Practices for Improving Soil Health and Its Broader Implications

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Soil Health in Salinas Valley Vegetable Production Systems

- **There is increased interest by growers in improving soil health**
- **Increased soil health improves many aspects of soil such as:**
  - **physical characteristics, tilth, water infiltration/retention, nutrient cycling, etc.**
- **Can practices to improve soil health contribute to suppression of soilborne diseases?**

Soilborne Diseases Out of Control

Complete loss due to INSV/Pythium Wilt

- Pythium wilt and other soilborne diseases continue causing devastating losses
- Severe soilborne disease occurs even on the best soils in the valley

Soilborne Disease Control Strategies

- **Cultural practices**
  - **Irrigation management**
  - **Rotations/sanitation**
  - **Resistant/tolerant varieties (staying ahead of new strains/races)**
- **Fungicides/Fumigation**
  - **Soilborne diseases are trickier to employ chemical controls – volume of soil to treat**
- **Biologicals**
  - **Suppressive/antagonistic microorganisms**

Challenge of Addressing Soilborne Diseases

- The site of infection for Pythium wilt can be high in the root profile, infecting feeder roots
- But can also infect the tap root farther down the soil profile
- This makes chemical control more challenging

Challenge of Addressing Soilborne Diseases

Broccoli Rotations Beneficial

- Crop rotations have been shown to be effective in suppressing Sclerotinia and Verticillium
- No effective rotational scheme has yet been seen for Pythium wilt

NRCS Definition of Soil Health

Soil health is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. Healthy soil gives us clean air and water, bountiful crops and forests, productive grazing lands, diverse wildlife, and beautiful landscapes. Soil does all this by performing five essential functions:

- **Regulating water**
- **Sustaining plant and animal life**
- **Filtering and buffering potential pollutants**
- **Cycling nutrients**
- **Providing physical stability and support**

Soil Health and Soilborne Disease Suppression

- **The emphasis of the NRCS definition of soil health focuses on practices that improve the ability to sustain healthy crop growth, nutrient cycling, improved water infiltration and increased microbial activity**
- **Can these soil attributes also help suppress soilborne diseases?**

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Soil Heath and its Impact on Soilborne Disease

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1 – UCCE Monterey; 2 – USDA ARS, Salinas; 3 – CSU, Monterey Bay; 4 – UC Davis; 5 – De La Valley Labs, Fresno; 6 – NRCS, Salinas; 7 – UC Santa Cruz

Lettuce production in the Salinas Valley has suffered unprecedented losses in the last three years due to infection with Impatiens Necrotic Spot Virus (INSV) and co-infection with soilborne pathogens. Pythium

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In this blog: We attempted to address the connection between soil health and soilborne disease suppression

Measurements of Soil Health
From: Soil Health Institute

Total Soil Carbon	**Dry combustion is the most accurate method**	**•Nutrient cycling and retention •Stable and distinct soil structure •Available water holding capacity**
Carbon Mineralization Potential	**24-hr CO_2 burst resulting from rewetting air dried, sieved soil**	**•Carbon and nutrient cycling capacity •Strongly related to microbial biomass and activity**
Aggregate Stability	**10-min change in slaking via image analysis**	**•Resistance to wind and water erosion •Soil water infiltration and storage •Stable soil structure**

Bottom Line:
Increasing Carbon Inputs to the Soil Improves Soil Health

- **In addition to benefits of soil physical characteristics, increased carbon facilitates greater microbial activity**
- **Increased soil microbial activity may help compete with (predate on or degrade) soilborne diseases**
- **This has not been shown with Pythium wilt at this point**

