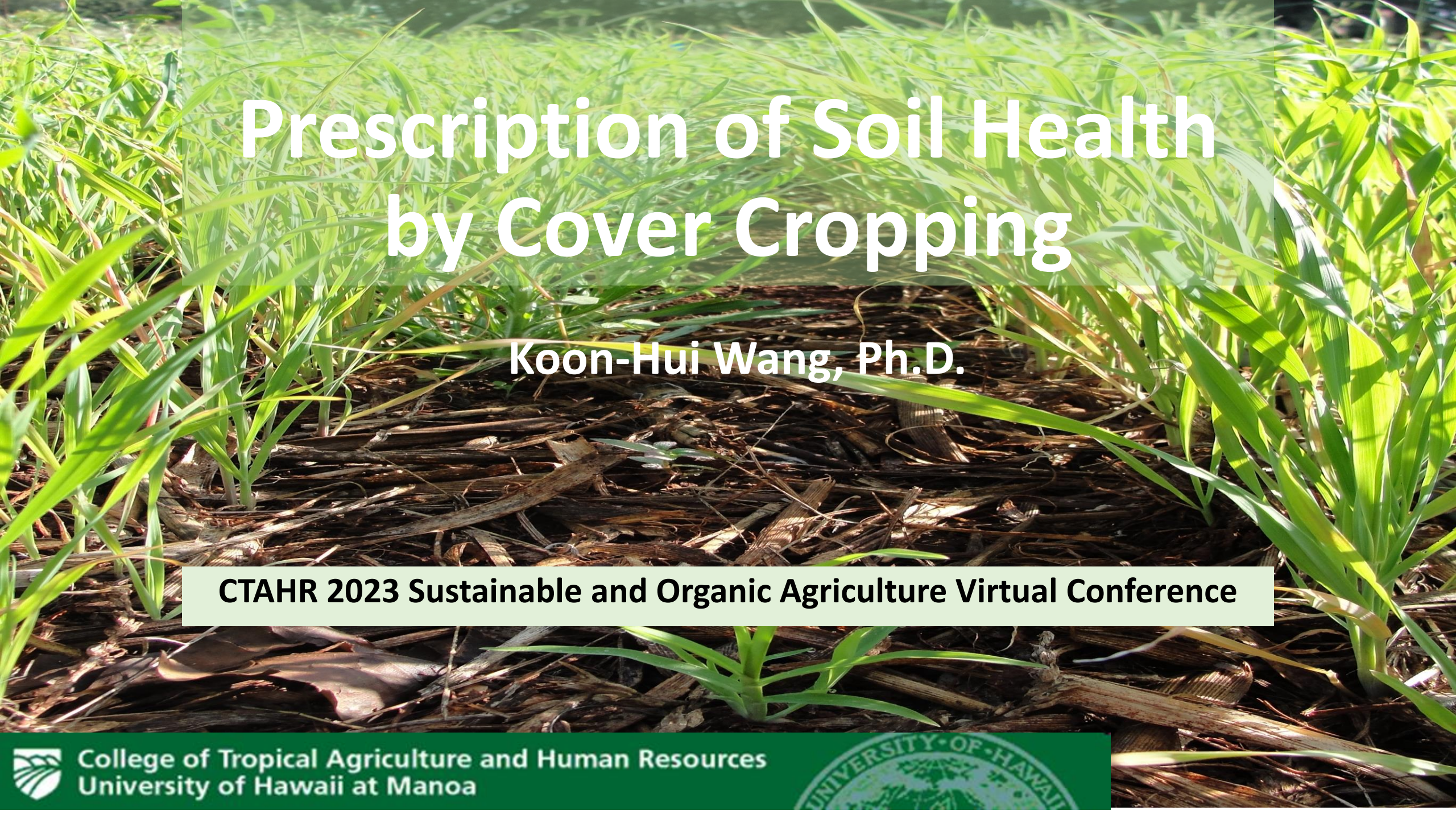


Prescription of Soil Health by Cover Cropping

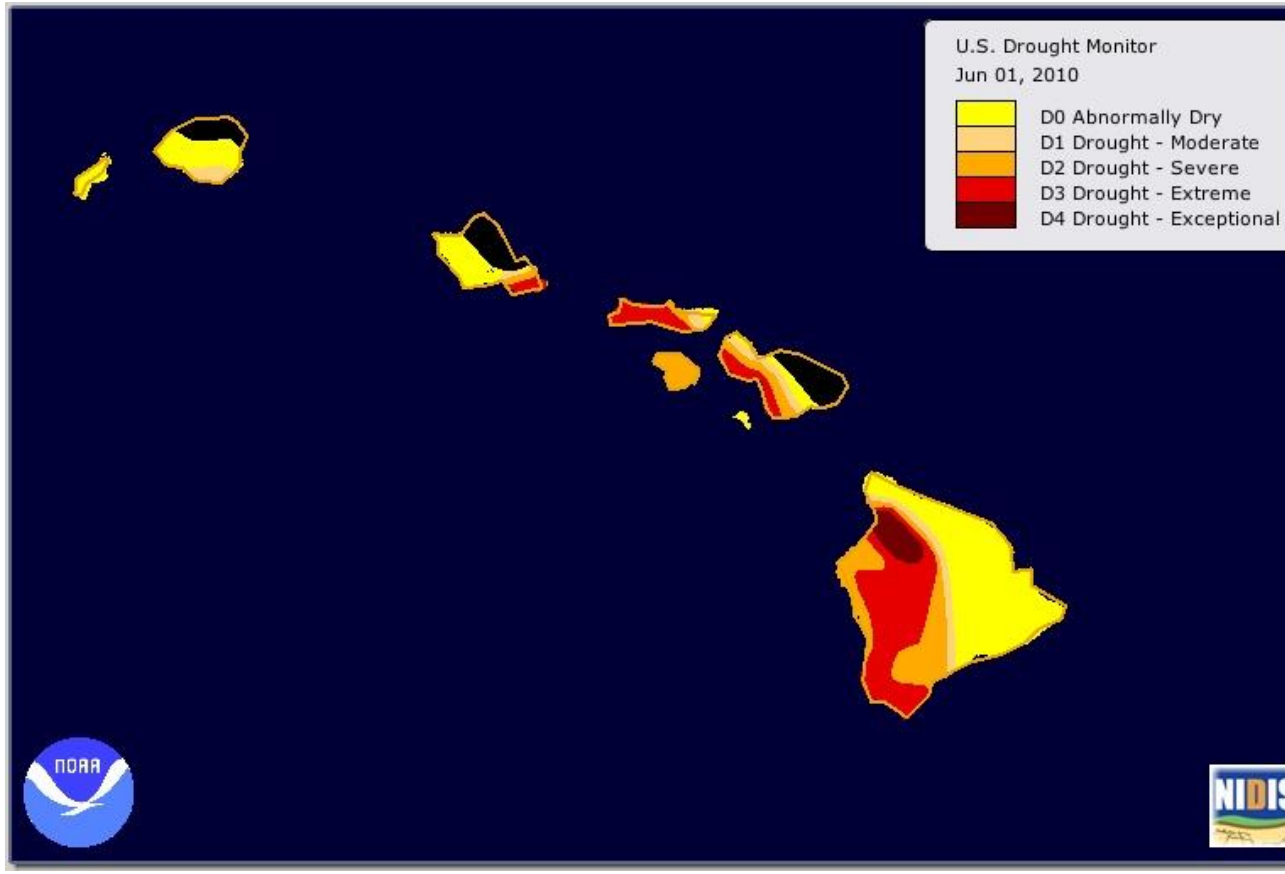
Koon-Hui Wang, Ph.D.

CTAHR 2023 Sustainable and Organic Agriculture Virtual Conference

College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa

Why do we need healthy soil?

1. World population is projected to reach more than 9 billion in 2050. To sustain this level of growth, food production will need to rise by 70 %.
2. Prime farmland were increasingly lost to development.
3. Continue planting in prime farmland led to soil degradation which is not sustainable.
4. Soil health management might be the solution to climate change.



The international "4 per 1000" Initiative

Soils for Food Security and Climate

https://4p1000.org/?lang=en

Why regenerative agriculture can be the solution to climate change?

Because soil contained 2-3 times more C than the atmosphere, increasing soil C by 0.4% per year in the top 30-40 cm of soil could stop the increase in CO_2 in the atmosphere (CIRAD, 2015).

Regenerative Agriculture

Cover the soil at all time

Reduce soil disturbance

Cover cropping

Adding Compost

Integrate

live stocks

Grow a living root 24/7

Synergize with diversity: Crop rotation/Cover crop

Healthy SOIL

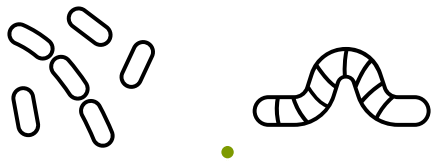
WESTERN SARE Sustainable Agriculture Research & Education

USDA NRCS

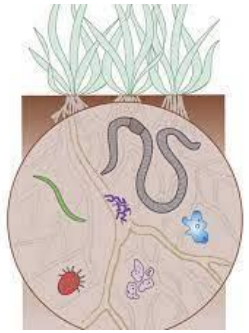
United States Department of Agriculture

Natural Resources Conservation Service

Prescription of Soil Health by Cover Cropping



Suppress plant-parasitic nematodes



Improve soil food web structure

Soil organic matter

Increase soil C by 0.4 %/yr

Tolerate high salinity and low pH

Suppress weeds

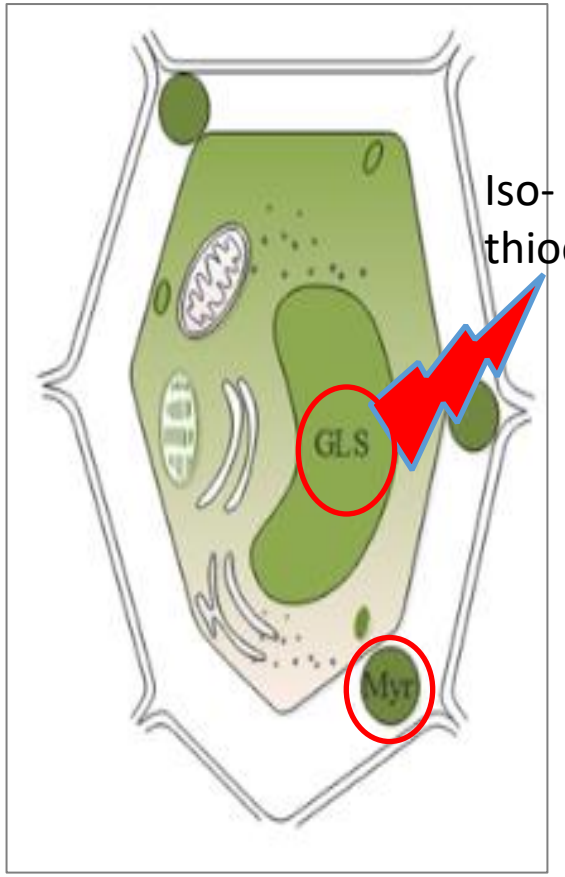
Soil nutrients & Improve crop yield

Sunn hemp, marigold, brown mustard, sorghum, velvet bean

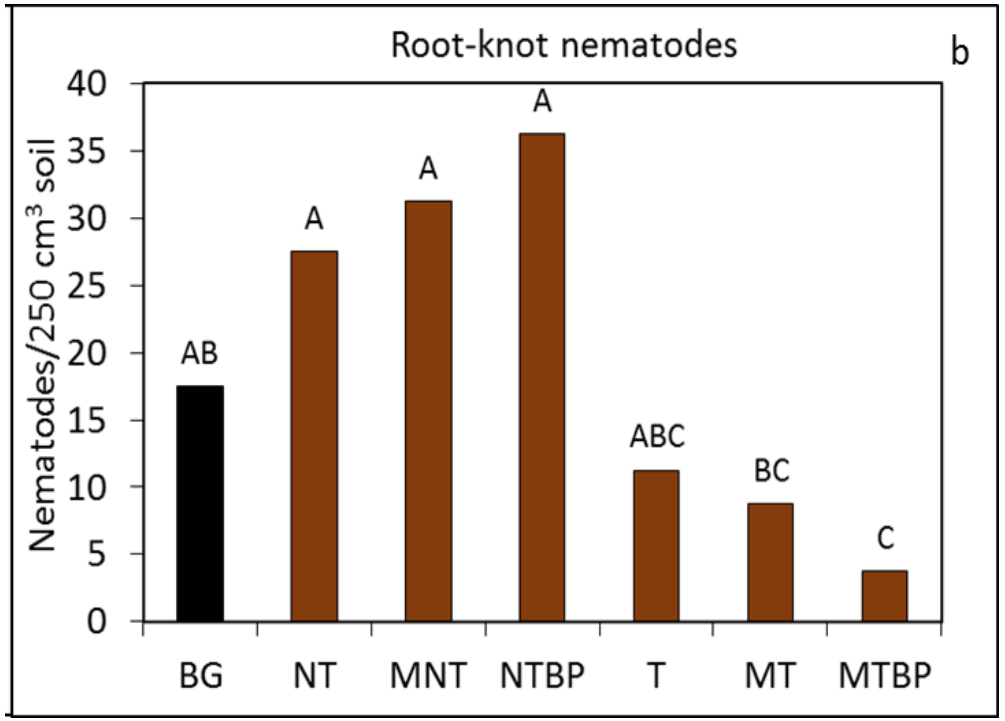
Tropical Cover Crops w/ Nematode Antagonistic Effect:

Glucosinolate Cover Crops

- Glucosinolate (GL)-derived isothiocyanate (ITC) from brassica cover crops is allelopathic (toxic) to many soil-borne fungi and nematodes (Kirkegaard et al., 1993).



