Nematode Linkage to Regenerative Agriculture:

Examples from Tropical/Subtropical Systems

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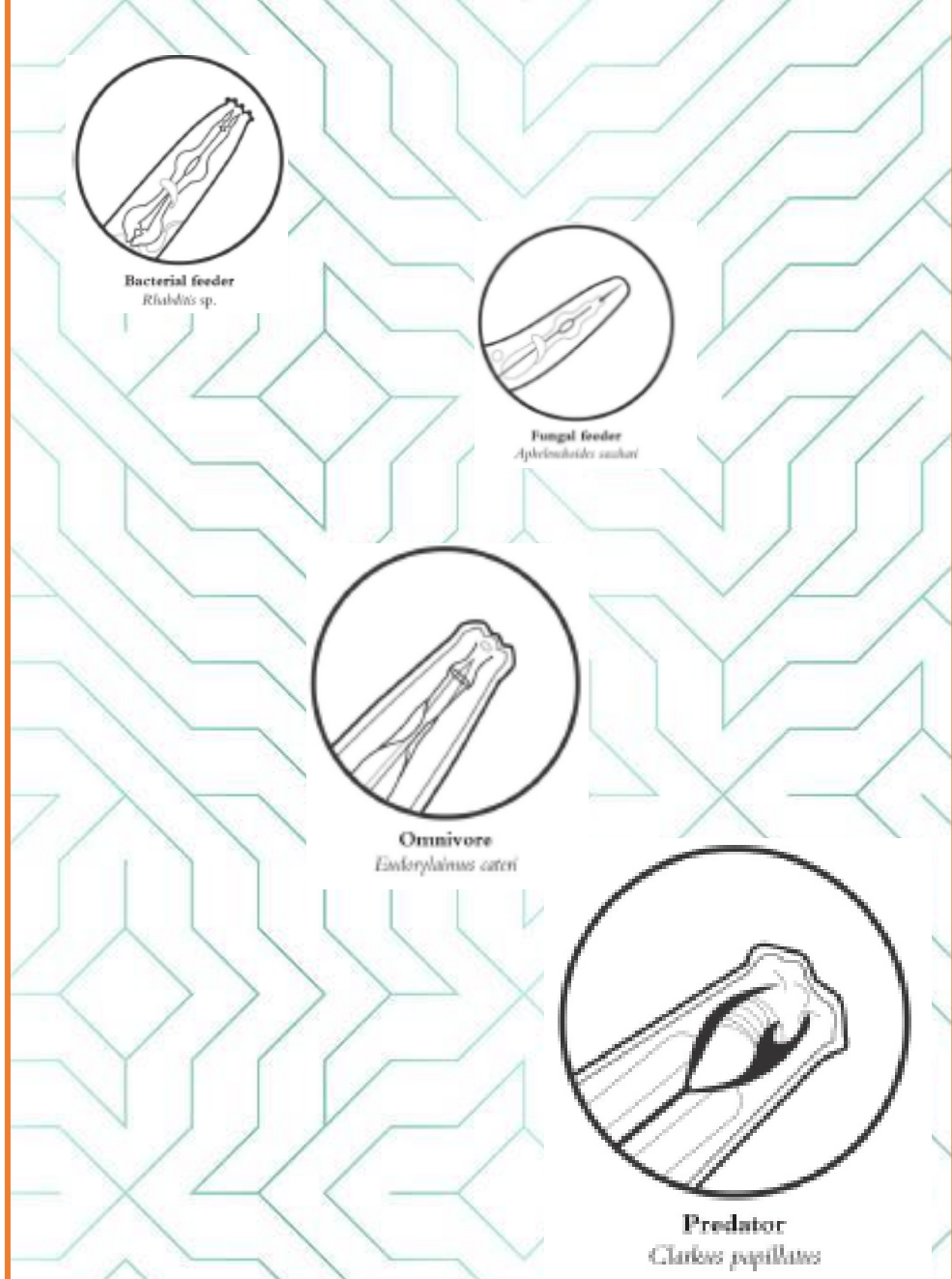


2023 Society of Nematologists Meeting, Columbus, Ohio

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

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

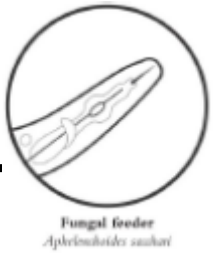
Natural Resources Conservation Service

Nematode Community Indices

- Abundance of each trophic group
- % trophic group
- Richness = # of taxa
- Simpson's index of dominance (λ)
- $\lambda = \sum P_i^2 = (^{\text{genus 1}}/\text{total})^2 + (^{\text{genus 2}}/\text{total})^2 \ldots (^{\text{genus i}}/\text{total})^2$
- Simpson's index of diversity ($1/\lambda$)
- Ratio of fungivores to bacterivores (F/B)

(Neher, 2001)

Nematode Guilds



Nematode life strategies (cp values 1-5)

Colonizers (r strategist)

- cp = 1
- Short life (days)
- High reproduction rate
- Bloom in enriched conditions, tolerate pollution
- e.g. rhabditids

Persisters (k strategist)

- cp = 5
- Long life (months)
- Low reproduction rate
- Sensitive to pollutants and other disturbances
- e.g. dorylaimids

Guild = feeding behavior + *cp* value (life strategy)

e.g. Ba_1, Om_4.

(Bongers & Bongers, 1998/Appl. Soil Ecol. 10: 239)

Nematode Community Indices

(Nematode Faunal Analysis)

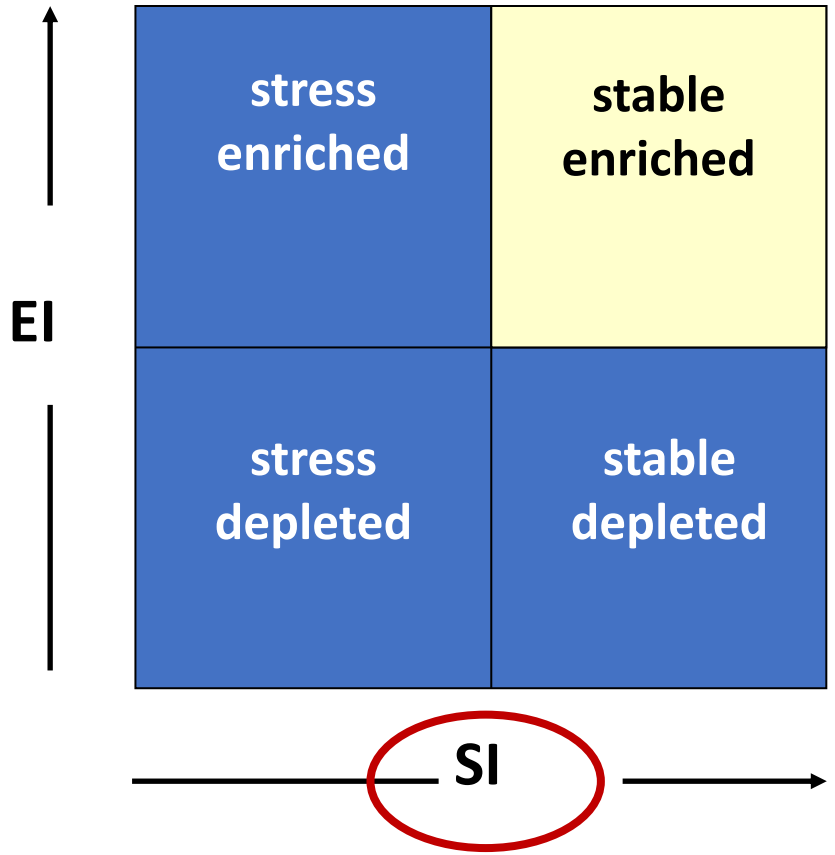
MI = maturity index
An index of community structure based on *c-p* scale.
(Bongers, 1990)

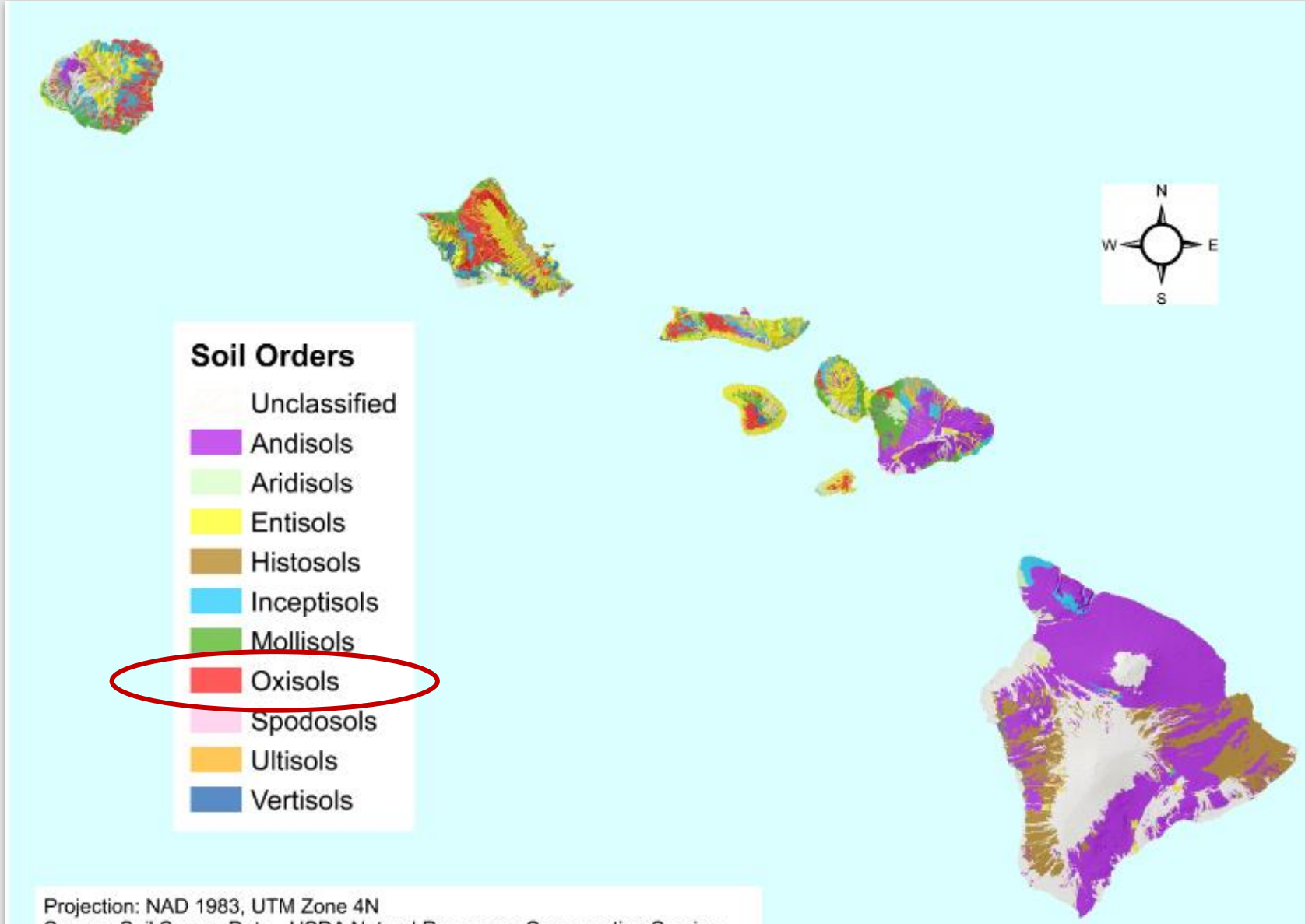
EI = enrichment index
Weight abundance of Ba_1 colonizers among *c-p* 1 and 2 groups.