Inputs of Carbon to Salinas Valley Soils

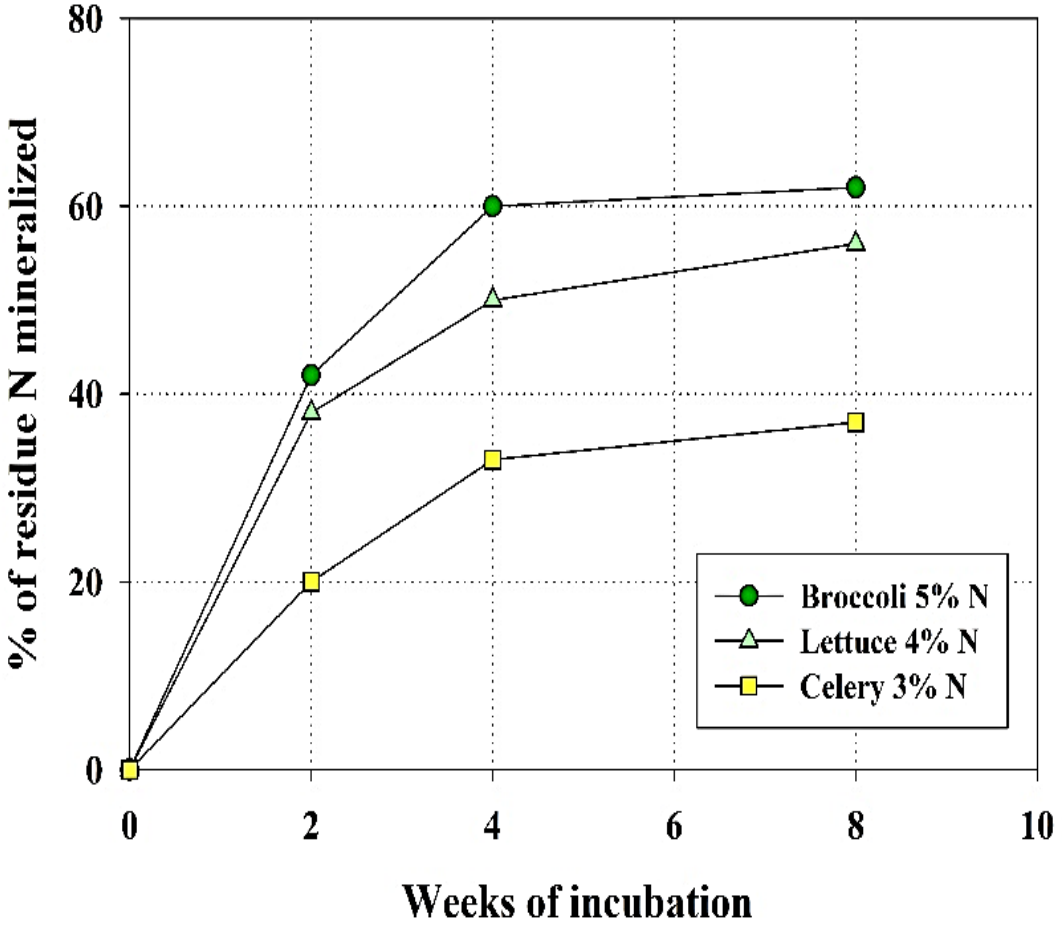
Key sources of adding or retaining carbon in the soil:

- **Cash crop and cover crop residues**
  - **above and below ground biomass, as well as root exudates**
- **Composts**
- **Organic fertilizers**
- **Reducing tillage**

Crop Residues

- **Lettuce, celery and cole crops leave a significant amount of residue in the fields**
- **All crop residue contains about 40-43% carbon**
- **Vegetable residues have a high N content (ranging from 2.5 to 6.0%), and therefore low C:N ratio**
- **This facilitates faster and higher net mineralization (plateaus after 4 to 6 weeks) which leaves a lower portion of residual carbon**

N Mineralization Data for Vegetable Crops Parallels Carbon Mineralization



After 4-6 weeks, the rate of mineralization slows to a level similar to the decomposition of soil organic matter.

