Soil Health Management in Vegetable Production

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Soil health has three main components

- Sustained biological productivity
- Environmental quality
- Plant and animal health

- Soil health is the integration of biological with chemical and physical measures of soil quality that affect farmers' profits and the environment.

This definition reflects the living and dynamic nature of soil

Soil health deals with both inherent and dynamic soil features.

- **Inherent soil quality** relates to the natural characteristics of the soil, such as its texture. These qualities are the result of soil-forming factors and cannot be changed easily.

- **Dynamic soil quality** components -- such as organic matter, soil structure, infiltration rate, bulk density, and water and nutrient holding capacity -- are readily affected by management practices. The dynamic component is of most interest to growers because good management allows the soil to come to its full potential.

Inherent and dynamic soil quality components interact with each other. Some soil types are much more susceptible to degradation and unforgiving of poor management than others.

http://soilquality.org/basics/inherent_dynamic.html

Soil quality assessments require measuring the current state of an indicator and comparing the results to known or desired values (Karlen et al., 1997)

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Soil Health

Lab Services

- Active carbon
  - Stiles, Cynthia A., et al. "Validation testing of a portable kit for measuring an active soil carbon fraction." *Soil Science Society of America Journal* 75.6 (2011): 2330-2340.
  - Weil, Ray R., et al. "Estimating active carbon for soil quality assessment: A simplified method for laboratory and field use." *American Journal of Alternative Agriculture* 18.01 (2003): 3-17.
- pH
  - Exchangeable aluminum with pH < 5.0
- Aggregate stability
- Bray 1, Bray 2 phosphorous
- Mineralizable nitrogen
- Phospholipid fatty acid analysis (PFLA)
  - Surrogate for enzyme presence & activity in the soil
  - Buyer, Jeffrey S., and Myron Sasser. "High throughput phospholipid fatty acid analysis of soils." *Applied Soil Ecology* 61 (2012): 127-130.
  - Buyer, Jeffrey S., et al. "Factors affecting soil microbial community structure in tomato cropping systems." *Soil Biology and Biochemistry* 42.5 (2010): 831-841.
- Total carbon
- Bulk density
- Particle size (by pipette)

Field Services

- Infiltration
  - Double ring infiltrometer
- Saturated hydrolic conductivity (KSAT)
  - Amoozemeter
- Whole soil profile characterization

University of Missouri
Soil Health Lab

- Active Carbon
- pH
- Aggregate Stability
- Available P
- Mineralizable N
- PLFA
- Total Carbon
- Infiltration
- SMAF SQI

http://engineering.missouri.edu/soil/soil-health-lab/

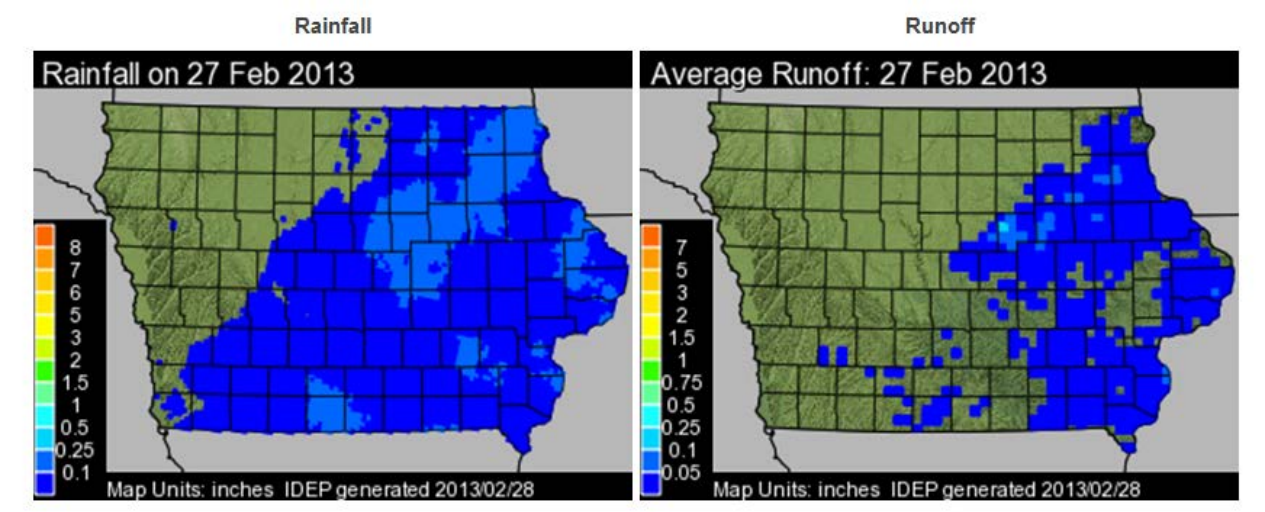
Parameters for Assessment

Indicator	Relationship to Soil Health
Soil organic matter (SOM)	Soil fertility, structure, stability, nutrient retention; soil erosion
Physical: soil structure, depth of soil, infiltration and bulk density; water holding capacity	Retention and transport of water and nutrients; habitat for microbes; estimate of crop productivity potential; compaction, plow pan, water movement; porosity; workability
Chemical: pH; electrical conductivity; extractable N-P-K	Biological and chemical activity thresholds; plant and microbial activity thresholds; plant available nutrients and potential for N and P loss
Biological: microbial biomass C and N; potentially mineralizable N; soil respiration.	Microbial catalytic potential and repository for C and N; soil productivity and N supplying potential; microbial activity measure

Why Soil Quality is Important

- Soil degradation is a major world-wide problem
- The vast majority of agricultural land in the US already has depleted levels of SOM
- Poor soil health can lead to reduced yields and reduced profits