SI = Structure index
Weight abundance of *c-p* 3 to 5 groups, as a measurement of disturbance.

CI = Channel index (Fungivores/Bacterivores)
Indicate decomposition pathways

(Ferris, Bongers, deGoede, 2001/Appl. Soil Ecol. 18: 13)





Soil degradation is happening faster in the tropics than the temperate, making this region more vulnerable to climate change.

Objectives of this symposium:

Can regenerative agricultural practices --

1) suppress plant-parasitic nematodes (PPN)?
2) Increase Soil Organic Matter (SOM) organic matter > 0.4%? and
3) Improve soil food web structure (SI)?

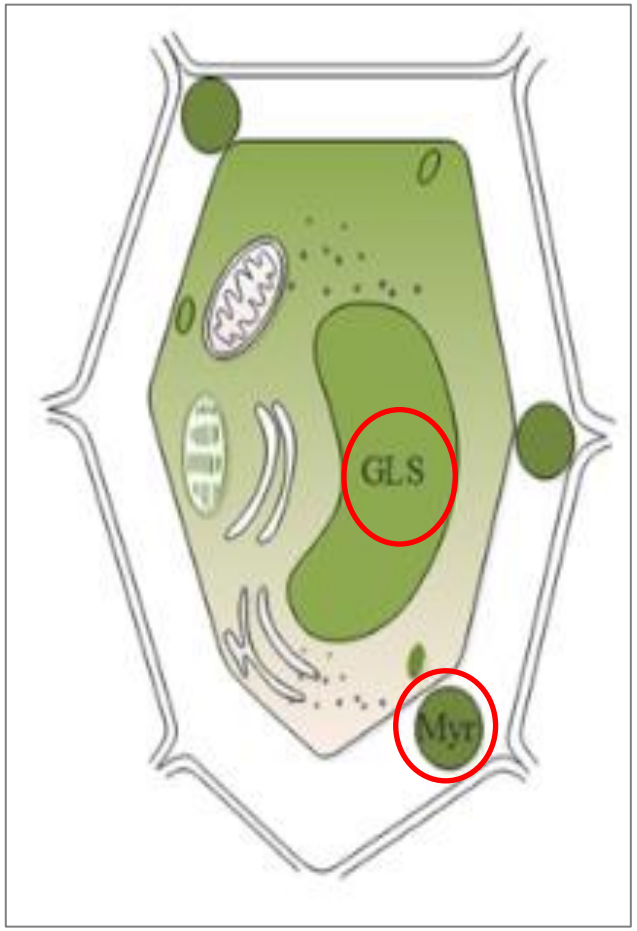
Review

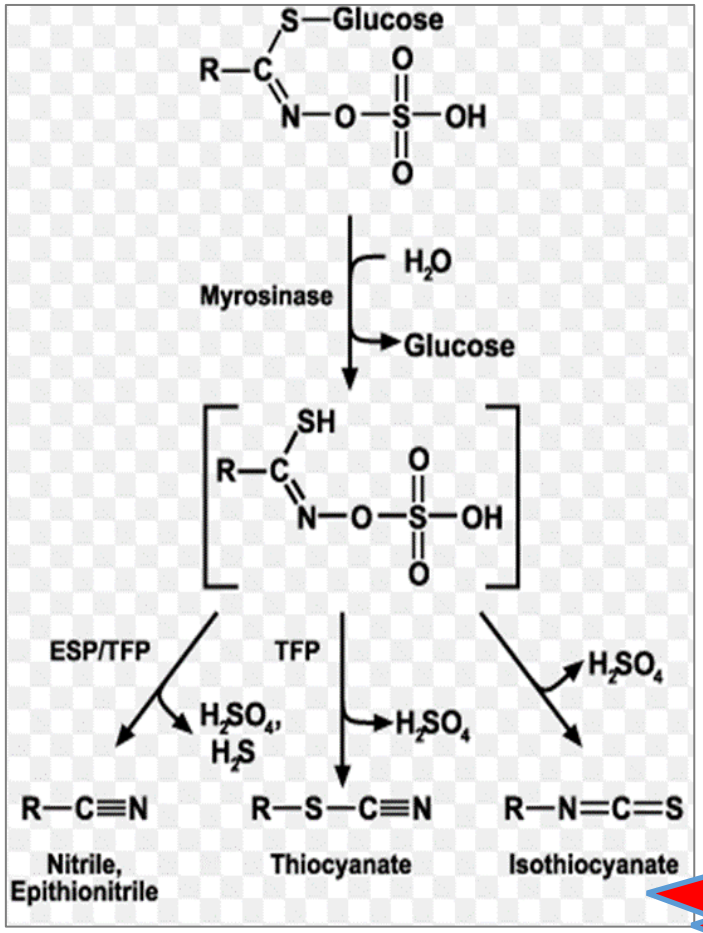
Tropical Cover Crops w/ Nematode Antagonistic Effect:

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

Biofumigation

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





Biofumigation by MTBP

(Macerated, Till, cover with Black Plastic)

Seeding: 10 lb/acre

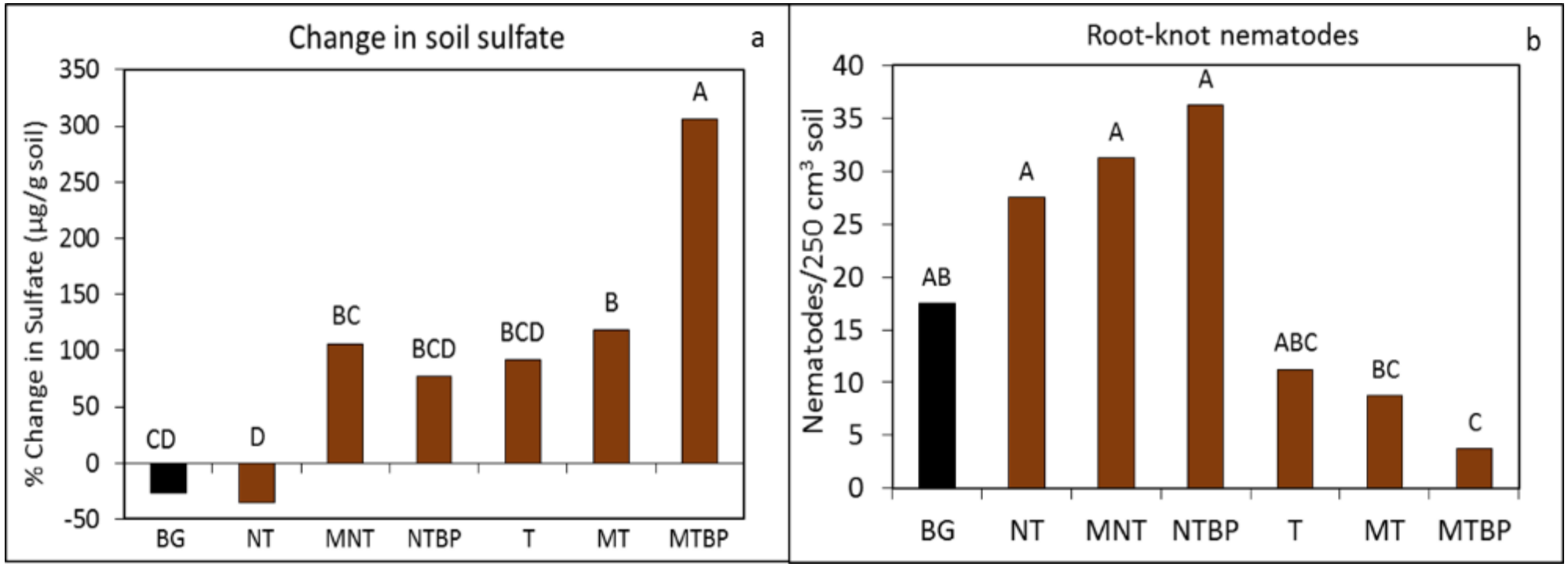
5 weeks

Flail mower

Till

Cover with plastic
(1 week)

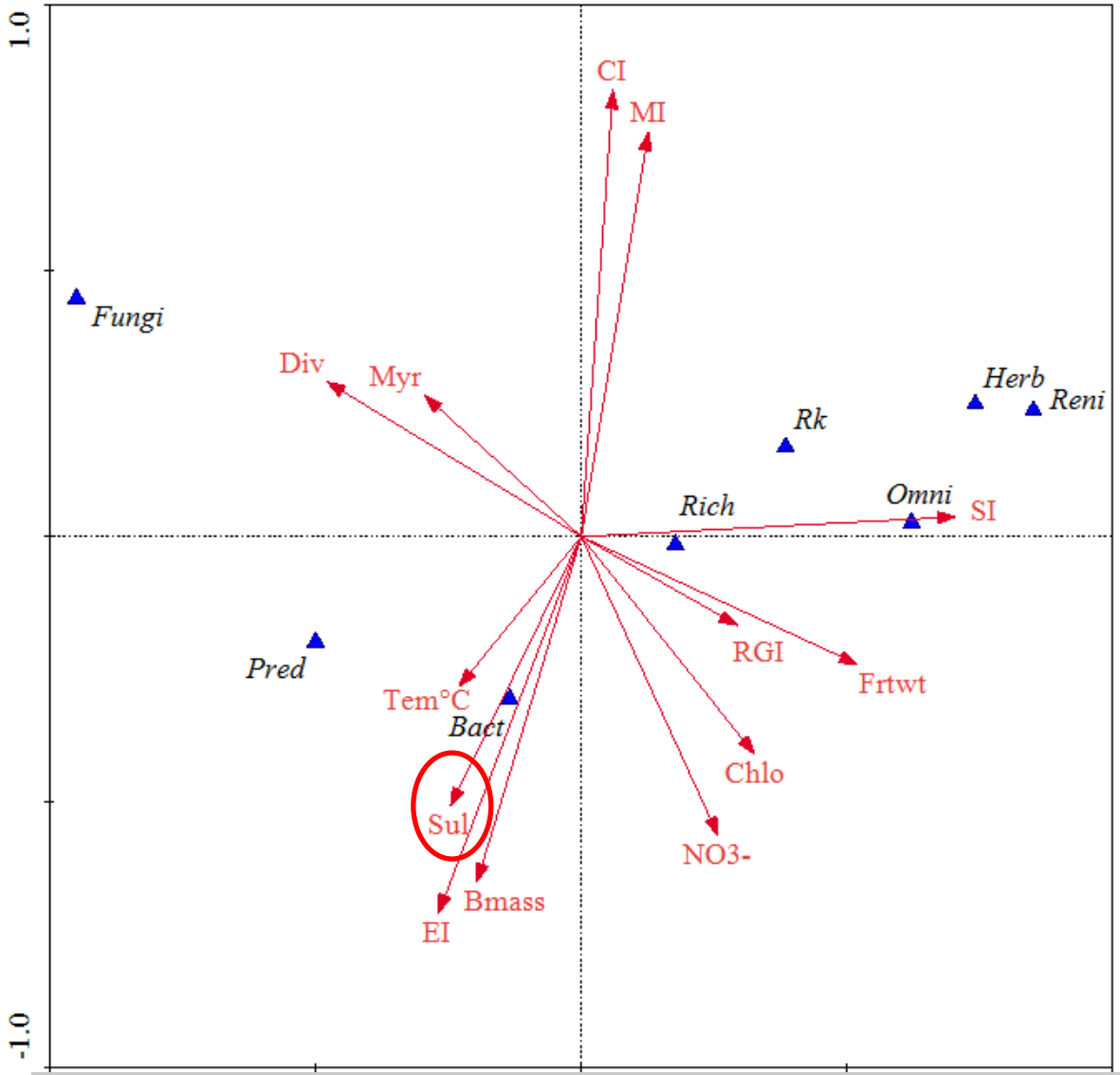
Suppression of Root-knot Nematodes by Biofumigation



- More effective biofumigation if brown mustard was terminated by moving, tilling and soil was tarped by black plastic.