2 phase breakdown of organic materials labile then recalcitrant decomposition

Net Carbon in Cash Crop Biomass after Harvest

Crop	Biomass T/A	Carbon lbs/A
Broccoli	2.6 - 3.2	2,205 – 2,700
Celery	1.3 – 2.8	1,090 – 2,300
Lettuce	1.5 – 2.0	1,260 – 1,680

40 – 60% of this carbon mineralizes in 4-6 weeks

Composts

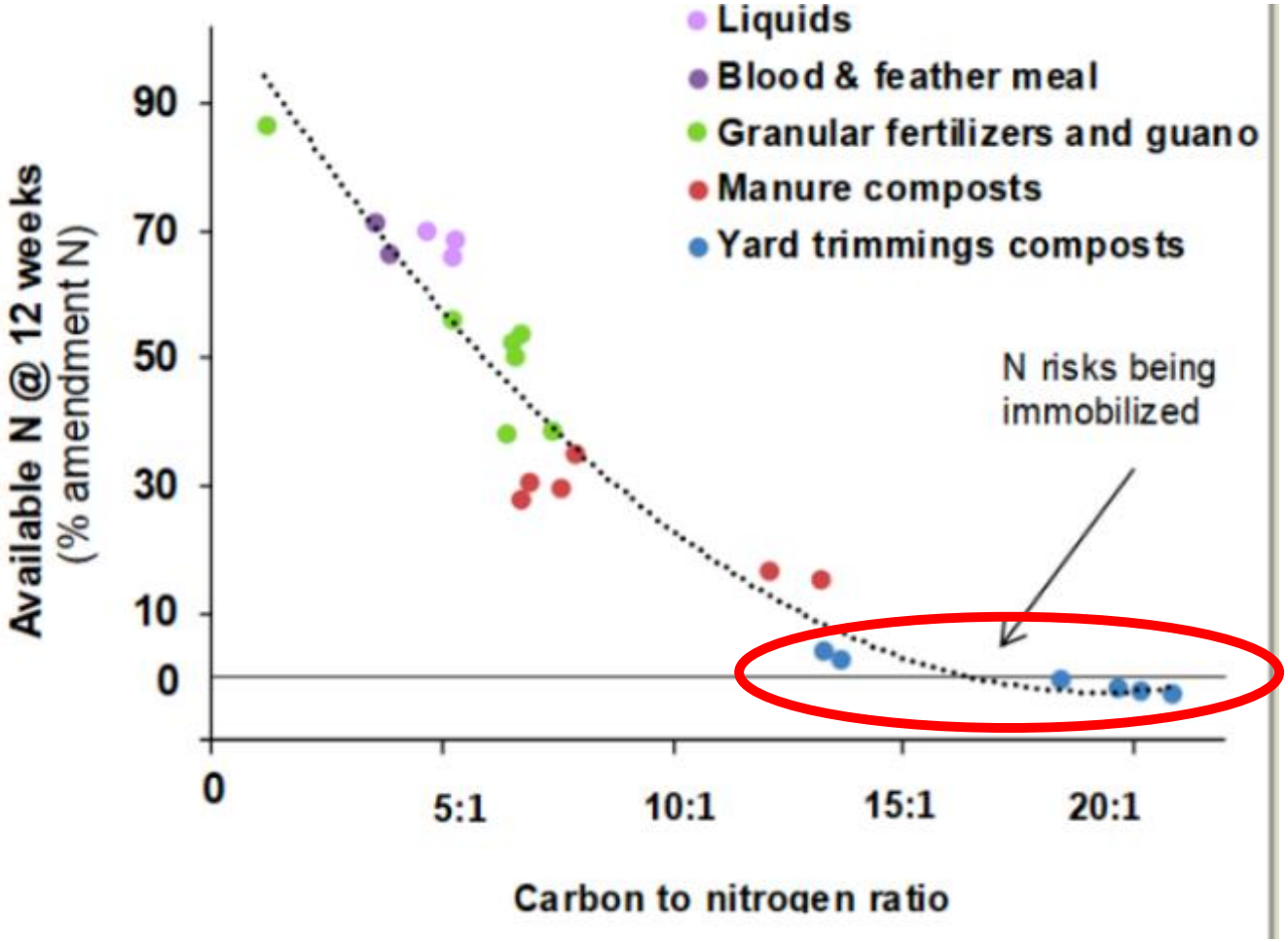
- **Composts (and manures) are a good source of carbon as well as other nutrients**
- **Here is the amount of C added to the soil from a typical yard waste compost used in the Salinas Valley. With a C:N ratio of 15-20, the C will be longer lasting:**