- Healthy soil absorbs and holds water better than degraded soil



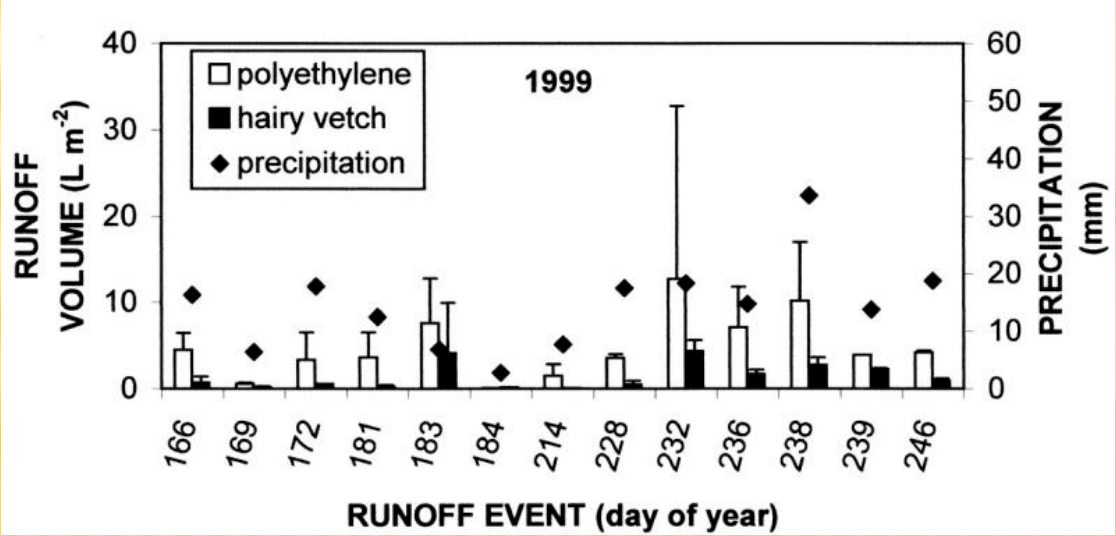
http://wepp.mesonet.agron.iastate.edu/index.phtml?dstr=02%2F28%2F2013

- Nutrients are lost through leaching and soil erosion in degraded soil

Erosion continues to be a major part of soil degradation.

In specialty crop production, plastic mulch is often used for weed control and to warm soil and preserve moisture

Rice et al. (2001) found that 2 to 4 times more water and 3 times more sediment is lost in fields with plastic mulch compared to fields that use hairy vetch mulch.



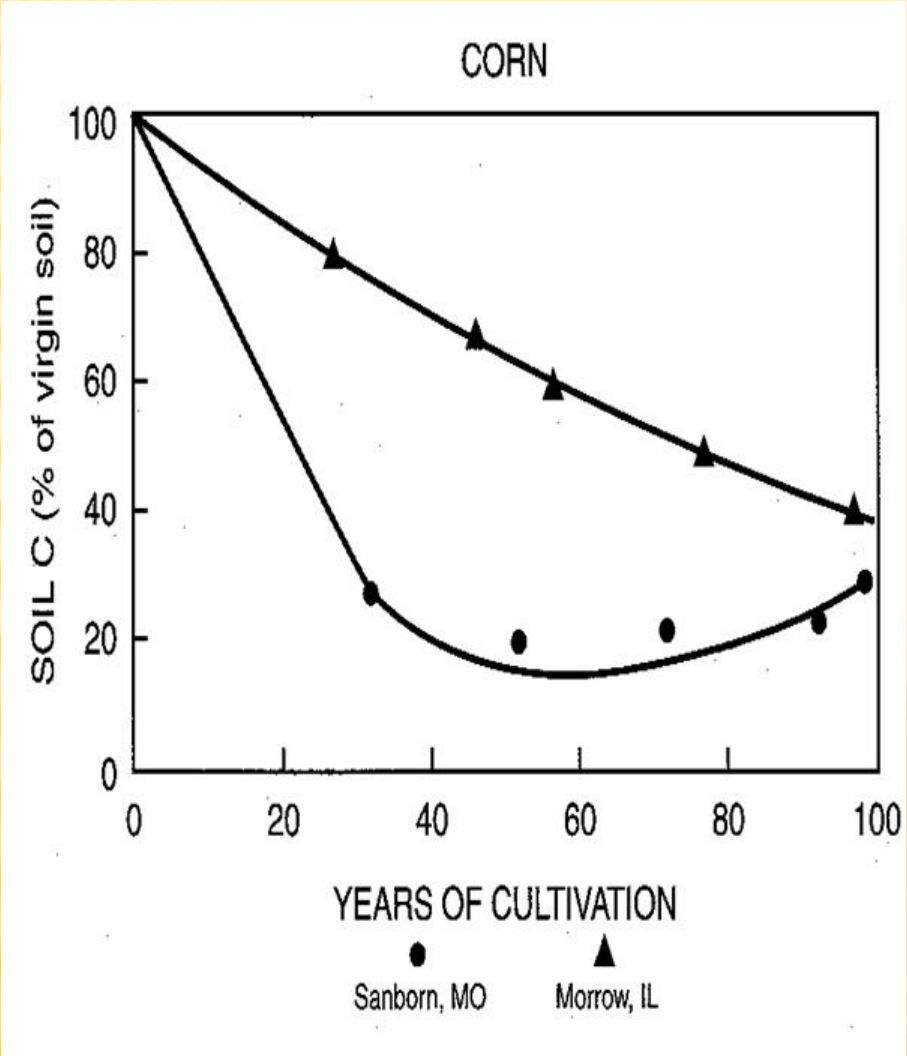
Maybe use plastic mulch and vegetative mulch together

Why Till?

- Improve seed/soil contact
- Aeration
- Weed suppression
- Residue management
- Incorporation of fertilizers, manure, etc.

What is the Problem with Tillage?

- Causes increased susceptibility to water and wind erosion
- Can compact soil below the depth of tillage
- Accelerates decomposition of soil organic matter and release of CO_2
- Damages fungal hyphae and earthworms
- Increases net nitrate production and leaching
- Can destroy macropores and lead to surface crusting, decreased water infiltration



Small changes in SOC resulting from changes in management practices can have large effects on soil behavior and microbial processes.

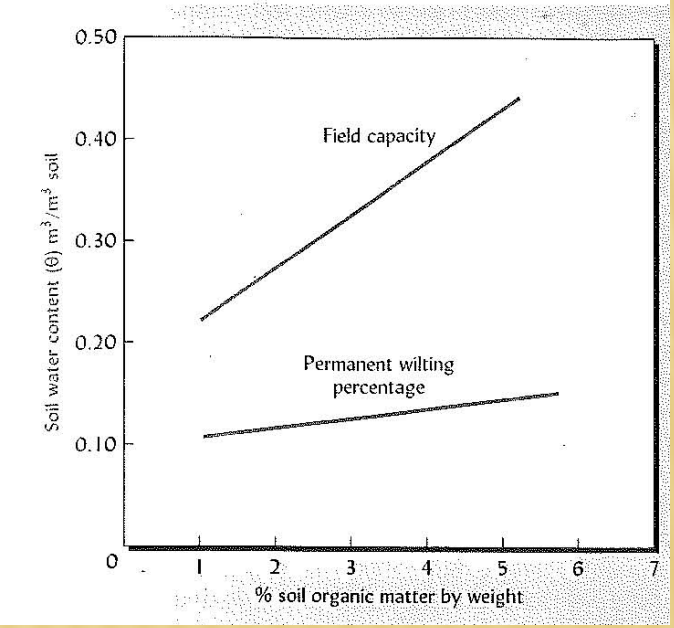
Conservation Tillage

- Leaves surface mulch, which creates microclimates, which stabilizes soil temperature and increases moisture retention
- Non-mobile nutrients will accrue in soil surface layer
- Reduced erosion
- Reduced crusting and better water infiltration

