Cover Crop Rotations in Vegetable Production Systems

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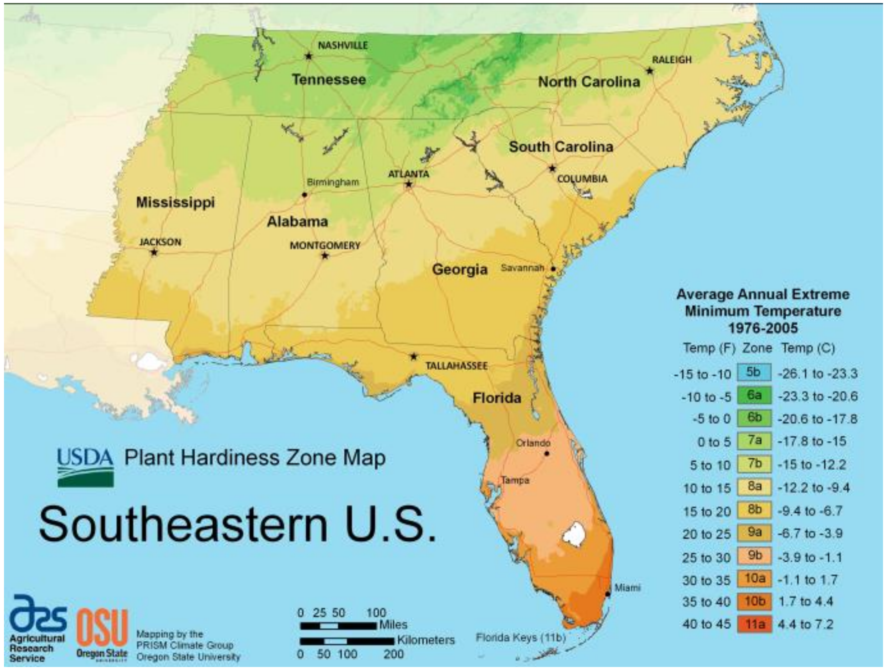
Outline

1. Key resources about cover crops and crop rotations,
2. Criteria for cover crop species selection,
3. Best seasonal opportunities to integrate covers in vegetable systems, and
4. Methods to optimize benefits through innovative planting and termination.

Sunn hemp in bloom at 83 Farms in Bell, Florida.

Key Cover Crop Resources

- **USDA-ARS and Land grant university faculty and extension specialists**
- eXtension
- You Tube
- SARE
- NCAT/ATTRA



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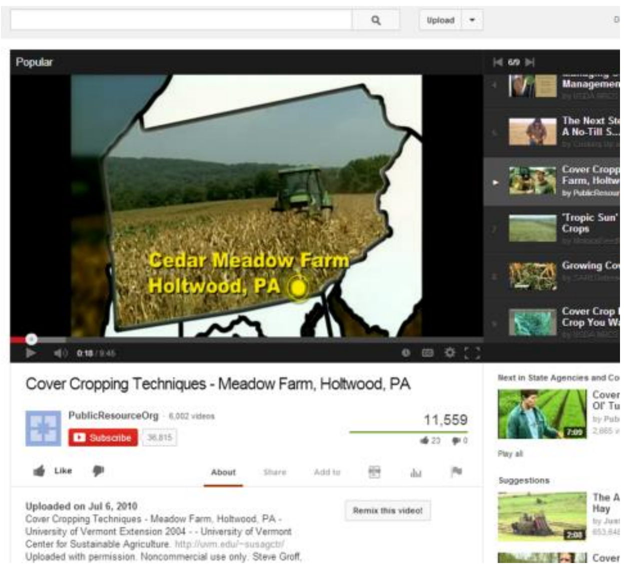

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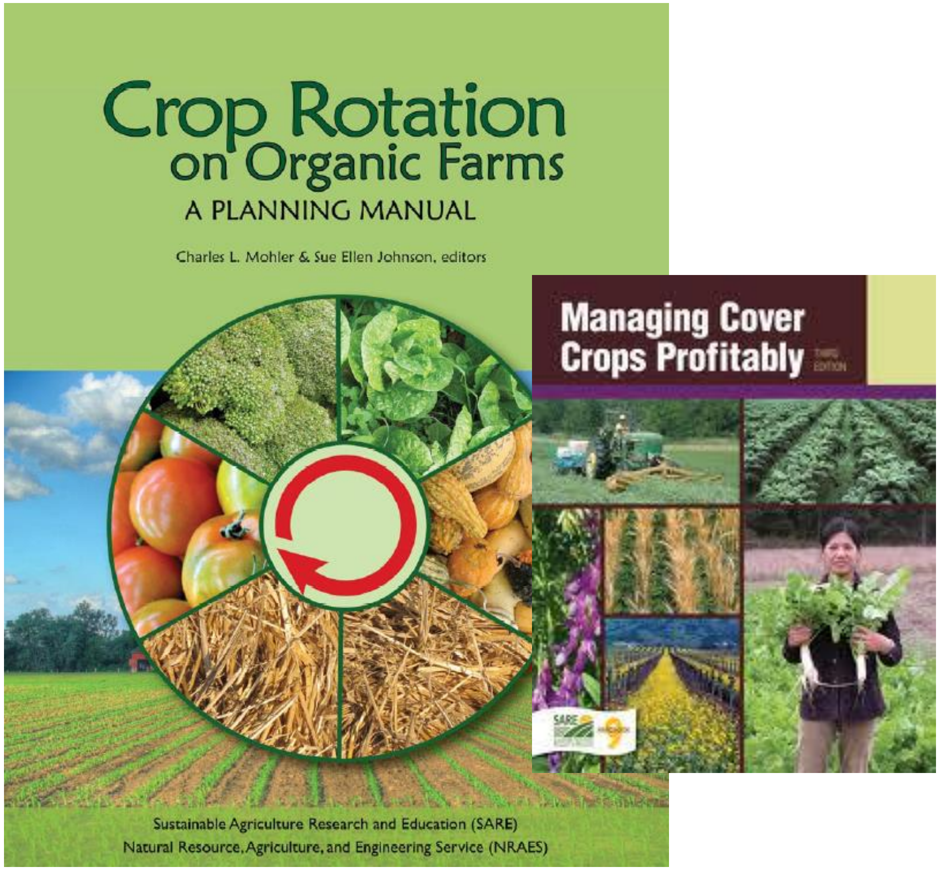
- **SARE/NCAT/ATTRA**
- Rodale Institute



