Engineered Substrates and Irrigation Management to Improve Nitrogen, Phosphorus and Water Retention in Nursery Container Production

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Project justification and objectives

Agricultural runoff containing nitrogen and phosphorus has been implicated in the eutrophication of aquatic ecosystems resulting in environmental and economic harm. Moreover, nitrate concentration in drinking water above 44.2 ppm has been associated with methemoglobinemia in infants while phosphorus is often the most limiting factor in eutrophication in freshwater systems, where concentrations of phosphate above 0.9 ppm are sufficient for algal blooms (Carpenter, 2008; Rubio-Armendáriz et al., 2022). Phosphate concentrations have been reported for nursery runoff to be up to 15 ppm. Nitrates are often found at higher concentrations in runoff, ranging from 0.1-135 ppm (Abdi et al., 2021; Altland et al., 2018; Pershey et al., 2015; Shreckhise & Altland, 2022; Warsaw et al., 2009). Various treatment systems have been identified to remediate these two contaminants in runoff water after they have leached out of containers. We proposed the use of engineered substrates and microirrigation applications to improve nutrient and water retention in containerized nursery production. Stratified substrates are expected to reduce the irrigation needed and increase nitrogen and phosphorus retention within the container. Microirrigation applications would reduce leaching, further improving nutrient retention. Substrates were amended with $FeSO_4$ to improve phosphorus retention by increasing anionic binding sites. The combination of stratified substrate, $FeSO_4$ amendment and reduced irrigation volume is expected to result in reduced water extraction, reduced leaching of nutrients from the root zone, reduced irrigation return flow generation and reduced nutrient movement in any irrigation return flow that does occur. Therefore, this research aimed to evaluate the impact of conventional and stratified substrates with/without a $FeSO_4$ amendment on leaching fraction and leachate nitrate and phosphate concentrations from nursery containers.

Methods

This study was located at the Horticulture Teaching and Research Center, Michigan State University. All plants were grown in 10.2 L containers and fertilized with 54 grams of 17%N - 2.6% P - 9.9% K controlled-release fertilizer in June 2022 and May 2023. Irrigation was applied using spray-stakes to individual containers. The taxa we used for this study include 1) *Spirea x* 'Tracy', 2) *Hydrangea macrophylla* 'SMHMES14', 3) *Buddleja x* 'Miss Violet', 4) *Ilex crenata* 'FARROWSK6', 5) *Hydrangea paniculata* 'Limelight', 6) *Physocarpus opulifolius* 'Seward', 7) *Cornus sericea* 'SMNCSBD', 8) *Cotinus coggygria* 'MINCOJAU3', 9) *Rosa x* 'ChewDelight'. We used four treatments, 3 replicates per treatment, and 45 plants per replicate. Treatments used:

1. 85:15 (by vol.) pine bark:sphagnum peat (Conv).
2. 85:15 pine bark: sphagnum peat with 3 kg/ m^3 $FeSO_4$ $7H_2O$ (Conv+Fe).
3. Stratified substrate (Strat) fine fiber peat amended bark substrate atop a coarse bark substrate.
4. Stratified substrate amended with 3 kg/m^3 $FeSO_4$ $7H_2O$ in the bottom layer (Strat+Fe).

The total volume of water applied to each replicate was measured and used to compare the water footprint between treatments. The growth index (average of the widest width, perpendicular width, and height) of 3 plants from each taxon per replication was measured bi-monthly to assess plant establishment and growth rate. Leachate from 9 plants (3 taxa) per replicate was collected weekly to measure the leachate volume, electrochemical properties, and macronutrient concentrations. Analyses of leachate included total and species of nitrogen and phosphorus, potassium, magnesium, and calcium via combustion, induced coupled plasma spectrometry post persulfate digest, and ion chromatography, respectively, at the USDA-ARS laboratory in Wooster, OH.

In June 2023, above-ground and below-ground biomass was harvested, controlled-released fertilizer applied in June 2022 was collected, and substrate samples were collected. This was for one plant rep, per treatment rep (108 containers in total, **Figure 1**.). By the end of the season, controlled-release fertilizer (CRF) applied in May 2023 will be collected, above-ground and below-ground biomass will be harvested, and substrate samples will be collected. Analysis of nutrients will be conducted for these samples. We will continue to measure leachate volume, collect leachate samples, measure growth index, and measure volumetric water content until late September 2023, with analytical costs covered using Michigan State University Project GREEEN funds. Finally, the initial physical properties of the container system will be compared to physical properties post-experiment.