Biomass lbs/A	Carbon content percent	Total carbon lbs/A
3 tons	29%	1,287[1]
5 tons	29%	2,146[1]

1 – 74% dry weight

Rate of Mineralization is Driven by the C:N Ratio

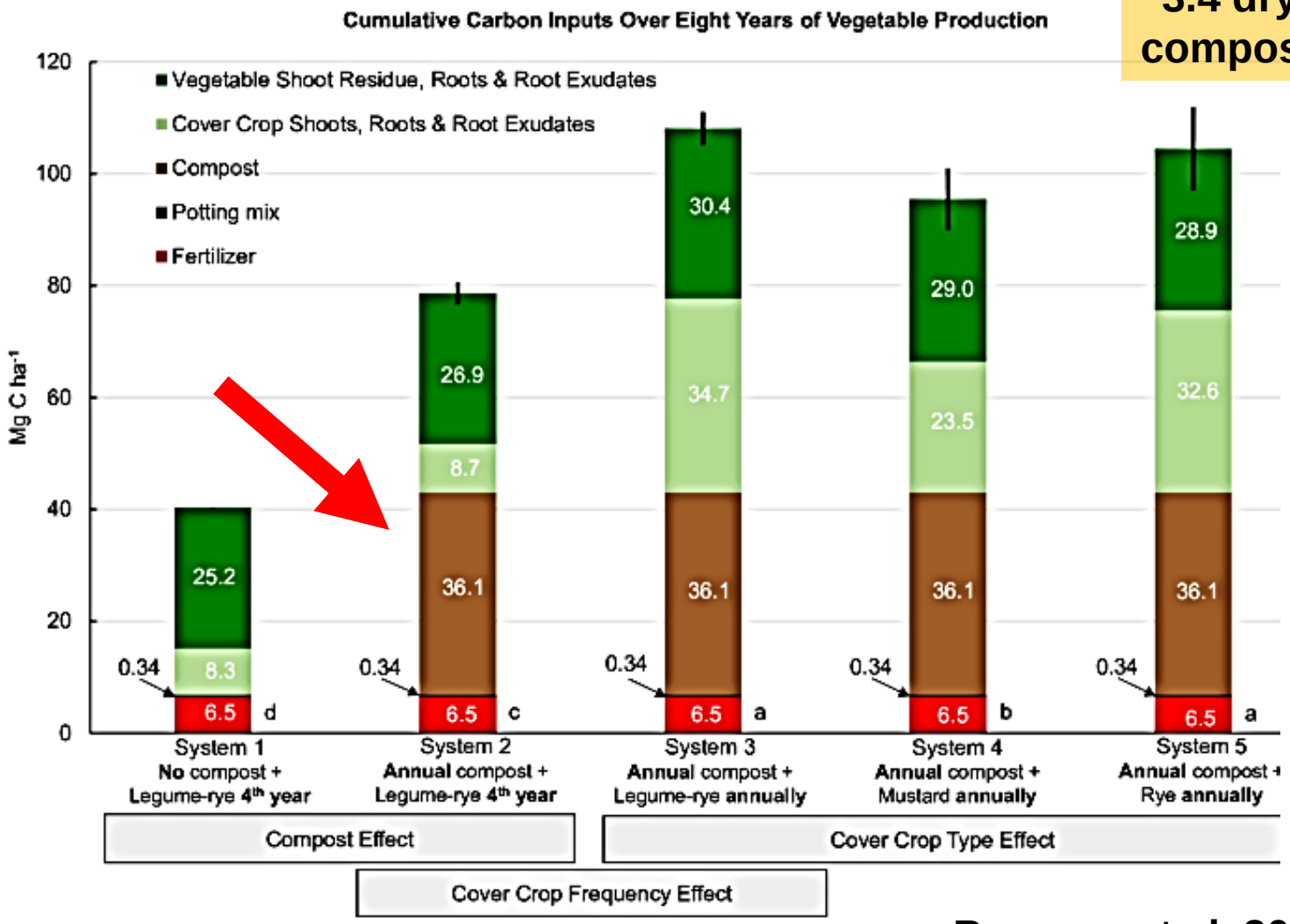
Using N mineralization as a proxy for Carbon