http://www.sare.org/publications/croprotation/croprotation.pdf

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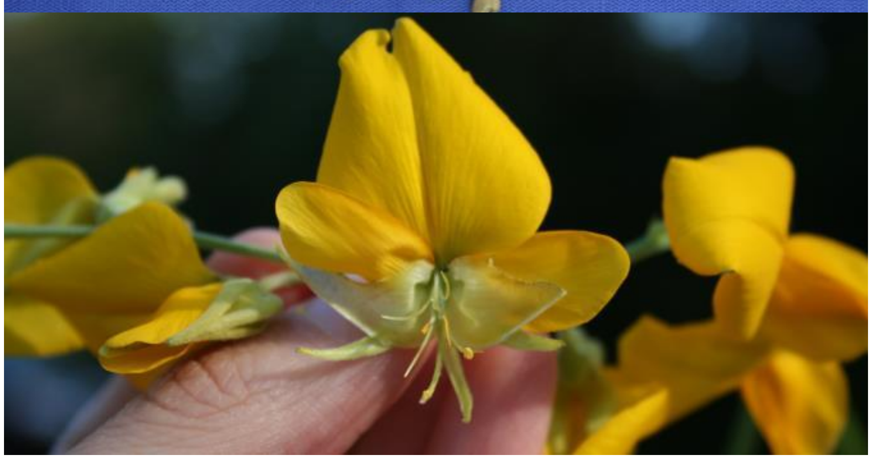
- You Tube
- SARE, NCAT/ATTRA
- **Rodale Institute**

http://www.rodaleinstitute.org/no-till_revolution

Criteria for Cover Crop Species Selection

- 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 life cycles and reduce pest populations
- Most of the cover crops currently in use in commercial production systems are not named varieties

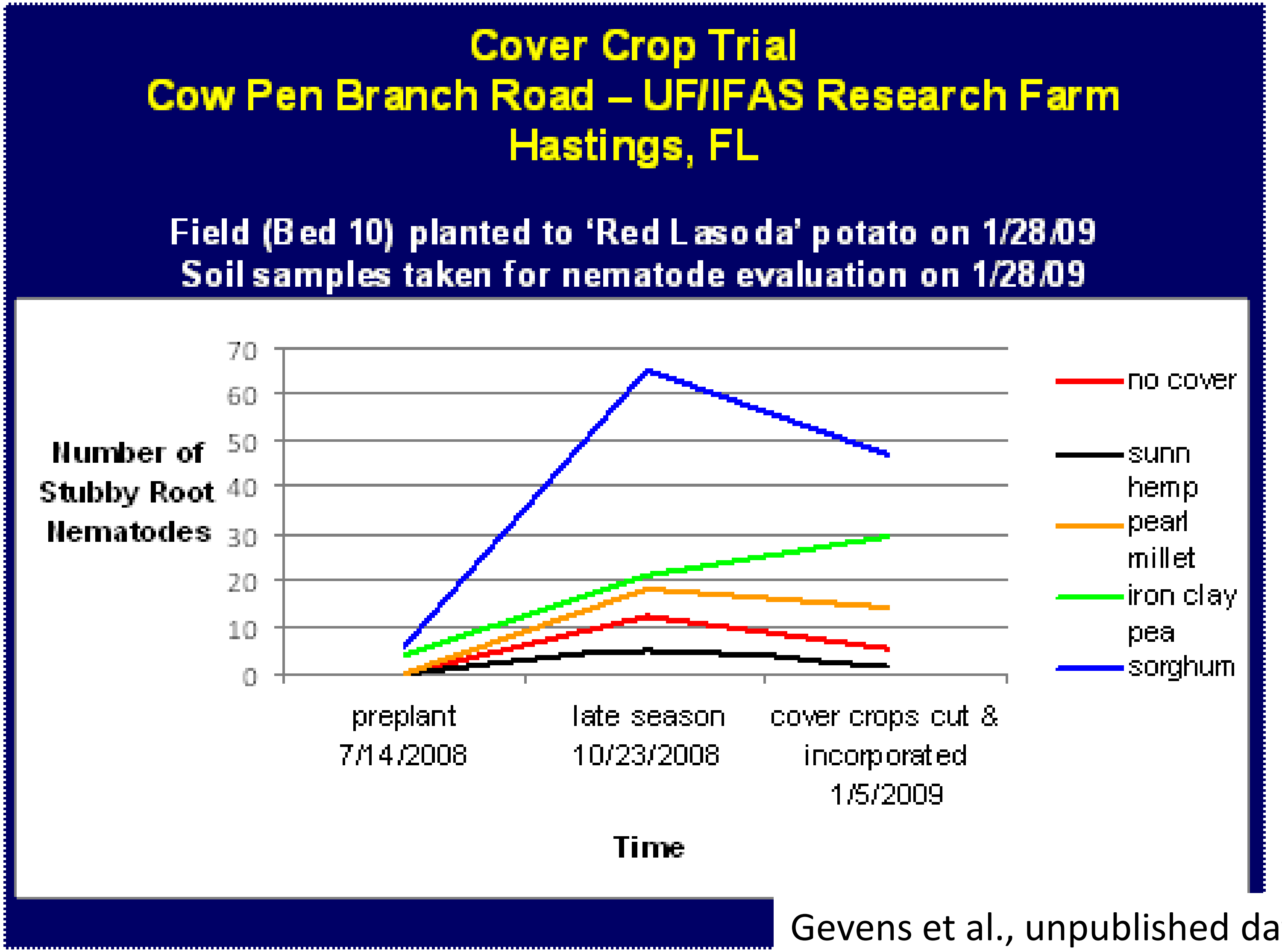
Crop Planning: Cultivar Selection and the Importance of Named Cultivars



