Discover the Cover!

Soil Health
Planning Principles & Cover Crop Management Strategies for the Virgin Islands

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Soil Health What is It?

- The continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans
  - Nutrient cycling
  - Water (infiltration & availability)
  - Filtering and Buffering
  - Physical Stability and Support
  - Habitat for Biodiversity

Soil Health
Planning Principles

- Manage more by Disturbing Soil Less
- Use Diversity of Plants to add diversity to Soil Micro-organisms
- Grow Living Roots Throughout the year
- Keep the Soil Covered as Much as Possible

Goal: To create the most favorable habitat possible for the soil food web

Soil Health Principle 1

Manage More by Disturbing Soil Less

- Agricultural Disturbance Destroys Dynamic Soil Properties
- Destroys “Habitat” for Soil Organisms
- Creates a “Hostile” Environment
- Three Types of Disturbance
  - Physical (tillage)
  - Chemical (Synthetic Fertilizer and Pesticides)
  - Biological (overgrazing)

What Happens to the Soil:

Tillage Impacts	No Tillage
• Destroys aggregates • Exposes organic matter to decomposition • Compacts the soil • Damages soil fungi • Reduces habitat for the Soil Food Web • Disrupts soil pore continuity • Increases salinity at the soil surface • Plants weed seeds	• Soil pores remain continuous • Soil aggregates form and are not destroyed • Soil Food Web increases and diversifies • Weed seeds are not planted • Water is captured and stored • Bulk density decreases • Soil fungi and earthworms increase • Microarthropods increase (>20% of nutrient cycle)

Soil Disturbance Impacts in Tropical Regions

- Farm management may need to be different in rainy and dry seasons.
  - Hot Humid Conditions with High Evapotranspiration
  - High ambient air temperatures and solar radiation
  - Increased microbial activity
  - Rapid Decomposition rates
  - Increased microbial activity
  - High soil temperatures
  - High nutrient volatization of nutrients

Results in Rapid SOM loss and difficulty to increase SOM

Tropical Cropping System (High Intensity)

- 3 crop rotation cycles per year (Includes Cover Crop Rotation)
- Amount of soil disturbance
  - 5 to 6 tillage passes to incorporate cover crop
  - 3 to 4 tillage passes to incorporate vegetable crop residue
  - 12 tillage passes per year with a tractor and implement
  - Degrades soils
  - Loss of soil organic matter

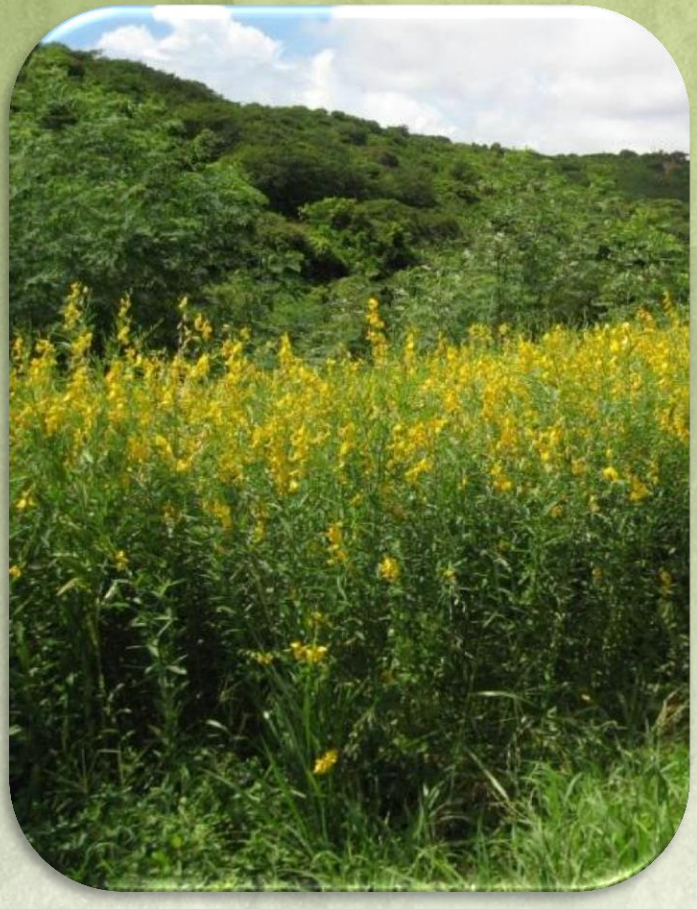
- What impact on soil organic matter can cover crops have?

