Response of Container-grown Ninebark to Crude and Nutrient-enriched Recirculating Compost Leachates

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Abstract. Ninebark [Physocarpus opulifolius (L.) Maxim] was grown on troughs under greenhouse conditions in 2.5-L containers filled with 100% composted pine bark and fertigated with drip irrigation using the following nutrient solutions: 1) a complete (control) solution, electrical conductivity (EC) of 1.75 dS·m⁻¹, nonrecirculated; 2) solution as in treatment 1 but recirculated; 3) unamended municipal solid waste compost (MSW) leachate, EC 1.75 dS·m⁻¹, recirculated; 4) solution as in treatment 3 amended in order of priority with NO₃⁻N, NH₄⁺-N, P, K, Ca and/or Mg, to match the concentrations in the complete solution, EC 2.60 dS·m⁻¹, recirculated; 5) unamended turkey litter compost (TLC) leachate, EC 1.75 dS·m⁻¹, recirculated; 6) solution as in treatment 5 amended as in treatment 4, EC 2.40 dS·m⁻¹, recirculated. Among the four recirculated compost leachate treatments, shoot (stems and leaves) dry weight of ninebark was least with the unamended MSW, intermediate with amended MSW, and greatest but similar with both unamended and amended TLC. The most growth occurred with the recirculated control solution. Among the four leachate treatments, ninebark grew acceptably well only with recirculated unamended TLC and was similar to this with the nonrecirculated control solution. Three treatments (nonrecirculated control, recirculated control and unamended TLC) showed no nutrient toxicity or deficiency symptoms. Poorer growth responses in the other treatments (amended TLC, amended MSW and unamended MSW) were related primarily to excess salts and/or nutritional disorders due to imbalance(s) in one or more nutrients.

Global concerns about water quality and scarcity, as well as increasing environmental regulations to prevent surface and ground water contamination from nutrient-laden effluents, have prompted the evaluation of alternative sources of water for agricultural irrigation and the recycling of nutrients in plant culture (Fitzpatrick, 1984; Jarecki et al., 2005; Poole and Conover, 1992; Purvis et al., 2000).

Compost leachate is a potential source of water and fertilizer for growing nursery stock (Jarecki et al., 2005; Schwartz, 1985). Composts such as spent mushroom, turkey litter and municipal waste are rich in certain nutrients (Bunt, 1988; Chong, 2002; Schulz and Romheld, 1997), Jarecki (2002) reported increased growth of five tree and one grass species in field plots fertigated with nutrient-fortified pond-collected spent mushroom compost leachate. Michitsch et al. (2003) successfully grew ‘Lynwood’ forsythia (Forsythia x intermedia) in greenhouse hydroponic solutions containing both crude and nutrient-enriched solutions from spent mushroom and municipal solid waste composts, and also from crude wastewater derived from anaerobic digestion of municipal solid wastes. The objective of this study was to evaluate the response of container-grown ninebark fertigated with both crude and nutrient-enriched compost leachates from municipal solid waste and turkey litter composts in a recirculating system.

Materials and Methods

Compost leachates. The compost leachates were prepared as described by Weltzien (1992). Finished municipal solid waste compost (MSW; Wet-Dry Recycling Centre, Guelph, Ont., Canada) or finished turkey litter compost (TLC; Cole Springs Farm, Thamesford, Ont., Canada) was mixed with deionized water (1:1, v/v) and aerated with daily air-stirrings for 7 d at room temperature. The compost-water mixtures were filtered through cheesecloth (28 × 24 threads/2.5 cm²) and then through a 155-mesh screen. The crude leachates [electrical conductivity, EC >11 and 13 dS·m⁻¹ for MSW and TLC, respectively] were dispensed in 30-L batches and frozen at –18 °C. When required, batches were thawed at room temperature and diluted with reverse osmosis-treated water to an EC of 1.75 dS·m⁻¹. The initial chemical composition of the diluted or unamended compost leachates (uMSW and uTLC) are shown in Table 1. Plug-rooted liners of 18 to 20 cm tall common ninebark [Physocarpus opulifolius (L.) Maxim] were grown in 2.5-L (♯1) nursery containers in a greenhouse (93 m²; natural photoperiod) at the University of Guelph, Guelph, Ont., Canada (lat. 43°33′ N, long. 80°15′ W) from 26 Apr. to 19 July 2002. The average day/night temperatures were: 21 ± 0.7 °C/17 ± 0.3 °C from 26 Apr. to 24 May; 22 ± 1.1 °C/18 ± 0.8 °C from 24 May to 21 June; and 23 ± 1.0 °C/19 ± 1.0 °C from 21 June to 19 July. The average relative humidities during these same periods were: 36 ± 14%; 61 ± 13%; and 70 ± 12%, respectively. The substrate was 100% composted pine bark (0.9 to 1.3