(Waisen et al., 2020)

Relationship between Biofumigation indicator to Nematodes



First two canonical analysis explained 89.0% of variance

Sul = sulfate
Rk = root-knot nematodes
Reni=reniform nematodes
Bact = bacterivorous nematodes
Pred= predatory nematodes

EI =Enrichment index
SI =Structure index
CI = Channel index
MI = Maturity index

Summary #1

Biofumigation:

- Suppressed Rk and Reni
- Increased bacterivorous and EI
- Negatively related to CI and MI
- Did not compromise bacterial decomposition and soil health conditions
- But it did not increase nor decrease SI.

(Waisen et al., 2022)

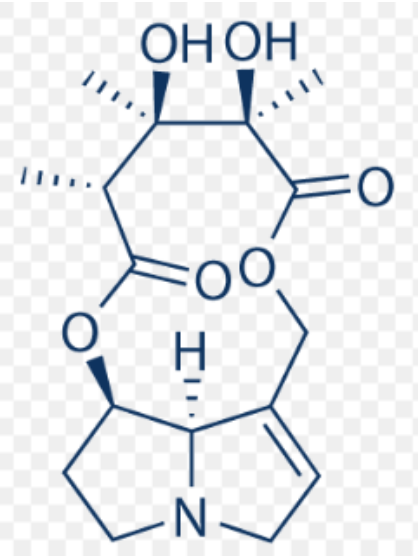
Review

Tropical Cover Crops w/ Nematode Antagonistic Effect:

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

Sunn hemp in a strip-till cover cropping system

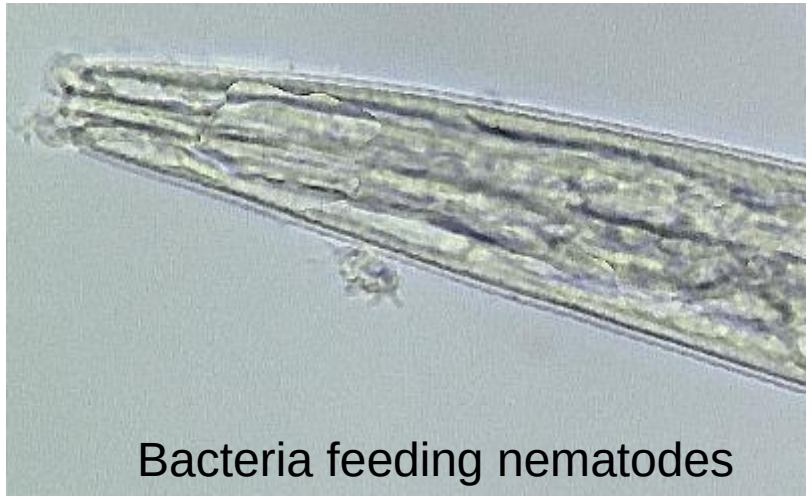
Sunn hemp (*Crotalaria juncea*)



Monocrotaline

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

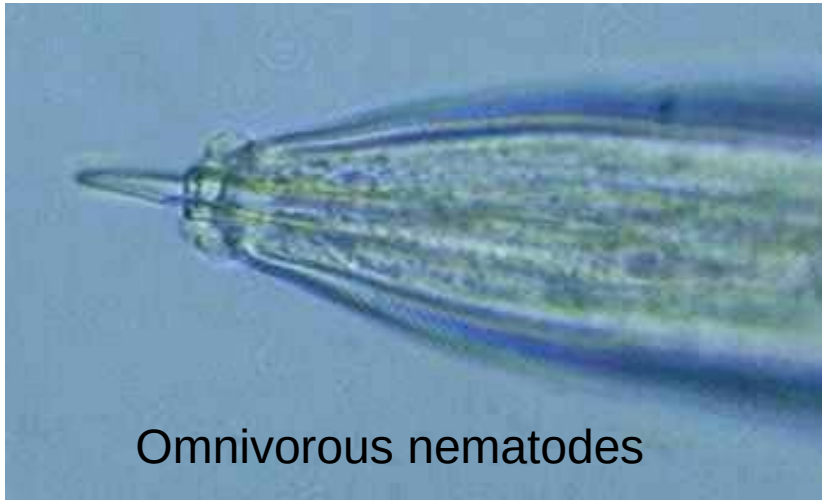
Year 1



Bacteria feeding nematodes

Fungal feeding nematodes

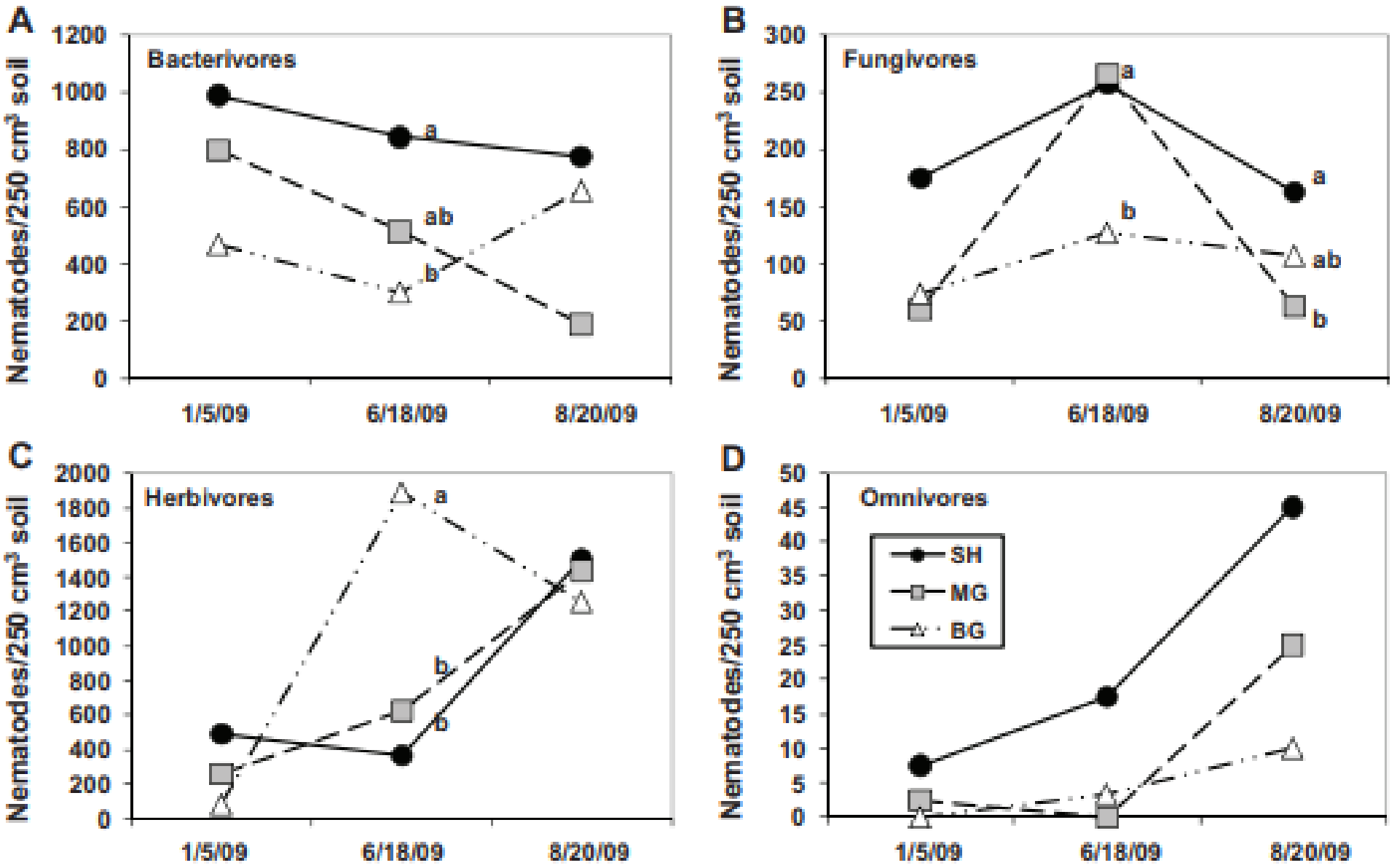
Plant-parasitic nematodes



Omnivorous nematodes

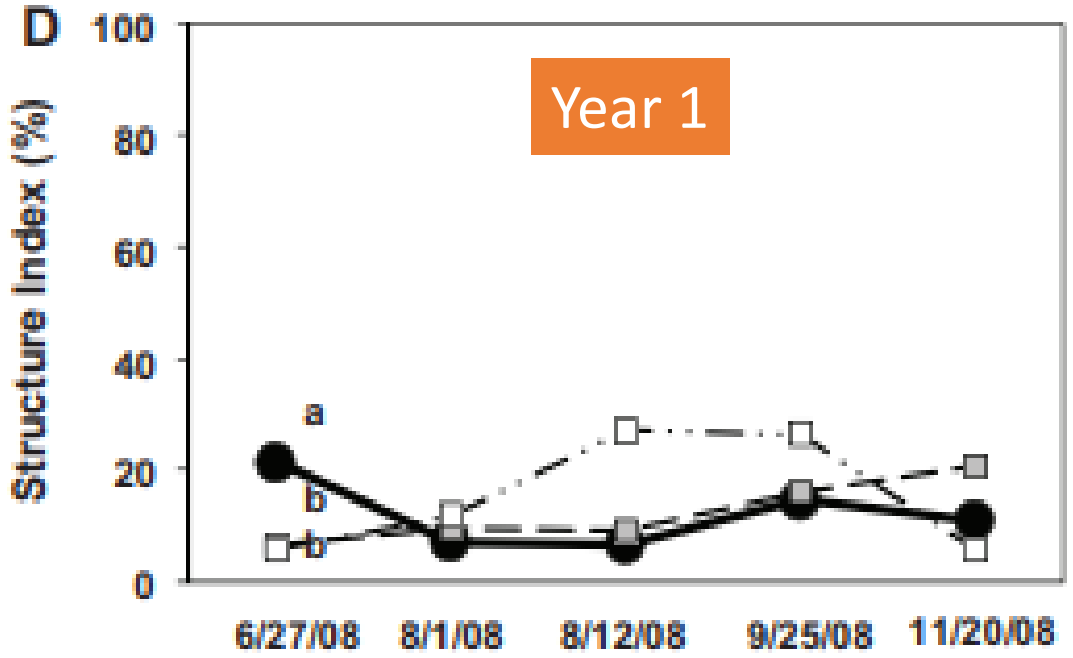
(Wang et al. 2011, Applied Soil Ecology 49: 107-117)