Grass Cover Crops - Monocultures

Sorghum-sudan
var. Mega Green

Pearl millet
var. Mega Mill

Legume Cover Crop and Grass/Legume Mixtures



Sunn hemp

Sunn hemp and Pearl Millet

Conventional Full Tillage Crop Rotations

		Year 1			Year 2	
	Cover Crop 1	Cash Crop 2	Cash Crop 3	Cover Crop 4	Cash Crop 5	Cash Crop 6
Complexity	Fall 2006	Spring 2007	Summer 2007	Fall 2007	Spring 2008	Summer 2008
Low	F	Tatsoi	Corn	Fallow	Tomato	Cucumber
Low	F	Tomato	Cucumber	Fallow	Tatsoi	Corn
MedG	SS	Tatsoi	Corn	PM	Tomato	Cucumber
MedG	PM	Tomato	Cucumber	SS	Tatsoi	Corn
MedG	SS	Tomato	Cucumber	PM	Tatsoi	Corn
MedG	PM	Tatsoi	Corn	SS	Tomato	Cucumber
MedL	VB	Tatsoi	Corn	SH	Tomato	Cucumber
MedL	SH	Tomato	Cucumber	VB	Tatsoi	Corn
MedL	VB	Tomato	Cucumber	SH	Tatsoi	Corn
MedL	SH	Tatsoi	Corn	VB	Tomato	Cucumber
High	SS + VB	Tatsoi + Bean	Corn + Pea	SH + PM	Tomato + Bean	Cuc + Pea
High	SH + PM	Tomato + Bean	Cuc + Pea	SS + VB	Tatsoi + Bean	Corn + Pea
High	SS + VB	Tomato + Bean	Cuc + Pea	SH + PM	Tatsoi + Bean	Corn + Pea
High	SH + PM	Tatsoi + Bean	Corn + Pea	SS + VB	Tomato + Bean	Cuc + Pea

Sorghum Sudan – SS Pearl Millet – PM Velvet Bean – VB Sunn Hemp - SH

Soil organic matter percent in the top 20 cm of soil following cover crop termination but prior to incorporation

Organic matter (%) by cover crop rotation							
CC	Year 1			CC	Year2		
	Cycle 1	Cycle 2	Cycle 3		Cycle 4	Cycle 5	Cycle 6
WF	4.9^{ab}	4.9	3.4^{ab}	WF	3.5	2.7^{b}	2.3
SS	5.5^{a}	5.7	3.1^{b}	PM	3.3	2.5^{b}	2.2
PM	4.4^{ab}	5.4	3.9^{ab}	SS	3.5	3.1^{ab}	2.6
VB	3.7^{b}	6.7	3.9^{ab}	SH	3.7	3.4^{a}	2.7
SH	4.5^{ab}	5.9	3.8^{ab}	VB	3.7	2.9^{ab}	2.6
SSVB	5.3^{ab}	5.6	3.6^{ab}	SHPM	3.7	3^{ab}	2.5
SHPM	4.5^{ab}	5.5	4.1^{a}	SSVB	3.4	2.9^{ab}	2.6

Soil nitrate concentration in the top 20 cm of soil at crop termination but prior to residue incorporation

NO_3-N (ppm) levels by cover crop rotation							
CC	Year 1			CC	Year 2		
	Cycle 1	Cycle 2	Cycle 3		Cycle 4	Cycle 5	Cycle 6
WF	71	58	29	WF	30	36	25[b]
SS	90	63	38	PM	30	44	28[ab]
PM	91	57	38	SS	27	44	27[ab]
VB	86	56	42	SH	34	31	32[a]
SH	88	54	46	VB	31	24	28[ab]
SSVB	92	69	35	SHPM	40	38	27[ab]
SHPM	84	64	34	SSVB	29	33	28[ab]

Implications

- In hot humid tropical environments cover crops may have little to no effect to improve or maintain soil fertility in intensive organic vegetable crop systems **utilizing conventional tillage** in low-external-input farming systems.

