa et al., 1980). Construction activities compact soils to bulk densities >1.40 g·cm⁻³ (Alberty et al., 1984). These levels of compaction limit lateral and vertical root growth, which exacerbates drought stress immediately after planting and during periods of high evapotranspiration (Gilman et al., 1987; Kozlowski and Davies, 1975).

Historically, horticulturists have incorporated organic amendments such as peat, manure, or sawdust into planting holes to improve soil structure, enhance soil moisture retention, and hasten plant establishment. Amending planting holes with organic matter may reduce compaction; however, plant growth and establishment have not been shown to be significantly improved (Corley, 1984; Hummel and Johnson, 1985; Pellet, 1971; Schulte and Whitcomb, 1975).

Recent studies suggest that vegetative growth and survival rates are improved by rotary tillage aged pine bark throughout the planting bed as opposed to within the planting hole (Banko, 1986; Bir and Ranney, 1991). Similarly, agronomic studies have shown that soil cultivation enhances root growth and improves seedling establishment rates, particularly when accompanied by a layer of surface mulch (Barber, 1971; Cox et al., 1990; Foil and Ralston, 1967; Jones et al., 1969). In addition, increasing planting-hole size, as is done with tilling, improved root growth after transplanting (Watson, 1986; Watson et al., 1992).

Reducing soil compaction enabled roots to colonize the surrounding soil and may have improved the ability of transplants to withstand critical drought periods (Barnett, 1986; Blessing and Dana, 1987; Gilman, 1990). This was important with container-grown plants that had small, fibrous root masses, which frequently reached soil water potentials that inhibited root elongation (–0.5 MPa) within 2 days after transplanting (Costello and Paul, 1975; Watson and Kupkowski, 1991).

Proper site preparation is a major tenet of xeriscaping and is frequently cited as one way to improve plant water relations after planting (Kozlowski and Davies, 1975; Wade et al., 1991). However, little research has evaluated how different site-preparation methods and soil amendments affect shoot growth, plant establishment, drought tolerance, and root growth during the establishment period. The objectives of this study were to determine 1) the effect of pine bark soil amendments on root and shoot growth of Viburnum plicatum var. tomentosum ‘Mariesii’ and 2) if plants grown in pine bark-amended plots are more drought tolerant than plants grown in unamended planting holes or tilled plots without amendments.

Materials and Methods

Sixty uniform, cutting-propagated V. plicatum var. tomentosum ‘Mariesii’ plants grown in 3.8-liter containers were transplanted into greenhouse beds. Before planting, the soil was compacted to a bulk density of 1.61 g·cm⁻³. The soil was a Cecil sandy loam (clayey, kaolinitic, thermic Typic Kanhapludult): 71% sand, 16% silt, and 13% clay with a pH of 5.5 (CaCl₂). Plants were planted 0.91 m apart in 2.75 × 0.91-m plots separated by compacted soil on 2 May 1992. Treatments were 1) planting holes 34 cm in diameter dug to a depth of 18 cm and backfilled with native soil; 2) plots rototilled to a depth of 18 cm; 3) plots amended by adding 7.5 cm of pulverized aged pine bark and rototilled to a depth of 18 cm; and 4) unamended planting holes 34 cm in diameter that were irrigated with 2.5 cm of water per week during the drought (well-watered control). All treatments were irrigated as needed for 108 days. Plants were mulched with 5 cm of pine straw and periodically hand weeded. Sixty-six days after planting, all plants were fertilized with 72 g·m⁻² of granular 19N–8.3K. The average maximum daily irradiance was 549 µmol·s⁻¹·m⁻². Maximum daily temperatures ranged from 18 to 38°C. The 95C : 1N ratio for the pine bark was determined with the CR-12 combustion system (Leco, St. Joseph, Mich.) and a modified Kjeldahl N analysis.
The length of three stems from each plant was measured every 13 days throughout the experiment. Stem growth was expressed as mean relative growth rate: \( \ln L_2 - \ln L_1 / t_2 - t_1 \), where \( \ln \) is the natural log and \( L_1 \) and \( L_2 \) are stem lengths at times \( t_1 \) and \( t_2 \), respectively (Evans, 1972).