- Can suppress root-knot nematodes effectively but not reniform nematodes.



Sunn hemp, marigold, brown mustard, sorghum, velvet bean

Tropical Cover Crops w/ Nematode Antagonistic Effect:

Anhydrobiotic reniform nematodes are hardy, can survive drought or nematicides, and revive after a susceptible host is planted

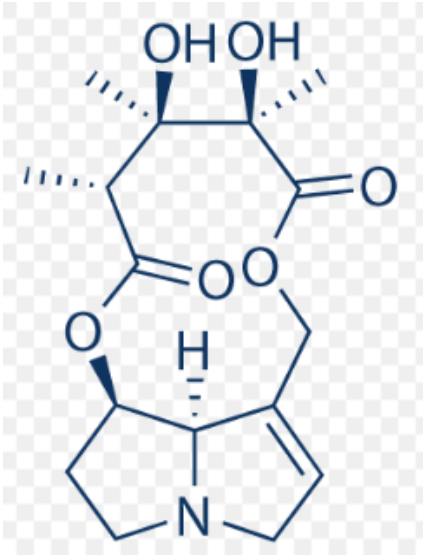
Reniform nematode life stages

Vermiform stage

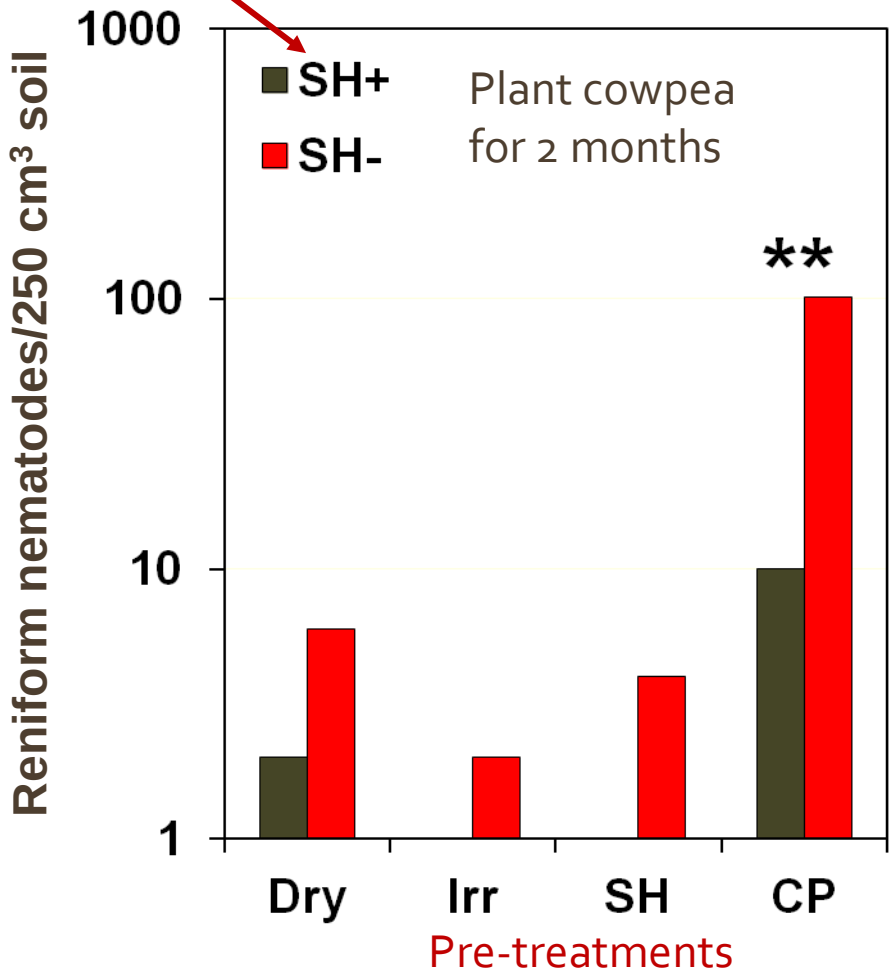
- Vermiform stages of reniform nematodes are easier to kill than the anhydrobiotic (survival) stage.
- Sunn hemp (SH) is a poor host of reniform nematode thus it will stimulate the anhydrobiotic reniform to turn into vermiform stages.
- Thus, when soil incorporate sunn hemp tissue can kill reniform efficiently

SH suppressed reniform if soil incorporate after a susceptible host

Post-treatments: amended (SH+) or not amended (SH-) with SH at 1% (w/w)



Monocrotaline is more concentrate in leaves tissues



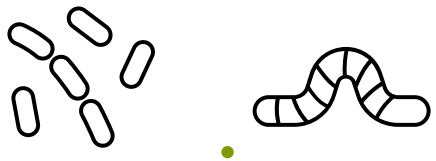
Pre-treatments

Dry = no irrigation
Irr = Irrigated
SH = planted with sunn hemp
CP = planted with cowpea

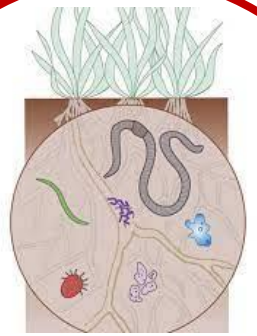
*** = significant difference between SH+ and SH-**

(Marahatta, Wang et al., 2012 Nematropica 42: 34-40)