- Cover crops contribute many sustainable ecosystem benefits and thus need to be incorporated into a holistic management plan.
  - Pest Management
  - Weed Control
  - Increase Water Efficiencies

Soil Health Principle 2

Use Diversity of Plants to add diversity to Soil Organisms

- Plants interact with particular microbes
  - Trade sugar from roots for nutrients
- Microbes convert plant material to OM
- Requires a diversity of plant carbohydrates to support the variety of microbes
- Lack of plant diversity will drive system to favor some microbes more than others

Impact of Biodiversity

- Low biodiversity limits any cropping system
- A diverse and fully functioning system provides nutrients, energy, and water
- Diversity above ground equals diversity below ground

How to Increase Diversity in a Crop Rotation

- Lengthen the rotation by adding more crops
  - Increases soil organic matter
  - Breaks pest cycles
  - Improves nutrient utilization and availability
  - Utilize available water deeper in the soil profile
  - Provide windows for management
    - spread manure
    - Plant & harvest crops

- Add more plants in the current crop rotation
  - Utilize cover crops during rainy season when water is abundant and pest pressure is HIGH!

Cover Crop Role in Diversity

1. Allows you to look at cropping periods rather than years
2. Can be used to accelerate rejuvenating soil health
3. Getting 6 to 8 weeks of Cover Crop growth is adequate to get “rotation” effect benefits!
4. Will increase soil biological diversity “Diversity above = diversity below”

Simplified Crop Classification

- Plant morphology
  - Broad leaf
    - Legumes
  - Grasses
- Plant growth habits
  - Rainy season
  - Dry Season
  - Photo Sensitivity

Consideration for Adding Diversity in Tropical Regions

- Consider the pathogen and insect spectrum important for income-producing crop
- Select cover crop species from different plant families as the income crop to interrupt pest life cycles and reduce pest populations
- Many of the cover crops currently in use in commercial production systems are not named varieties
- Photo period sensitivity – impacts growth, plants will go into reproductive stage too early
- Method of termination affects benefits