VNS *Crotalaria juncea* from Africa

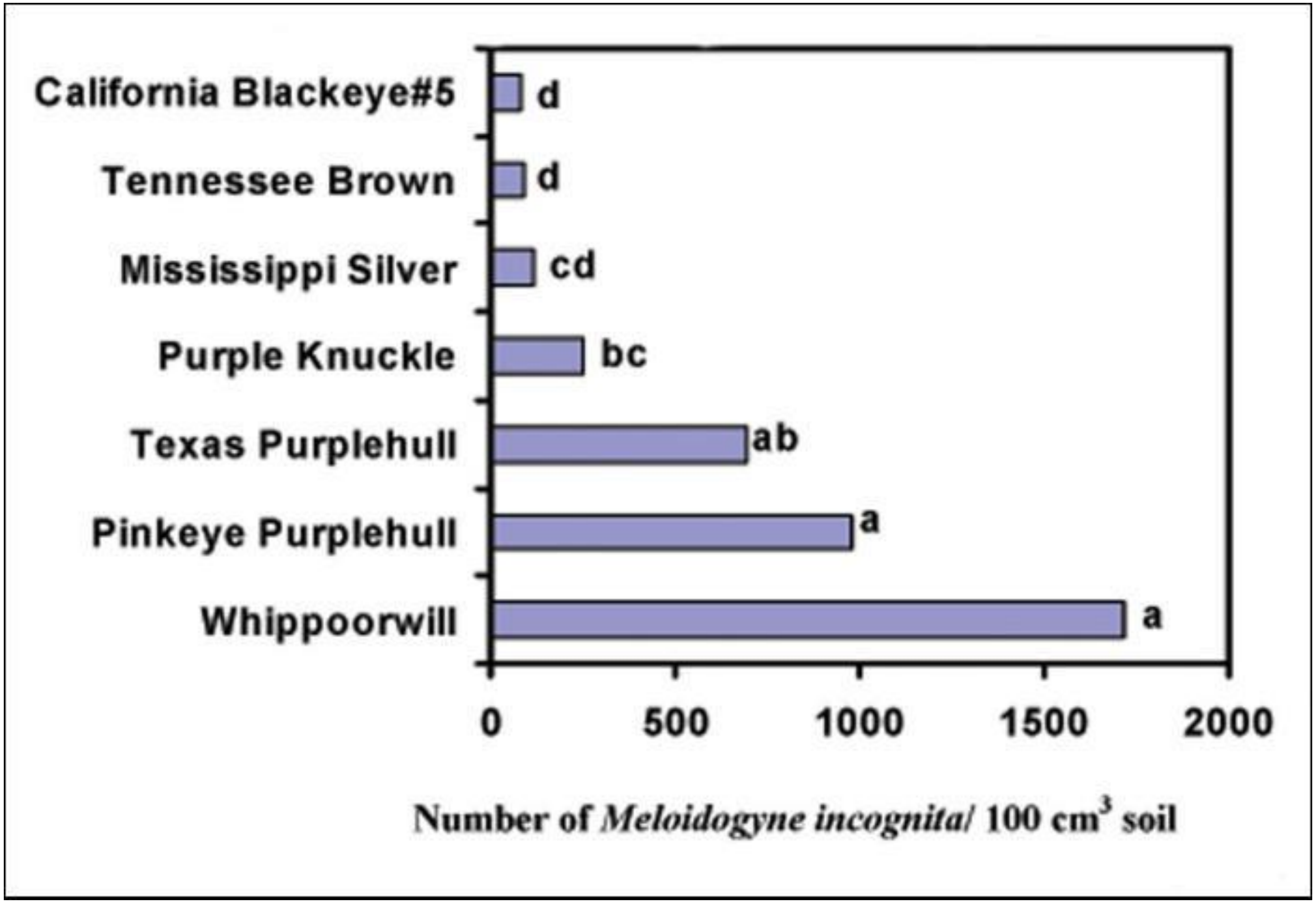
- FL producers import seed
- Most seed is labeled "Common" or "VNS"
  - Sunn hemp (*Crotalaria juncea* L.) 'Tropic Sun' developed by the University of HI and 'Auburn Gold' developed by Auburn University
  - Other sunn hemp is shipped from India and Africa
  - Small grains from NC and the midwest
  - Other tropicals grown in Brazil, Mexico, Thailand, & Africa