Prescription of Soil Health by Cover Cropping



Suppress plant-parasitic nematodes



Improve soil food web structure

Soil organic matter

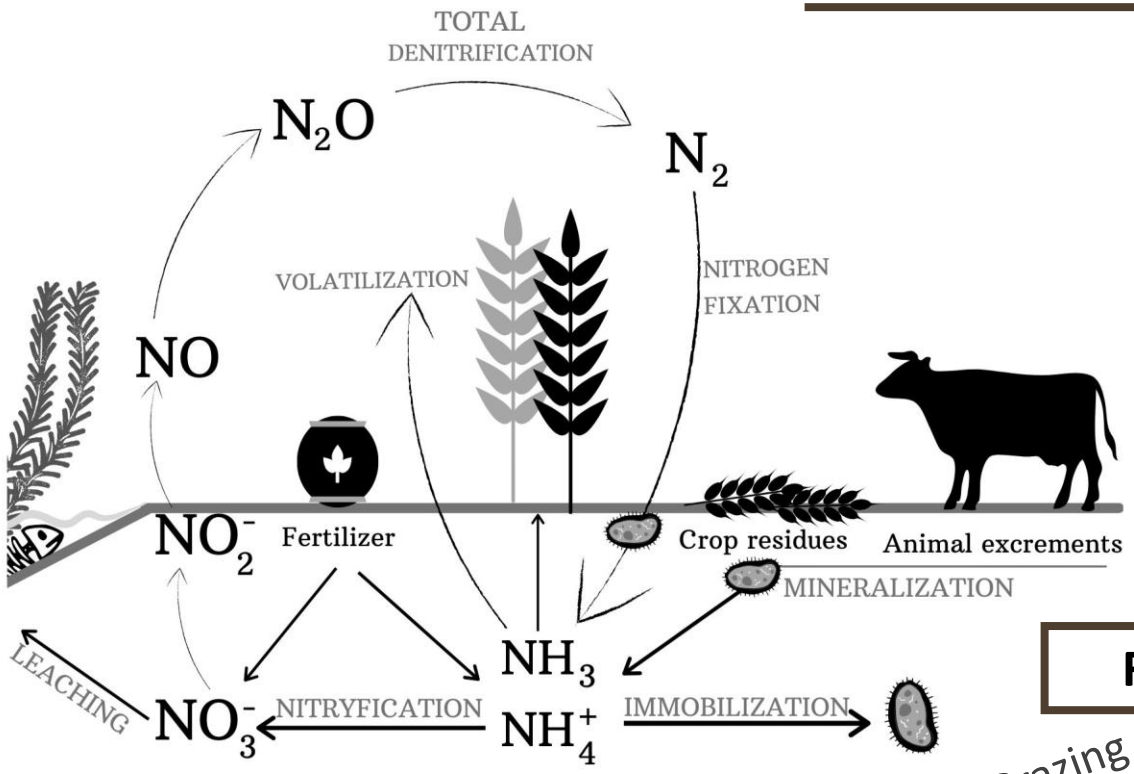
Increase soil C by 0.4 %/yr

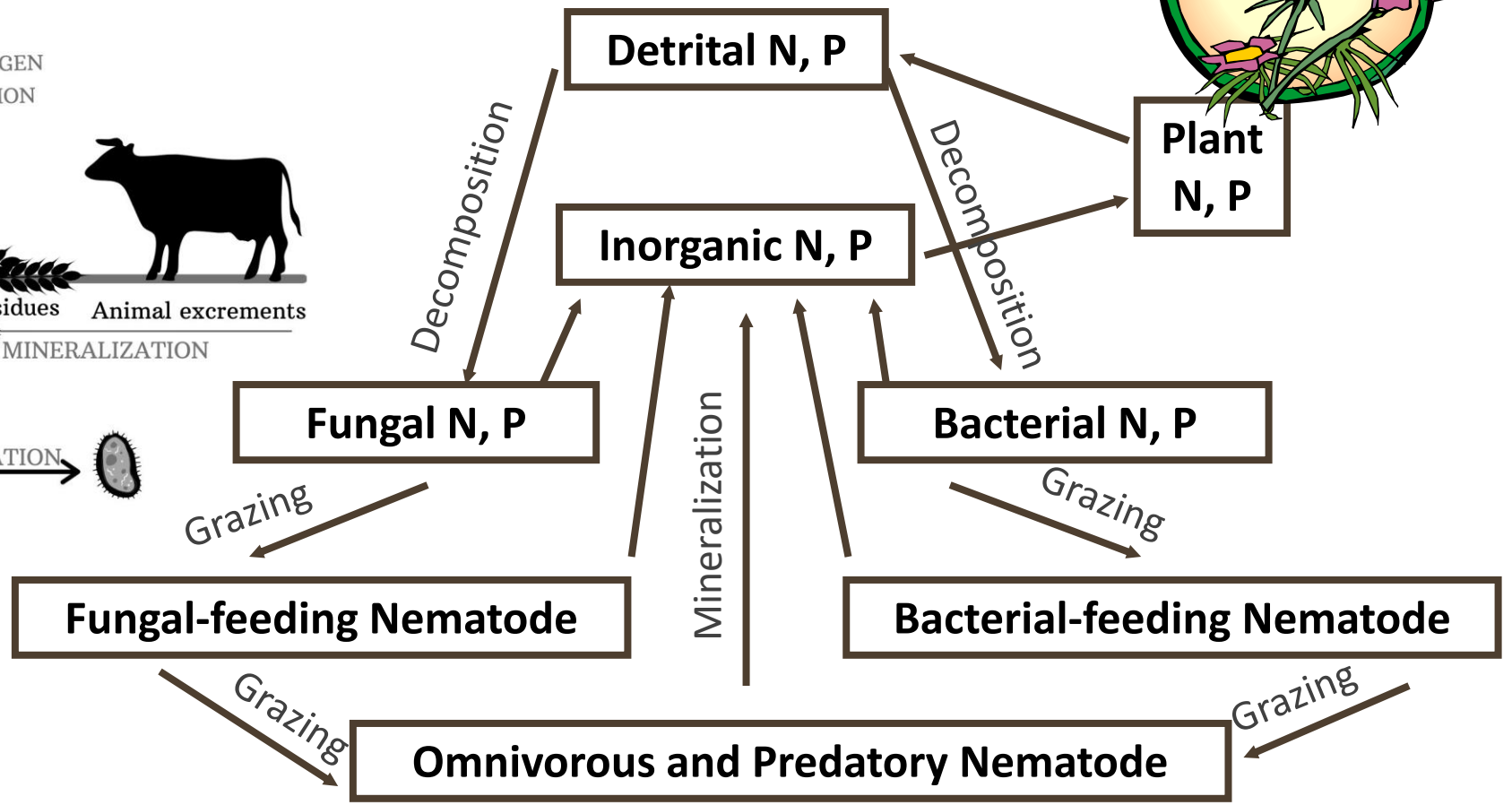
Tolerate high salinity and low pH

Suppress weeds

Soil soil nutrients & Improve crop yield

Healthy Soil Improves Soil Nutrient cycling





(modified from Ingham *et al.*, 1985)

Sunn hemp in a strip-till cover cropping system

Sunn hemp (*Crotalaria juncea*)

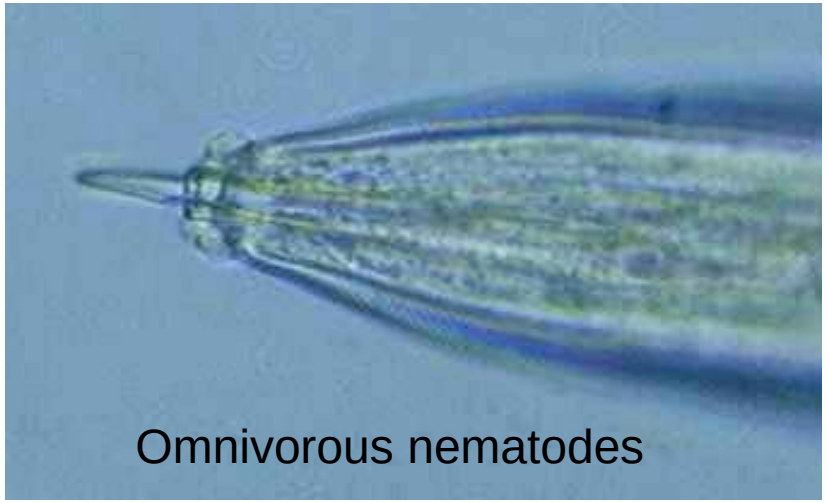
Cover crop enhance beneficial soil nematodes while suppressing plant-parasitic nematodes

Year 1

Bacteria feeding nematodes

Fungal feeding nematodes

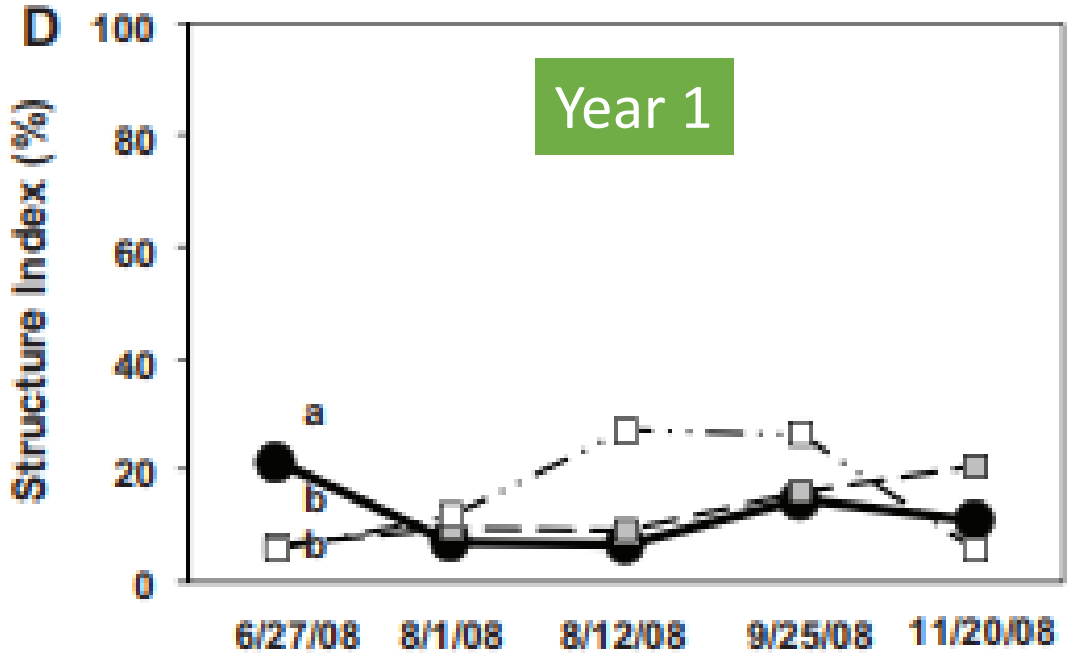
Plant-parasitic nematodes

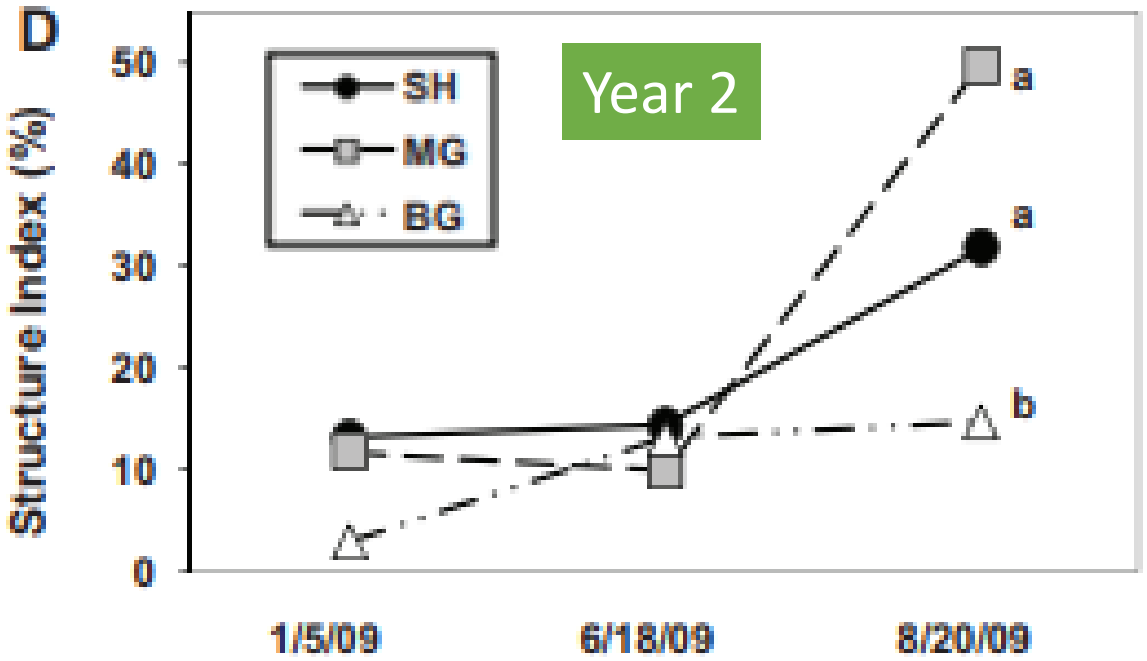


Omnivorous nematodes

(Wang et al. 2011, Applied Soil Ecology 49: 107-117)

Sunn hemp and Marigold in a strip-till cover cropping system



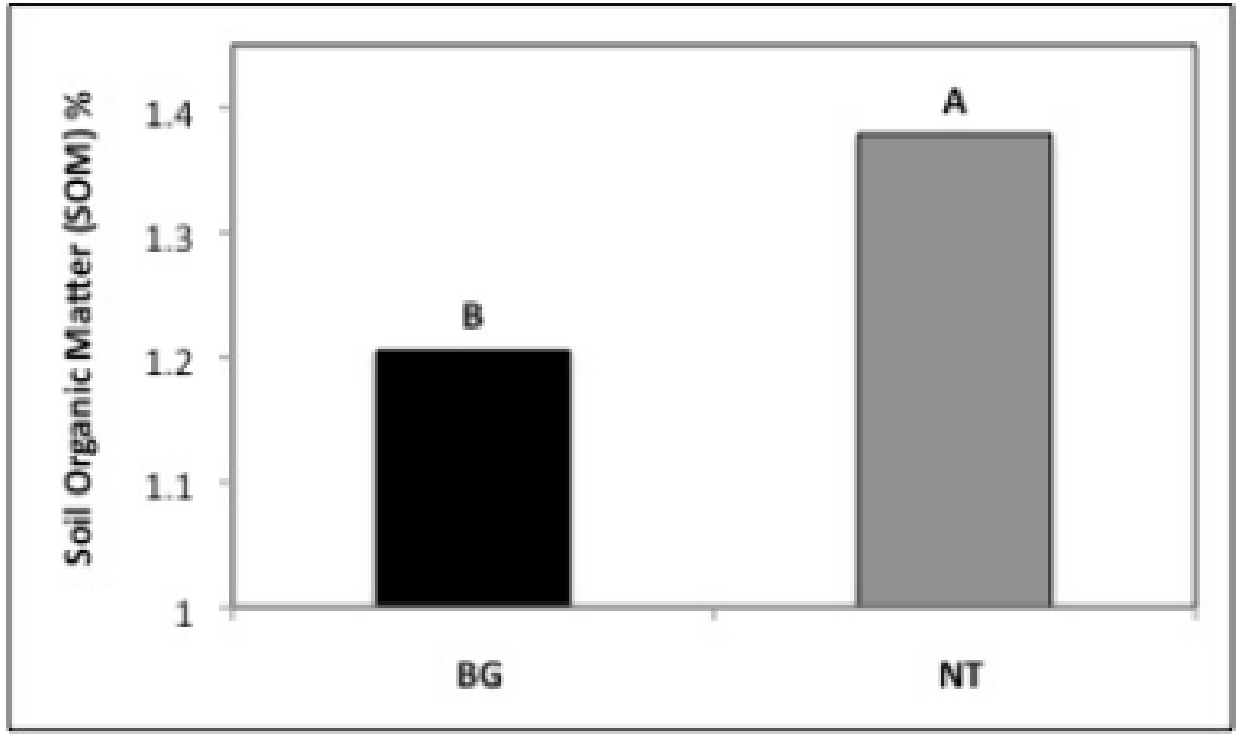


(Wang et al. 2011, Applied Soil Ecology 49: 107-117)

Sunn hemp in a strip-till cover cropping system

- ✓ Can suppress plant-parasitic nematodes effectively.
- ✓ Can increase omnivorous or predatory nematodes within one cropping cycle, but only increase SI in the second cropping cycle.
- ✗ Increase soil C slowly, even after 7 years of consecutive SH-vegetable crop conservation tillage practice, it did not increase soil C close to 0.4%.

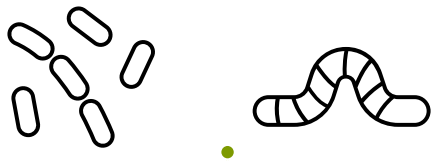
0.18% increase in Soil Organic Matter



7 consecutive years of no-till (NT) or strip-till with sunn hemp compared to conventional till with bare ground practice.