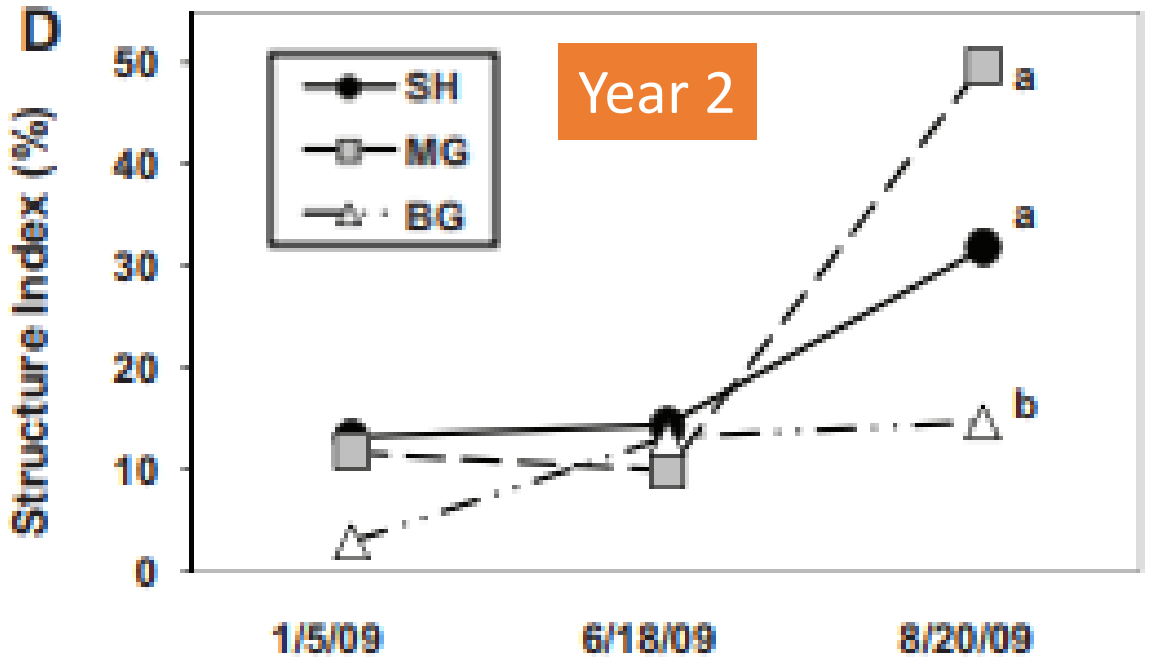
Year 2



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

Sunn hemp in a strip-till cover cropping system





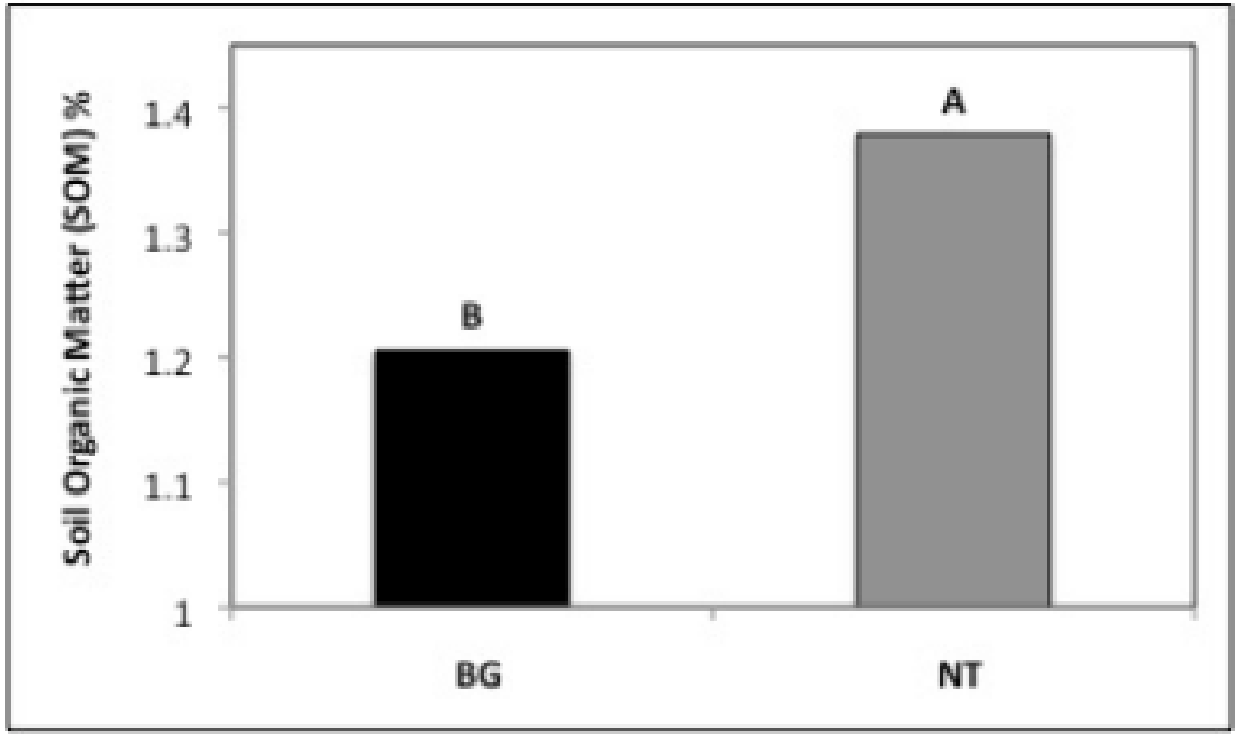
(Wang et al. 2011, Applied Soil Ecology 49: 107-117)

Summary #2

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.

Review

Tropical Cover Crops w/ Nematode Antagonistic Effect:

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

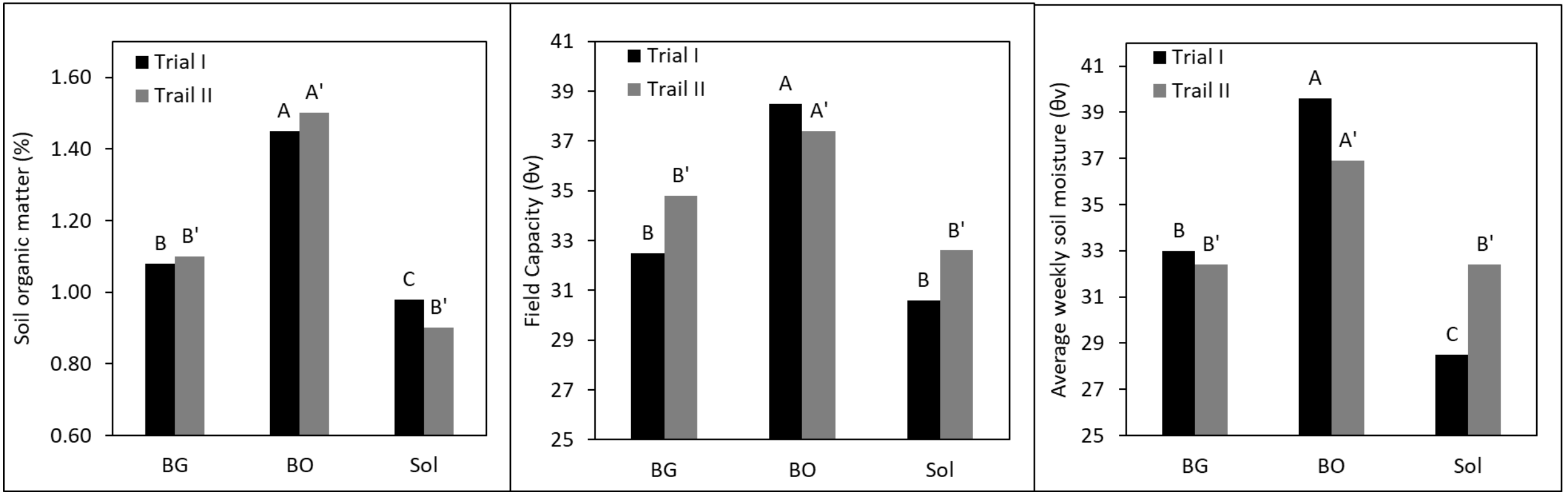
Effects of Black Oat Cover Cropping & No-till following 8 years of Conservation tillage practices

Trial I 2015
Trial II 2016

Plant corn after

Effects of Black Oat Cover Cropping & No-till on Soil Properties

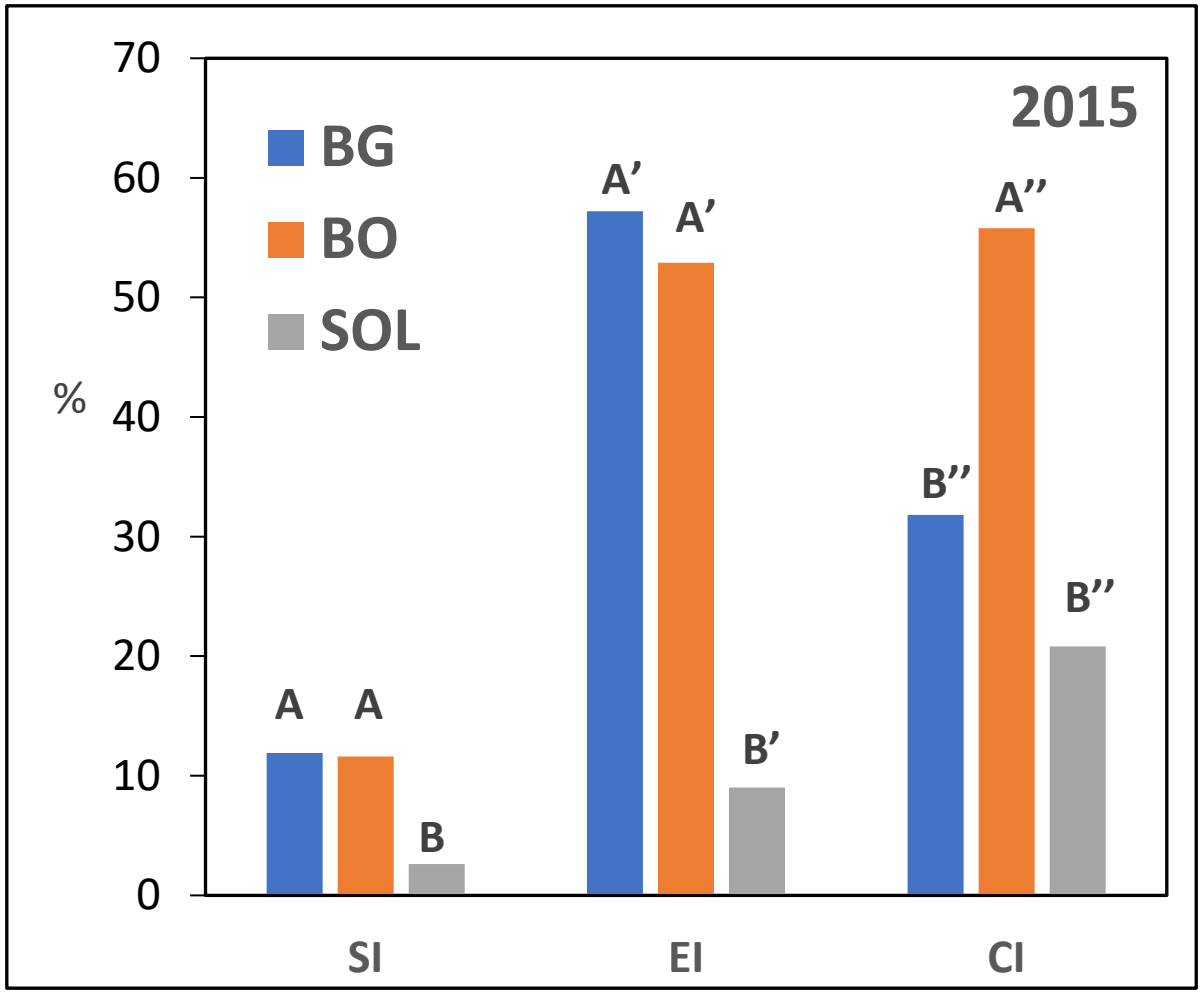
BO = No-till with black oats, BG = bare ground, Sol = solarization

