Mulch addition increase growth, yield, soil C and N in a managed full-sun coffee system in Hawaii

Adel Youkhana  Travis Idol

Department of Natural Resources and Environmental Management, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, Hawaii 96822

Corresponding Author: 808-956-2620  adel@hawaii.edu

Introduction

• Climate change is an enduring challenge for sustainability (Fig. 1).
• Increased use of trees in agriculture can remove excess CO₂ from the atmosphere, storing it in biomass and soil-C (Fig. 2).
• Studies with coffee shaded by an interspecific Leucaena hybrid (variety “KX2”) demonstrate rapid potential for increasing soil C and N while balancing coffee yield.
• One alternative for full-sun coffee is to grow trees separately and use as a source of mulch.

Objectives

• Evaluate the potential of chipped pruning residues of Leucaena variety KX2 as a mulch source for full-sun coffee production in a cut-and-carry system
• Investigate:
  (1) mulch decomposition, N mineralization, and changes in major biochemical constituents over one year
  (2) changes in soil CO₂ efflux and total soil C and N after mulch additions over 3 years
  (3) coffee tree growth and yield in plots amended with mulch vs those where equivalent amounts of inorganic N were added

Materials and Methods

Site - CTARH Waimanalo Research Station, Honolulu, Hawaii.
• Eight open-grown coffee assigned to mulch or no-mulch treatments.
• Leucaena-KX2 coffee grown in adjacent stand and polluted at 1 m every year.
• Material chipped and added on an equal-area basis. Approx 65 Mg C ha⁻¹ of mulch dry matter was added over a 3 year period, including ~27.5 Mg ha⁻¹ of C and ~350 kg ha⁻¹ of N.
• No-mulch plots fertilized with equivalent amounts of inorganic N for comparison.
• Microplot decay unit established in each plot with four 10-cm diameter cores.
• 50g fresh-weight of mulch placed inside each cylinder (Fig. 4).
• Mulch removed from at 3-mo intervals to estimate loss of mass, C, and N and changes in biochemical composition.

Results (cont.)

Soil C and N

<table>
<thead>
<tr>
<th>Year</th>
<th>No Mulch (carbon, Mg ha⁻¹)</th>
<th>Mulch (carbon, Mg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>45.60</td>
<td>45.60</td>
</tr>
<tr>
<td>2008</td>
<td>38.80</td>
<td>48.50*</td>
</tr>
<tr>
<td>Change</td>
<td>-6.80*</td>
<td>2.90</td>
</tr>
<tr>
<td>Nitrogen (Mg ha⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>2008</td>
<td>2.40</td>
<td>3.92*</td>
</tr>
<tr>
<td>Change</td>
<td>-0.10</td>
<td>1.42*</td>
</tr>
</tbody>
</table>

• Mulch increased soil C, N and CO₂ efflux (Table 1)
• Decrease in bulk density over time masked changes in soil C concentration in mulch-addition plots

Coffee Growth and Yield

<table>
<thead>
<tr>
<th>Growth and yield characteristics</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main stem (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant H (cm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIH content (SPAD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield (g) / tree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit / node</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nodules / lateral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral / stem</td>
<td></td>
<td></td>
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<tr>
<td>100 green beans (g)</td>
<td></td>
<td></td>
</tr>
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• Mulch increased growth and yield components of coffee in both years (Table 2).
• Leaf chlorophyll content significantly greater in 2008

Materials and Methods (cont.)

• Biochemical composition determined using sequential fiber digestion analysis (Fig. 5).
• Soil samples and bulk density cores from 0.0-20 cm collected to monitor changes in soil C and N (Fig. 6).
• Soil-surface CO₂ efflux (µ mol m⁻² sec⁻¹) measured monthly in decay microplots using portable infrared gas analyzer attached to a soil respiration chamber (Fig. 7).
• Coffee leaf chlorophyll concentration (Fig. 8), main stem height and diameter, and components of fruit yield measured from 2006-2008.
• Annual green bean yield estimated for 2007 and 2008.

Statistics:

• Mulch decomposition fitted to a negative exponential decay model: L(t) = L₀ e⁻ᵃᵗ
• Repeated measures multivariate analysis of variance (MANOVA) used for comparison of changes in soil C and N.
• One-way ANOVA used to analyze coffee growth and green bean yield each year.

Materials and Methods

Table 1: Changes in soil C & N & CO₂ efflux due to mulch

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Results

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• Significant change between 2006 and 2008
• Significant difference between mulch and no-mulch.

Fig. 10: Mass loss from mulch biochemical components

Conclusions

• Leucaena mulch added to full-sun coffee improved soil C and N, sequestering ~17% of added mulch.
• Mulch benefited coffee growth and yield beyond comparable inorganic N fertilization.
• Thus, a cut-and-carry system for soil C sequestration and crop growth improvement is a viable alternative to overhead shade for capturing benefits of trees in coffee and likely other perennial cropping systems in the tropics.

Related studies