Field Experiments on Tillage and Organic Matter Management: Effects on Soil Carbon, Crop Yields and Pests

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Soil Organic Matter (SOM)

- Mainly composed of C and N
- **Most abundant:** recalcitrant and protected SOM
  - humic substances and other material that is hard to breakdown
  - can be physically or chemically protected to resist breakdown
- **Much less abundant:** active SOM
  - sugars, amino acids, readily decomposable plant material, dead and live microbial cells
- Microbes break down SOM to get soluble, available C for growth and maintenance. CO_2 is produced. N is released and made available for plant growth.

Benefits of Soil Organic Matter (SOM)

- Carbon sequestration
- Increased water infiltration
- Decreased soil crusting
- Greater aggregate stability
- Increased microbial activity
- Higher nutrient availability and enhanced soil fertility

Two-Year Experiment: Cover Crops, Compost, and Tillage Practices (Salinas)

- **Goal:** Examine changes in yield, SOM, microbial biomass, N availability, weeds, pests, diseases, and economics in an on-farm study (Tanimura & Antle)
- **Salinas clay loam:** sprinkler and surface-drip irrigation
- **Four treatments started in April 1998**
  - Minimum till ("Sundance") + cover crops & compost
  - Minimum till ("Sundance") - cover crops & compost
  - Conventional tillage (disc) + cover crops & compost
  - Conventional tillage (disc) - cover crops & compost
- **Compost added for each spring crop and cover crop (4 tons/acre)**
- **Three lettuce crops (July 98, May 99, Aug 99); one broccoli crop (Apr 00)**