Soil Organic Matter

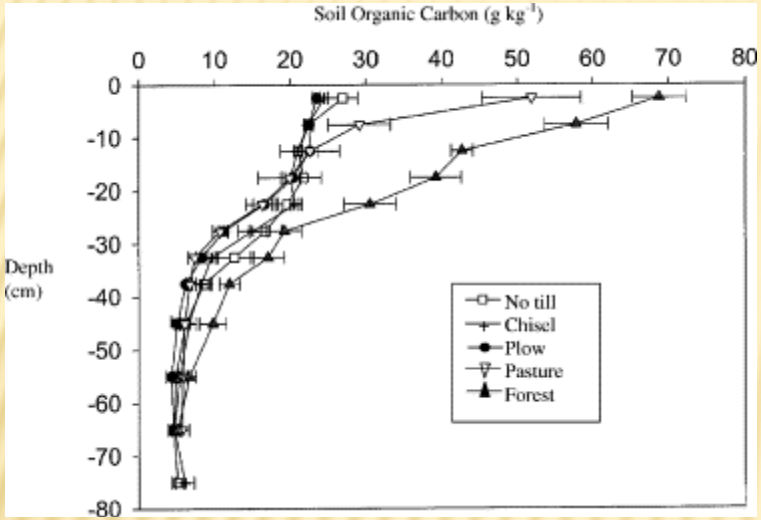
- Comprises only a tiny fraction of total mass of most soils (<3% in MO)
- Exerts a dominant influence on may soil chemical, physical and biological properties

- Much of water holding capacity of surface soils
- Majority of cation exchange capacity of surface soil
- Formation and stabilization of soil aggregates
- Contains large amounts of plant nutrients
- Slow release nutrient storehouse
- Supplies energy for soil microorganisms
- Contains compounds with growth stimulating effects on plants



Brady and Weil, 2002

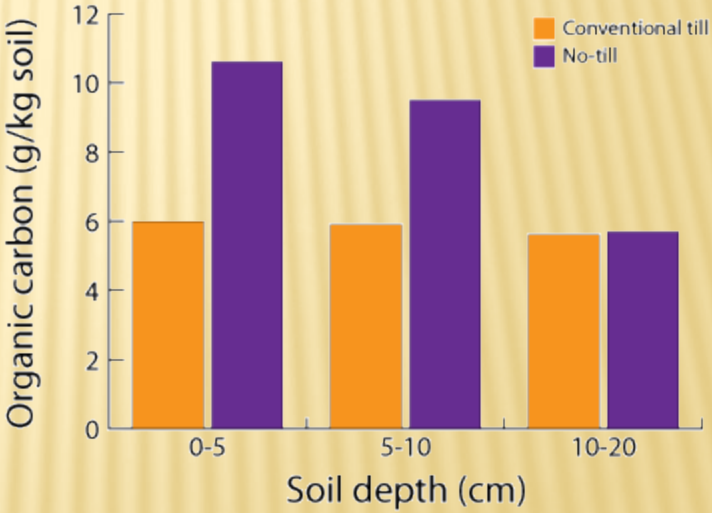
Soil organic matter and its major constituent, organic carbon, can be depleted from soil during tillage



Soil profile organic carbon concentration under plow till, chisel till, no till, pasture and forest.

Puget and Lal, 2005

Effect of 10 years of conventional till and no-till on OC (calculated from SOM data in Edwards et al., 1999).

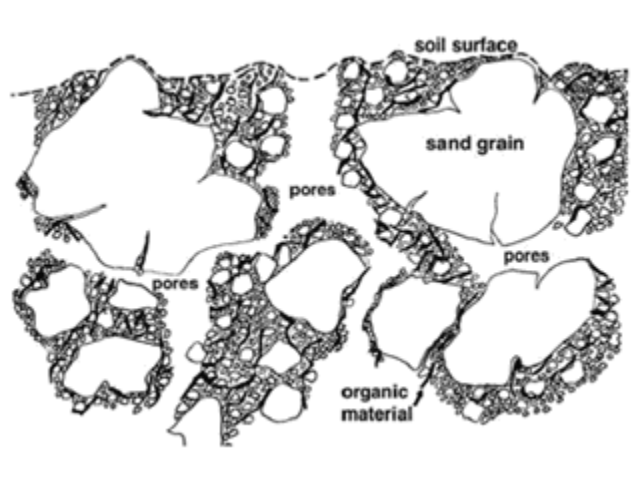


http://soilquality.org/indicators/total_organic_carbon.html

Soil Structure

- Arrangement of soil solids and voids
- Soil structure influences water infiltration and retention, erosion, crusting, nutrient recycling, root infiltration and crop yield
- Aggregation is controlled by SOC, microorganisms, ionic bridging, clay
- Expressed as degree of aggregate stability