Cover Crop Species & Nematodes



Gevens et al., unpublished data

Cowpea Cultivars & Nematodes



Gallaher and McSorley, 1993

Monocultures

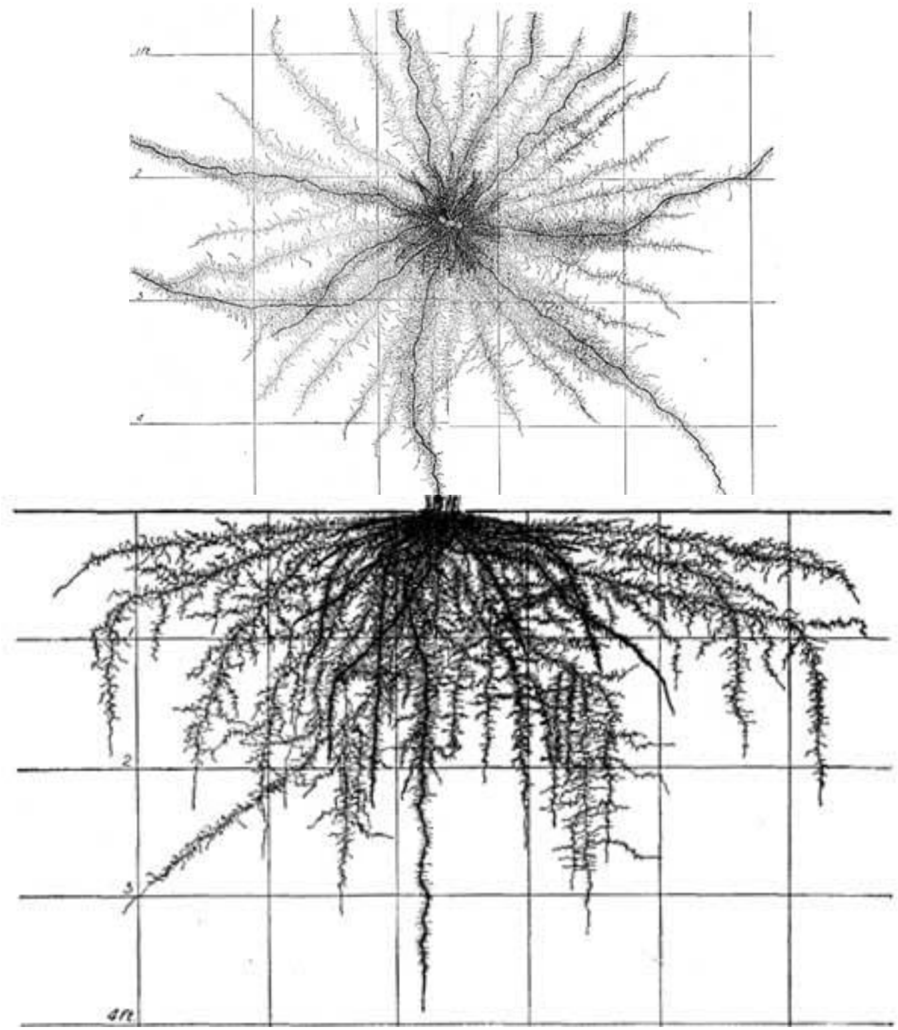
Neighbor's land use, previous and subsequent crop families very important. Plant architecture and carbon form and content will influence termination method.

Polyculture (mixed) Species

Polycultures reduce the period of time needed for soil biota to return to equilibrium but may differ in maturity rates, complicating termination plans.

Root Distribution in the Soil

- Cover crop roots take some time to develop.
- Winter annuals tend to invest more plant energy in root production than summer annuals early on.
- Consider mixing species with different root architecture.