Table 1. Initial chemical composition of the six nutrient solutions.a

| Variable | Recommended concn | NRC, RC | uMSW | uTLC | aMSW | aTLC |
|----------|-------------------|--------|------|------|------|------|
| NO₃⁻-N   | <3.0              | 175    | 175  | 175  | 175  | 2.40 |
| NH₄⁺-N   | 100–199           | 147    | 147  | 147  | 147  | 1.75 |
| P        | 6-9               | 39     | 39   | 39   | 39   | 3.9  |
| K        | 150–250           | 156    | 156  | 156  | 156  | 1.75 |
| Ca       | 200–300           | 140    | 140  | 140  | 140  | 1.75 |
| Mg       | 70–200            | 34     | 34   | 34   | 34   | 0.70 |
| SO₄²⁻    | <200              | 144    | 144  | 144  | 144  | 1.75 |
| Cl       | <350              | 0      | 260  | 92   | 260  | 0.26 |
| Na       | <70               | 0      | 194  | 60   | 194  | 0.60 |
| HCO₃⁻    | 150–200           | 13     | 189  | 86   | 189  | 0.42 |
| Zn       | <2.0              | 0.14   | 0.14 | 0.14 | 0.14 | 0.15 |
| Mn       | <1.0              | 0.09   | 0.27 | 0.27 | 0.27 | 0.25 |
| Cu       | <0.2              | 0.04   | 0.05 | 0.05 | 0.05 | 0.07 |
| Fe       | <5.0              | 1.46   | 1.46 | 1.46 | 1.46 | 0.56 |
| B        | <0.8              | 0.19   | 0.19 | 0.19 | 0.19 | 0.30 |
| Mo       | <0.07             | 0.02   | 0.04 | 0.04 | 0.04 | 0.02 |

aNRC = nonrecirculated control; RC = recirculated control; uMSW = unamended municipal solid waste; aMSW = amended municipal solid waste; uTLC = unamended turkey litter compost; aTLC = amended turkey litter compost.

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Table 2. Chemical analysis of the growth substrate before first fertigation.

| Nutrient (mg·L⁻¹) | NO₃-N | NH₄-N | P | K | Ca | Mg | SO₄ | Cl | Na | Fe | Mn | Zn | Cu | B | Mo |
|------------------|-------|-------|---|---|----|----|-----|----|----|----|----|----|----|---|---|
| Mean             | 0.6   | 0.5   | 1  | 27| 4  | 9  | 30  | 3  | 6  | 0.45| 0.05| 0.05| 0.06| 0.01| 0.17| 0.01|
| SE               | 0.17  | 0.2   | 0.7| 0.6| 0.2 | 1.7 | 0.6 | 0.6| 0.032| 0   | 0.006| 0   | 0   | 0   | 0.006|

*Concentration measured using pour-through nutrient extracts.

Each datum is the mean of three samples ± standard error (SE).

Results

Growth response. Among the four recirculated compost leachate treatments, shoot (leaf and stem) dry weight of ninebark (Fig. 1) was least with unamended MSW, intermediate with amended MSW, and greatest but similar with unamended and amended TLC. With unamended MSW, ninebark developed chlorosis and scorched leaf tips within two weeks after first fertigation (26 Apr.). By 24 May, symptoms included marginal scorch, dark brown spots and blottches on both old and new leaves, older foliage senescence and lower leaf abscission. By 21 June, leaf margins were curled. At harvest (19 July), leaves were small and growth was sparse, and present only at the ends of slender shoots. Similar or some variation of these symptoms developed progressively later and in order of decreasing severity: amended MSW (leaves small but dark green; lower leaf abscission about 25% of total canopy at harvest); amended TLC (mild(<5%) leaf scorch by 21 June; and some brown spots and blottches primarily on some older leaves after this date; sprawling growth habit with larger leaves and longer internodes).