Visual quality was assessed before fertilization, and before and after the drought. Plants were ranked on a 5-point scale, with 1 being unacceptable and 5 being excellent.

Before the drought began, six plants from each treatment were harvested to determine the influence of treatments under well-watered conditions. Total leaf area and average leaf size were determined using a leaf area meter (LI-3000; LI-COR, Lincoln, Neb.). Leaf dry weight and stem dry weight were also determined.

All roots outside of the original container root mass were excavated. The average root spread diameter was measured in a straight line from root tip to root tip through the trunk. Mean root spread diameter was calculated from the largest root spread diameter and three other equally spaced diameters (Gilman and Kane, 1991). New roots were separated into two groups: ≤2 mm and <2 mm. Root lengths for each plant were estimated using the line-intersect method (Tennant, 1975). Root dry weights were determined after roots were dried at 70°C.

Seven fully expanded leaves were collected from each plant 65 and 107 days after planting. Tissue was dried at 70°C and ground in a Wiley mill to pass a 20-mesh screen. Nitrogen content was determined using a modified Kjeldahl method with a continuous-flow N analyzer (Lachat Autoanalyzer, Milwaukee).

A 36-day drought was begun 108 days after planting. Predawn (0630 HR) and midday (1400 HR) relative leaf water contents (RLWCs) were determined daily on one fully expanded leaf from each plant. Percent RLWC was expressed as (fresh weight – dry weight)/(turgid weight – dry weight) × 100 (Bennett et al., 1987).

Throughout the drought, the length and width of three newly expanding leaves on each plant were measured daily. After the first set of leaves was almost fully expanded, second and third sets of leaves were measured. Leaf lengths and widths were correlated with leaf area (\( y = -0.35625 + 0.66861x \), \( r^2 = 0.99 \)). Daily relative leaf expansion rates (RLERs) were calculated using \( \text{RLER} = (\ln A_2 - \ln A_1) / (t_2 - t_1) \), where \( \ln \) is the natural log and \( A_1 \) and \( A_2 \) are leaf area at times \( t_1 \) and \( t_2 \), respectively (Sobrado and Rawson, 1984).

During the drought, soil water was monitored every 2 days using time domain reflectometry (1502C Cable Tester; Tectronix, Beaverton, Ore.). Vertically installed rods 15 cm in length were placed 1) within the original container root mass; 2) 5 cm outside the root mass; and 3) 15 cm outside the root mass. The parallel pair transmission rods were 6-mm-diameter steel rods placed 5 cm apart. The volumetric soil water content was calculated using the empirical equation developed by Topp et al. (1980).

Six intact soil cores were collected from each treatment 42 and 150 days after planting. Cores were oven-dried at 105°C, and soil bulk density was determined. Soil moisture retention curves were developed from cores collected 150 days after planting with a low-range pressure-plate apparatus as described by Klute (1986). Pressure settings were 0.05, 1.0, 2.0, 5.0, 10.0, 20.0, 30.0, 50.0, and 100.0 kPa.

The experimental design consisted of a randomized complete-block design with six replications and was analyzed by analysis of variance using the general linear model procedure (SAS Institute, Cary, N.C.).

### Results

**Predrought.** Pine bark soil amendments suppressed the relative rate of shoot elongation beginning 43 days after planting (Fig. 1). After fertilization (66 days after planting), relative shoot growth in amended plots increased from 0.02 cm·cm⁻¹ per week to 0.14 cm·cm⁻¹ per week 95 days after planting. Shoot growth of plants in planting holes decreased linearly beginning 69 days after planting. Similarly, shoot growth of plants in tilled and amended plots began to decrease 95 days after planting.

By 65 days after planting, plants in amended plots developed visual N-deficiency symptoms. Leaf tissue analyses revealed that tilled, planting-hole, and amended treatments had N contents of 2.2%, 2.1%, and 1.1%, respectively. After fertilization and before the drought began, N levels for plants in tilled, planting-hole, and amended plots were 2.4%, 2.4%, and 2.0%, respectively.