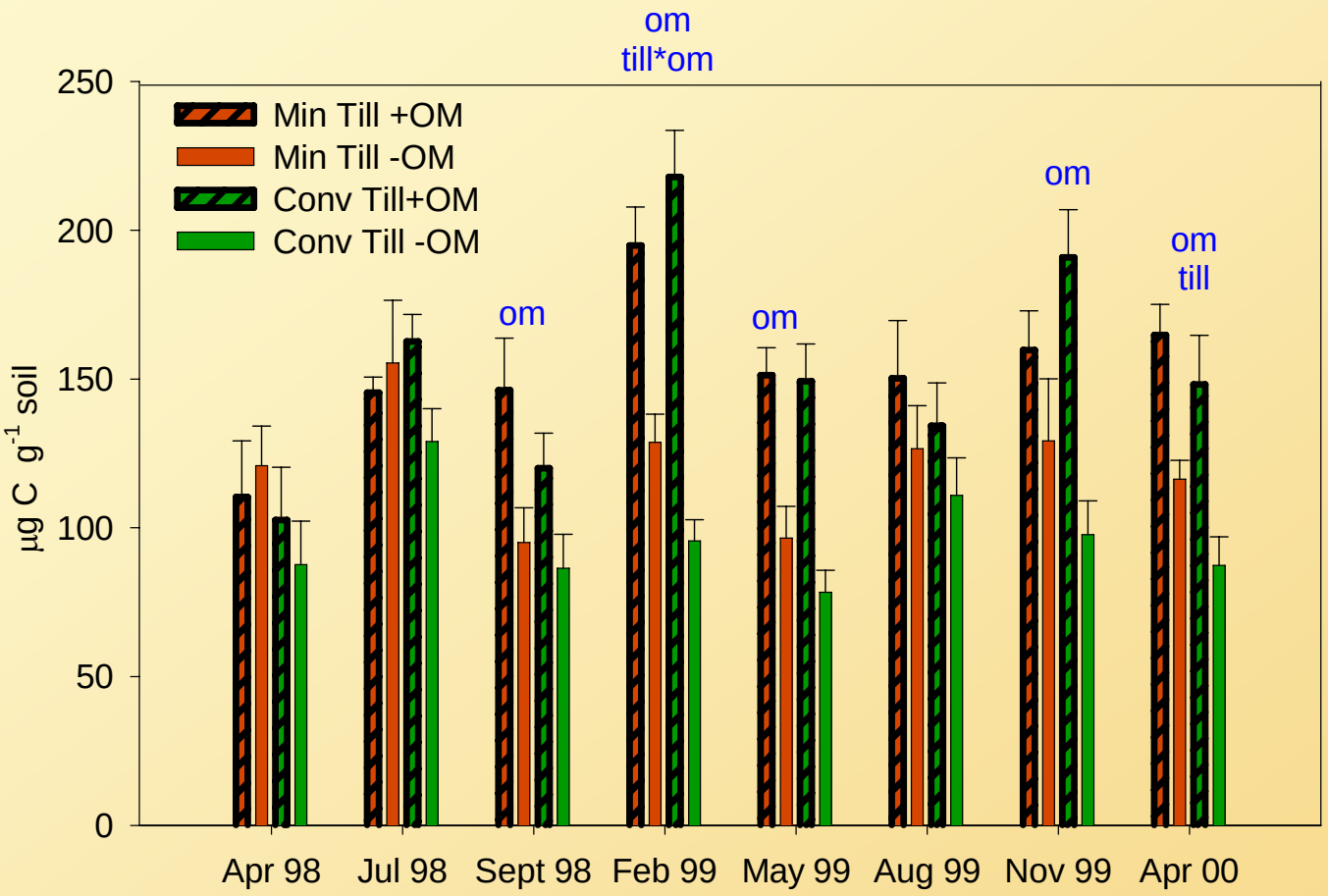

Minimum till beds
with cover crop
Minimum till bed
without cover c

	Min Till +OM	Min Till -OM	Conv Till +OM	Conv Till -OM
Soil Organic C at 0-15 cm depth (%)				
1998	1.52 *a*	1.41 *a*	1.45 *a*	1.38 *a*
2000	1.51 *w*	1.41 *w*	1.48 *w*	1.37 *w*
Soil Organic N at 0-15 cm depth (%)				
1998	0.17 *a*	0.16 *a*	0.16 *a*	0.15 *a*
2000	0.16 *w*	0.15 *wx*	0.16 *wx*	0.15 *x*
Bulk Density at 0-6 cm depth (g cm^{-3})				
1998	No Data	1.25 *a*	1.26 *a*	No Data
2000	1.16 *x*	1.31 *wx*	1.25 *wx*	1.36 *w*
Bulk Density at 47-53 cm depth (g cm^{-3})				
1998	No Data	1.37 *a*	1.40 *a*	No Data
2000	1.47 *w*	1.46 *w*	1.33 *w*	1.41 *w*

After two years:

- Soil C and N content did not increase as a result of minimum tillage or OM inputs
- Min Till was less compacted in the surface layer

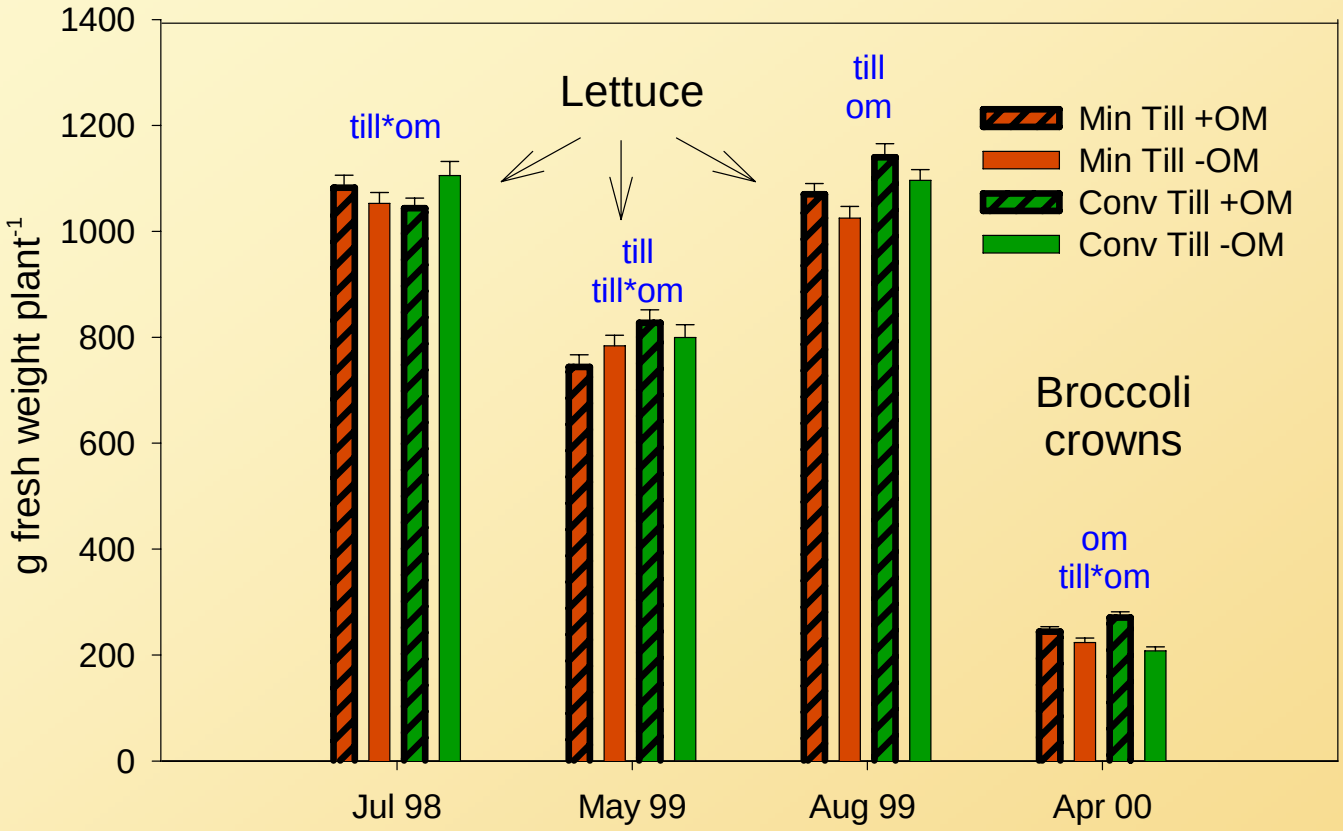
Soil Microbial Biomass Carbon



- MBC was higher with OM additions
- Min Till had no effect until 2 yrs had passed