In contrast, with unamended TLC and the two control (RC and NRC) solutions, there were no symptoms. Plants grew rapidly in these three treatments and, according to standards of the Canadian Nursery and Landscape Association (CNLA, 2002), attained marketable size even before termination of the experiment. The growth habit was compact and the plants were attractive. Shoot dry weight with uTLC was comparable to that with aTLC, and also with the nonrecirculated control (NRC), but less than with the recirculated control (RC) (Fig. 1). The RC treatment notably produced the greatest shoot dry weight. Stem and leaf dry weights showed similar patterns (Fig. 1), but leaf dry weights for aTLC and RC were similar.

With both TLC solutions, root dry weights (Fig. 1) were similar, comparable with those for NRC and RC, but greater than their MSW counterparts. The shoot/root dry weight ratios were greatest with aMSW, intermediate with aTLC, NRC and RC, and least with the two unamended compost solutions (Fig. 1).

Foliar nutrients. More N, P, Mg, and S tended to accumulate in leaves of ninebark plants grown with TLC than with MSW solutions (Fig. 2). The concentrations of these nutrients were each consistently and positively correlated with each of the growth parameters (Table 3). In contrast, most of the remaining foliar nutrients were negatively correlated with one or more growth parameters.

Nutrient changes in solution tanks. Concentrations of NO₃-N (uMSW), NH₄-N and P (all recirculated treatments), K (uMSW and aMSW), Ca (aMSW) and Mg (uTLC) decreased by between 14% and 87% over the course of the experiment, while concentrations of Mg (except NRC and uTLC), SO₄ (all recirculated treatments), Cl and Na (aMSW and uTLC) increased by between 13% and 98%. The EC values (except NRC and uMSW)
grown ninebark (Chong, 1999). pH values (Fig. 3) are acceptable for container-grown ninebark because values in both amended TLC solutions and the substrates were nearly as high or higher during the experiment and especially closer to harvest. Furthermore, ninebark is considered to be a salt tolerant species (Transportation Association of Canada, 2003). While criteria provided by Reisenauer (1976) suggest that ninebark is salt tolerant to about 355 mg·L−1 of Cl, our data suggest tolerance to near 100 mg·L−1 of Cl and near 70 mg·L−1 Na.

Thus with amended MSW, plants likely were stressed from Na (scorched leaf tips and margins; limited leaf expansion; excess amounts in the leaf tissue, 0.65%), but perhaps not Cl due to the relatively low tissue content (1.03%) (Marschner, 1986; Mathers, 2000).

For best results, using leachates rich in certain nutrients, it is necessary to first dilute and then to amend or fortify with specific nutrients, especially macro-nutrients, that are deficient (Michitsch et al., 2003). In so doing, the initial EC values in the two amended solutions (Table 1) were higher (MSW, 2.60 dS·m−1; and TLC, 2.40 dS·m−1) compared with the unamended or control solutions (1.75 dS·m−1). These EC values are not considered per se to be toxic to ninebark because values in both amended TLC solutions and the substrates were nearly as high or higher during the experiment and especially closer to harvest. Furthermore, ninebark is considered to be a salt tolerant species (Transportation Association of Canada, 2003). While criteria provided by Reisenauer (1976) suggest that ninebark is salt tolerant to about 355 mg·L−1 of Cl, our data suggest tolerance to near 100 mg·L−1 of Cl and near 70 mg·L−1 Na.

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The additional NO$_3$-N (129 mg·L$^{-1}$) in the solution formula (Table 1) may have reduced Cl toxicity symptoms (relative to unamended MSW plants) as NO$_3$-N tends to compete with Cl for uptake (Mills and Jones, 1996).

The impaired root growth with the MSW leachates is interesting since this did not occur with the TLC leachates. Although the plant tissue was not analyzed for heavy metal contents, typical symptoms of heavy metal toxicity (root damage and chlorosis similar to that induced by Fe deficiency; Bergmann, 1992) were not seen. As Cl and Na are the two major constraints for plant growth in medium to high salinity conditions, the notably higher concentrations of these nutrients in the MSW leachate versus the TLC leachate, may have interfered with root development (Baligar et al., 1998; Schwarz, 1985). It is also possible that phytotoxic organic compounds, such as phenols, may have been present in the MSW leachates (Öman and Hynning, 1993; Revel et al., 1999; Shrive et al., 1994).