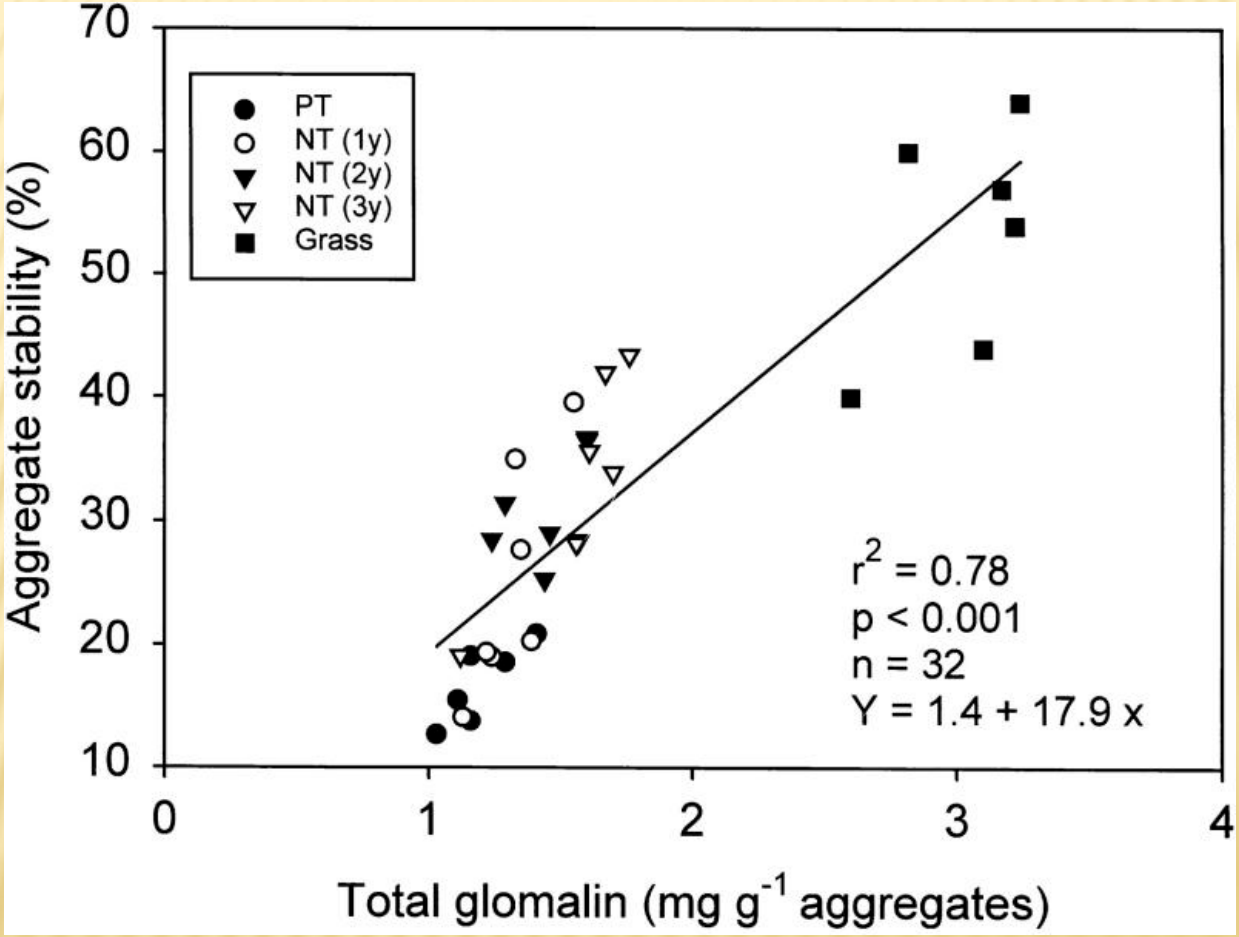
http://ecomerge.blogspot.com/2010/05/what-soil-aggregates-are-and-how-its.html



http://vro.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/soilhealth_soil_structure

Aggregate Stability

Fungal-produced glomalin helps bind aggregates



Wright, et al., 1999

Tillage reduces aggregate stability and sizes

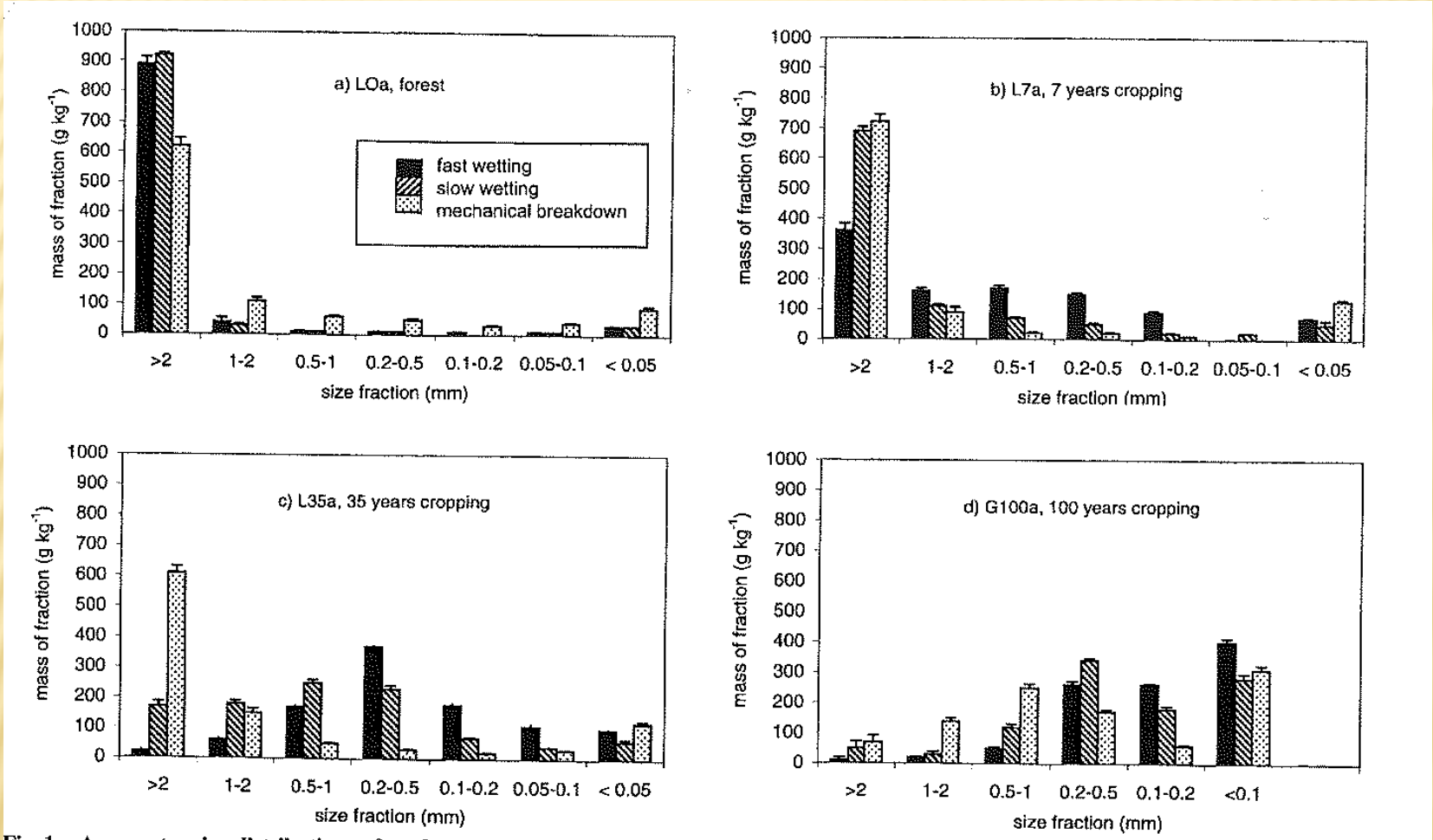


Fig. 1. Aggregates size distributions after the water stability tests for four of the studied soils having decreasing C contents in relation to time of cultivation: (a) L_{0a}, forest; (b) L_{7a}, 7 yr cropping; (c) L_{35a}, 35 yr cropping; and (d) G_{100a}, 100 yr cropping.