- ✗ Sunn hemp also can't grow in highly acidic soil nor in soil with high salinity.

Prescription of Soil Health by Cover Cropping



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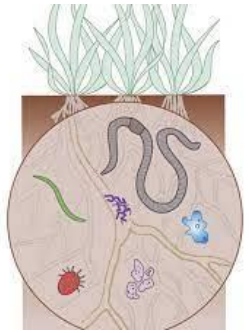


Improve soil food web structure

Soil organic matter

Increase soil C by 0.4 %/yr

Tolerate high salinity and low pH

Suppress weeds

Soil soil nutrients & Improve crop yield

Tropical Cover Crops w/ Nematode Antagonistic Effect:

Sunn hemp, black oat, brown mustard, sorghum, velvet bean

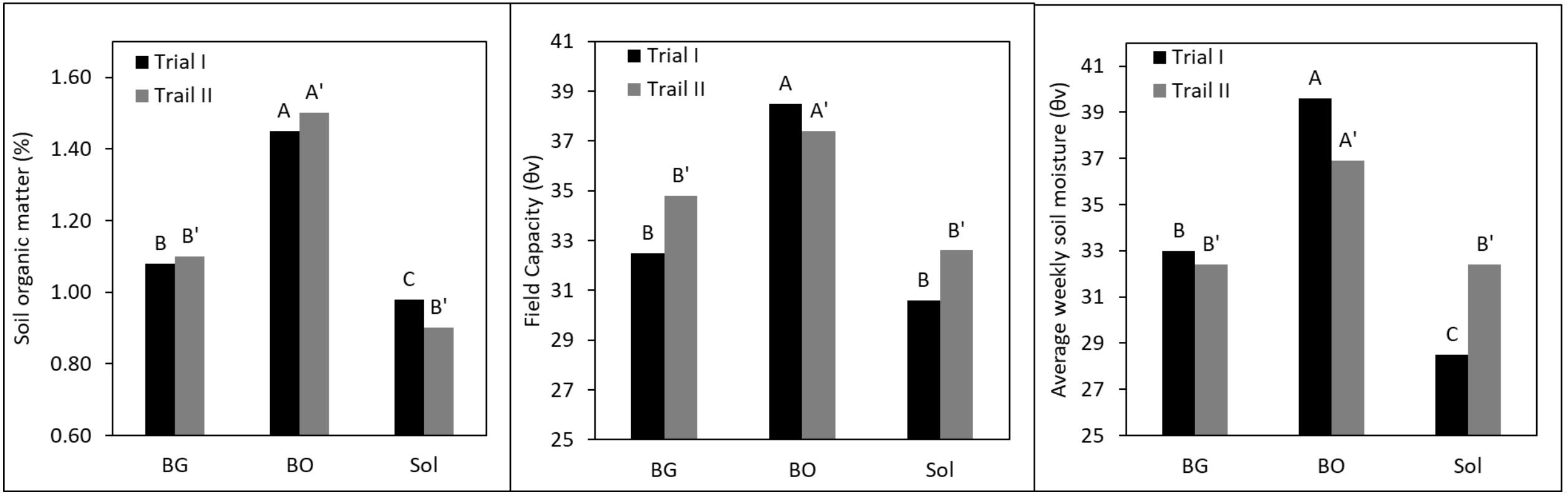
Effects of Black Oat Cover Cropping & No-till following 8 years of Conservation tillage practices

Trial I 2015
Trial II 2016

Plant corn after

No-till of Black Oat increased soil C by 0.4% after 2 years

BO = No-till with black oats, BG = bare ground, Sol = solarization

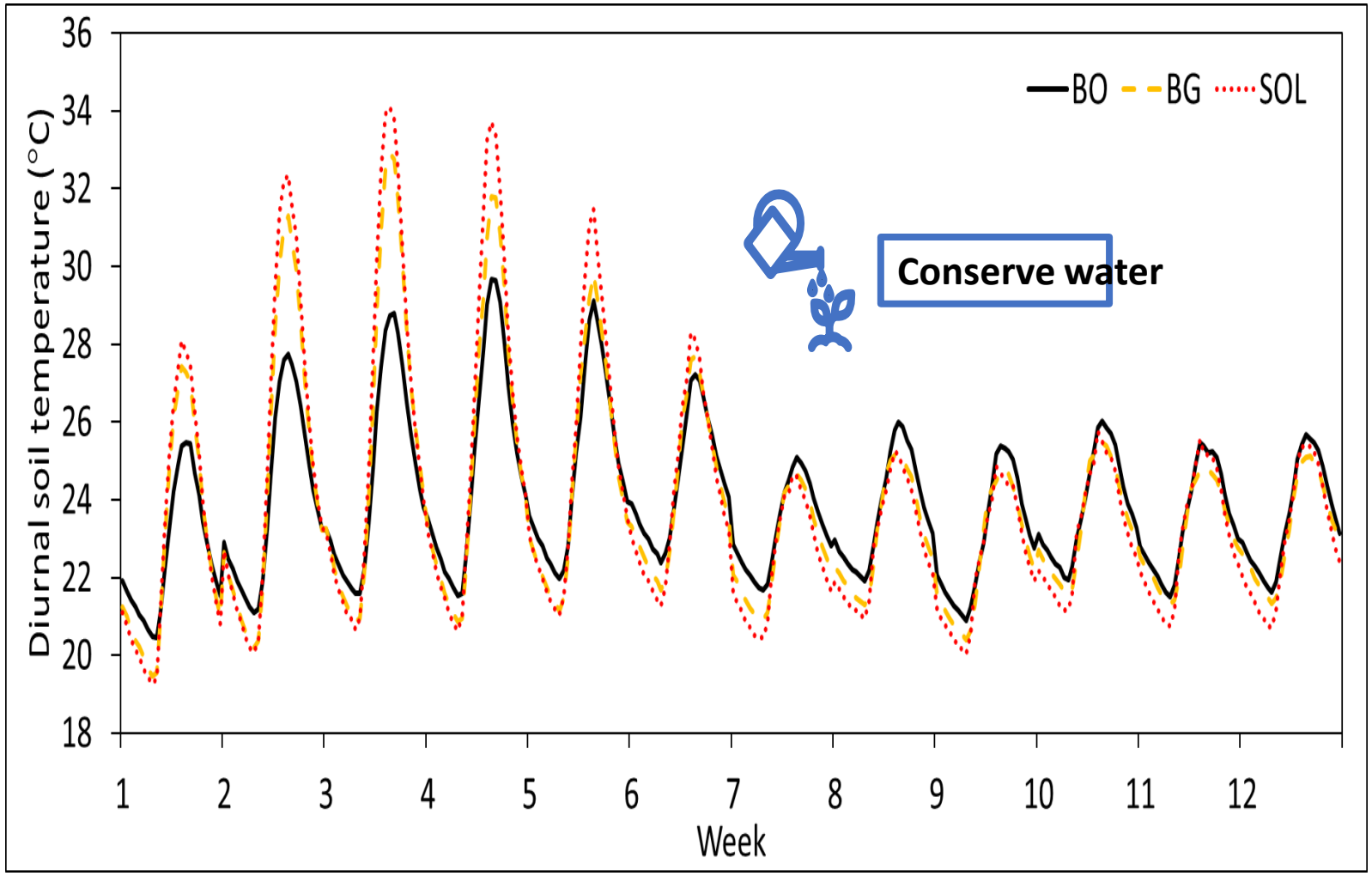


- BO+No-till increased SOM by 0.38% in Trial I and 0.4% in Trial II (✓); and increased water holding capacity by 7.5-18%; and soil moisture on corn crop by 14-20%

(Marquez et al., 2022)

Black Oat in a No-till cover cropping system

- ○ Did not suppress plant-parasitic nematodes due to low PPN pressure on corn.
- ✓ Increase SI in the second cropping cycle.
- ✓ Increased soil C close to in Year 1 and achieved 0.4% in Year 2.
- ✗ Did not improve water infiltration rate



BO surface organic mulch last for ~6 weeks after corn planting, thus, reduced evapotranspiration rates in the soil thus maintained higher soil moisture .

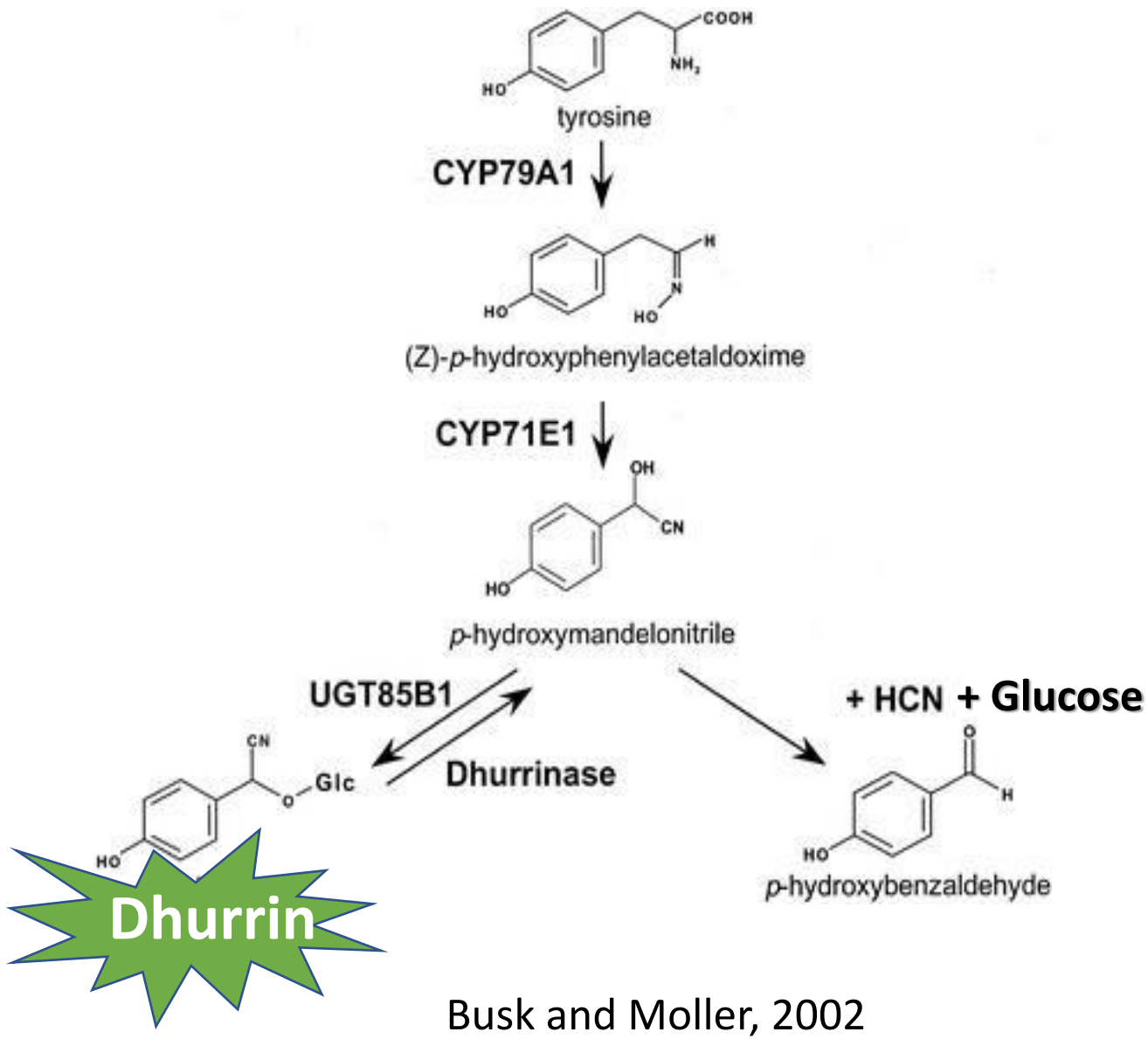
(Marquez et al., 2022)

Sorghum also have allelopathy against weeds.