Using the same MSW leachate source in stationary hydroponic solutions, Michitsch et al. (2003) found that both unamended and amended leachates produced tops and roots of forsythia and weigela equal to or larger than those with a control solution, despite high concentrations of Na (137 to 173 mg·L$^{-1}$) and Cl (288 to 364 mg·L$^{-1}$) in the leachate solutions. This greater tolerance to Na and Cl may be due to difference in species or in part to their adaptation to these salts in solution rather than in solid medium (Zayed, 1987).

With the aTLC treatment, the large foliage, excessively long internodes and sprawling growth habit may have resulted from excessive fertilization (Blom, 2002; Salisbury and Ross, 1992). In this treatment, an essential nutrient, Ca, was added in the form of CaCl$_2$. 

![Fig. 2. Foliar nutrient concentrations of ninebark in response to various compost leachates. uMSW = unamended municipal solid waste; aMSW = amended municipal solid waste; uTLC = unamended turkey litter compost; aTLC = amended turkey litter compost). Leachate treatments with different letters are significantly different by LSD ($P \leq 0.05$). The horizontal dotted lines represent concentrations with the two control treatments. NRC = nonrecirculated control, RC = recirculated control. Comparisons to the controls were made using Dunnett’s test at $P \leq 0.05$. 'Significant difference from NRC. ‘Significant difference from RC.](image-url)
Table 3. Correlations (r) between shoot, stem, leaf and root dry weights and foliar nutrient concentrations in ninebark.

| Foliar nutrient | Shoot          | Stem          | Leaf          | Root          |
|-----------------|----------------|---------------|---------------|---------------|
| N               | 0.90**         | 0.88**        | 0.90**        | 0.83**        |
| P               | 0.91**         | 0.89**        | 0.91**        | 0.80**        |
| K               | −0.42**        | −0.40         | −0.44**       | −0.20         |
| Ca              | 0.35           | 0.31          | 0.37          | 0.16          |
| Mg              | 0.72**         | 0.66**        | 0.75**        | 0.51**        |
| S               | −0.83**        | 0.79**        | 0.83**        | 0.71**        |
| Cl              | −0.78**        | −0.75**       | −0.78**       | −0.58**       |
| Na              | 0.30           | 0.39          | 0.23          | 0.36          |
| Fe              | 0.36           | 0.26          | 0.42**        | 0.16          |
| Mn              | 0.06           | −0.07         | 0.05          | −0.20         |
| Zn              | 0.05           | −0.001        | 0.10          | 0.05          |
| Cu              | −0.48**        | −0.03         | −0.43**       | −0.45*        |
| B               | −0.84**        | −0.77**       | −0.87**       | −0.65**       |

*,**Significant at P ≤ 0.05 or 0.01, respectively; n = 22.

Fig. 3. Substrate EC and pH of ninebark in response to two control and four compost leachate treatments over time. When two regressions were not significantly different at P ≤ 0.05, a common regression (solid line) was fitted. The horizontal broken lines represent the desirable upper and lower EC (1.0 – 4.6 dS·m–1; BCMAF, 1999) and pH (5.5 – 7.0; OMAF, 2003) thresholds for container-grown nursery crops. NRC = nonrecirculated control; RC = recirculated control; uMSW = unamended municipal solid waste; aMSW = amended municipal solid waste; uTLC = unamended turkey litter compost; aTLC = amended turkey litter compost. Regression equations for substrate EC (partial r² = 0.98): NRC and RC, y = 0.28 + 0.55x – 0.063x² + 0.0048x³; uMSW, y = 0.28 + 0.97x – 0.15x² + 0.0065x³; aMSW, y = 0.28 + 0.93x – 0.023x² – 0.0014x³; uTLC, y = 0.28 + 0.89x – 0.16x² + 0.0098x³; aTLC, y = 0.28 + 1.0x – 0.085x² + 0.0044x³. Regression equations for substrate pH (partial r² = 0.93): NRC, y = 7.4 – 0.56x + 0.076x² – 0.0031x³; RC, y = 7.4 – 0.6x + 0.088x² – 0.0037x³; uMSW, y = 7.4 – 0.69x + 0.12x² – 0.0056x³; aMSW, y = 7.4 – 0.78x + 0.11x² – 0.0049x³; uTLC, y = 7.4 – 0.70x + 0.13x² – 0.0061x³; aTLC, y = 7.4 – 0.82x + 0.13x² – 0.0061x³.