Laziki et al, 2020

Cumulative Carbon Inputs Over Eight Years

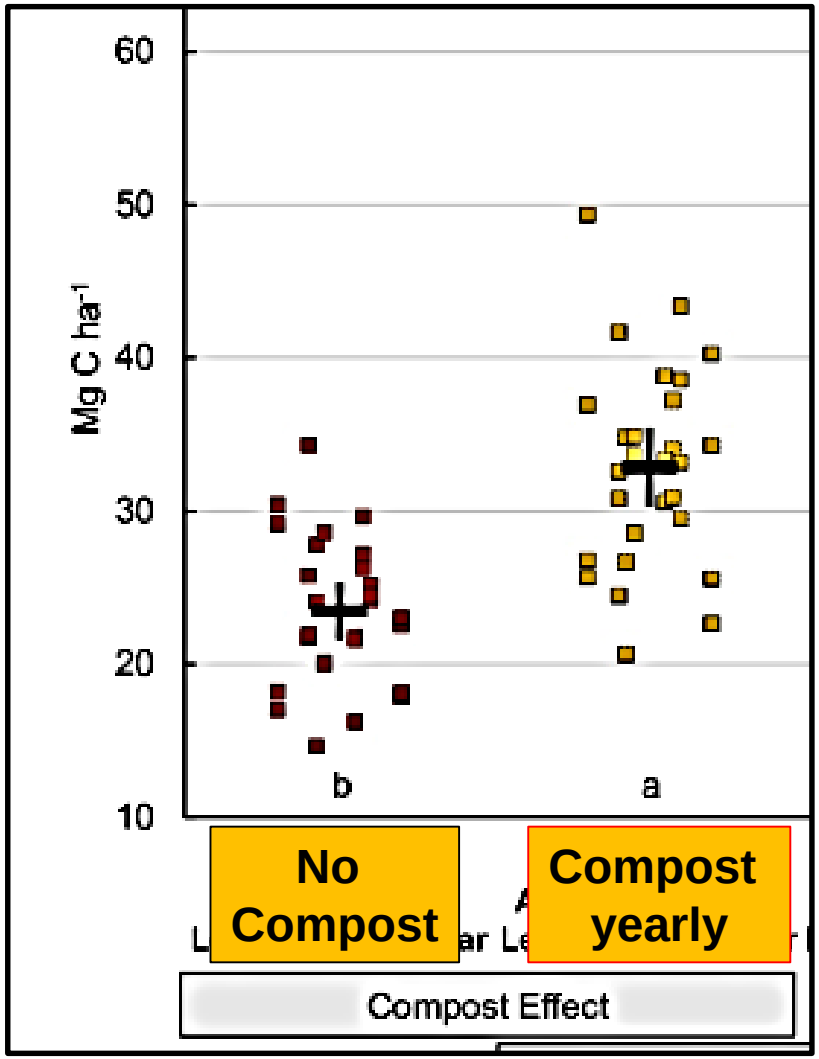
3.4 dry tons compost /A/yr



Brennan et al, 2020

Soil Carbon Levels in Plots With and Without Compost

Cover Crop Every 4th Year



In systems where cover crops were rarely used, compost becomes a key long-term source of carbon to the soil

