Belowground Impact of Napier and Guinea Grasses Grown for Biofuel Feedstock Production

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Introduction

- High yielding C_4 tropical grasses such as *Pennisetum purpureum* (Napier grass, var. Bana) and *Panicum maximum* (Guinea grass) prospected as lignocellulosic feedstocks for biofuel production
- U.S. Dept of Energy funded project is investigating the potential of 25 grass varieties as a biofuel feedstock.
- One aspect is to assess the impact of feedstock grasses on soil carbon dynamics.

Grass cultivation as carbon sink

- Carbon input quantity
  - Carbon input from plant is major source of soil carbon (Six et al., 2004).
  - Napier grass has root mass of 3000 g m^{-2} in 0-60 cm depth (Singh, 1999).
  - Above ground yield of up to 49 Mg of dry fiber ha^{-1} yr^{-1} (Kinoshita et al., 1995).
  - Varietal differences in root biomass (Singh, 1999).
- Carbon input quality
  - Tissue chemistry such as lignin content, lignin to N ratio affect decomposition rates of plant roots (Johnson et al., 2007).
  - Less decomposition -> more carbon input to soil.


Figure 1. Schematic of University of Hawaii multidisciplinary biofuel development project


Figure 2. Mechanical harvest of Bana grass

Figure 3. Photos of field plots right after harvest and 4 moths after harvest, 2010

Goals

- Measure both quantity and quality of belowground carbon input and observe their impacts on soil carbon pools
- Determine variety that is best suited for carbon sequestration and biofuel production within the whole system context

Objectives

1. Measure the quantity and quality of belowground carbon input
2. Observe and explain the differences between varieties and species
3. Determine how those two factors affect soil carbon content after 2 ratoon cycles

Hypotheses

1. Roots with recalcitrant characteristics will result in lower decomposition rate than one with more labile nature
2. Grass varieties with higher quantity of belowground carbon input and recalcitrant belowground biomass characteristics result in higher amount C stored in soil C at the end of 2 ratoon cycles of those grasses. On the time frame of this study, these increases should be apparent in active and intermediate carbon pools.

Materials and Methods

Experimental Design

- Site: Waimanalo Agricultural Research Station (21º 20'15" N, 157º 43' 30" W).
- Soil: Waialua gravelly clay variant (a very-fine, mixed, superactive, isohyperthermic Pachic Haplustoll).
- Randomized complete block of 2 x 3 m^{-2} plots with 25 grass varieties and 4 reps.
- The treatments are varieties.
- 8 out of 25 varieties were chosen as varieties of interest.
- Seedlings were planted on Oct. 2009, harvested on March 2010, and will be harvested on Nov. 2010.
- Two controls: 4 plots each in bare cultivated soil and grassed, fallow areas adjacent to the study site.

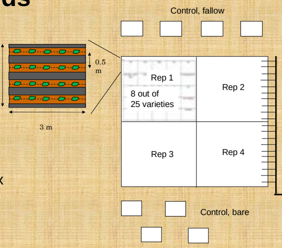

Figure 4. Field map of the study site

Species	Varieties	Island of Origin	Abbreviation
Guinea	Oahu Guinea 03	Oahu	OG03
	Oahu Guinea 05	Oahu	OG05
	Kauai 06	Kauai	K06
	Maui Guinea 04	Maui	MG04
Napier	Purple Napier	Hawaii	Purple
	Local Napier	Hawaii	Local
	Pearl Millet x Dwarf Napier	Hawaii	P x D
	254	Oahu	254

Table 1. List of varieties observed in the study

Materials and Methods

Total Belowground Carbon Flux (TBCF)

- TBCF is based on mass balance equation which characterize the plant's ability to sequester carbon belowground and expressed as (Litton et al., 2007):

$$\text{TBCF} = \text{Soil } CO_2 \text{ efflux} - \text{Litter fall} + \Delta \text{Soil Carbon Pools}$$

- Soil CO_2 flux is measured monthly with Li6400 Portable Photosynthesis system (5 collars/plot).
- Annualized total CO_2 flux will be calculated from monthly flux rates of one year.
- Two soil cores per plot will be collected for root biomass and soil carbon content.
- Root biomass before and after will be collected on 0.5 mm sieve after dispersing soil with 10 % sodium hexametaphosphate (HMP) solution.
- Soil carbon content will be analyzed with Elemental Analyzer.
- Litterfall will be estimated at harvest.


Figure 5. Li 6400 portable photosynthesis system with soil respiration chamber.


