

Title: Nitrogen Supply and Partitioning in Managed Understories of Organic Apples

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Abstract: Sustainable methods of nitrogen (N) fertility and weed management in organic production systems remain a challenge. Composted animal manures are commonly used to supply N, but only a fraction is in immediately available forms with the remainder released slowly as a result of microbial driven processes. These amendments come at a high cost, and excess application may result in salt damage, nutrient and profit loss, and environmental degradation. Systems are needed that will help reduce N fertility costs, mitigate N loss, and enhance availability at times corresponding with critical tree uptake periods. Intensive cultivation, a common management practice used to control weeds, can disrupt soil quality by degrading soil structure and accelerating nutrient cycling and organic matter loss. Alternative systems with reduced soil disturbance, such as organically approved herbicide or residues with natural herbicidal abilities, wood chip mulch, and maintenance of living cover crops, may help to ameliorate soil quality and alter soil fertility dynamics. Thus to address the needs of Washington organic orchardists for sustainable N fertility and weed management, an integrated study was established in spring 2005 to determine N-use efficiency and optimize fertility guidelines in these alternative systems.

Objectives:

1. Determine the influence of understory management practices on the mineral nutrient status of organically managed apple trees.
2. Determine how understory management practices influence N and C partitioning between cover crop, wood chip residue, and soil components in organic apple orchards.
3. Develop an extension publication on organic orchard floor management alternatives for the Pacific Northwest.

Procedures to meet above objectives: The trial was implemented in May of 2005 and is being conducted at the Wenatchee Valley College organic orchard research site in East Wenatchee, WA. Orchard floor management strategies include: no disturbance + clove oil herbicide, no

disturbance + wood chip mulch, minimal disturbance with integration of Brassica (*S. alba*) seed meal residue, reduced disturbance through the use of a Wonder weeder, and living cover mulch crops previously identified by Granatstein et al. (2004) as producing sufficient biomass and effective weed control ability (Table 1). The living cover mulch crops are either planted on the entire plot or limited to a strip within the tree row in a “sandwich” system. Each wood chip, Wonder weeder, and living mulch strategy is split into subplots to compare different rates of N application. In addition, small plots with zero fertilizer amendments were included as a control.

Table 1. Summary of treatments in Integrated Multiple Mulch Trial

Weed Control	Soil Disturbance	Compost Fertilizer
Control	Low	0X
Brassica Seedmeal Herbicide	Medium	0.5X
Clove Oil Herbicide	Low	1X
Wood Chip Mulch	Low	1X, 1.5X
Living Mulch Legume	Low	0.5X, 1.5X
Living Mulch Non-Legume	Low	0.5X, 1X, 1.5X
Cultivated	High	0.5X, 1X, 1.5X
Sandwich Legume	Medium	1X
Sandwich Non-Legume	Medium	1X

Upon evaluation of our first growing season, it became apparent that we undershot our initial fertility rates due to low N availability in the compost amendment. As a result, we applied soluble fertilizers to help supplement tree N needs but observed substantial leaching of the remaining fertilizer from the active soil zone over the winter season. To address this issue, we conducted laboratory analyses to estimate the fraction of available N we could expect from compost during the current growing season and adjusted our 1X fertility rate upward to reflect this. In addition, we divided the total compost amendment into three equal split-applications to reduce any potential salt damage that might arise from the high amount of compost needed to meet tree N needs and to help provide available N throughout the critical tree uptake period.

To better track N movement in the alternative systems, we initiated a ¹⁵N-monitoring component in our 1X Wonder weeder, wood chip, and living mulch legume treatments. A pre-determined amount of ¹⁵N-enriched fertilizer was applied to the compost amendment and allowed to incubate prior to field application. Samples of the initial compost amendments, wood chip and living mulch residues, soil, and tree leaves were evaluated to track ¹⁵N movement using a mass spectrometer. Due to inadequate weed control with our single Brassica amendment in 2005 and given data collected in a different study on the short-term efficacy of these amendments for weed suppression, we increased our Brassica amendment to include three separate applications in 2006.

Chemical and biological indicator analyses were carried out using pooled soil cores collected each spring (including baseline), summer and fall of 2005 and 2006. All soil samples were analyzed for total available N and potentially available N as determined by KCl extraction. In addition, fall samples from a subset of the treatments were analyzed for total C and N, active (particulate organic matter fraction) C and N, mineralizable C, and dehydrogenase enzyme activity. Samples collected in summer 2006 were evaluated for total nematode

abundance and diversity using a molecular procedure (T-RFLP). Statistical analyses of T-RFLP data and species identification are in progress. Apple tree leaves were selectively sampled in late July and sent to an independent laboratory for analysis of N as well as 12 other mineral elements. Tree cross-sectional area was measured in the fall following soil collection. Local orchard managers and industry representatives with extensive experience in organic orchard management were interviewed using a questionnaire focused on N dynamics.