Brennan et al, 2020

Composts

- **Produce buying companies often stipulate whether growers can/cannot use compost due to food safety concerns**
- **Produce buying companies are also stipulating that growers use sustainable growing practices**
- **There is a need to reconcile these two requirements placed on growers**
- **Compost is a practice that can be used when cover cropping is not possible**
- **Question has to be asked: If compost is properly prepared, is it a food safety concern?[1]**

1 - Trevor Suslow is working on a panel to address this issue

Organic Fertilizers

- **All of the dry organic fertilizers are made from manures, meat, fish, seed meals, etc., which contain a substantial amount of carbon**
- **At high use rates and if used on multiple crops per season, the input of carbon to the soil can be significant:**

Fertilizer	% C	C:N	Rate/A	lbs C/A
4-4-2	28	7	6,000[1,2]	1,512
12-0-0	46	4	1,000[1]	414
8-5-1	37	5	5,000[1]	1,665

1 – 90% dry weight; 2 – sum of 2 crops/year

Comparison of 20 Paired Organic and Conventional Farms

- **The organic farms evaluated were large-scale operations that, like their conventional neighboring farms, rarely used cover crops and composts**
- **A notable difference between the two is the use of organic fertilizers by organic growers**

Farm System	Organic Matter %	Total C %	OM Mineralization lb N/A/day	POXC %	FDA mg/kg/hr
Conventional	2.01	0.99	0.40	26.9	11.5
Organic	2.07	1.30	0.60	30.7	18.6*

Cover Crops

- **The use of cover crops can provide significant inputs of carbon to the soil from above ground biomass, root biomass and root exudates**
- **They prove tangible benefits to the soil such as N sequestration, improved soil tilth, temporary rotation, etc.**

Cover Crops

- **The reality is that about 5% of the vegetable production land is cover cropped each year:**
  - **That is equivalent to a given parcel receiving a cover crop once every 20 years**
- **The reasons for this is due to the high land rents, scheduling issues, etc.**

Cover Crops

- **Ag Order 4.0 provides a N credit for cereal cover crops on the R side of the A minus R metric**
- **Allowing the cover crop to reach a higher C:N ratio increases the input of carbon to the soil and increase the beneficial impact it may have on the soil**
- **A general recommendation would be to allow cover crops to get as high a C:N ratio as possible to maximize the longevity of the carbon input to the soil**

Fall-Grown Cover Crop Evaluation
October 2022

Date	Dry Biomass	Nitrogen lbs/A	Carbon lbs/A	C:N
Oct 5	5,002	163	2,054	12.6
Oct 11	6,279	186	2,609	14.0
Oct 17	6,823	174	2,862	16.5
Oct 24*	8,237	199	3,471	17.5

*** Cover crop at the 10.5.4 (watery ripe stage); it was definitely time to incorporate this cover crop before the grains ripened further**

Heads fully emerged.
Feekes 10.5

Anthers at center of head
Feekes 10.5.1

Anthers at top of head
Feekes 10.5.2

Anthers at bottom of head
Feekes 10.5.3

Carbon Storage and Energy Flow

- **Carbon storage is important and is achieved to some degree with the use of cover crops and composts**
- **However, the work done by the mineralization of carbon and the energy flow through the microbial community stimulates organisms that can compete with soilborne pathogens**

Summary Comparison of Carbon Sources

Material	Carbon Content %	Carbon Addition lbs/ton	Mineralization Rate
Cash Crop	40-43	800-860	Rapid
Compost	±30	450	Slow
Org. Fertilizers	28-46	540-830	Rapid
Cover Crop	40-43	800-860	Rapid-Medium

Practical Recommendations

- **Use every opportunity to increase soil carbon**
  - **Creative timings for cover crops, use compost!**
  - **Talk to buyers about the importance of the use of compost**
- **Track soil carbon levels with dry combustion soil analyses**
- **Most other soil health tests are not commonly done by commercial labs at this point**
- **Explore/utilize all other disease management options**