Chen et al., 2000

Water Infiltration

Good infiltration allows for less runoff and erosion

Soils with poor aggregate stability will crust, damaging emerging seedlings and increasing runoff

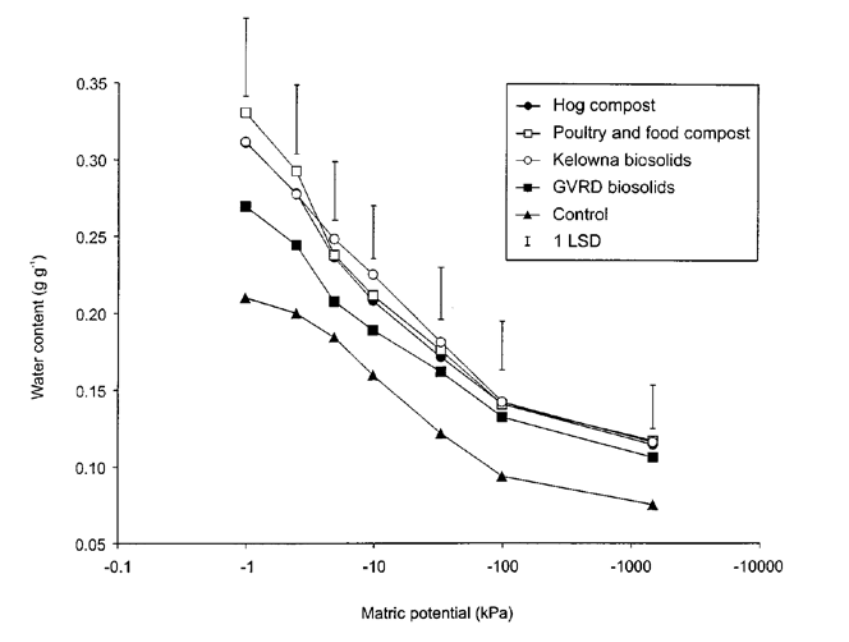
Improving Soil Quality

- Reduce or eliminate tillage. Tillage causes soil organic carbon loss, affects microbial biomass, depletes the soil nutrient pool and damages soil structure
- Crop rotation
- Don’t leave ground bare
- Maintain lots of plant residue
- Add organic matter, such as manure and compost
- Plant cover crops

Manure and Compost

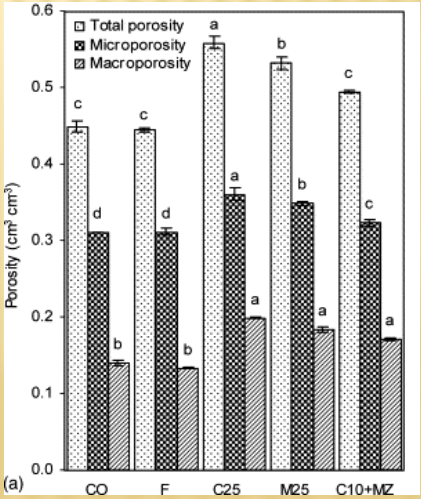
- Improve water infiltration and retention
- Improve structure
- Add nutrients

Water content after 3 years of compost addition



Zebarth et al., 1999

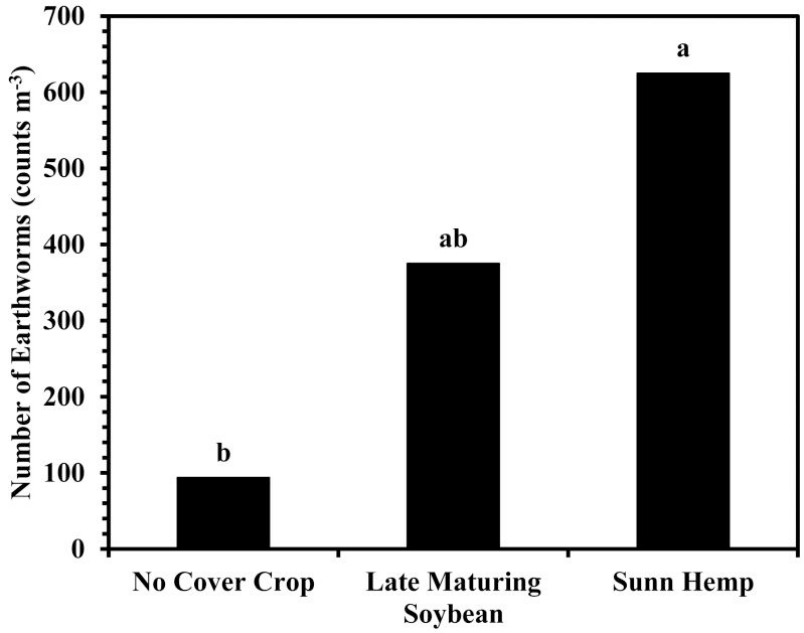
Porosity after 4 years of fertilizer, compost or manure addition