Progress towards objectives: We have generated an extensive amount of data and can begin to make conclusions regarding alternative management treatments. In the short-term, the standard practice of weed control using extensive tillage successfully eliminates nutrient and water competition and results in trees with good growth and acceptable levels of leaf N and most other essential nutrients. There were no significant differences in tree growth among the N application levels within this treatment, indicating that we met N needs and maximized nutrient-use efficiency at the low .5x N rate. In contrast, this treatment ranks among the lowest in available N and C pools and soil faunal abundance and activity, indicating loss in soil quality that may have negative consequences on nutrient cycling and tree health in the long-term. Tree leaf Ca and Zn were below acceptable levels in all treatments, but were among the lowest in the cultivated treatments along with leaf P. Research has shown that root mycorrhizae, which are negatively impacted by soil tillage, can increase tree uptake of these elements. In our study leaf concentrations of these elements were greatest among undisturbed treatments, which suggests that reduced mycorrhizae in more disturbed treatments may have been responsible for the reduced Ca and Zn.

None of the reduced-disturbance, alternative treatments resulted in a combination of good growth and acceptable levels of leaf N. Although the 1X legume and non-legume treatments had the greatest amount of leaf N and were well within acceptable limits, all living mulch treatments continued to exhibit the least tree growth. In contrast, these treatments ranked the highest in terms of all soil quality indicators, which implies long-term improvement that may lead to increased nutrient-use efficiency. Analyses of ^{15}N confirm initial immobilization in living mulch residue, that along with increased availability of labile C may help to retain N in the active soil zone. Given the high amount of available soil N in these treatments and an insignificant response to increased compost amendment, low tree growth may be the result of competition for moisture by living cover crops, and/or a result of severe stunting in year one. Sandwich treatments were intermediate in tree growth and leaf nutrients. Application of wood chip mulch resulted in good tree growth, but tree leaf N remained well below desirable levels. Increasing compost amendment led to higher leaf nutrient levels, but not enough. While ^{15}N analyses indicate initial immobilization of N in the wood chip residue, available N slowly cycles into the soil and is subsequently lost from the system as confirmed by analyses of total and available N in the active soil fraction. In this treatment, we seem to have abundant soil moisture that enhances tree growth but may also be contributing to N loss through denitrification or leaching mechanisms. Despite substantial inputs of total C in wood chip mulch, soil pools of labile C and soil faunal abundance and activity are among the lowest of all treatments, which may negatively impact long-term soil and tree health. Application of clove oil herbicide resulted in lower leaf N and tree growth in comparison to cultivated treatments and had no impact on soil quality parameters. In contrast, brassica amendment resulted in relatively good tree growth, greater soil N and C availability, and soil faunal biomass. However, leaf N did not reach acceptable levels and many of the other essential nutrients were lowest in this

treatment. Tree leaf chlorosis was observed following the early season Brassica amendment in 2006 and may be the result of reduced soil iron availability that has been observed in other studies.

Our results indicate that during orchard establishment there is a trade-off between maximizing tree growth and improving soil quality, which may have long-term impacts on orchard productivity and fruit quality. Although maintenance of a living cover understory results in substantial soil quality improvement, it severely competes with young orchard trees and may be a more desirable alternative after trees have become established.

In addition to the field and laboratory research, 5 interviews with experienced orchardists were completed this year, and 2 more are planned toward Objective 3.

Outputs: Preliminary results were presented in July at the annual meeting of the American Society of Horticultural Sciences held in New Orleans, LA, and final results will be presented at the Western Nutrient Management Conference to be held this March in Salt Lake City, UT. Two manuscripts are in preparation, including a research article to be submitted for publication in a peer reviewed journal and an overview of management implications for inclusion in the proceedings of the Western Nutrient Management Conference. In addition, a summary of our results will be combined with information obtained during stakeholder interviews to construct an extension publication focused on nitrogen fertility management in organic orchard systems.

Impact: Data generated in this study have allowed us to evaluate N availability of different compost amendments and the impact of alternative organic understory management practices on N availability and tree uptake. Combining these results with extensive experience of Pacific Northwest producers will allow us to make more site-specific recommendations for growers transitioning to or currently in organic apple production in Washington State and throughout the Pacific Northwest.

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