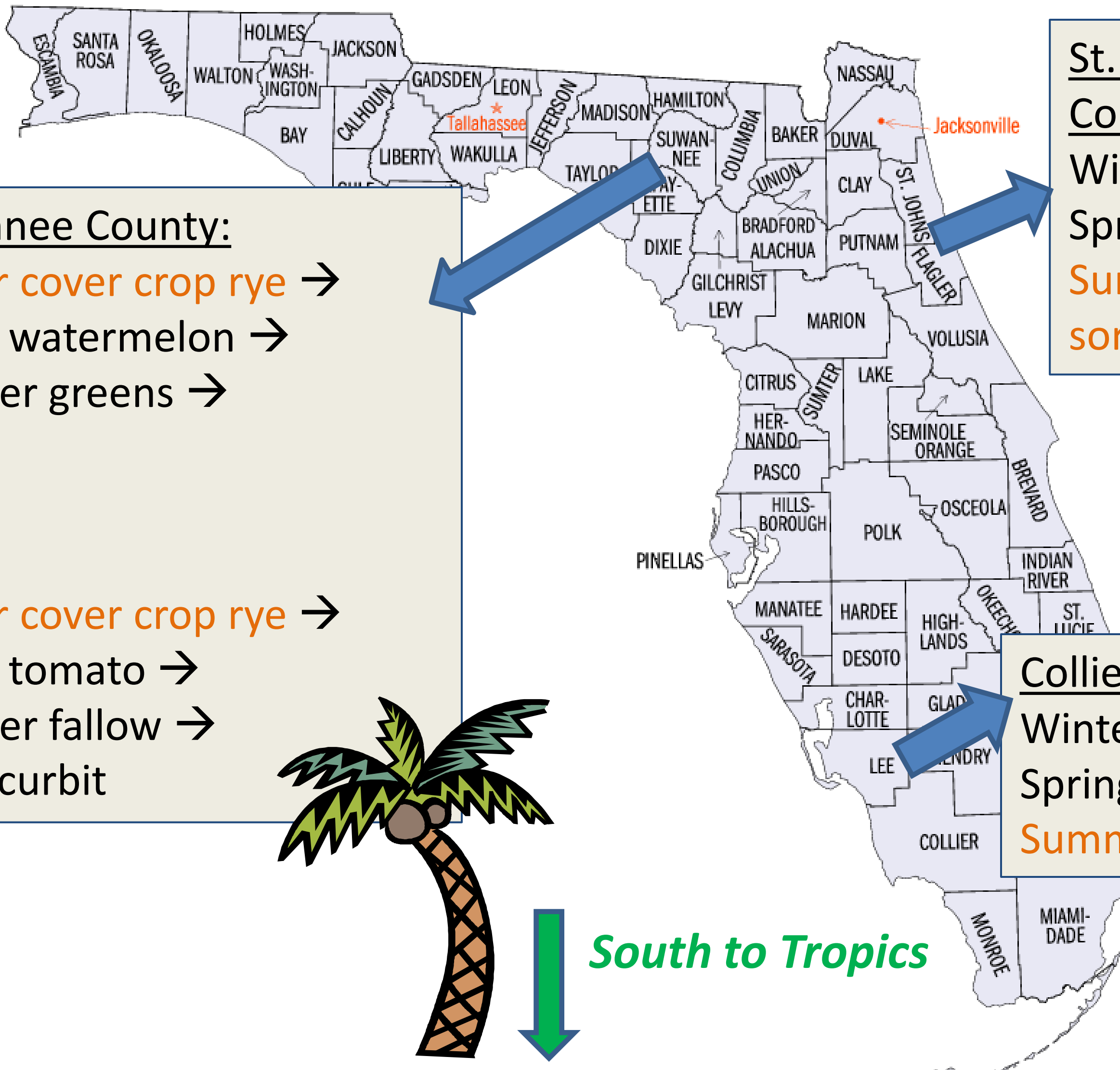


Increased Direct and Seasonal Costs

Modify Existing Equipment

Great Plains 3P605 NT Drill
with raised drive wheels

Florida Vegetable Rotations



<u>Suwannee County:</u>

Winter cover crop rye →
Spring watermelon →
Summer greens →

OR

Winter cover crop rye →
Spring tomato →
Summer fallow →
Fall cucurbit

<u>St. Johns/Flagler County:</u>

Winter cabbage →
Spring potato →
Summer cover crop sorghum

<u>Collier County:</u>

Winter strawberry →
Spring water/muskmelon →
Summer cover crop sorghum

South to Tropics

Leveraging Seasonal Changes

Fall mustard mix following summer sorghum Sudangrass and preceding winter potato in St. John's County FL

1. For most of the southeastern U.S., winter is a good fit for cover crops (temperature)
2. Summer and Winter are both possible in Gulf States (temperature and rainfall)
3. Cover crops can be produced year-round in subtropics/tropics, but best during summer (rainfall)

Vegetable Transplants or Seeds?

- Larger transplants and seeds establish more readily in surface sheet mulch systems than smaller ones
- Small seeds and small transplants may be slow to establish (or perish)
    - if planted during the ***Green Bridge*** or
    - if planted in heavy residue.

How Do I Begin the Process of Cover Crop Integration?

1. Identify major constraints to profit, and select covers and management practices that will reduce external costs in the short or long term
2. Identify current resources and equipment
3. Narrow species options by ruling out those that require more or less time to develop than your current rotational plan allows
4. Eliminate species and cultivars that are alternate hosts to pests
5. Select species that attract beneficials
6. Leverage seasonal temperature and precipitation changes to manage covers and reduce labor/fuel costs

Methods to Optimize Benefits of Cover Crop Integration

1. In-situ
2. Cut and Carry
3. Green Manure
4. Roller-Crimp

1. Cover Crop In-situ Benefits and Risks

- Trap /retain nutrient - enriched sediments and particulates
- Improve water infiltration and nutrient adsorption
- Extend growing season to use available nutrients
- Reduce in-field volume of runoff water

(Dinnes, 2004)

- A poor cover stand encourages weed establishment
- Alternative host for pests

Cover Crops Retain N in the Soil

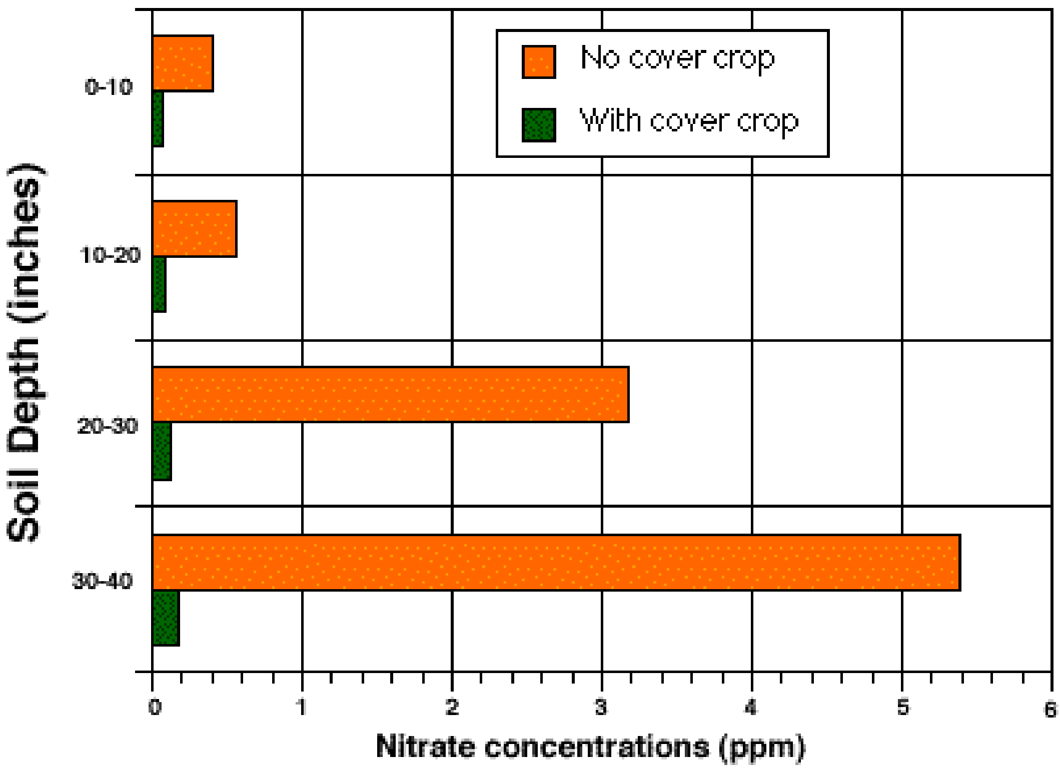


Figure 3. Effect of a cereal rye cover crop on soil nitrate concentrations (ppm) in broccoli plots fertilized the previous spring with 250 pounds N/acre. Samples were taken April 15, 1992. (Data from Hemphill and Hart, 1993.)

Using winter cover crops to reduce nitrate contamination of ground water requires the establishment of the crop early enough in the fall to have adequate growth during the fall and winter rains. Relay interplanting of the cover crop into the standing cash crop during the summer has shown promise in getting a crop well established by winter. Selection of fast-growing cultivars is also important.

J. Luna, OSU, Corvallis

2. Cut and Carry Best Practices

- Producing biomass, harvesting straw for another location, and keeping stubble residue in place serves a dual purpose.
- Be mindful of the risk of contamination from weed seeds or pathogens. Herbicide residues may also be a concern.
- 4 tons/acre dry matter is the commonly accepted threshold for weed suppressive benefits, but more may be needed to suppress large seeded weeds or perennial weeds.