Tropical Cover Crops w/ Nematode Antagonistic Effect:

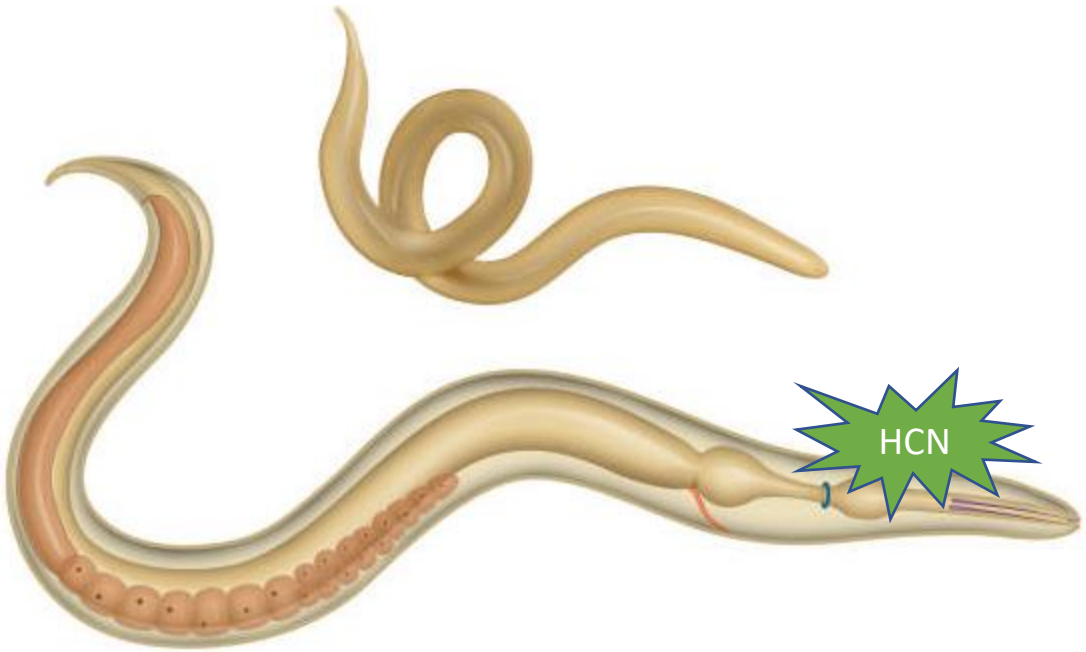
Sunn hemp, black oat, brown mustard, sorghum, velvet bean

Biofumigant from Sorghum/Sorghum-Sudangrass (SSgH)



Busk and Moller, 2002

Need to be soil incorporated

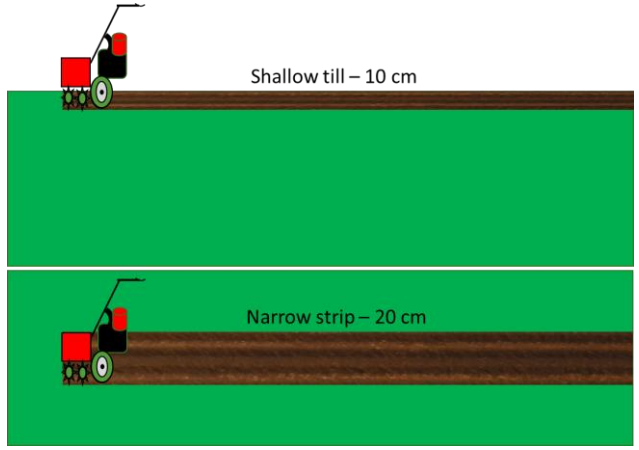


Leaf tissues release HCN (nematicidal) upon hydrolysis of dhurrin (= Biofumigation).

Evaluate SSgH for soil building and water conservation properties in a Strip and Low-till system

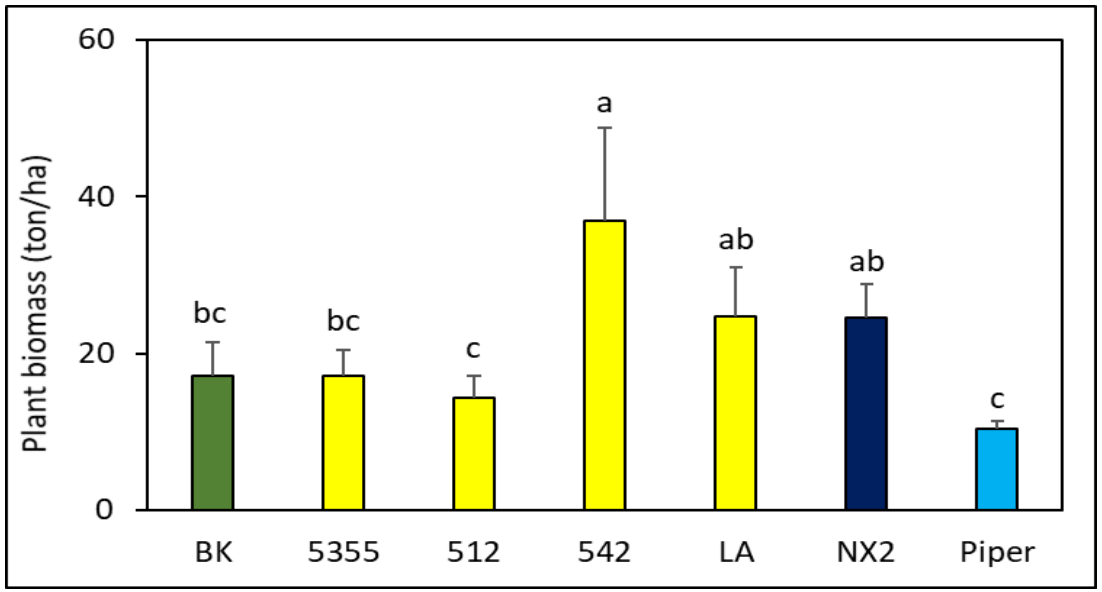
Field Trial at Poamoho Station

- Treatments – 7 SSgH varieties and one bare ground (BG) control.
- Terminated with a flail mower at 2.5 months.
- Strip till of 20-cm wide and 10-cm deep strip for all SSgH plots. Till BG.
- Planted eggplant for 6 months.