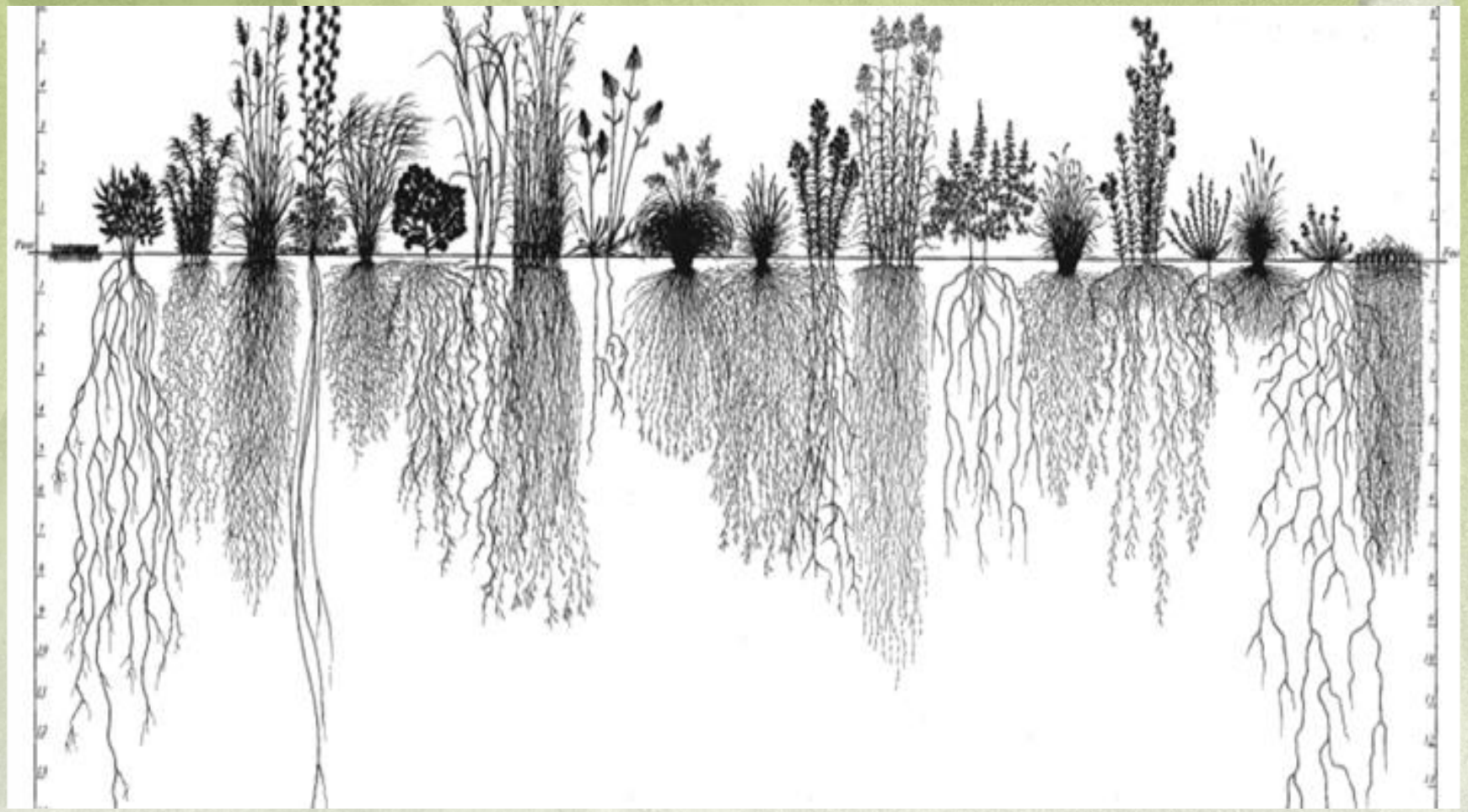
Soil Health Principle 3

Grow Living Roots Throughout the Year

Benefits:

- Increases microbial activity that influences N mineralization and immobilization
- Increases plant nutrient/nutrient uptake/ and mychorrhizal and bacteria associations
- Increases biodiversity and biomass of soil organisms
- Improves physical, chemical and biological properties of soils
- Sequesters and redeposit nutrients
- Increases OM

Diversity of Plants



Provides Diversity in Roots

How to Keep a Living Root All Year Long

- Lengthen Multi-Crop Rotation
- Select Shorter Season Varieties
  - Choose 80 to 100 day varieties
  - Only need 6 - 8 weeks to provide benefit
- Inter plant into Growing Crops
  - Planting cover crop before final harvesting of cash crop
  - Planting cash crop at termination of cover crop

Soil Health Principle 4

Keep it Covered as Much as Possible

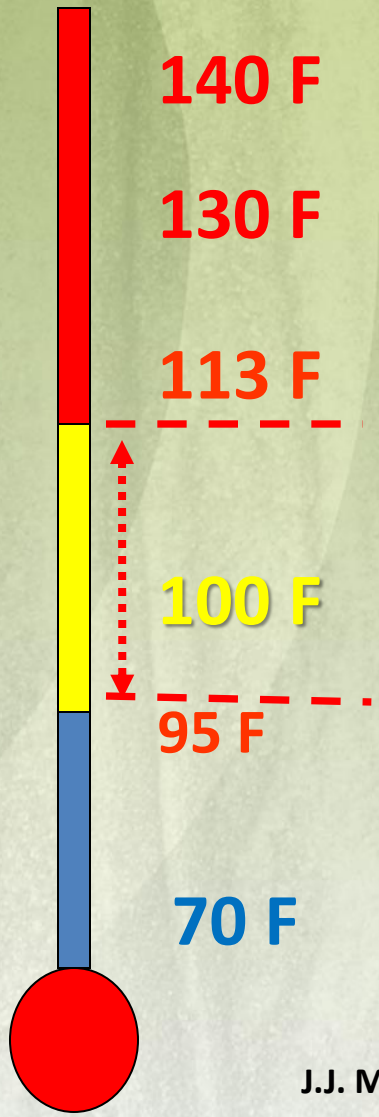
Benefits:

- Control Erosion
- Protect Soil Aggregates
- Suppresses Weeds
- Conserves Moisture
- Cools the Soil
- Provides Habitat for Soil Organisms

Soil Temperatures

- Conserve moisture and reduce temperature.
- Crop yields are limited more often by hot and dry, not cool and wet.