Figure 6. Wet sieved root biomass after dispersion by 10 % HMP

Preliminary Results

Soil CO_2 Flux

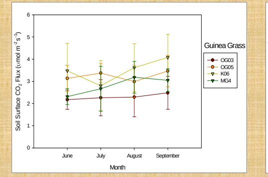

Figure 7 . Monthly soil surface CO_2 flux for Guinea Grass varieties

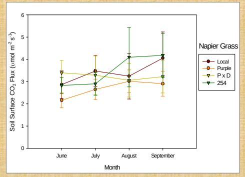

Figure 8 . Monthly soil surface CO_2 flux for Napier Grass varieties

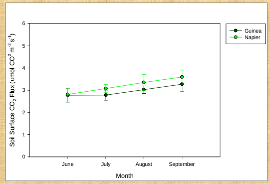

Figure 9. Monthly soil surface CO_2 flux averaged for two species

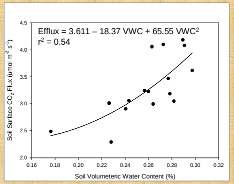

Figure 10. Quadratic relationship between soil moisture vs CO_2 Flux

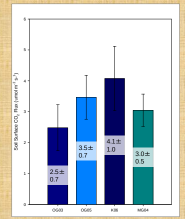

Figure 11. Soil CO_2 flux of Guinea grass varieties for September 2010

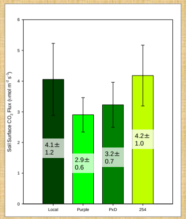

Figure 12. Soil CO_2 flux of Napier grass varieties for September 2010

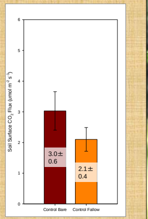

Figure 13. Soil CO_2 flux of controls for September 2010

Materials and Methods

Root Tissue Chemistry

- Root tissue collected from each of 4 replicated plots from each varieties.
- Samples will be analyzed for neutral and acid detergent fiber, acid detergent fiber (NDF& ADF) and permanganate lignin (PML)(Van soest, 1963), and total C and nitrogen (N) contents.
- Van soest method is coarse estimates of solubles, hemicellulose, cellulose, and lignin in tissue sample, where:

Soluble (non structural components) = 100 - NDF
Hemicellulose = NDF – ADF
Cellulose = ADF – PML
Lignin = PML

- Root tissue (0.5 g) will be buried on soil in nylon litter bags (5 x 5 cm^{-2}, 132 micron mesh).
- Bags will be harvested on 1st, 2nd, 3rd, 5th, and 7th months
- Mass loss over time will be plotted to determine decay rates.
- Regression analysis will be used to analyze the influence of tissue chemical variables on decay rates.


Figure 14. Litterbag filled with root tissue used for litterbag decay study


Figure 15. Litterbags will be buried at 10 cm depth in 45º angle

Preliminary Results

Root Tissue Chemistry

- Root tissues were collected on April 2010 from four reps, homogenized, and analyzed for NDF, ADF, and PML.
- Samples were analyzed for C and N content by elemental analyzer.

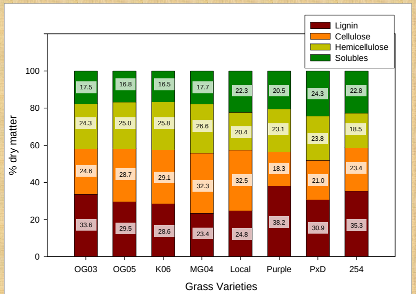

Figure 16. Root tissue soluble, hemicellulose, cellulose, and lignin contents of grass varieties: preliminary results

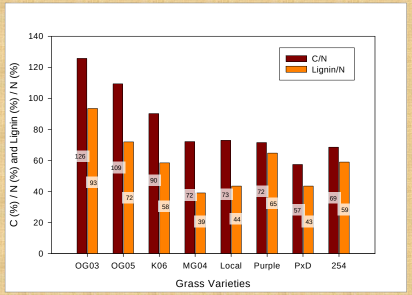

Figure 17. Root C/N and Lignin/N ratios of grass varieties: preliminary results

Discussion

TBCF

- Soil CO^2 flux is highly variable probably due to irrigation inequality problem.
- Irrigation tubes could be ruptured on half way resulting in wet (Rep 2 & 4) and dry (Rep 1 & 3)
- Tubes will be fixed on next harvest at Nov. 2010.
- CO^2 flux vs moisture curves will be developed for all 8 varieties to predict and gap fill monthly flux data

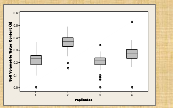
Figure 18. Boxplots of soil VWC separated by replicates

Root Tissue Chemistry

- Preliminary results showed lignin/N ratio varies with varieties, suggesting the possible variability in decay rate.
- More elaborate techniques such as Pyrolysis field ionization mass spectrometry (PyFIMS) might be utilize for precise estimate of chemical composition.

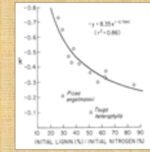
Figure 19. Decomposition constant (K) against Lignin/N ratio from: Melillo et al. 1982

Future Research

- Soil cores will be obtained and analyzed for bulk density, root biomass, dissolved organic carbon, and nutrient contents.
- Soil cores will be obtained in April 2011 to estimate carbon contents after 2 ratoon cycles of growth
- Soil carbon content differences between 2010 and 2011 samples will be sequestration rates.
- Comparison will be made with fallow and bare soil control plots.
- ANOVA will be used to compare varieties on decay rates and carbon sequestration rates.
- Regression analysis will be used to determine influences of carbon quantity and quality variables to carbon sequestration rates.
- Variety that is suited for biofuel may not be suited for carbon sequestration.


Figure 20. Soil coring using slide hammer from the field plots

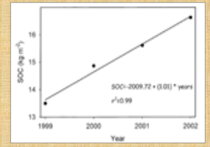
Figure 21. Example of carbon sequestration rate derivation from (Frank, Berdahl, Hanson, Liebig, & Johnson, 2004)

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