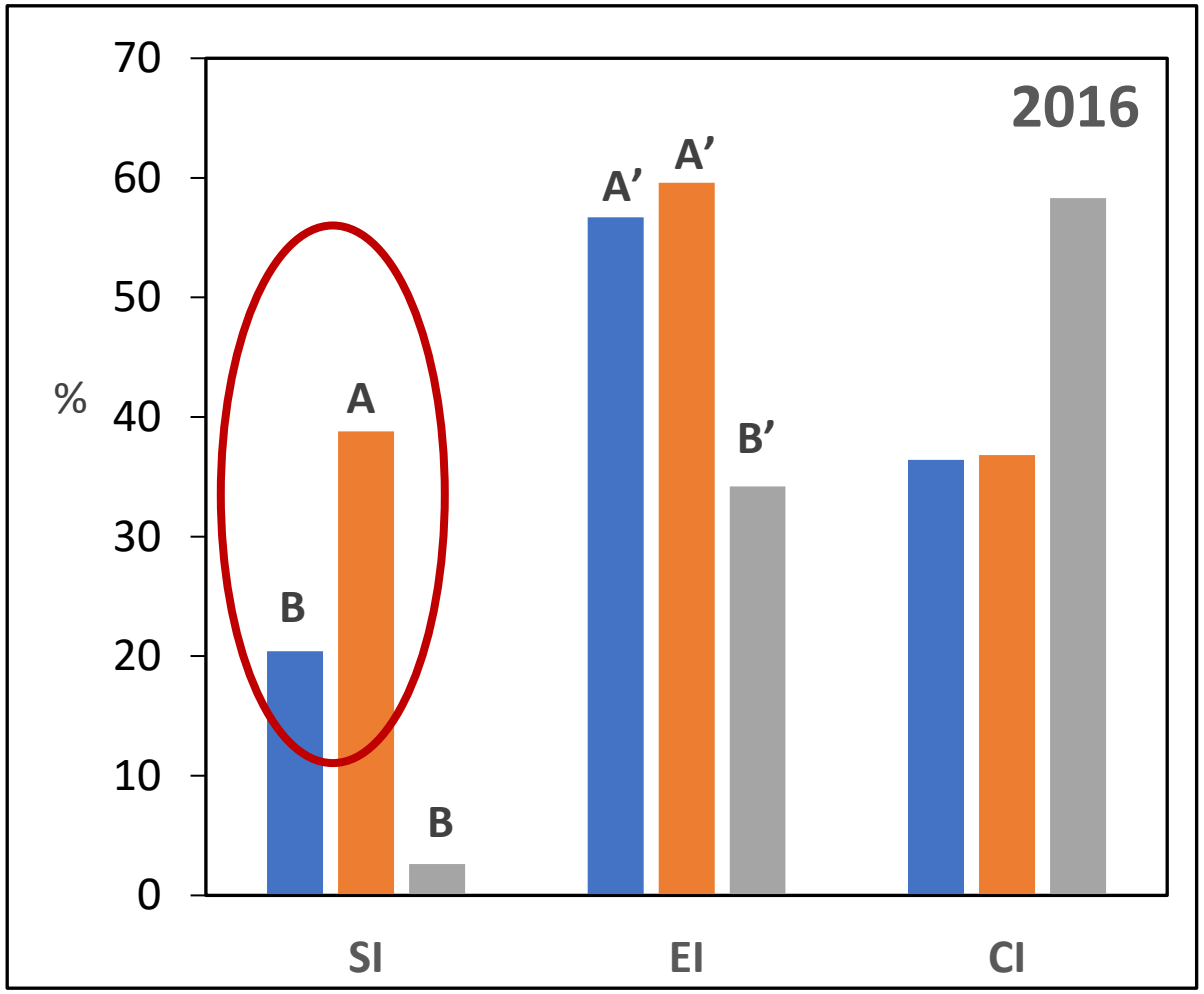


- BO+No-till increased SOM by 0.38% in Trial I and 0.4% in Trial II (✓); and increased water holding capacity by 7.5-18%; and soil moisture on corn crop by 14-20%

(Marquez et al., 2022)

Effects of No-till Black Oat and Solarization on Nematode Communities



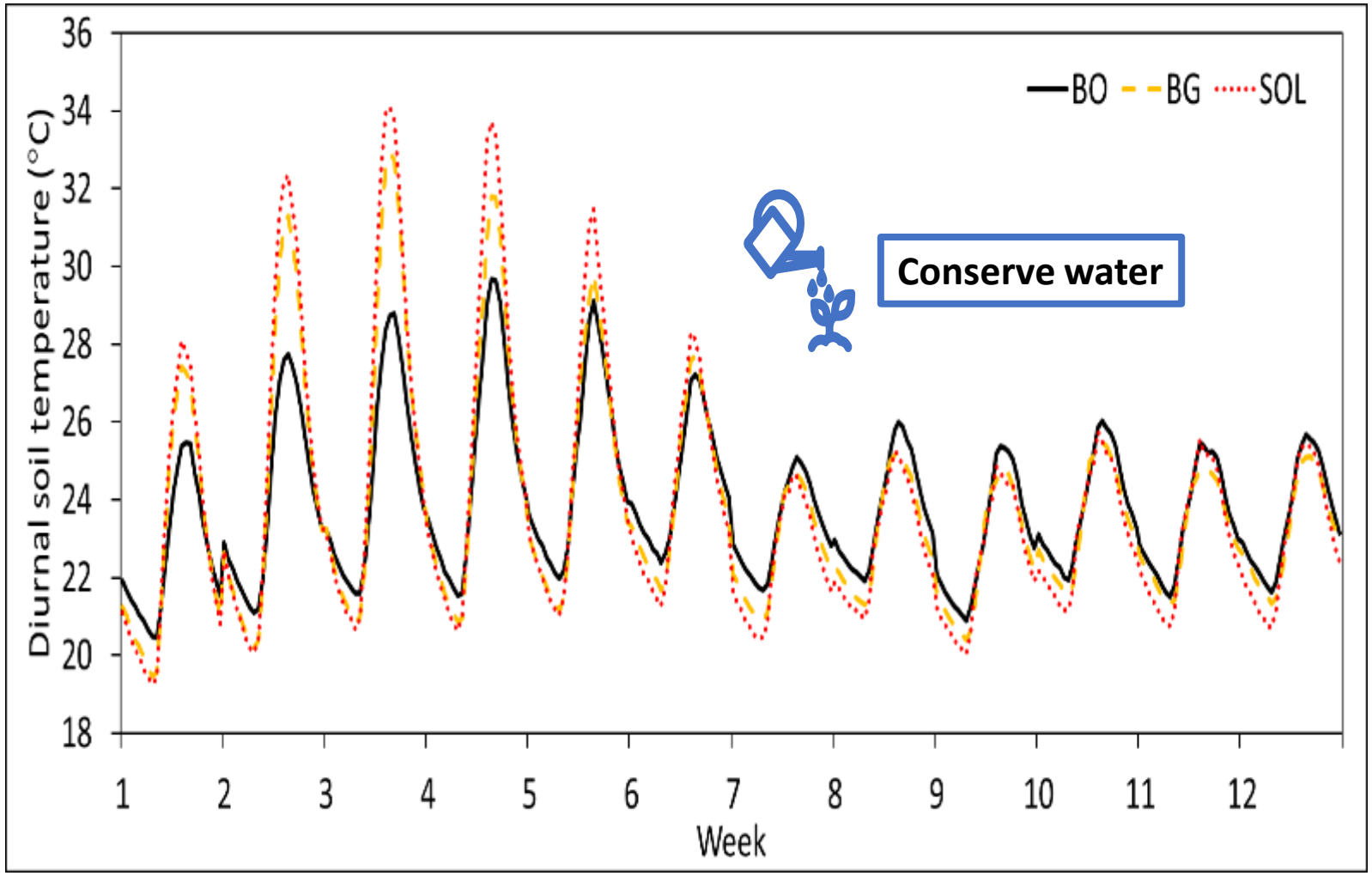


(Marquez et al., 2022)

Summary #3

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 .

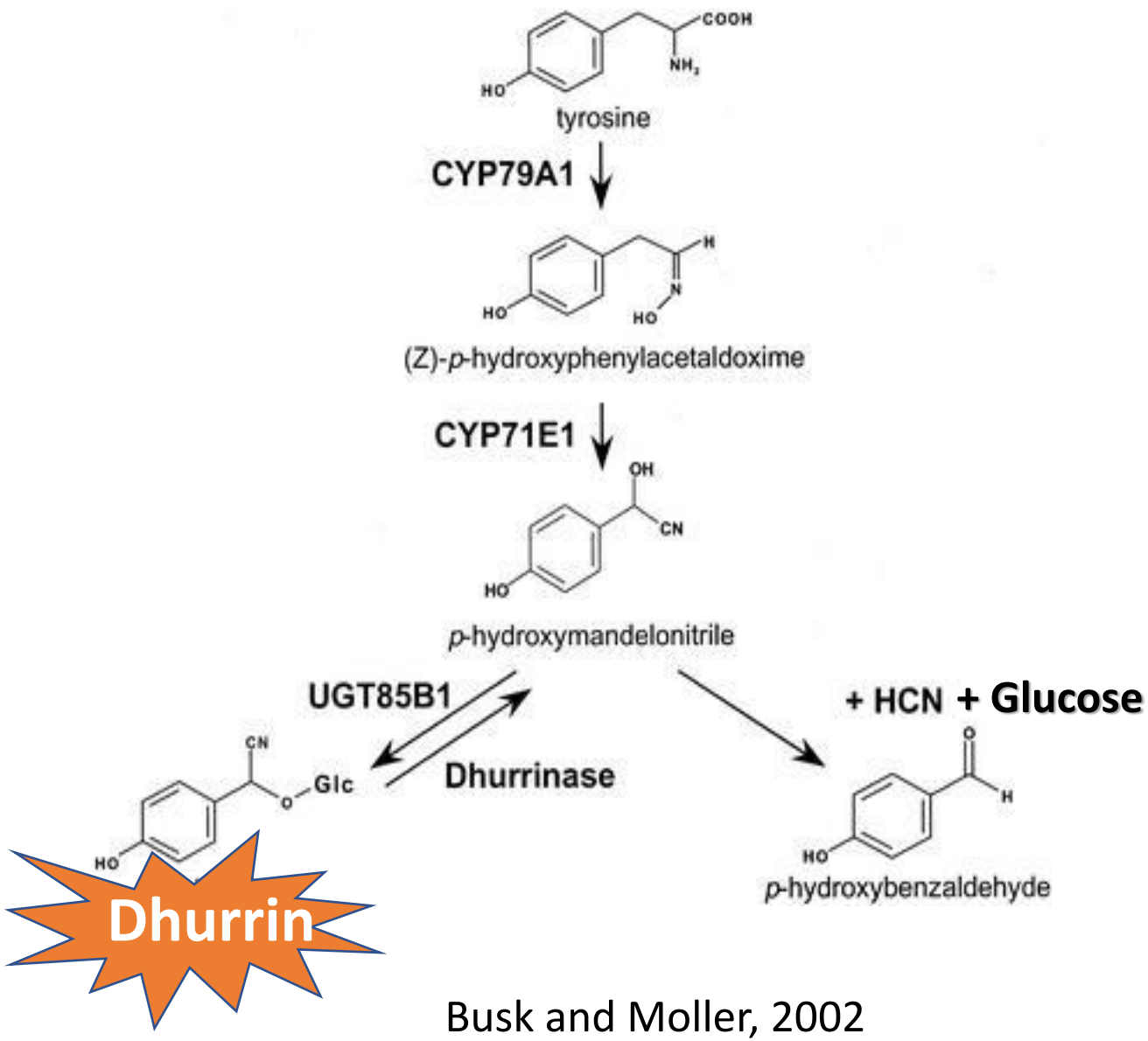
(Marquez et al., 2022)