When soil temperature reaches



140 F — Soil bacteria die

130 F — 100% moisture is lost through evaporation and transpiration

113 F — Some bacteria species start dying

100 F — 15% moisture is used for growth

95 F — 85% moisture lost through evaporation and transpiration

70 F — 100% moisture is used for growth

J.J. McEntire, WUC, USDA SCS, Kernville TX, 3-58 4-R-12198. 1956

Soil Organic Matter & Available Water Capacity

Percent SOM	Sand	Silt Loam	Silty Clay Loam
1	1.0	1.9	1.4
2	1.4	2.4	1.8
3	1.7	2.9	2.2
4	2.1	3.5	2.6
5	2.5	4.0	3.0

Inches of Water/One Foot of Soil

1 acre inch = 27,150 gallons of water

Berman Hudson
Journal Soil and Water Conservation 49(2) 189 194 189-
March April 1994 –
Summarized by:
Dr. Mark Liebig, ARS, Mandan, ND
Hal Weiser, Soil Scientist, NRCS, Bismarck, ND

Soil Organic Matter Facts

- Soil organic matter (SOM) is <6% of soil by weight but controls >90% of the function
- Density of SOM: .6 g/cm^3 Density of Soil: 1.45 g/cm^3
- SOM has less density than soil so it has more space for air and water storage.
- SOM is negatively charged, but binds both cations and anions
- Every Pound SOM holds 18-20 lbs of Water!
- As soil organic matter increases from 1% to 3%, the available water holding capacity of the soil doubles (Hudson, 1994).
- Soils stockpile 1,500 gigatons of carbon in SOM, more than Earth's atmosphere and all the plants combined (Dance, 2008).
- The majority of the SOM is present in the top 10 cm of soil