2. Vegetable Management following Cut and Carry

- In early spring, delay application of straw until after transplants/seeds have established root system if soil temperatures are less than optimal, or soil moisture is limiting
- Apply dry granular fertilizer and incorporate into soil via BMP recommendations prior to applying straw
- If drip tape is used, apply before straw
- Fewer pests with cut and carry than green surface sheet mulch initially (mammals, birds, cutworms)

3. Cover Crop Mowing Best Practices

- Flail mowers (ex. Befco, Alamo) use blades and deposit residue under deck (safety) in uniformly sized pieces. Can be offset, good for uneven terrain if outfitted with a gauge roller.
- Rotary mowers (ex. Bush Hog) use chains, deck size larger, throws mulch outside of deck, uneven pieces.

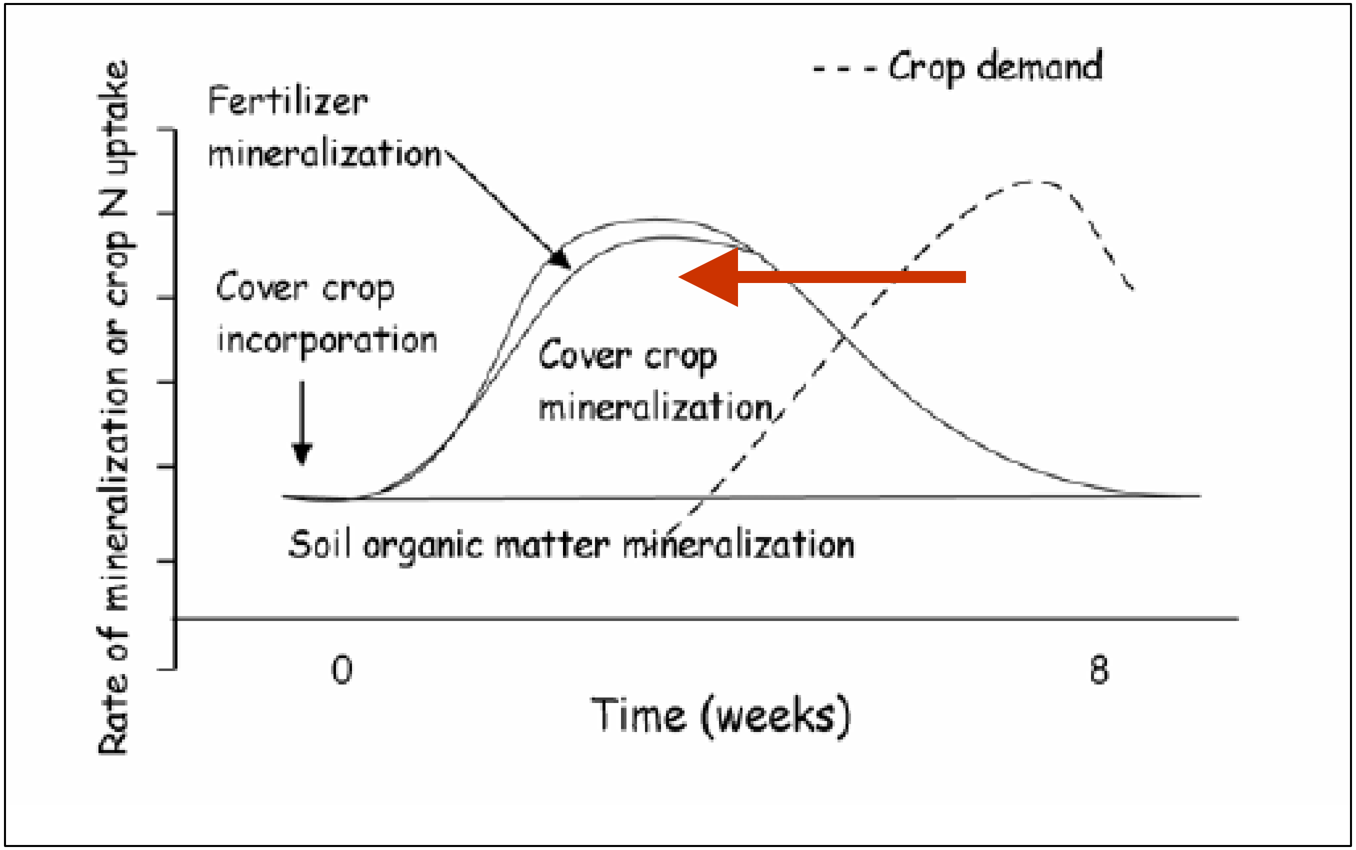
3. Vegetable Management following Mowing, with Residue on the Surface

- Mechanical transplanting may be difficult
- Direct seed with drill possible with no-till drill
- Small seeded vegetables direct seeded into soil may exhibit poor germination due to allelopathic chemicals from cover crops
- Increased predation of seeds, transplants from mammals and birds

3. Green Manure/Full Incorporation Best Practices

- Heavy residue may require multiple passes with disk to fully incorporate.
- A 2-6 week period is recommended to allow soil biota to return to equilibrium (Green Bridge). Time period is reduced as temperatures increase and soil moisture is optimal.
- Nitrate leaching is possible during the Green Bridge, so timing is critical.

Goal: Synchronize N with Crop Demand



Gaskell et al., 2006

4. Surface Sheet Mulch – Rolling/Crimping

- Best practices following successful rolling/crimping
- Large-seeded, larger transplants establish more readily
- Spacing – canopy closure and drip emitter spacing
- Regrowth

Brock Family Farms, Monticello, FL

4. Vegetable Management following Roller-Crimping

- Mechanical transplanting follows direction of rolling
- Direct seed with drill possible with no-till drill
- Consider banding dry granular organic or conventional fertilizer
- Small seeded vegetables direct seeded into soil may exhibit poor germination due to allelopathic chemicals from cover crops
- Young transplants may survive early frost in fall, and have access to increased soil moisture due to reduced evapotranspiration rates

Managing Summer Cover Crop to Vegetable Crop Rotations in Hot Humid Environments

- Farm management may need to be different in summers compared to the other seasons.