Review

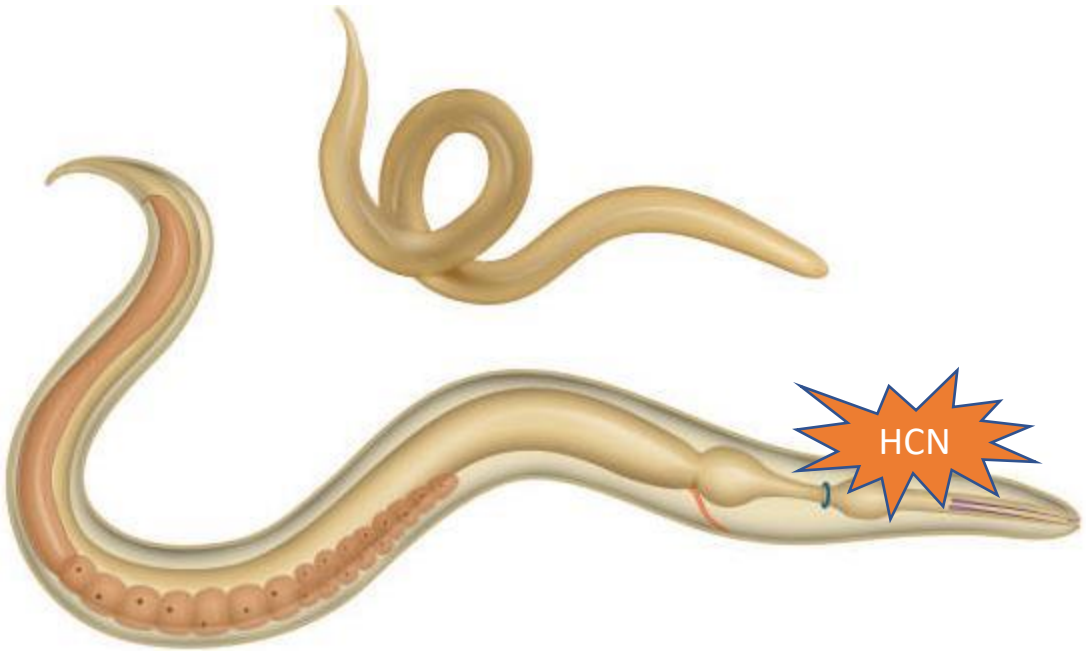
Tropical Cover Crops w/ Nematode Antagonistic Effect:

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

Biofumigant from Sorghum/Sorghum-Sudangrass (SSgH)



Busk and Moller, 2002

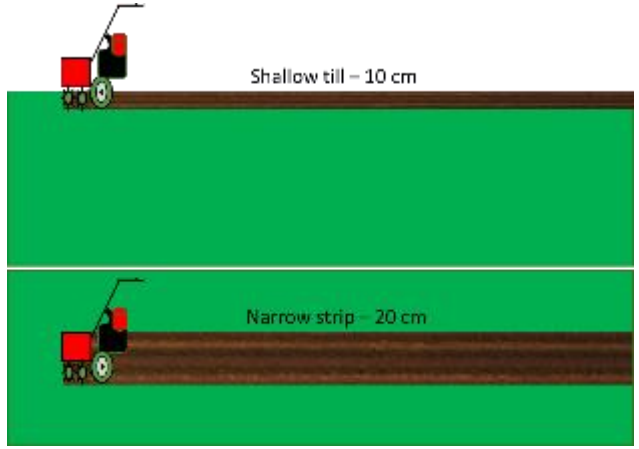


Leaf tissues release HCN (nematicidal) upon hydrolysis of dhurrin (= Biofumigation).

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

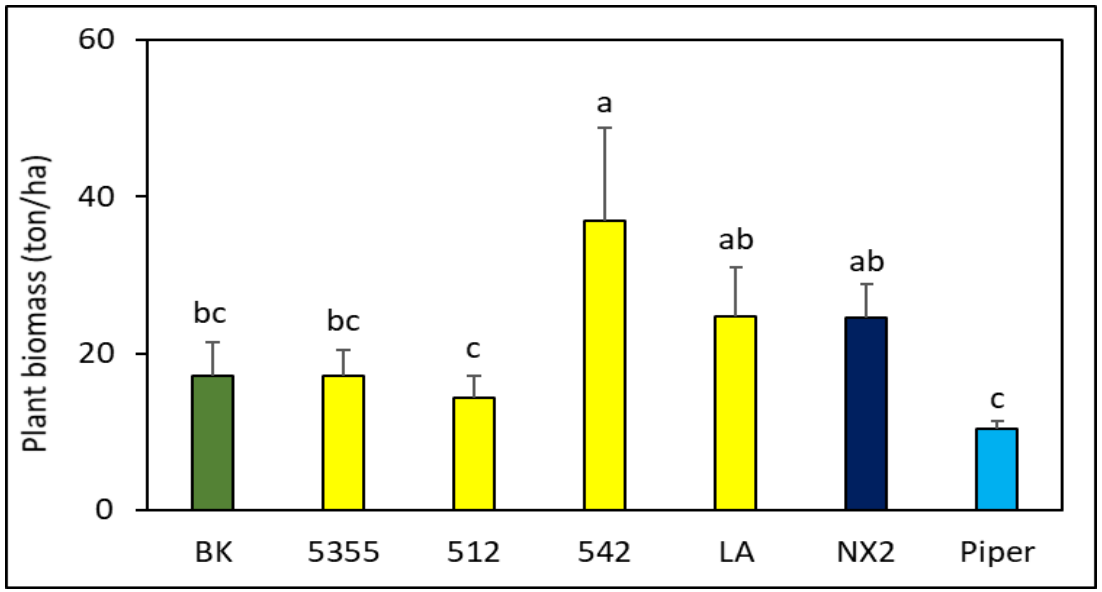
Field Trial at Poamoho Station

- 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.