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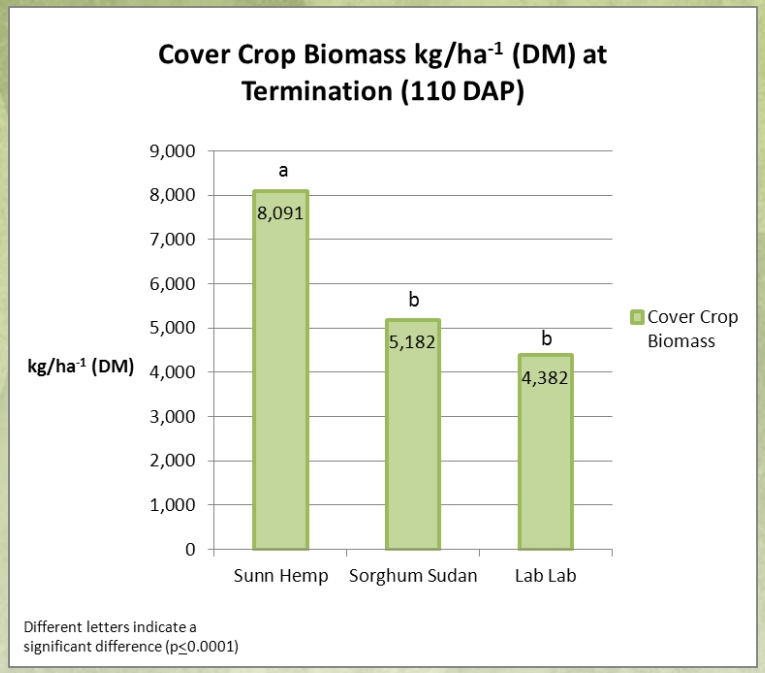
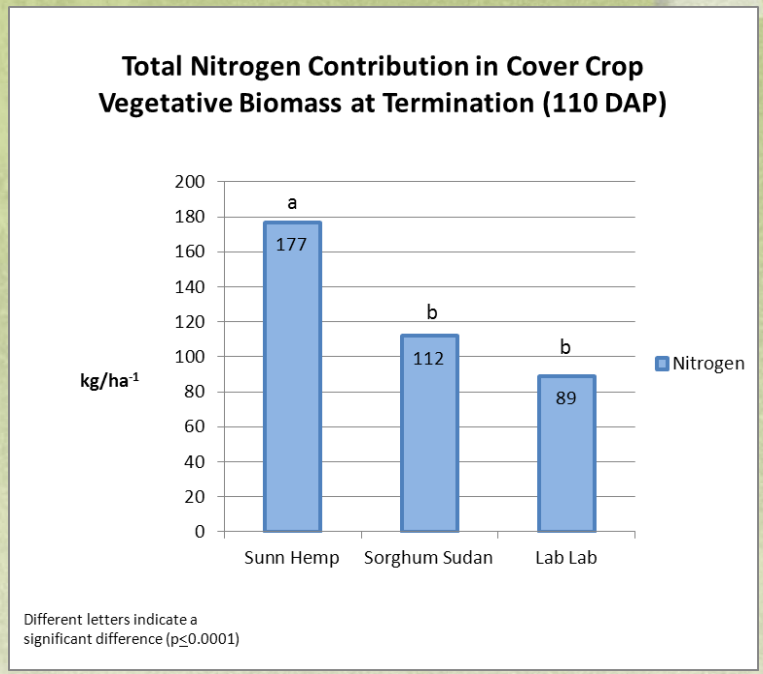
Managing Cover Crop Residue in Tropical Regions

Cover Crop Performance and Nitrogen Contribution from Vegetative Biomass at Termination





No difference was observed in CC plant tissue phosphorus or potassium levels

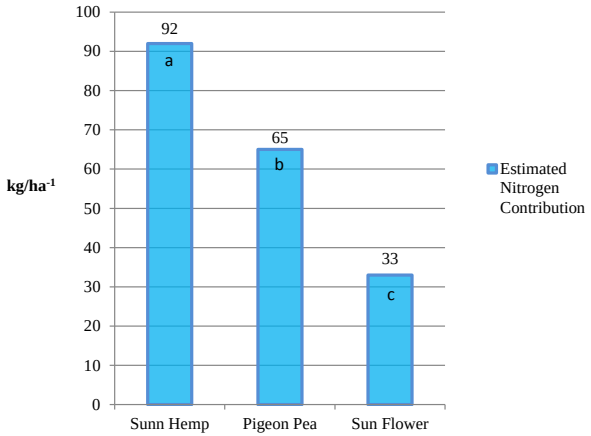
Cover Crop Performance. Weed Development, and Nitrogen Contribution Termination

Cover crop (CC), broad leaf (BL) weed, and poacea (GW) weed biomass (kg/ha^{-1}) within treatments assessed at cover crop termination (112 DAP)

Treatment	Plant	Biomass at CC Termination kg/ha^{-1}	Total kg/ha^{-1}
Control	NA	NA	NA
Control	BL	862 ± 293^{a}	2,291 ± 336^{a}
Control	GW	1,429 ± 293^{ac}	
Pigeon Pea	PP	4,747 ± 293^{b}	4,747 ± 336^{b}
Pigeon Pea	BL	273 ± 293^{ad}	667 ± 336^{c}
Pigeon Pea	GW	393 ± 293^{ad}	
Sun Flower	SF	2,027 ± 293^{ac}	2,027 ± 336^{a}
Sun Flower	BL	180 ± 293^{d}	180 ± 336^{c}
Sun Flower	GW	<1 ± 293^{d}	
Sunn Hemp	SH	6,418 ± 293^{e}	6,418 ± 336^{d}
Sunn Hemp	BL	<1 ± 293^{d}	<1 ± 336^{c}
Sunn Hemp	GW	<1 ± 293^{d}	

Values within the same column group followed by different letters differ ($p<0.05$) according to a least significant range seperation.