- Differences in seasonal decomposition rates, precipitation, temperature, microbial activity, solar radiation, nutrient volatilization (to name a few) impact cover crop management choices.

- Full tillage vs. conservation tillage choices

Conventional Full Tillage Crop Rotations

	Cycle 1	Cycle 2	Cycle 3
Rotation	**Fall (Rainy)**	**Spring (Dry)**	**Summer (Dry)**
1	SS	tatsoi	sweet corn
2	PM	tomato	cucumber
1	SS	tomato	cucumber
2	PM	tatsoi	sweet corn
1	VB	tatsoi	sweet corn
2	SH	tomato	cucumber
1	VB	tomato	cucumber
2	SH	tatsoi	sweet corn

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

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

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 following cover crop termination but prior to 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.

Cover Crop Residue Surface Sheet Mulch

- Increases soil conservation through reduced tillage
- Decomposition of CC sheet residue allows for the slow release 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
- Surface plant residues provides a beneficial microorganism rhizosphere
- Allows for planting of the vegetable rotation shortly after termination when the crop residue dries.

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

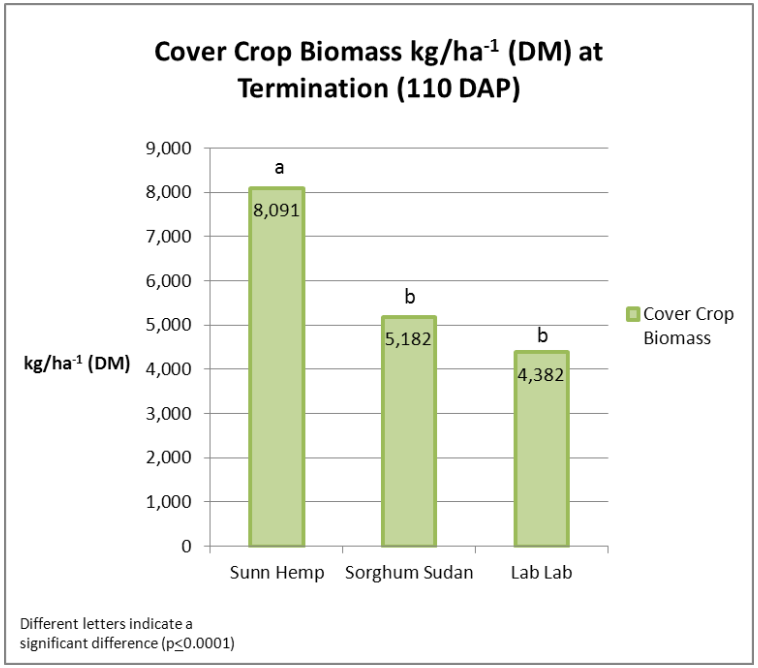

Sunn Hemp

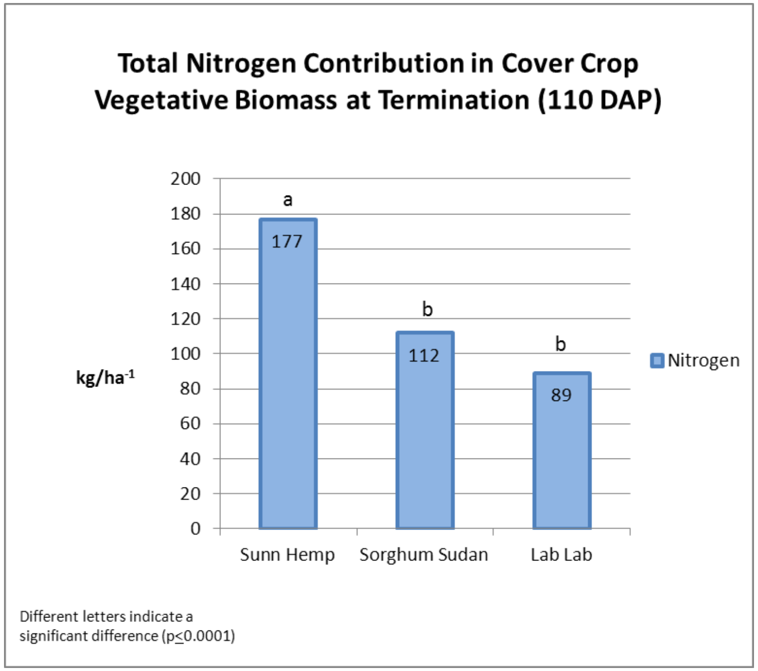

Sorghum Sudan


Lab Lab


Replicate

Cover Crop Performance and Nitrogen Contribution from Vegetative Biomass at Termination





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

Measuring Results After Roll Down Termination

- Cover crop residue height and re-growth was assessed at 28 and 42 days post roll down to determine the effectiveness of roller-crimper technology on cover crops in the tropics

- Weed biomass was measured at 28 and 42 days post roll down to determine the impact of the resulting surface sheet mulch to inhibit weed development.