### Table 1. Shoot growth, leaf area, and visual quality of *Viburnum plicatum var. tomentosum* ‘Mariesii’ grown in planting holes, tilled plots, and amended plots 100 days after planting.

| Treatment       | Total shoot wt (g) | Shoot : root ratio (g·g⁻¹) | Leaf area (cm²) | Avg leaf size (cm²) | Visual quality |
|-----------------|--------------------|-----------------------------|-----------------|--------------------|---------------|
| Planting hole   | 134.3 a'           | 11.8:1 a                    | 12,319 a        | 58.8 a             | 3.8 ab        |
| Tilled          | 130.1 a            | 9.7:1 a                     | 12,183 a        | 65.1 a             | 4.4 a         |
| Amended         | 79.8 b             | 4.5:1 b                     | 5,535 b         | 24.0 b             | 3.3 b         |

*Means followed by the same letter within a column are not significantly different using Duncan’s multiple range test, \( P = 0.05 \); \( n = 6 \), except visual quality (\( n = 18 \)).*
Root excavations revealed that plants from amended plots had 57% more new root dry weight than plants from planting holes and 32% more root dry weight than plants from tilled plots (Table 2). Because of decreased shoot growth and increased root growth, plants from amended plots had significantly lower shoot : root ratios. Amended and tilled plots had larger root-system diameters than planting holes; however, total root lengths did not differ between treatments. Soil bulk density of amended and tilled plots was 0.98 and 1.26 g·cm–3, respectively.

Drought. Midday RLWCs of drought-stressed treatments decreased with soil drying, while well-watered treatments maintained consistently higher RLWCs. Plants in tilled plots maintained higher RLWCs than plants in planting holes 8, 9, 11, 14, 15, 17, and 19 days after drought (DAD) initiation (Fig. 2). However, after day 19, no differences were observed. Beginning 7 DAD, the RLWCs of plants from amended plots were significantly higher than those of planting holes and tilled plots. Once differences developed, the RLWCs of plants from amended plots were higher than those of planting holes on 20 of 27 days. Similarly, the RLWCs of plants from amended plots were higher than those of tilled plots on 12 of 27 days. Predawn RLWC data followed a similar trend (data not presented).

After the drought began, leaf expansion and final leaf size of all treatments were reduced compared to the well-watered control (Fig. 3). As the drought intensified, plants from amended plots developed more leaf area than those of either tilled plots or planting holes. Plants from amended and tilled plots had significantly higher RLERs than those of planting holes on 8, 11, 13, and 15 DAD (Fig. 4). As the drought progressed, the RLERs of plants from amended plots were significantly higher than those of planting holes and tilled plots. Between 14 and 35 DAD, plants from amended plots had higher RLERs than those of planting holes and tilled plots on 14 of 22 days.

Soil volumetric water content in the root mass and 5 cm from the root mass was similar for all drought-stressed treatments. Soil water determinations, 15 cm from the root mass, revealed that tilled and amended plots had significantly less soil water than planting holes at 15 and 30 cm deep (Fig. 5). Soil moisture release curves showed that amended soils held more water than tilled plots across most pressure settings between 0.05 and 100 kPa (Fig. 6).

Discussion

Predrought. Bark amending induced N deficiencies and decreased shoot growth; however, shoot growth resumed after fertilization. Plants from amended plots remained smaller throughout the experiment because of early N deficiencies. Root excavations suggest that the linear decrease in shoot growth of planting-hole treatments beginning 69 days after planting (Fig. 1) may have been caused by root confinement. Similarly, root excavations suggest that root confinement may have reduced shoot growth of tilled and amended treatments 95 days after planting.

| Root system diam (cm) | Root system New root wt (g) | New root length (m) |
|-----------------------|-----------------------------|----------------------|
|                       | Total ≥2 mm diam <2 mm diam | Total ≥2 mm diam <2 mm diam |
| Planting hole         | 61 c 11.4 b 3.3 b 8.1 b     | 212 a 9.4 c 203 a |
| Tilled                | 87 b 13.6 ab 3.7 b 9.9 ab    | 223 a 10.4 b 213 a |
| Amended               | 111 a 17.9 a 5.6 a 12.3 a    | 283 a 17.8 a 266 a |

Values represent means of six plants. Means followed by the same letter within a column are not significantly different using Duncan’s multiple range test, \( P = 0.05 \).