Estimated Nitrogen Contribution from Cover Crop Biomass at Termination (112 DAP)



Different letters indicate a significant difference ($p<0.05$)

No difference was observed in CC plant tissue phosphorus or potassium levels

Cover Crop Residue Surface Sheet Mulch

- Increases soil conservation through reduced tillage
- Decomposition of CC sheet residue allows for the slow release of nutrients and conversion of organic matter to plant available nutrients
- Sheet residue more efficiently converts carbon into soil organic matter
- Sheet residue acts as a barrier against weeds

(Southern SARE, 2012, Sullivan, 2011; Curran and Ryan, 2010, Hoorman et al., 2009; Wang and Klassen, 2005; Sullivan, 2003; NRCS, 2002)

- Surface plant residues benefit the microorganism rhizosphere
- Allows for planting of the vegetable rotation shortly after termination when the crop residue dries

Custom Built Roller-Crimper

- Cover crops were terminated at 112 DAP with a custom built roller-crimper
  - Built from a recycled 24 inch disc plough using the disc and plough hubs, 24 inch steel pipe, steel tubing, and steel flat bar.


Sunn Hemp


Pigeon
Pea


Lab Lab


Sunflower

Measuring Results After Roll Down Termination

- Cover crop residue height and re-growth was assessed after termination to determine the effectiveness of roller-crimper technology on cover crops in the tropics
- Weed biomass was measured to determine the impact of the resulting surface sheet mulch to inhibit weed development.

Vegetable Management following Roller-Crimping

- Young transplants may survive dry season and have access to increased soil moisture due to reduced evapotranspiration rates
- May get up to 8 weeks of weed suppression

Vegetable Management following Rolling/Crimping

- Select the correct cover crop to vegetable crop pairing.
- Cover crops that produce large amounts of biomass resulting in coarse, thick matted surface mulch can be paired with long rotation vegetables (70 to 120 days to harvest)
- These transplants should be larger and more mature than when transplanted into fully tilled beds.
- Cover crops that result in less biomass, produce surface mulch that has a rapid decomposition rate, or is finer in nature can be paired with short rotation vegetables (30 to 60 days to harvest) and may be transplanted or direct seeded.

Cover Crop Establishment

- Germination 7 DAP and drip tape placement

Pigeon Pea 47 DAP

Sun Flower 47 DAP

Weedy Fallow Control

Sunn Hemp 47 DAP

Cover Crop Termination with Roller-Crimper and Crop Residue Surface Sheet Mulch

Sunn Hemp

Sun Flower

Pigeon Pea

Control

Jalapeno peppers (Invicto-F1) grown in a green house and transplanted into treatment plots 42 DAP and 7 days after CC termination

Control

Sun Flower

Pigeon Pea

Sunn Hemp

Cover Crop Re-Growth and Weed Development at 3 and 6 weeks after CC Termination

Sunn Hemp

Control

Pigeon Pea

Sun Flower

Cover crop (CC), broad leaf (BL) weed, and poacea (GW) weed biomass (kg/ha^{-1}) by treatment at 3 and 6 weeks after cover crop termination

3 Week Harvest

Treatment	CC	BL	GW
Control	NA	27 ± 80^{a}	47 ± 80^{a}
Pigeon Pea	307 ± 80^{b}	416 ± 80^{b}	93 ± 80^{a}
Sun Flower	0 ± 80^{a}	440 ± 80^{b}	451 ± 80^{b}
Sunn Hemp	144 ± 80^{b}	13 ± 80^{a}	0 ± 80^{a}

6 Week Harvest

Treatment	CC	BL	GW
Control	NA	378 ± 328^{a}	591 ± 238^{a}
Pigeon Pea	1,413 ± 328^{b}	1,676 ± 328^{b}	282 ± 238^{ac}
Sun Flower	0 ± 328^{a}	1,691 ± 328^{b}	782 ± 238^{ab}
Sunn Hemp	2,229 ± 328^{b}	409 ± 328^{a}	20 ± 238^{c}

Values within the same column group followed by different letters differ ($p<0.05$) according to a least significant range seperation.