Figure 1. Sampling of above-ground biomass, below-ground biomass, substrates (top half and bottom half), and controlled-release fertilizer.

Preliminary results

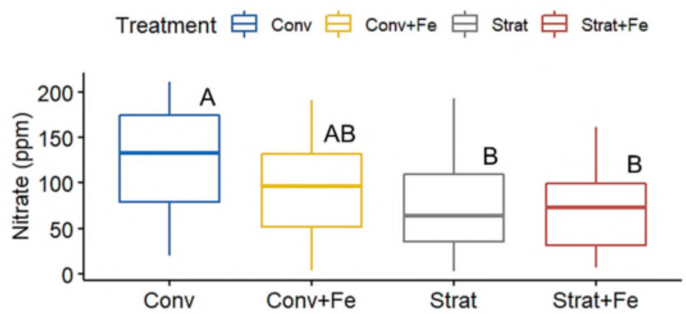

Figure 2. Leachate nitrate content in conventional and stratified substrates with/without a $FeSO_4$ amendment.

It is hypothesized that the use of stratified substrates and the incorporation of CRF in the top half of the container results in a more efficient reallocation of nutrients along the container, which results in reduced nutrient leaching. As observed in **Figure 2**, lower nitrate content was reported in the Strat treatment (12 ppm, $p = 0.03$) and Strat+Fe (13 ppm, $p = 0.02$) compared to the Conv treatment (23 ppm).

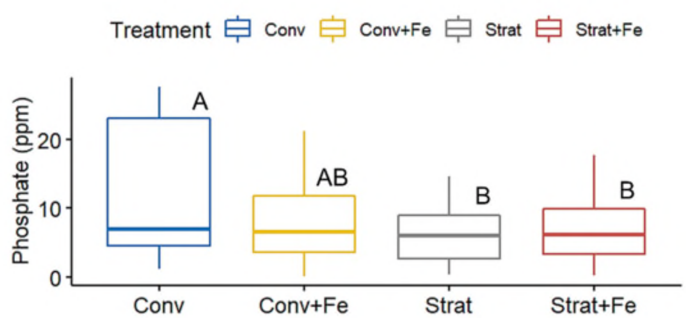

Figure 3. Leachate phosphate content in conventional and stratified substrates with/without a $FeSO_4$ amendment.

Similarly, as observed in **Figure 3**, lower phosphate was reported in Strat treatment (6.33 ppm, $p = 0.01$) and Strat+Fe (6.74 ppm, $p = 0.02$) compared to Conv treatment (11.78 ppm).

However, nutrient analysis of substrates is still in process to compare the nitrate and phosphate concentrations among treatments and plant species.

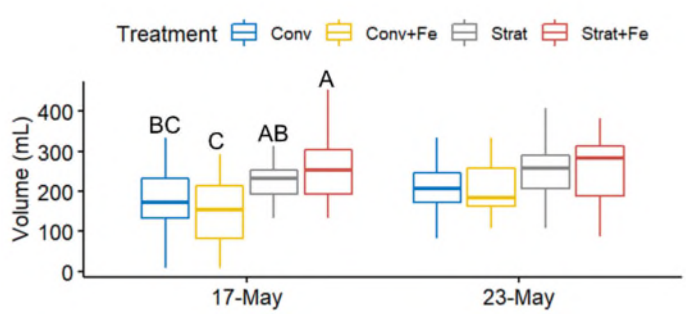

Figure 4. Leachate volume in conventional and stratified substrates with/without a $FeSO_4$ amendment.

As observed in **Figure 4**, a higher leaching fraction was reported in the Strat treatment (38%, $p = 0.04$) and Strat+Fe (41%, $p > 0.01$) compared to the Conv treatment (32%). Additionally, the leaching fraction in the Strat treatment (38%, $p > 0.01$) and Strat+Fe treatment (41%, $p > 0.01$) was higher compared to the Conv+Fe (31%). Although no differences were reported in the second sampling, a similar trend was observed.

Although stratified substrates have been designed to reduce infiltration speed and increase water-holding capacity in the upper half of the container profile (Criscione et al., 2022; Milks et al., 1989), significantly greater dry masses have been reported in the upper half compared to the lower half of the container, which alters pore distribution and influences water movement and retention (Criscione et al., 2022; Fields et al., 2022).

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