Harvest data collected 100 days after planting revealed that plants from tilled plots and planting holes had 63% and 68% more dry weight, respectively, than plants from amended plots. Total shoot dry weight, leaf area, and average leaf size of plants from amended plots were all significantly reduced (Table 1). As a result, before the drought began, plants from amended beds had significantly lower visual quality ratings (3.3) than plants from tilled plots (4.4).
Amending plots with pine bark improved soil water retention and reduced soil bulk density. This may partially explain the increased root growth in amended plots. While the improved soil physical environment would increase root growth, the increase in root-system diameter and total root dry weight of plants grown in amended plots may have resulted from amendment-induced N deficiencies. Increased partitioning of dry matter to roots under N-limiting conditions was observed in Betula pendula Roth. by McDonald et al. (1986). Similarly, Brouwer and De Wit (1969) and Ennik and Baan Hofman (1983) observed that root growth increased with decreasing N fertility. Amending soil with pine bark that has a high C : N ratio would limit N availability and increase root growth. This would avail plants to a larger supply of soil water and, thereby, increase drought tolerance.

Drought. The smaller shoot : root ratio of plants grown in amended plots may have been caused by amendment-induced N deficiencies that reduced leaf area and increased root-system size. This more favorable shoot : root ratio enabled plants from amended plots to maintain higher RLWCs during the drought. Maintenance of a higher RLWC suggests greater drought tolerance, since it is a direct measure of plant water status. Our results agree with the findings of Landsberg (1986) and Eghball and Maranville (1991), who reported that, as N fertilization rates increased, leaf water potentials decreased when plants were subjected to drought. If N levels were supra-optimal or if the pine bark amendment had a lower C : N ratio, the observed differences in RLWC may have been reduced.

Root signals control leaf expansion during soil drying by sensing decreasing soil water and increasing soil strength (Passioura and Gardner, 1990). As a result, leaf expansion is a sensitive indicator of water stress (Hsiao, 1973). During the drought, plants from amended plots maintained higher RLERs than those in tilled plots and planting holes, despite having lower N concentrations. Lower N concentrations have been reported to decrease the rate of leaf area development (McDonald et al., 1986; Terry et al., 1983). We expected the lower N leaf contents of plants in amended plots to reduce the RLER; however, plants from amended plots maintained the highest RLERs. We suspect that the reduced mechanical impedance and increased soil water retention of amended plots compensated for any reduction in RLER caused by limited N availability. In addition, the smaller shoot : root ratio of plants in amended plots would reduce the rate of soil water

Fig. 3. Mean cumulative leaf area development of individual leaves measured daily during the drought: n = 54 for the planting-hole, tilled, and amended treatments; n = 18 for the irrigated treatment. Vertical bars are s.e.

Fig. 4. Relative leaf expansion rates (RLERs) of drought-stressed plants. *Tilled and amended plots had significantly higher RLERs than planting holes. *Amended plots had significantly higher RLERs than planting holes and tilled plots using Duncan’s multiple range test, \( P = 0.05 \). Vertical bars are s.e.
holes. While plants grown in amended plots were more drought
tolerant than plants grown in tilled plots, their visual quality and
size were compromised. Site tillage may improve the ability of
transplants to withstand critical drought periods and perhaps
lengthen the time between irrigations without compromising vi-
sual quality. It is unclear whether the increased drought tolerance
of plants from amended plots was imparted by the improved
rooting environment or the N deficiency. Follow-up experiments
are being conducted to determine how pine bark amendments and
different nutritional levels affect drought tolerance in
*V. plicatum* var. *tomentosum* 'Mariesii'.

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