1.) At 3 weeks after CC termination, SH surface residue provided the greatest reduction in weed development.

2.) Sun flower was effectively killed with a roller-crimper showing no regrowth.

3.) At 6 weeks after CC termination, SH continued to reduce weed development with less GW than all other treatments and less BL weeds than PP or SF, but similar to the control.

Sunn Hemp

Control

Pigeon Pea

Sun Flower

Jalapeno Pepper Plant Development at 1st Harvest (62 DAT) in Weeded Sub-Plots

Sunn Hemp

Control

Sunflower

Pigeon Pea

Jalapeno Pepper Harvest

First pepper harvest occurred on April 31, 2013 (70 DAT) and on March 31, 2014 (62 DAT)

Peppers where harvested from data rows, graded (marketable or unmarketable), and weighed.

Jalapeno Pepper Production

Jalapeno pepper yields (kg/ha^{-1}) from weeded and non-weeded sub-plots by treatment

Weeded Pepper Yield

Treatment	Marketable	Unmarketable
Sunn Hemp	8,567 ± 1,325^{a}	151 ± 45^{a}
Control	6,060 ± 1,325^{ab}	84 ± 45^{a}
Sun Flower	2,697 ± 1,325^{b}	38 ± 45^{a}
Pigeon Pea	2,214 ± 1,325^{b}	69 ± 45^{a}

Non-Weeded Pepper Yield

Treatment	Marketable	Unmarketable
Sunn Hemp	3,468 ± 754^{a}	99 ± 25^{a}
Control	1,312 ± 754^{ab}	35 ± 25^{ab}
Sun Flower	617 ± 754^{b}	9 ± 25^{a}
Pigeon Pea	155 ± 754^{b}	5 ± 25^{a}

Values within the same column group followed by different letters differ ($p<0.05$) according to a least significant range seperation. Sub-plots weeded at 6, 9, &12 weeks.

Mean marketable jalapeno pepper fruit per plant and individual fruit weight (g) from weeded and non-weeded sub-plots by treatment

Mean Marketable Fruit/Plant

Treatment	Weeded	Non-Weeded
Sunn Hemp	17 ± 3^{a}	6.1 ± 1^{a}
Control	13 ± 3^{ab}	2.3 ± 1^{ab}
Sun Flower	6 ± 3^{b}	0.3 ± 1^{b}
Pigeon Pea	5 ± 3b	1.1 ± 1^{b}

Mean Marketable Fruit Wt. (g)

Treatment	Weeded	Non-Weeded
Sunn Hemp	15.1 ± 1^{a}	16 ± 3^{a}
Control	14.5 ± 1^{ab}	17 ± 3^{a}
Sun Flower	12.7 ± 1^{b}	10 ± 3^{a}
Pigeon Pea	12.7 ± 1^{b}	18 ± 3^{a}

Values within the same column group followed by different letters differ ($p<0.05$) according to a least significant range seperation. Sub-plots weeded at 6, 9, &12 weeks.

- **Low frequency weeding of Sunn Hemp plots resulted in the greatest pepper yield, more fruit per plant, and the heaviest fruit.**
- **Non-weeded plots followed similar trends, but with severely reduced yields , fruit per plant, and individual fruit weight.**

Implications and Summary

Cover crops can be a valuable management tool in the tropics that require few if any external inputs.

Cover crop re-growth may cause weed problems when using a roller-crimper for termination of specific CC species in tropical or extended warm season environments.

For indeterminate cover crops, roller-crimper termination may not be viable without additional management.

Surface sheet mulch resulting from CCs terminated with a roller-crimper can be used for natural weed suppression and to protect soil quality for subsequent crop rotations.

Summary

We still have a lot to learn, but we will get there together…

- We have made a lot of progress on refining these systems, but they are not without risk - be prepared to have a back up plan to manage undesirable cover crop results.
- Design an approach that is fully supported by the equipment on hand.
- Recommended vegetable cultivars, planting practices and fertilization strategies apply for conventional practices and not necessarily high residue cover crop systems.