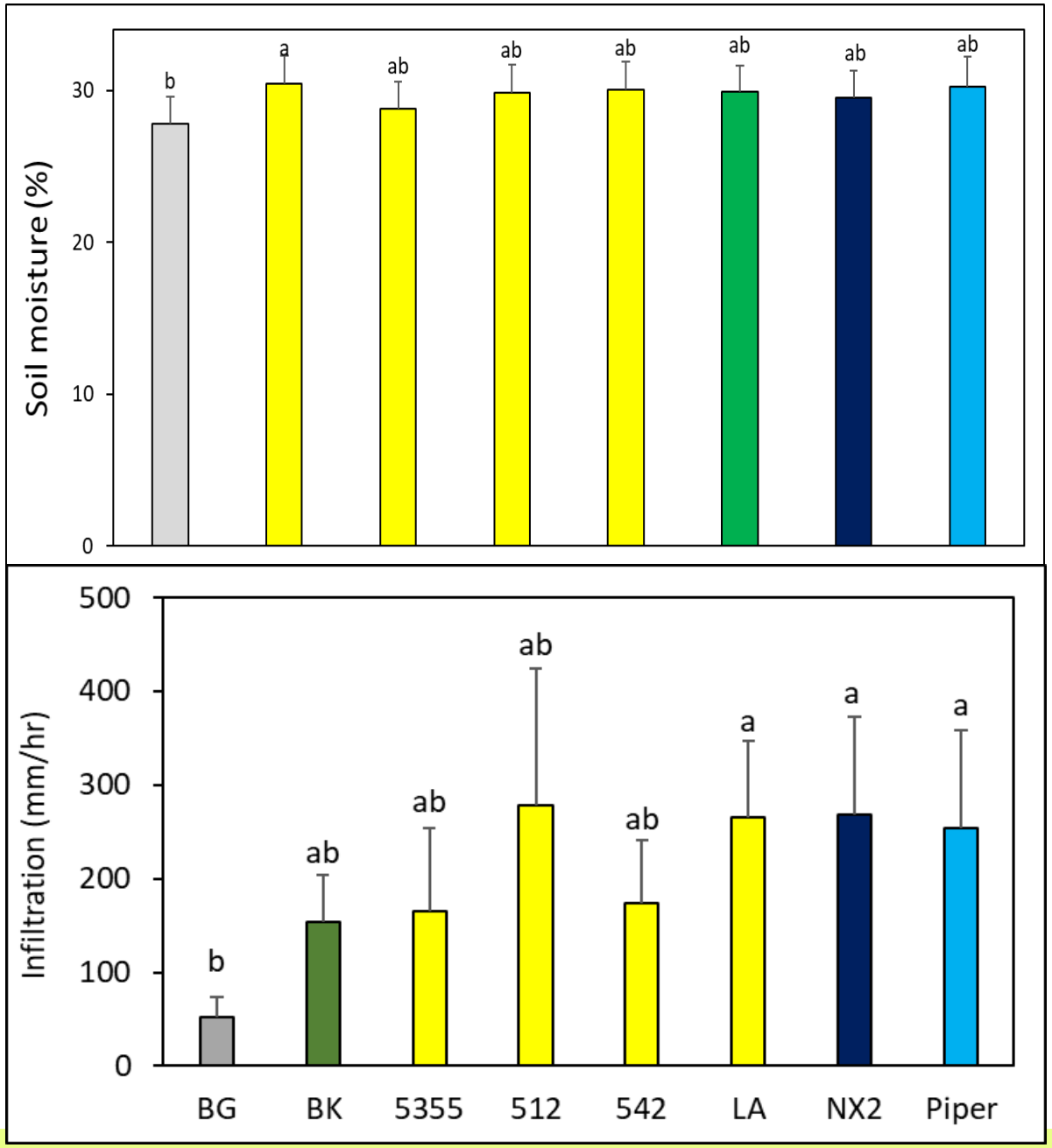


SSgH's Water Conservation Abilities

SSgH biomass in 2.5 months



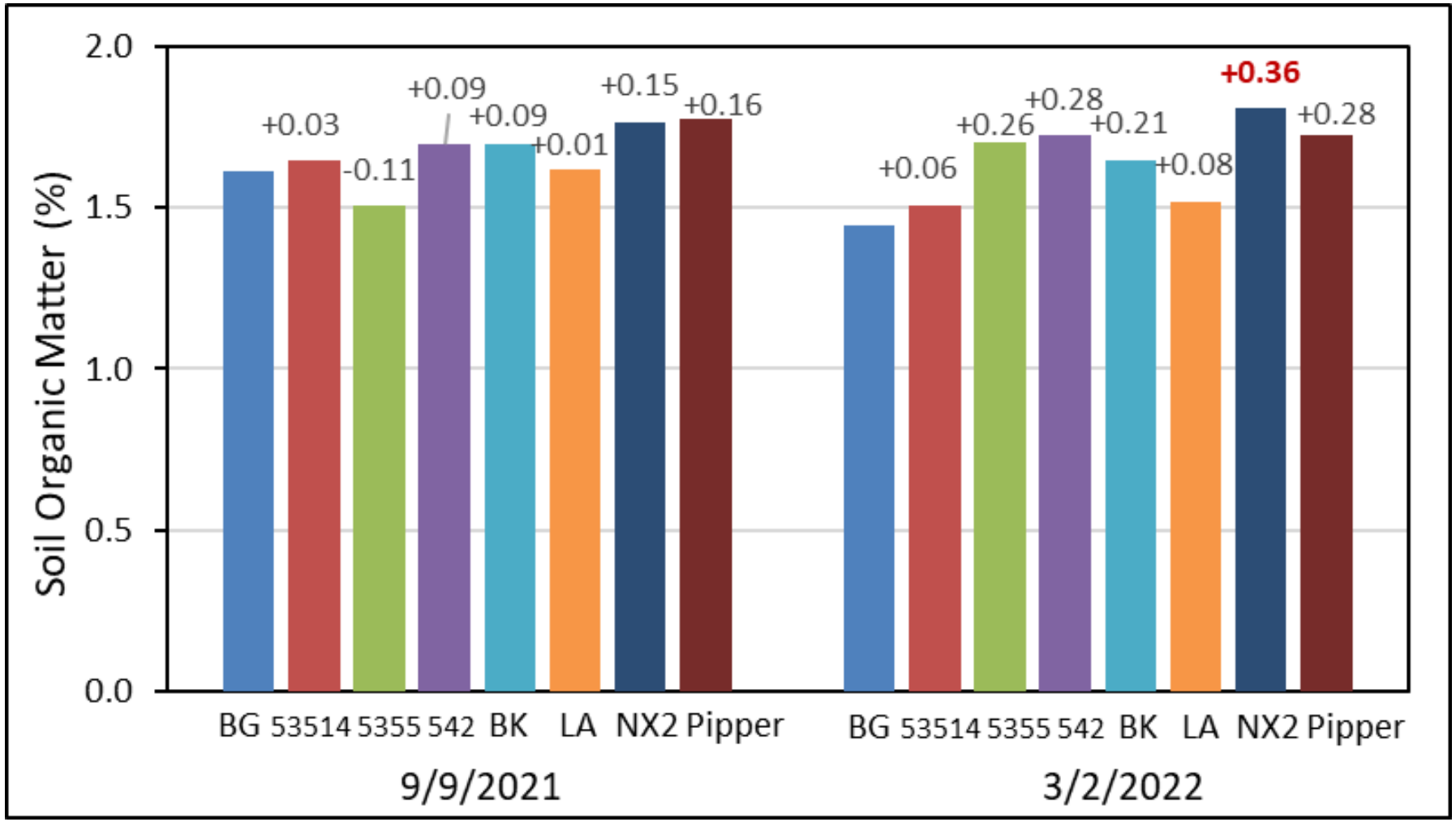
Throughout 5 months of eggplant



Soil C

Year 1

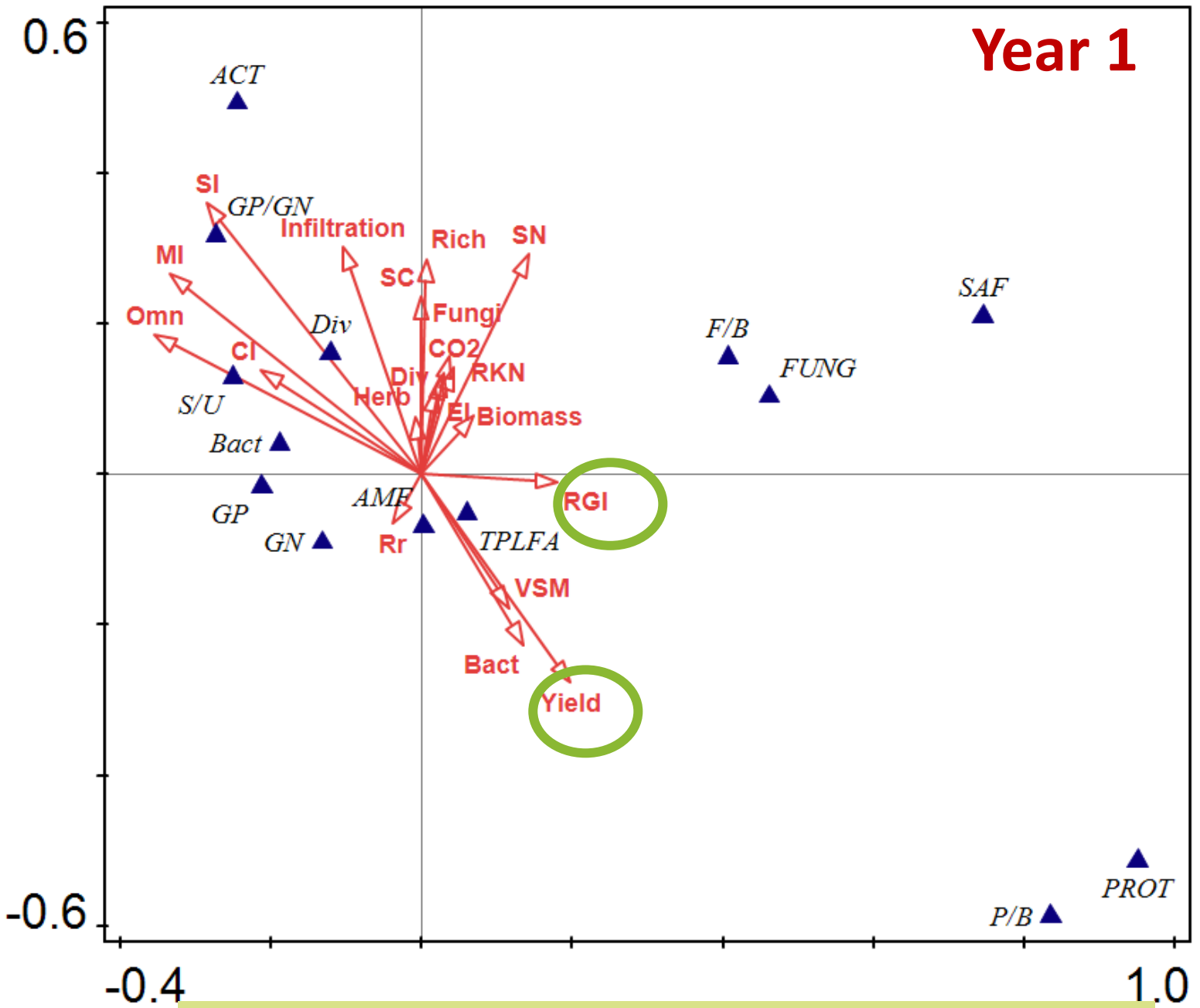
- ‘NX2’ increased soil C ~0.4%, and also supported highest numbers of omnivores and fungivores in Year 1, and increased these trophic groups again in Year 2 plus significantly higher richness and SI.



2.5 months cover cropping| ----------3 months of eggplant-------|

Relationships b/t Soil Food Web Structure & Eggplant Yield in a SSgH Strip-till System

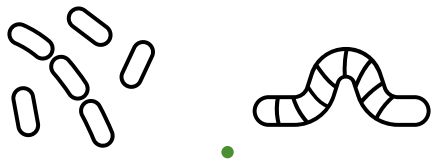
- Eggplant yield was positively related to total microbial biomass (TPLFA), volumetric soil moisture (VSM), and abundance of bacterivorous nematodes (Bact).
- Root-gall index (RGI) was reduced at higher SI, CI and abundance of omnivorous nematodes.

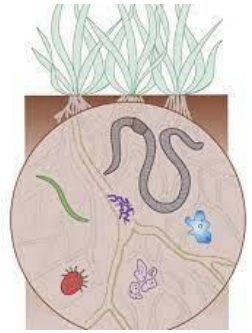


First two canonical analysis explained 76.59% of variance

(Paudel et al., 2022)

Prescription of Soil Health by Cover Cropping





Soil organic matter

Suppress plant-parasitic nematodes

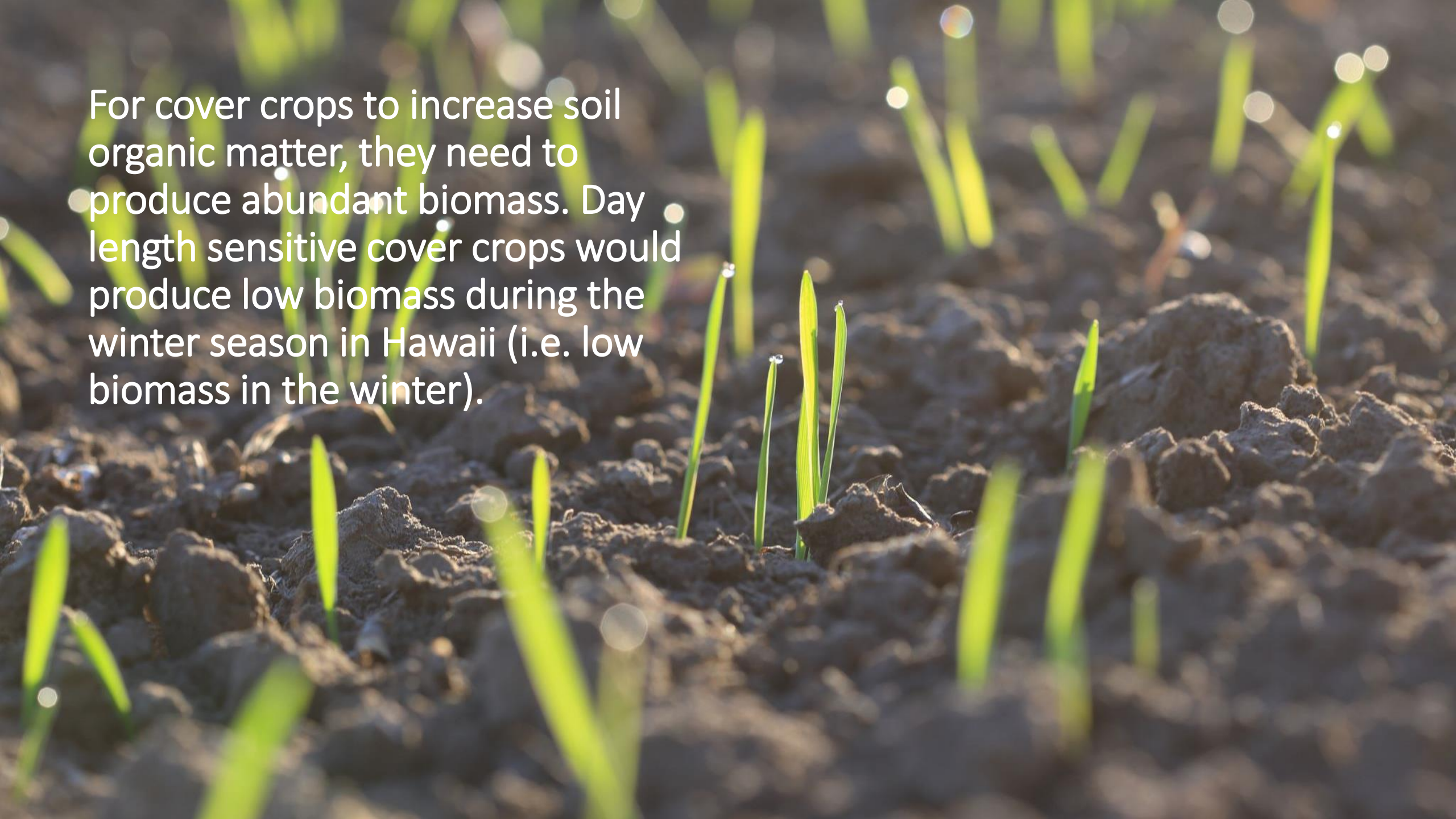
Improve soil food web structure

Increase soil C by 0.4 %/yr

Tolerate high salinity and low pH

Suppress weeds

Soil nutrients & Improve crop yield



For cover crops to increase soil organic matter, they need to produce abundant biomass. Day length sensitive cover crops would produce low biomass during the winter season in Hawaii (i.e. low biomass in the winter).