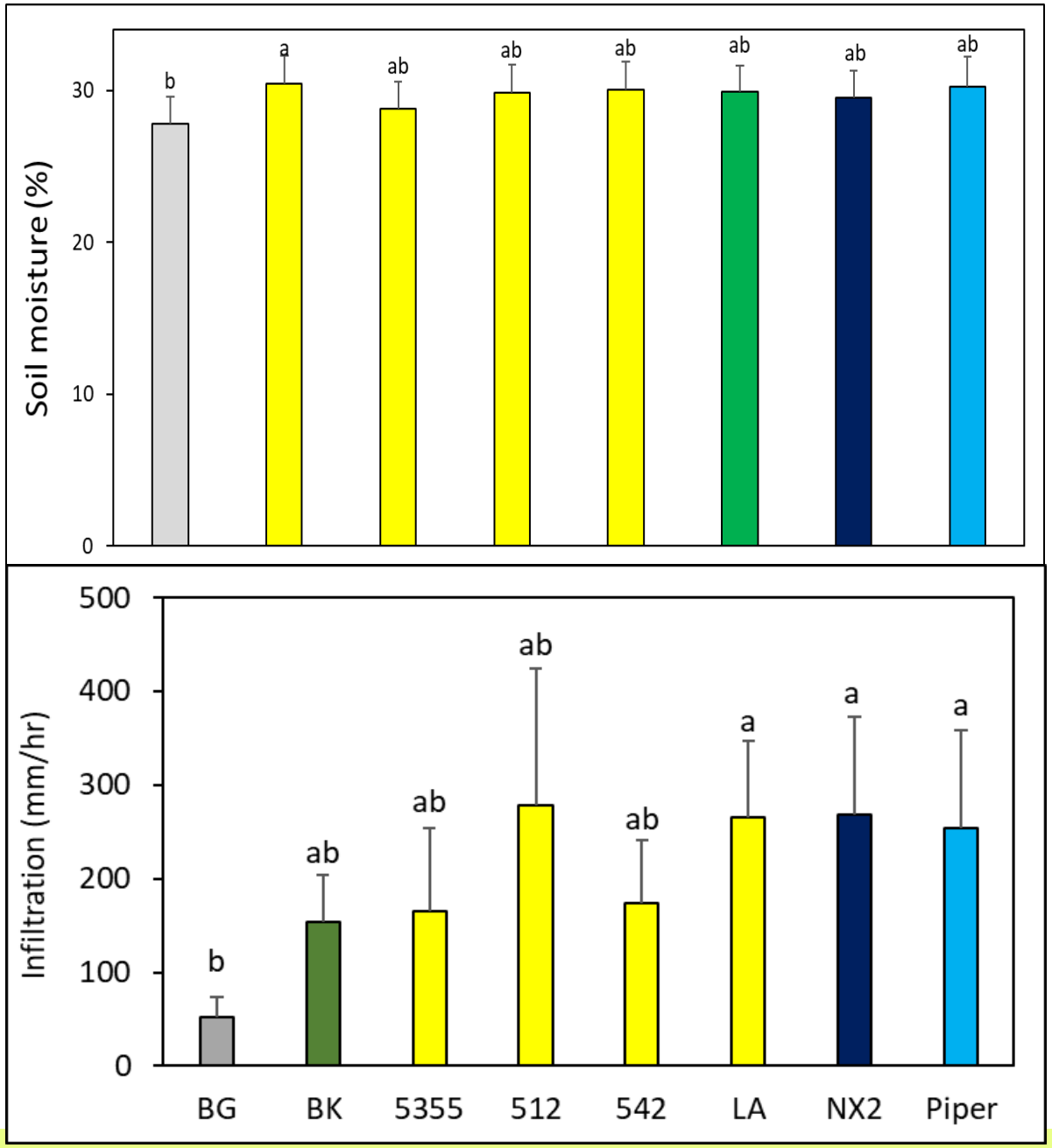


SSgH's Water Conservation Abilities

SSgH biomass in 2.5 months

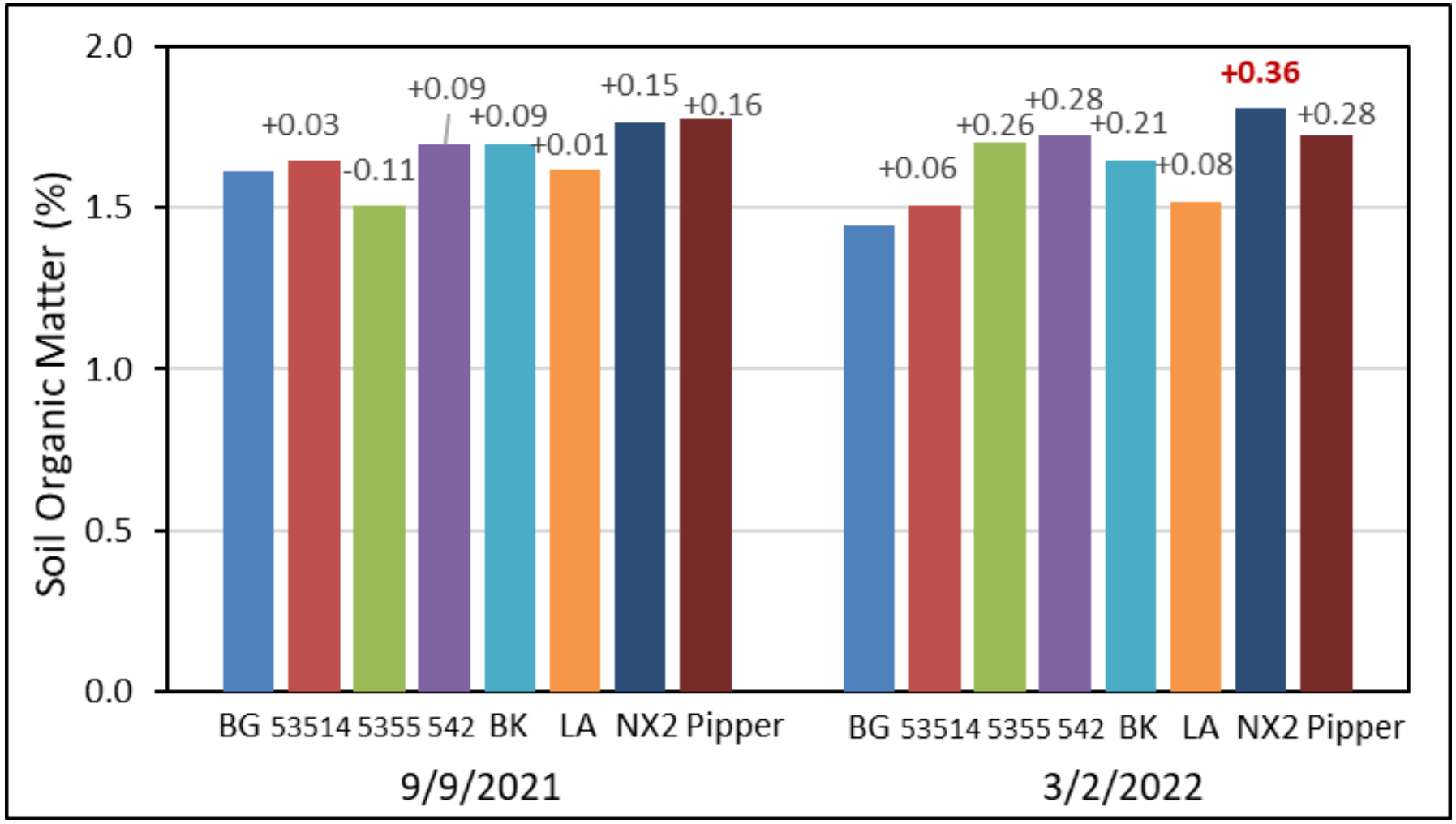


Throughout 5 months of eggplant



Soil C

Year 1


Soil Organic Matter (%)
2.0
1.5
1.0
0.5
0.0
+0.03
-0.11
+0.09
+0.09
+0.01
+0.15
+0.16
+0.06
+0.26
+0.28
+0.21
+0.08
+0.36
+0.28
BG 53514 5355 542 BK LA NX2 Pipper
9/9/2021
BG 53514 5355 542 BK LA NX2 Pipper
3/2/2022

Nematode Community Analysis

(combined 6.5 months of sampling dates)

Year 1

Trt	RKN	Reni	Bac	Fungi	Omni	Rich	EI	SI	CI
BG	35 a	426 a	172 a	111 b	6 b	9 a	54 ab	25 a	55 a
512	63 a	293 abc	306 a	171 ab	13 ab	10 a	58 ab	24 a	50 a
LA	40 a	422 ab	243 a	198 ab	19 ab	10 a	58 ab	30 a	52 a
5355	314 a	267 bc	259 a	194 ab	25 ab	9 a	61 a	30 a	51 a
542	49 a	343 ab	293 a	230 ab	19 ab	9 a	49 b	27 a	63 a
BK	79 a	275 abc	252 a	239 a	27 a	11 a	55 ab	29 a	58 a
NX2	105 a	337 ab	264 a	243 a	27 a	10 a	54 ab	32 a	58 a
Piper	56 a	200 c	328 a	251 a	17 ab	10 a	59 ab	24 a	49 a

Nematode Community Analysis

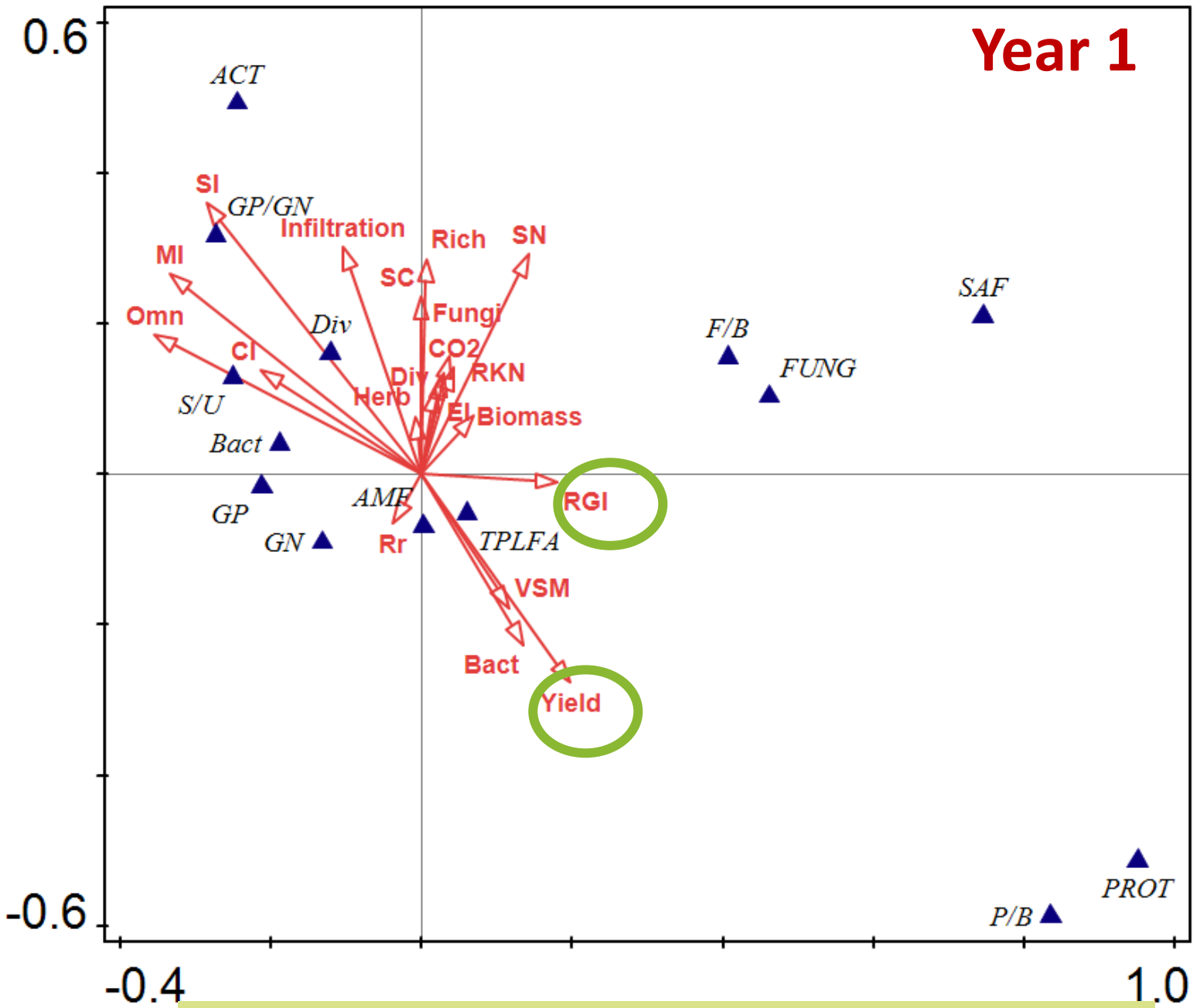
Year 2

(combined 6.5 months of sampling dates)

Trt	RKN	Reni	Bac	Fungi	Omni	Rich	EI	SI	CI
BG	144 a	427 a	138 a	83 c	3 c	7 c	54 a	13 d	37 a
53514	113 a	351 a	104 a	144 abc	12 ab	9 bc	59 a	26 bc	48 a
BK	119 a	543 a	226 a	219 a	10 bc	10 ab	58 a	18 cd	44 a
5355	83 a	319 a	190 a	137 bc	13 bc	10 ab	63 a	32 ab	33 a
542	126 a	396 a	246 a	168 ab	6 bc	9 b	63 a	19 cd	37 a
LA	69 a	327 a	200 a	145 abc	16 b	9 ab	61 a	25 bc	41 a
NX2	101 a	452 a	259 a	166 ab	38 a	11 a	63 a	42 a	33 a
Piper	13 a	408 a	190 a	211 ab	19 ab	10 ab	58 a	27 bc	42 a

Relationships b/t Soil Food Web Structure, edaphic factors & 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.



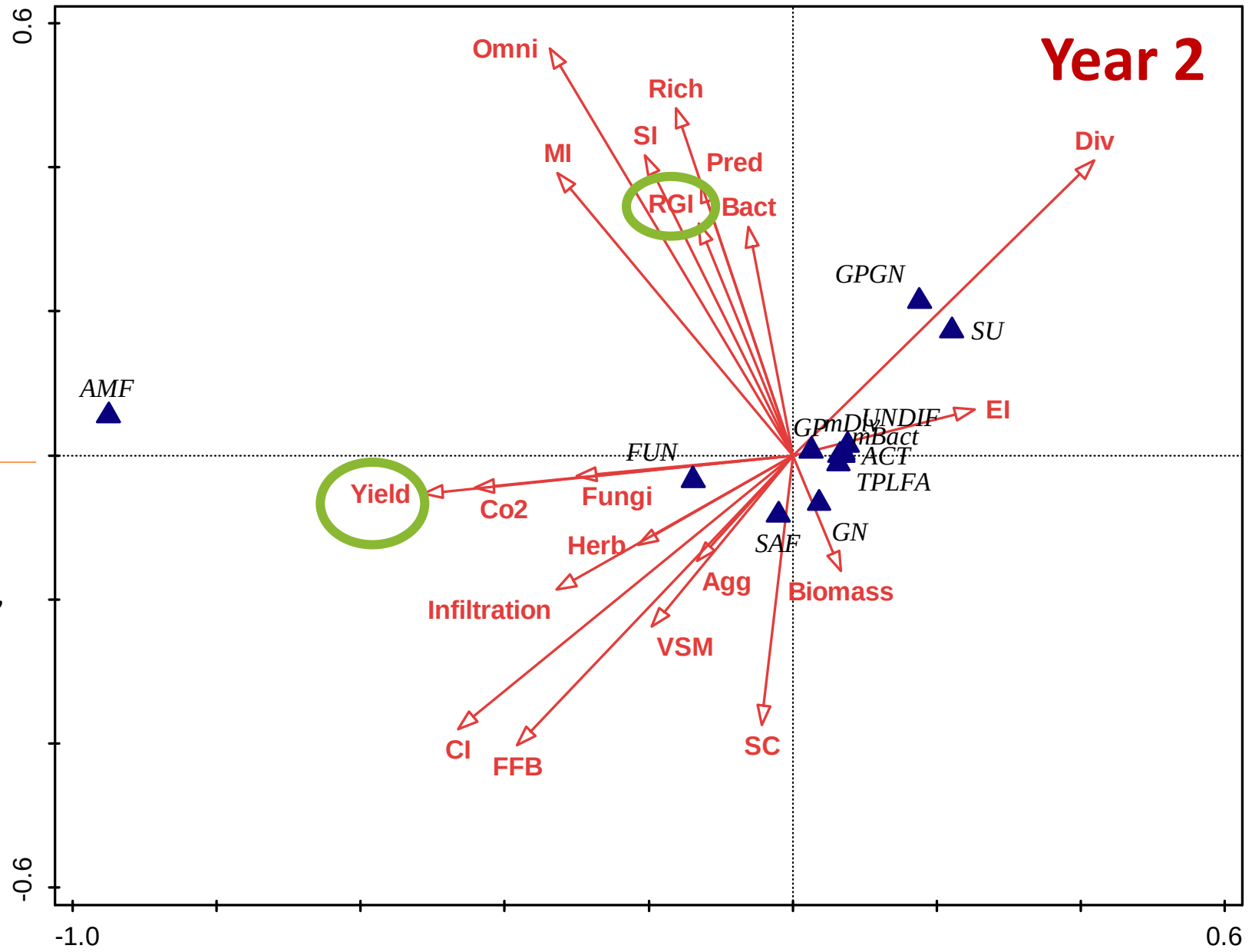
First two canonical analysis explained 76.59% of variance

(Paudel et al., 2022)

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

- Eggplant yield was positively related to arbuscular mycorrhizal fungi biomass (AMF), soil microbial respiration (CO2), infiltration (I) and volumetric soil moisture (VSM), and abundance of fungivorous nematodes.
- SSgH biomass was negatively related to root-gall index (RGI), but positively related to G-bacteria.