28 days post roll down

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 Crops at Maturity Prior to Termination (112 DAP)

Sampling Procedures Prior to Termination

- Biomass sampling of cover crops and volunteer weeds
  - 3 random 0.25m^2 samples collected per plot prior to CC kill
  - CCs and weeds were separated
  - Weeds were sorted by class (grass and broad leaf)
  - Samples were dried in a forced air oven to determine dry matter

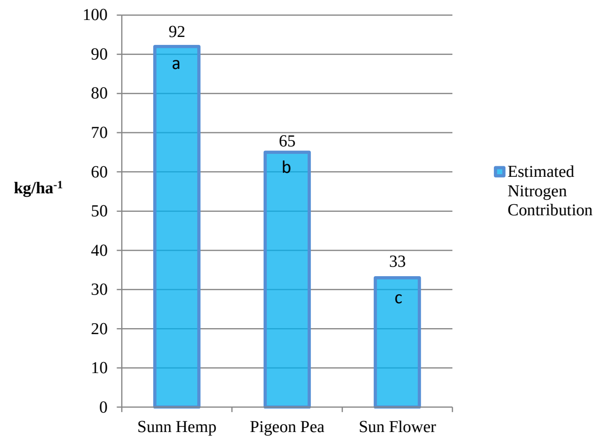
Cover Crop Performance. Weed Development, and Nitrogen Contribution from at Termination

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

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.

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

Sunn Hemp

Sun Flower

Pigeon Pea

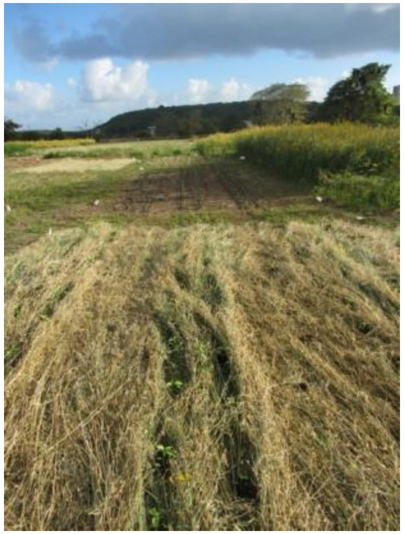
Control

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	$1,413 \pm 328^{b}$	$1,676 \pm 328^{b}$	282 ± 238^{ac}
Sun Flower	0 ± 328^{a}	$1,691 \pm 328^{b}$	782 ± 238^{ab}
Sunn Hemp	$2,229 \pm 328^{b}$	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 SH, but similar to the control. SH regrowth increased.

Sunn Hemp

Control

Pigeon Pea

Sun Flower

Cover Crop Re-Growth and Weed Development at 9, 12, and 15 weeks after CC Termination

Control

Sunn Hemp

Pigeon Pea

Sun Flower

Cover crop (CC), broad leaf (BL) weed, and poacea (GW) weed biomass (kg/ha^{-1}) from WEEDED sub-plots by treatment at 9, 12, and 15 weeks after CC termination

9 Week Harvest

Treatment	CC	BL	Grass
Control	NA	69 ± 52[a]	167 ± 52[ab]
Pigeon Pea	71 ± 52[a]	253 ± 52[b]	204 ± 52[a]
Sun Flower	0 ± 52[a]	51 ± 52[a]	98 ± 52[ab]
Sunn Hemp	64 ± 52[a]	207 ± 52[b]	40 ± 52[bc]

12 Week Harvest

Treatment	CC	BL	Grass
Control	NA	67 ± 44[a]	220 ± 44[ab]
Pigeon Pea	0 ± 44[a]	196 ± 44[b]	160 ± 44[ab]
Sun Flower	0 ± 44[a]	109 ± 44[ab]	127 ± 44[a]
Sunn Hemp	20 ± 44[a]	153 ± 44[ab]	247 ± 44[b]

15 Week Harvest

Treatment	CC	BL	Grass
Control	NA	896 ± 289[ab]	1,251 ± 289[a]
Pigeon Pea	53 ± 289[a]	1,471 ± 289[b]	1,444± 289[a]
Sun Flower	0 ± 289[a]	616 ± 289[a]	1,498 ± 289[a]
Sunn Hemp	0 ± 289[a]	1,409 ± 289[b]	2,409 ± 289[b]

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.

Cover crop (CC), broad leaf (BL) weed, and poacea (GW) weed biomass (kg/ha^{-1}) from NON-WEEDED sub-plots by treatment at 9, 12, and 15 weeks after CC termination

9 Week Harvest

Treatment	CC	BL	Grass
Control	NA	1,018 ± 457[a]	2,138 ± 457[b]
Pigeon Pea	2,904 ± 457[c]	1,471 ± 457[a]	422 ± 457[a]
Sun Flower	0 ± 457[a]	1,962 ± 457[a]	1,880 ± 457[b]
Sunn Hemp	1,027 ± 457[b]	820 ± 457[a]	207 ± 457[a]

12 Week Harvest

Treatment	CC	BL	Grass
Control	NA	1,282 ± 560[a]	3,256 ± 560[a]
Pigeon Pea	3,387 ± 560[a]	1,807 ± 560[a]	793 ± 560[b]
Sun Flower	0 ± 560[b]	1,856 ± 560[a]	2,344 ± 560[a]
Sunn Hemp	3,147 ± 560[b]	1,873 ± 560[a]	147 ± 560[b]

15 Week Harvest

Treatment	CC	BL	Grass
Control	NA	1,031 ± 629[a]	4,844 ± 629[c]
Pigeon Pea	3,849± 629[a]	451 ± 629[a]	1,651 ± 629[a]
Sun Flower	0 ± 629[b]	1,204 ± 629[a]	3,396 ± 629[bc]
Sunn Hemp	1,193 ± 629[b]	2,113 ± 629[a]	1,738 ± 629[ab]

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

Low frequency weeding at 6, 9, and 12 weeks reduced SH and PP regrowth to minimal levels, however, SH and PP regrowth in non-weeded plots became major weeds.

In weeded plots, CCs minimized weed development similar to conventional tillage through week 12.

Control

Sunn Hemp

Pigeon Pea

Sun Flower

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.

Jalapeno Pepper Harvest

First pepper harvest occurred on April 8, 2013 (112 DAP or 70 DAT).

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

There were a total of 9 pepper harvests with the final harvest on June 21, 2013.

Jalapeno Pepper Plant Development at 1st Harvest (112 DAP) in Weeded Sub-Plots

Sunn Hemp

Control

Sun Flower

Pigeon Pea

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, most 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 cc systems.

Acknowledgements

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