Celik et al., 2004

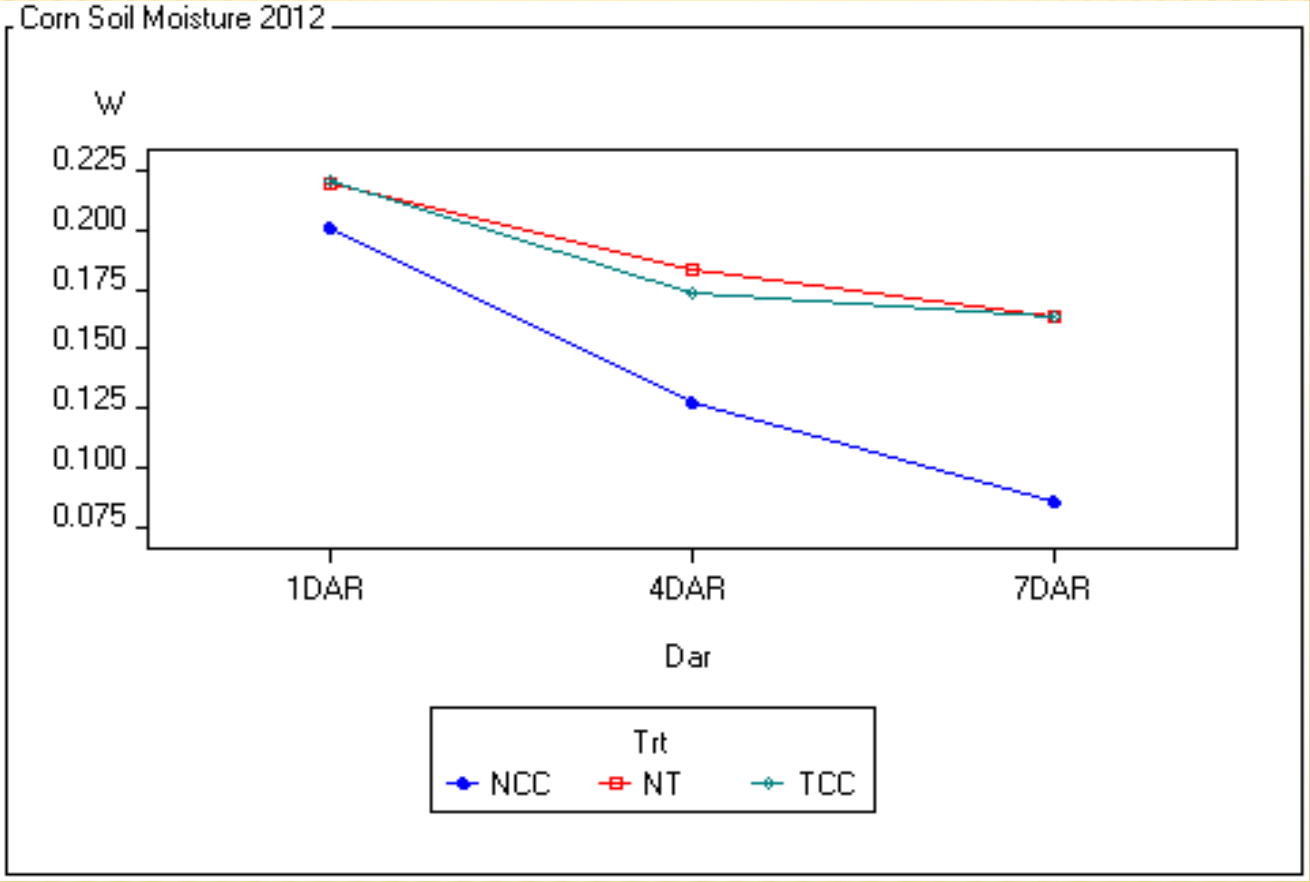
COVER CROPS

- Provide food for beneficial soil microbes and earthworms
- Increase soil organic matter, which helps improve soil quality and fertility



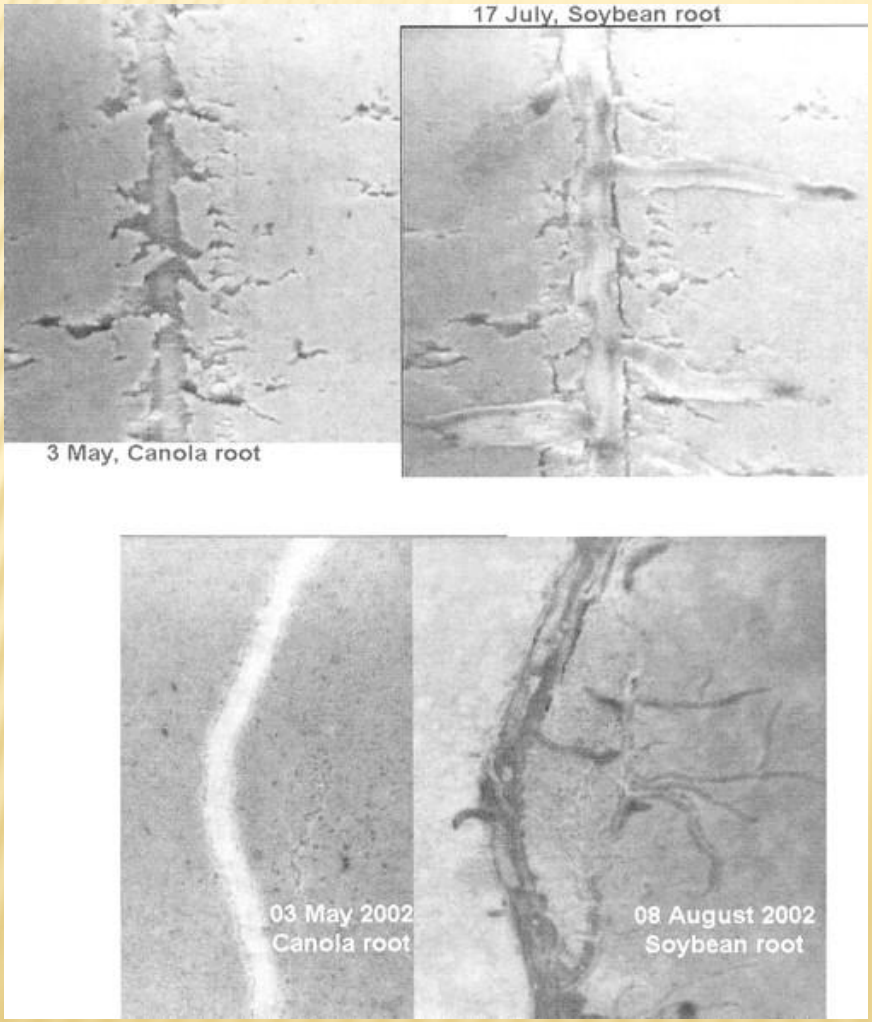
Blanco-Canqui et al., 2011

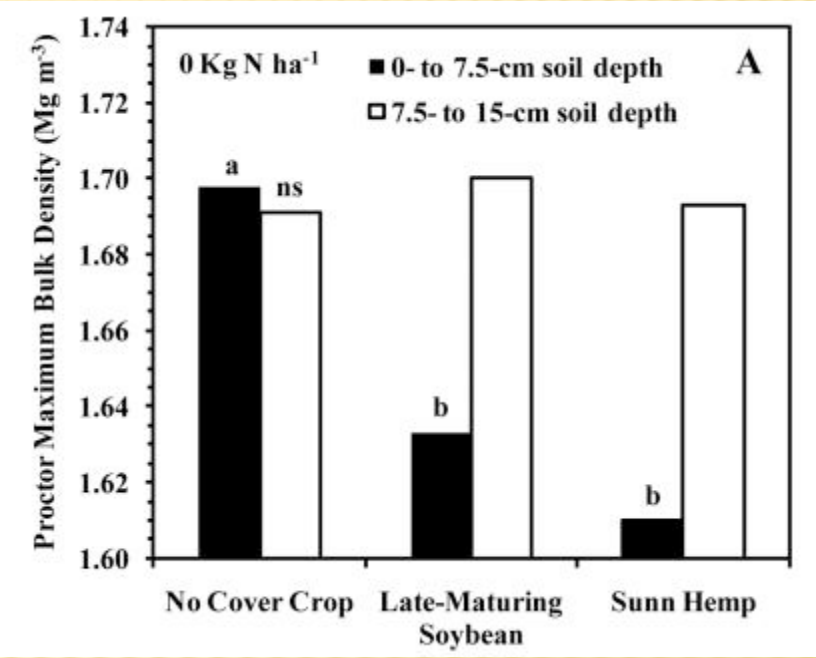
Soil Moisture Retention By Cover Crops In Corn