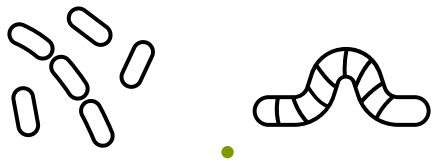
Cover Crops for soils with high salinity

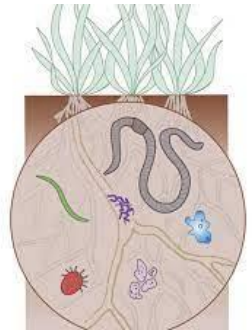
	Black oat	Sorghum/ SSgH	French Marigold	Sunn hemp	Velvet bean	Brown mustard	Sunflower	Alfalfa	Cowpea
Root-knot and reniform nematodes	No allele-pathic Non host	Allelo-pathic Non host	Allelo-pathic Resistant	Allelo-pathic Poor host	Allelo-pathic Poor host	Allelo-pathic Good host	No Allelo-pathic, some var are resistant	No Allelo-pathic, some var are resistant to root-knot	No Allelo-pathic, some resistant to root-knot, all susceptible to reniform
High salinity	Tolerant	Tolerant	Moderately tolerant	x	x	x	Tolerant	Tolerant	X when young, Tolerant when old
Day length sensitive	Inter-mediate	yes	yes	yes	yes	no	yes	no	no

Not good to grow in winter for HI

X

Prescription of Soil Health by Cover Cropping





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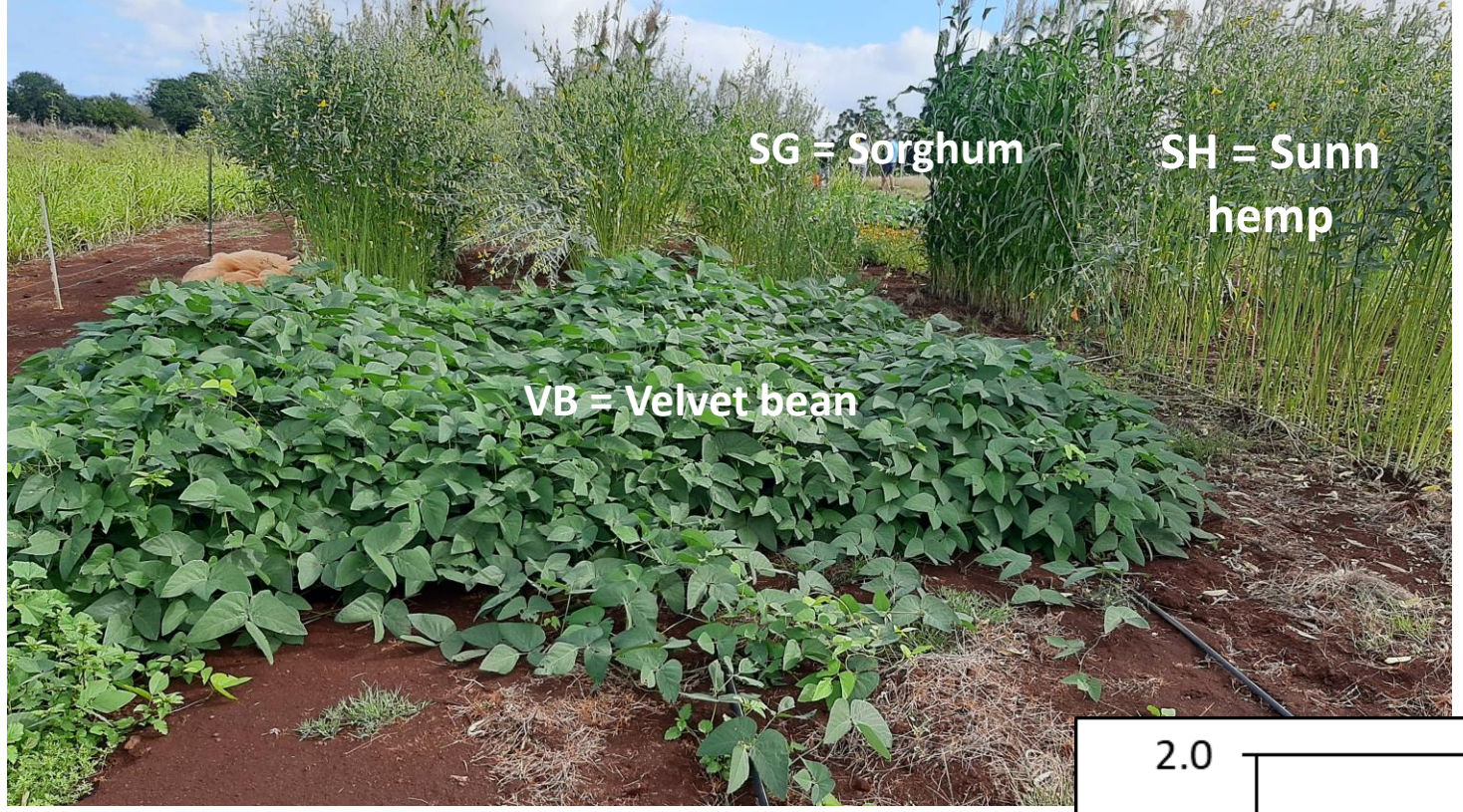
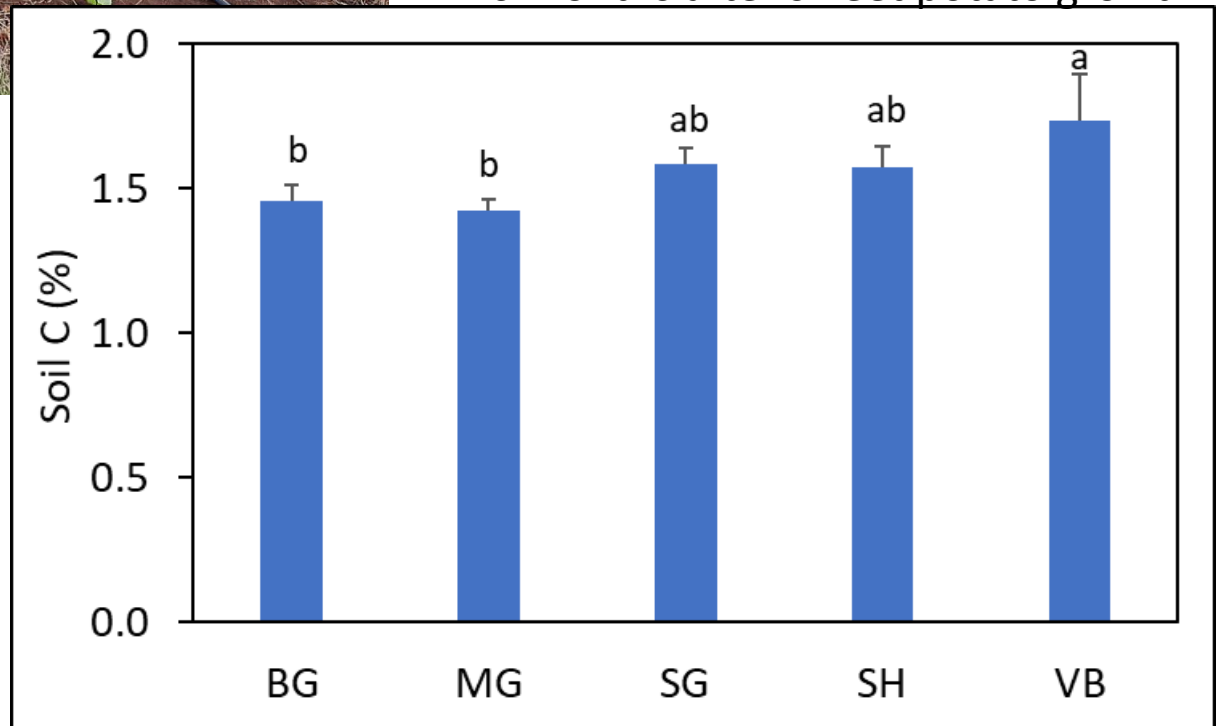
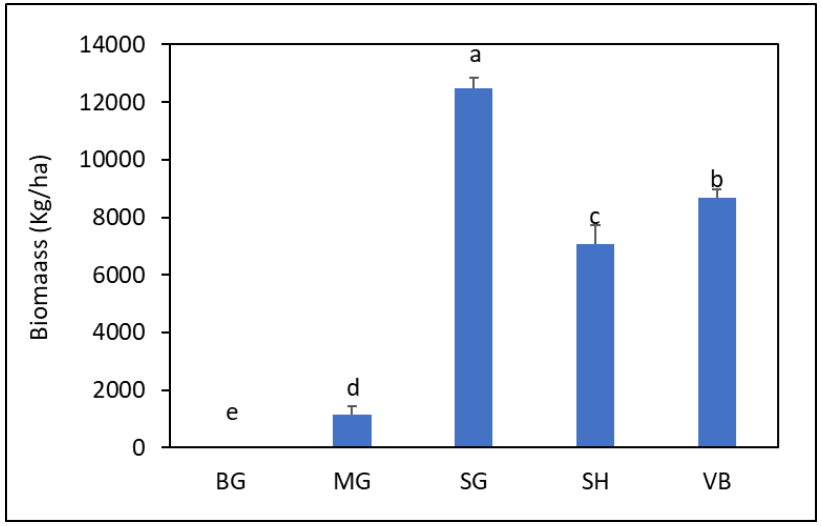


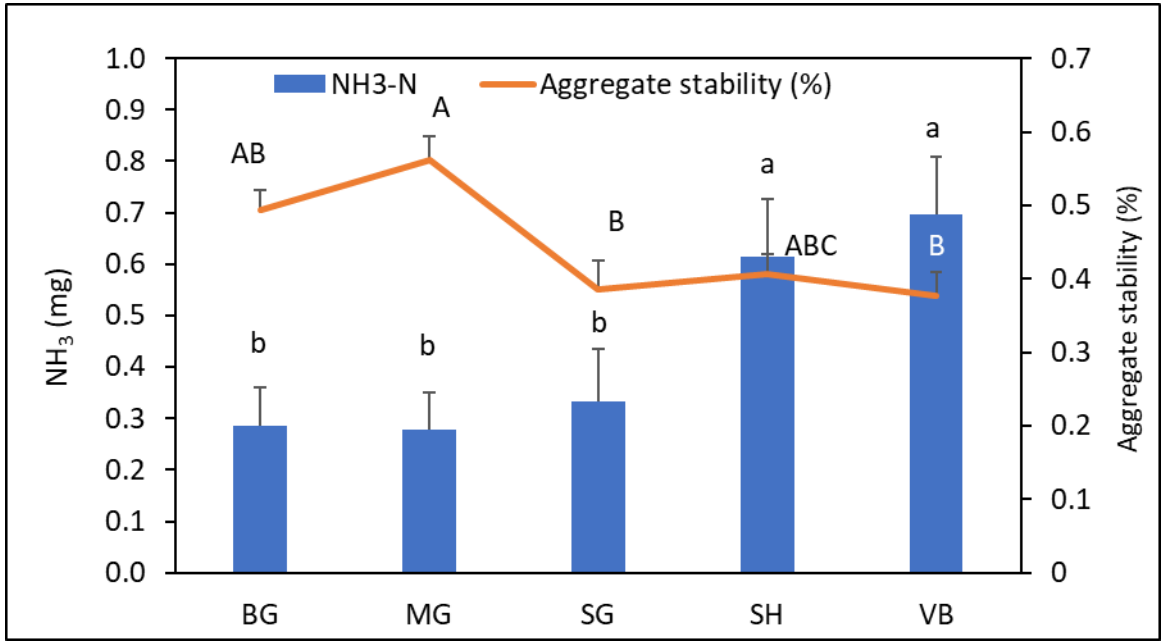
- VB required the least irrigation among the tropical cover crop tested.
- VB increased soil C by 0.38% at cover crop termination.