(Paudel et al., 2023)



First two canonical analysis explained 98.750% of variance

Summary #4

Sorghum in a Strip- and Low-till system

- Suppression of PPN was more apparent in Year 2, negatively related to G- bacteria.
- Increase SI in the second cropping cycle.
- Increased soil C in Year 1 (close to 0.4%) but not in Year 2.
- Improve water infiltration rate, microbial respiration, microbial biomass but results varies by SSgH varieties.

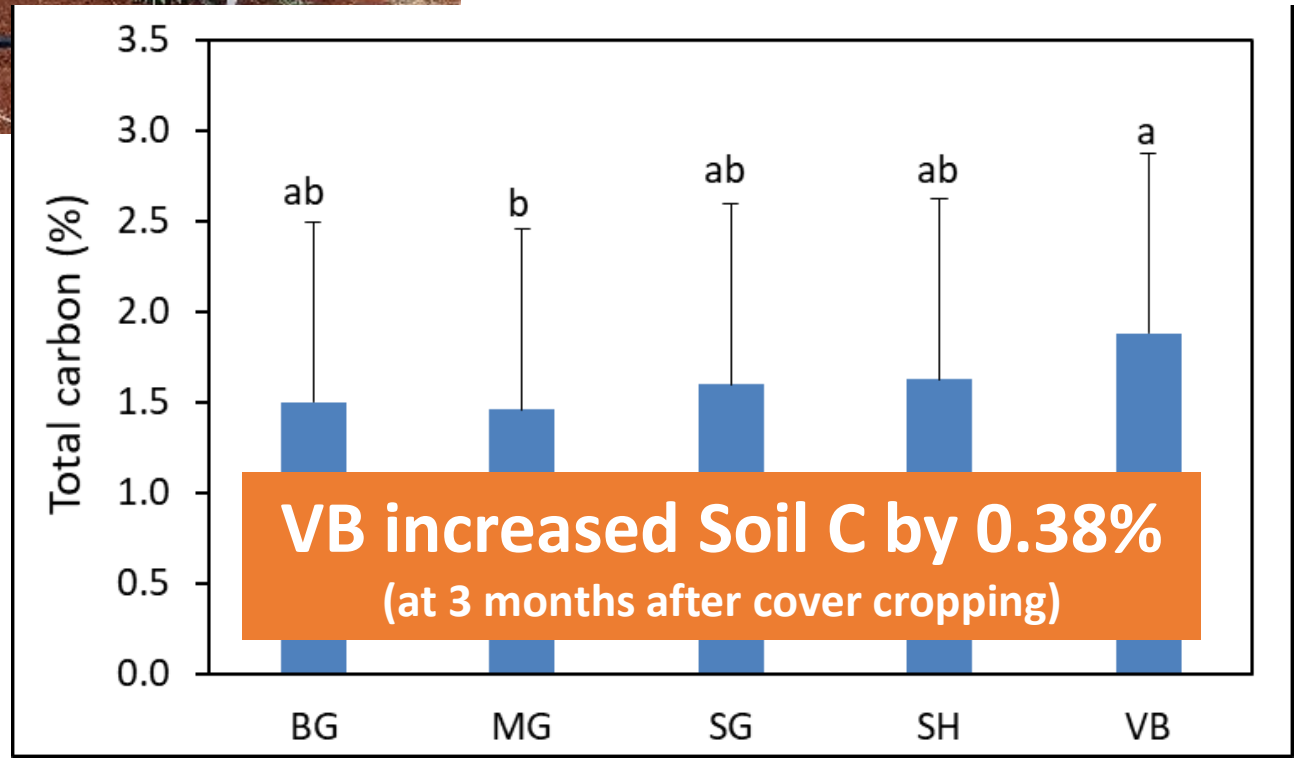
(Paudel., 2023)

Highly disturbed soil

Tropical Cover Crops w/ Nematode Antagonistic Effect:

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


MG = Marigold


Total carbon (%)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ab
b
ab
ab
a
BG
MG
SG
SH
VB
VB increased Soil C by 0.38%
(at 3 months after cover cropping)

Summary #5

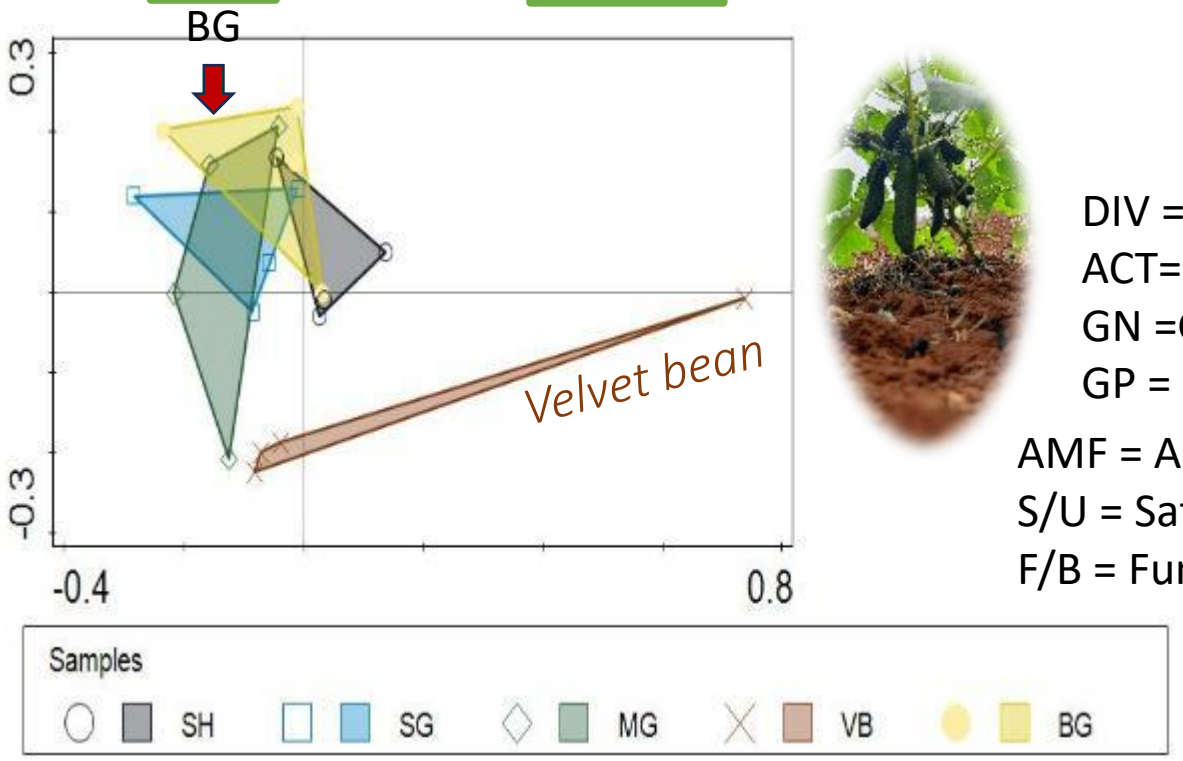
3 months after cover cropping & 4 weeks after soil incorporation

- ✓ VB increased arbuscular mycorrhizal fungi (AMF), saprophytic fungi (SF), and resulted in a higher fungi: bacteria (F/B) microbial biomass ratio.
- ✓ In the CCA scatter plot, soil health of VB was most segregated from BG.
- ✓ Increased soil C by 0.38%.

Microbial biomass (PLFA assay)

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

Stress/fungal dominated



DIV = Diversity
ACT= Actinomycete
GN =Gram – bacteria
GP = Gram + bacteria
AMF = Arbuscular mycorrhizal fungi
S/U = Saturated/Unsaturated PLFA
F/B = Fungi/Bacteria PLFA

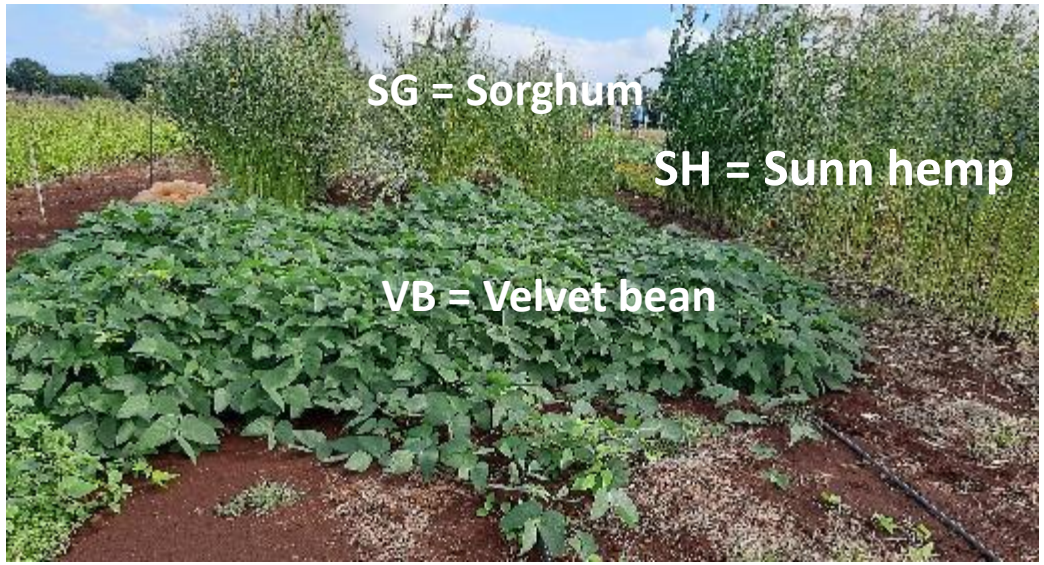
First two canonical analysis explained 89.43% of variance

Regenerative Agriculture

Happy Soil = Happy Farmers

Overall 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 have an additional benefits of regenerative ag for nematode management.

Acknowledgement

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