DAR= days after rain (irrigation)

- Cover crops help reduce soil compaction and soil erosion



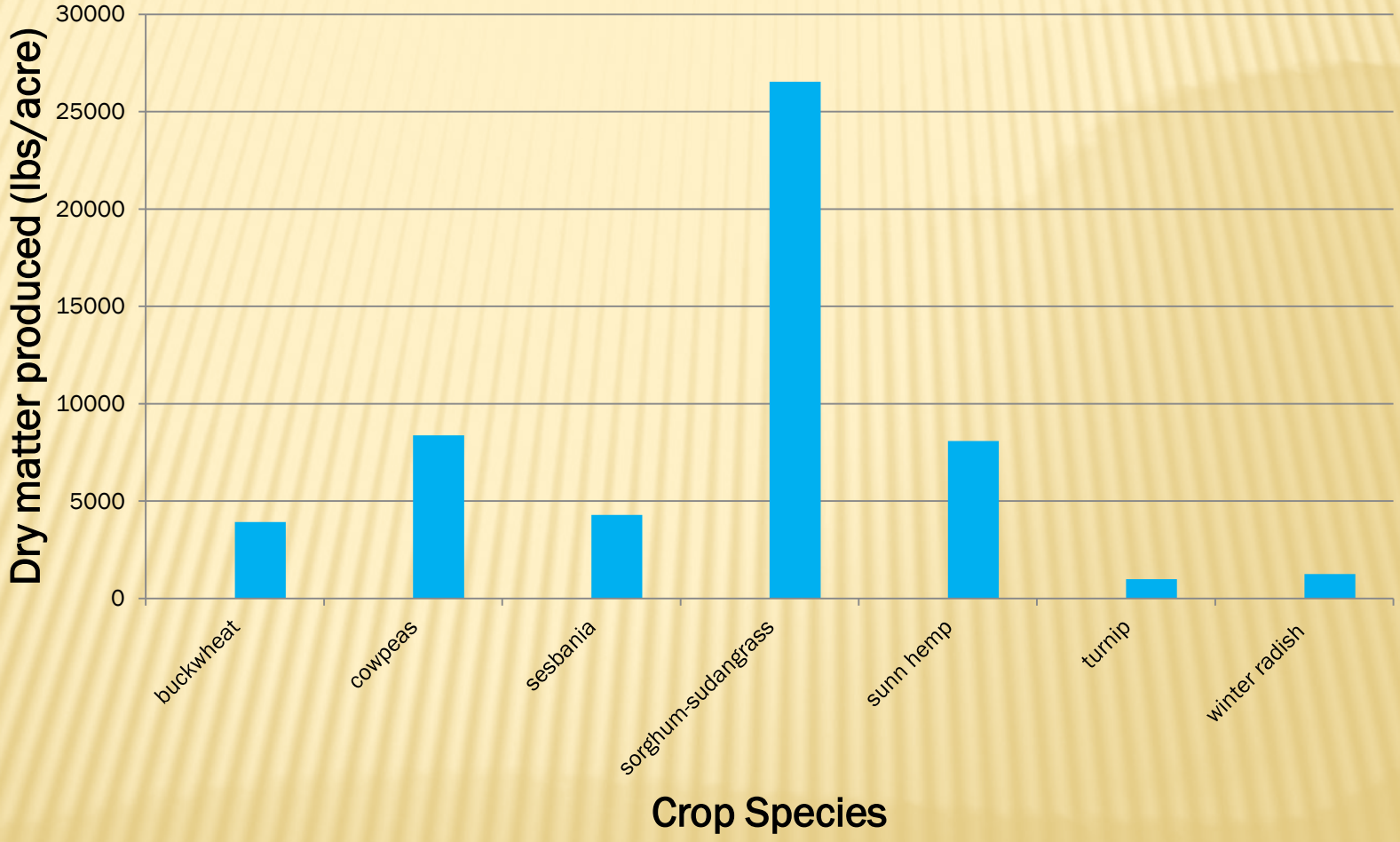


Blanco-Canqui et al., 2011

Williams and Weil, 2004

- Weed Control
  - Cover crops produce a lot of biomass, which helps to prevent weed germination and growth
  - Fallow fields grow weeds, plant a cover crop in the off season

Summer Cover Crop Yields



- **Nutrient advantages**
  - **Winter cover crops capture and hold nitrogen so that it is not lost to the atmosphere**
  - Increased organic matter is a nutrient reservoir
  - Legume cover crops produce nitrogen that can then be used by the following crop, reducing fertilizer costs

Table 3. Nitrogen fertilizer replaced by three legume cover crops based on yield and grain-N regression equations for wheat and fallow at the Limestone Valley location.

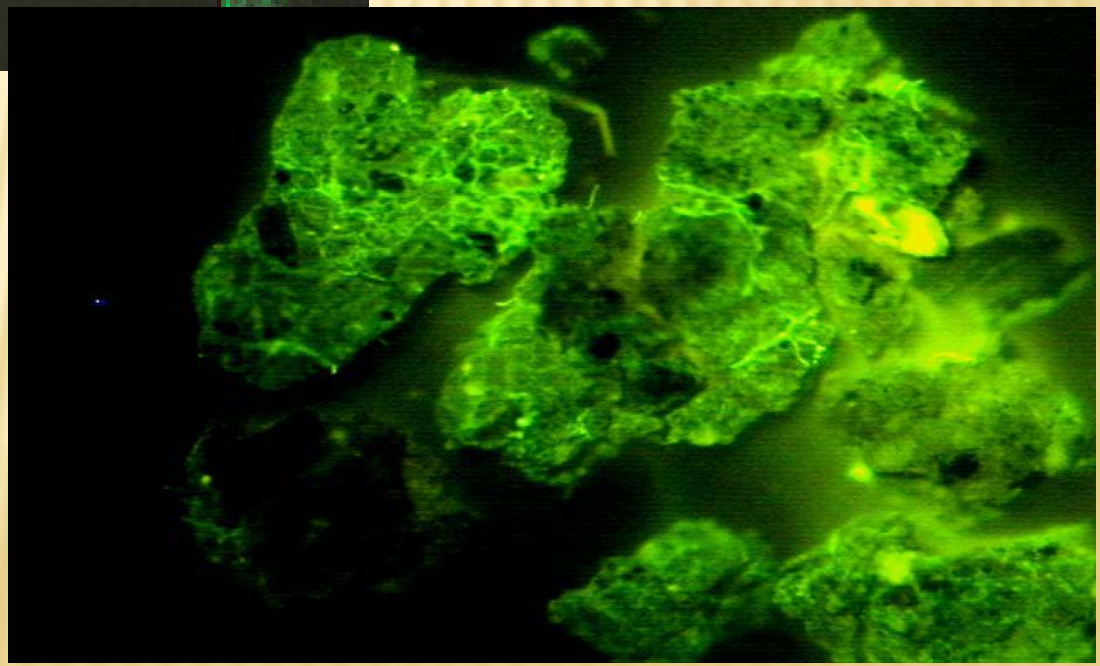
Cover crop	N fertilizer replaced			
	Based on yield of		Based on grain N of	
Year	Wheat	Fallow	Wheat	Fallow
	kg ha^{-1}			
Winter pea				
1985	87	78	92	90
1986	113	108	109	73
1987	73	50	85	57
Mean	91	79	96	73
Hairy vetch				
1985	119	110	180	202
1986	103	96	137	105
1987	130	124	212	205
Mean	117	110	176	171
Crimson clover				
1985	94	85	156	202
1986	115	110	125	91
1987	124	115	139	110
Mean	110	103	140	134
Year	R^2 of regression equation			
1985	0.91	0.91	0.86	0.78
1986	0.88	0.56	0.94	0.69
1987	0.70	0.61	0.84	0.72