to the TLC leachate, which also increased the Cl concentration to 200 mg·L–1 (Table 1). Mild (≤5% of leaves affected) symptoms of apparent toxicity were evident on aTLC plants on 21 June; however, symptoms increased in severity after this date as the concentration in solution increased to 239 mg·L–1. Tissue Ca in uTLC plants was sufficient despite low concentrations in the leachate (near 30 mg·L–1 Table 1). Therefore, the use of CaCl₂ could have been avoided.

Dark brown spots on the older leaves of aTLC plants, similar to those observed on uMSW plants, suggested possible B toxicity; however, the concentration of B (47 mg·kg⁻¹) in the leaf tissue was normal (Gilliam and Smith, 1980). The spotting, in combination with the loss of apical dominance, could have resulted from Mn toxicity, as the leaf tissue concentration (195 mg·kg⁻¹) was highest in this treatment (Marschner, 1986). Further experimentation is required to differentiate the symptoms observed herein, as diagnosing the symptoms of nutritional disorders can be especially difficult when more than one mineral nutrient is deficient or toxic, or when there is a deficiency of one nutrient and, simultaneously, toxicity of another (Marschner, 1986).

Berry et al. (1977), working with container grown plants, found that iron deficiency could be a problem in unamended water. Foliar Fe concentrations with the unamended leachates were lower than with the nonrecirculated control (Fig. 2), but were similar to the recirculated control. Thus, foliar Fe concentrations were not considered to be deficient (Gilliam and Smith, 1980). The concentrations of other micronutrients were higher with the unamended (Zn and Cu) and amended (Zn, Cu, and Mn) compost leachate solutions compared to the control solutions. As reported by Gratten and Grieve (1999), the uptake of Mn, Zn, and Cu can increase in crop plants under salinity stress. Concentrations of Cu were lower than recommended (Gilliam and Smith, 1980) for all treatments. However, control plants showed no symptoms of Cu deficiency, therefore concentrations were considered adequate or tolerable.

Raymond et al. (1998) found that initial substrate EC values were positively correlated with growth of each of four container-grown shrubs. Chong (1999) found that end-of-season growth of three woody species was positively correlated with early-season [‘Minnesota Snowflake’(mockorange) (Philadelphus × virginalis) Rehd. ‘Minnesota Snowflake’) and midseason [silverleaf dogwood (Cornus alba L. ‘Argenteo-marginata’) and variegated weigela (Weigela florida) (Bunge.) A. DC. ‘Variegata Nana’)] substrate EC readings. In this study, we found substrate EC positively correlated with shoot dry weight on the final sampling date (r = 0.79*). The (a) upward trend in substrate EC throughout the 12 week study for all leachate solutions, except uMSW, and (b) above-recommended EC values observed in the two amended solutions during the later
half of the study, and also in the two control solutions close to harvest (Fig. 3), suggest that to maintain container nursery plants for a longer period of time would likely require periodic emptying of the solution tanks (Zekki et al., 1996) and/or flushing of the substrate with water to reduce the possibility of toxic salt buildup (Resh, 1989).

Conclusion

In a comparative study using recirculated turkey litter and municipal solid waste compost leachate solutions as nutrient sources, each unamended or fortified with extra nutrients, container-grown plants grew acceptably well only with the unamended turkey litter leachate. In this solution, the concentration of nutrients, especially NO₃⁻, P, and K were close to or within normal ranges. Comparative quantitative data for growth, foliar nutrient contents and nutrient changes measured in the treatment solutions and container substrate during the experiment, indicate that poorer results with the other leachates were due to imbalances or disorders of one or more nutrients. Notwithstanding the preliminary nature of this study, the results show promise for using and recirculating compost leachates in commercial production.

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