6 months after sweet potato growth



3 months after cover cropping & 4 weeks after soil incorporation



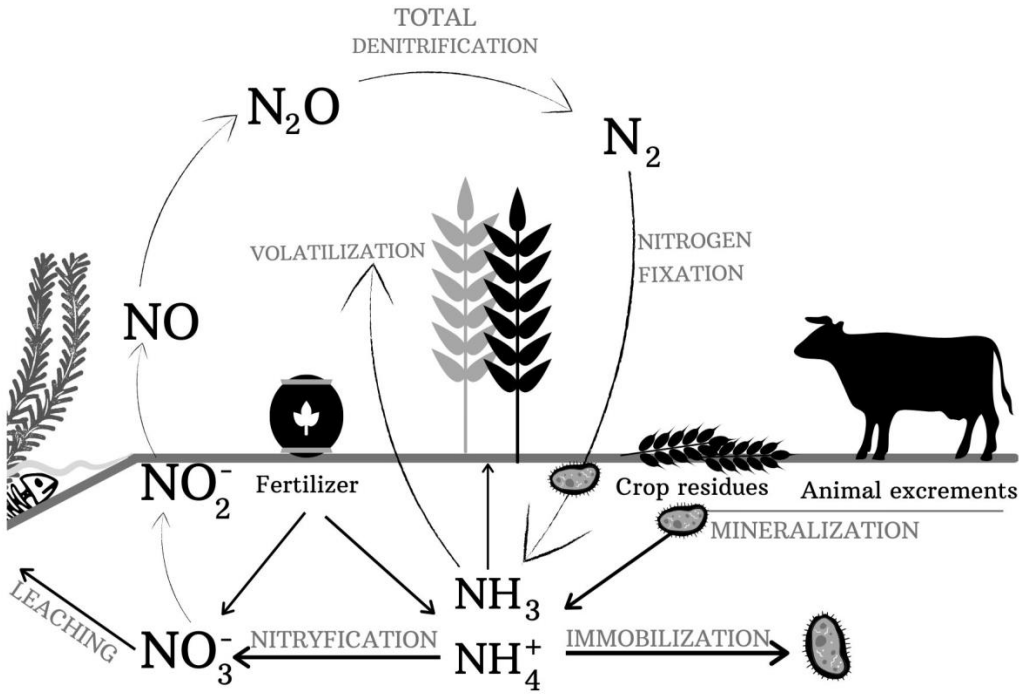


Solvita Tests

SLAN-Test (NH3-N)

BUST Test (CO2)

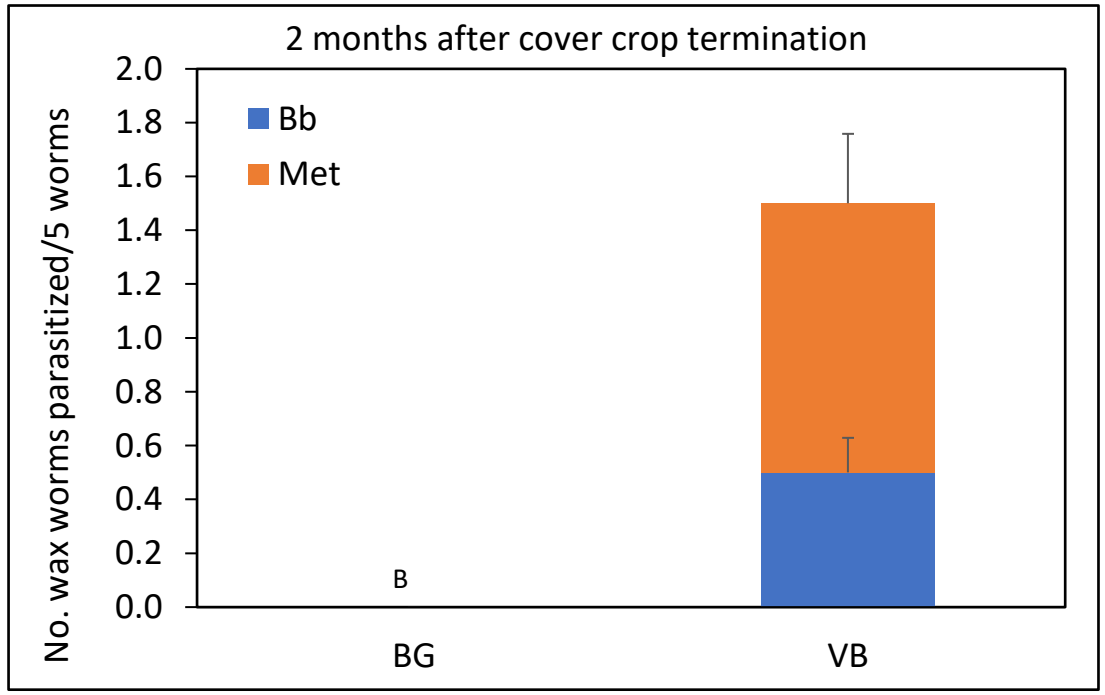
VB and SH had higher NH_4^+-N that other treatments, which would be more available to the plants and less likely to leach in the soil, thus more N efficient for the crop especially when soil moisture can also maintain higher in these treatments.



3 months after cover cropping & 4 weeks after soil incorporation

Trt	TPLFA (ng/g)	DIV	ACT (ng/g)	GN (ng/g)	Fungi (ng/g)	AMF (ng/g)	Un (ng/g)	GP/GN (ng/g)	S/U (ng/g)	F/B
BG	1585.78	1.11 b	140.51a	120.28 b	13.05 b	0.00 b	66.20 a	3.68 a	9.16 a	0.03 b
MG	1584.07	1.14 b	132.43a	145.73 b	51.80 ab	3.79 b	64.01 a	3.53 a	9.26 a	0.06 b
SG	1956.59	1.16 b	153.45ab	217.39 ab	27.96 b	4.86 b	61.30 ab	2.43 ab	5.91 ab	0.04 ab
SH	1979.20	1.13 b	157.60ab	201.29 ab	22.70 b	0.40 b	63.37 ab	2.77 ab	7.42 ab	0.03 b
VB	2227.05	1.30 a	141.66b	288.49 a	105.96 a	33.06 a	58.13 b	1.89 b	4.17 b	0.13 a

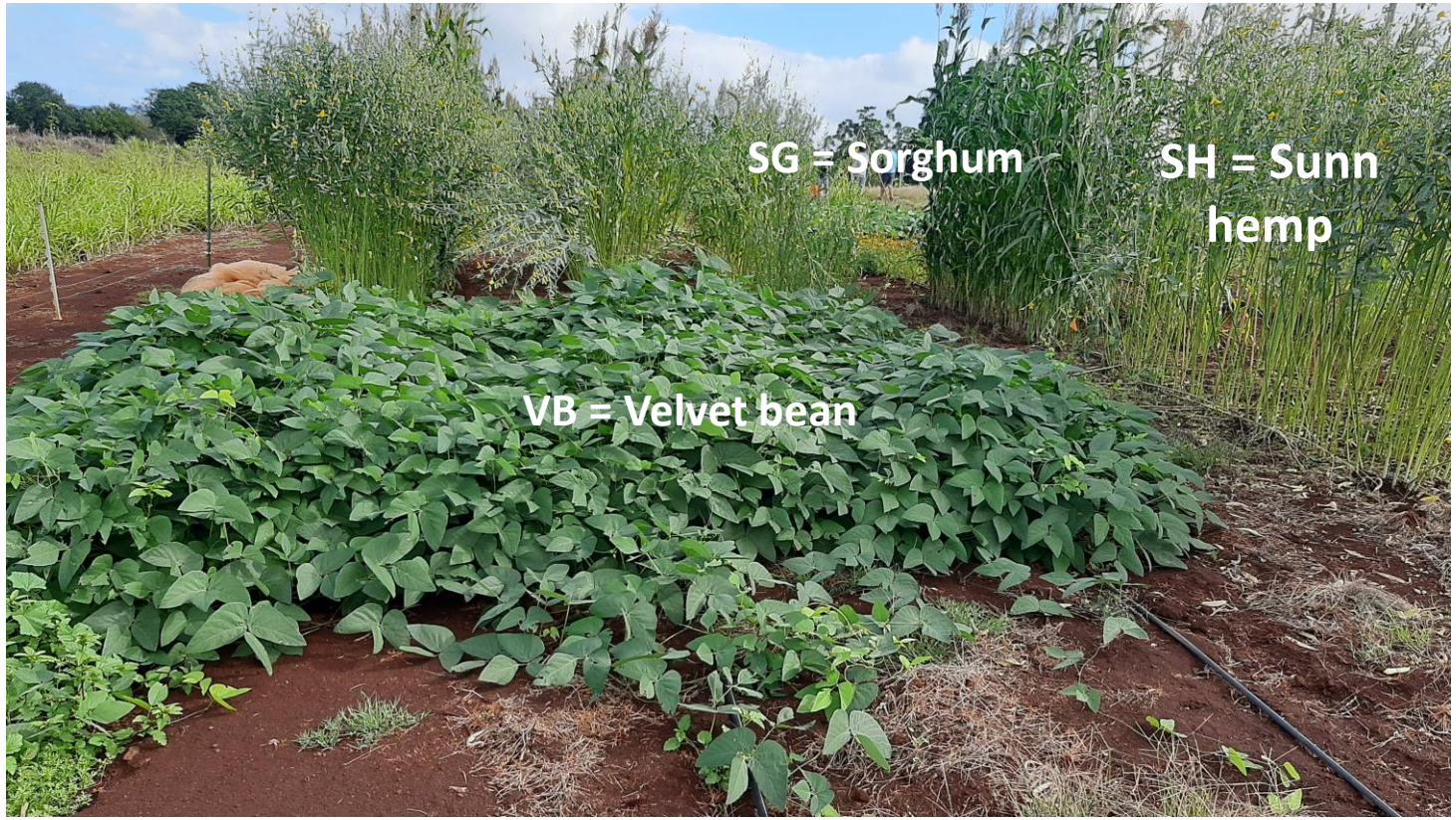
- ✓ VB increased arbuscular mycorrhizal fungi (AMF), saprophytic fungi (SF), and resulted in a higher fungi: bacteria (F/B) microbial biomass ratio.
- ✓ VB enhanced indigenous entomopathogenic fungi (*Metharhizium* and *Beauvaria*) within 2 months after strip-till.



Velvet bean

Summary

- High C: N tropical cover crops (sorghum, black oat) as well as velvet bean are most effective in increasing soil C.
- Strip-till cover cropping allows allelopathic compounds from SG, SH, VB to suppress PPN while reducing disturbance to soil food web compared to conventional tillage.



- Low-till might not protect deep rooted cash crops from PPN, but induction of PGPR (G+ or G-) or AMF by strip-till cover cropping might induce host plant resistance of the cash crops against PPN and led to better yield.

Prescription for Soil Health by Cover Cropping for HI

For annual cropping systems

	Black oat	Sorghum/ Sudangrass	French Marigold	Sunn hemp	Velvet bean	Brown mustard	Sun-flower	Alfalfa	Cowpea	Lablab
Root-knot (RKN) and reniform nematodes	No allele-pathic	Allelo-pathic	Allelo-pathic	Allelo-pathic	Allelo-pathic	Allelo-pathic; susc. to RKN	No Allelo-pathic	No Allelo-pathic	No allelo-pathic, susc. to reniform	No allelopathic susc. to RKN and reniform
High salinity	Tolerant	Tolerant	Moderately tolerant	x	x	x	Tolerant	Tolerant	Tolerant when old	x
Acidity (pH range)	4.5-7.3	5.5-8.5/ 5.0-9.0	6.0-7.0	5-7.5	<5.0 - 8.0	5.8-7.8	6.0-6.8	6.2-7.0	4.3-7.9	4.5-6.5
Suppress weeds	medium	✓	no	ok	✓	no	medium	slow	✓	✓
* Increase C ~0.4%/yr	Yes (yr 1)	Yes (yr 1)	No	No	Yes (yr 1)	No	No info	No info	No info	No info
Day length sensitive	Inter-mediate	yes	yes	yes	yes	no	yes	no	no	yes

(* Conservation tillage system)

Will not produce sufficient biomass in the winter

x = not tolerant

https://cms.ctahr.hawaii.edu/soap/Hanai-Ai

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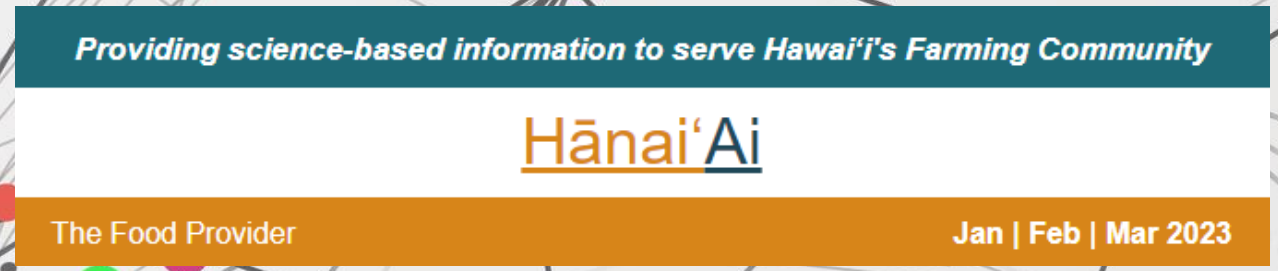

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