McVay et al., 1989

Similar yields were achieved in tomatoes grown under plastic and with cover crops (Buyer et al., 2010) in Maryland, but soil microbial populations differed significantly under the different treatments

Table 3. PLFA concentrations

Treatment	Total	Gram+	Gram−	Actino	Fungi	AM Fungi	Protozoa
Bare	15.07 DE	4.45 CD	3.94 DE	2.17 BC	0.42 BC	0.58 DE	0.07 B
Black Poly	13.27 E	4.10 D	3.28 E	1.87 C	0.36 C	0.48 E	0.04 B
White Poly	15.49 CDE	4.61 BCD	4.04 DE	2.20 BC	0.45 BC	0.59 CDE	0.08 AB
Rye	19.33 AB	5.48 AB	5.58 AB	2.69 A	0.61 AB	0.85 A	0.18 AB
Rye Roots	18.39 ABC	5.26 ABC	5.16 ABC	2.53 AB	0.60 AB	0.73 ABC	0.14 AB
Rye Shoots	16.72 BCD	4.90 BCD	4.51 CD	2.41 AB	0.44 BC	0.66 BCD	0.11 AB
Vetch	20.38 A	5.82 A	5.76 A	2.71 A	0.73 A	0.81 AB	0.20 AB
Vetch Roots	19.04 AB	5.47 AB	5.36 ABC	2.59 AB	0.54 BC	0.72 ABCD	0.27 A
Vetch Shoots	17.39 BCD	5.05 BC	4.77 BCD	2.46 AB	0.55 ABC	0.71 ABCD	0.13 AB



Fall planted winter annuals improved yield and phosphorus uptake in sweet corn in Pennsylvania (Kabir and Koide, 2002)

An oat and cereal rye mix increased mycorrhizal colonization of a subsequent sweet corn crop compared to no cover crop.

Winter fallow is harmful to VAM fungi because they are without a host

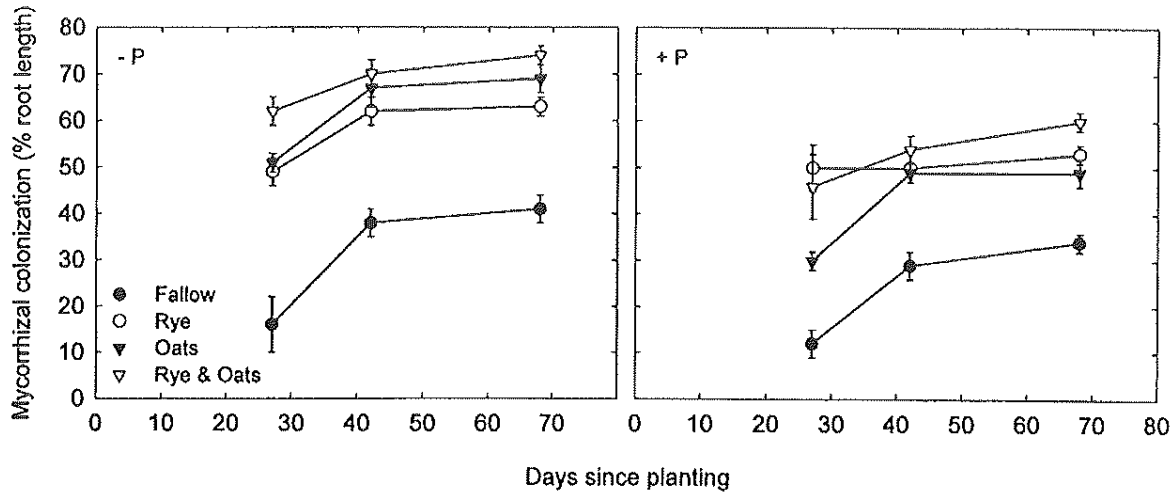


Figure 1. Mycorrhizal colonization (% of root length) of sweet corn on 22 June, 7 July and 2 August 1999 (27, 42 and 68 days after planting)

Kelly et al. (1995) fund that a hairy vetch mulch system was more profitable over a three year period than a plastic mulch system in Maryland.

They attributed this to higher yields with a lower cost structure and to higher late season prices. Tomatoes grown in plastic matured more quickly but prices were higher late in season when vetch mulch tomatoes matured

	Yield[z] ($t \cdot ha^{-1}$)		
System	1991	1992	1993
Bare soil	53.4 c	35.5 b	77.3 b
Black polyethylene	107.3 b	45.3 b	88.0 ab
Hairy vetch	129.2 a	85.8 a	95.8 a

Table 6. Average annual returns per hectare under different yield scenarios

		Yield scenario	
System	Optimistic	Expected	Pessimistic
Bare soil	$10,339	$6,993	$3,648
Black polyethylene	$14,721	$10,219	$5,717
Hairy vetch	$24,379	$18,207	$12,034

JOHN DEE
L&J

2014 Soil Health Workshops
NRCS and University of Missouri

Locations

Edina, MO	January 27th	9am-4pm	Knox County Community Center; 207 N. Fourth St.
Marshall, MO	February 3rd	9am-4pm	Martin Community Center; 1985 South Odell Ave.
Butler, MO	February 11th	9am-4pm	Bates County Fairgrounds: Youth Building;

Upcoming locations: address to be determined

Kennett, MO	March 5th
LaMar, MO	March 14th
Sikeston, MO	March 19th
Albany, MO	March 25th