Note: om, till indicate significant treatment effects (P<0.05) by ANOVA

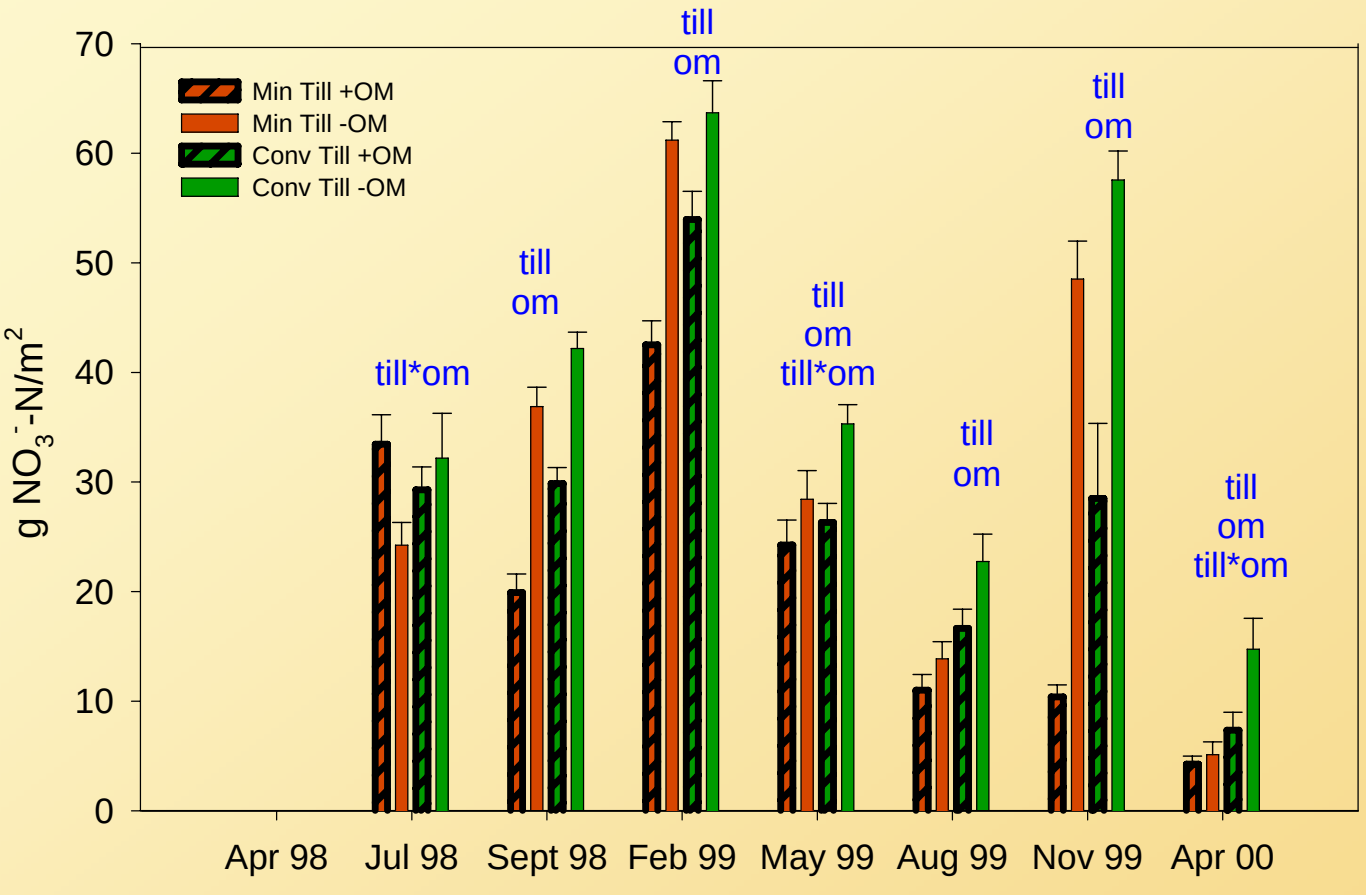
Crop Fresh Weight



- Lower yields with minimum tillage
- OM tended to increase yields
- Conv Till +OM had highest yields

Note: om, till indicate significant treatment effects (P<0.05) by ANOVA

Soil Nitrate N (0-90 cm depth)



Note: om, till indicate significant treatment effects (P<0.05) by ANOVA

- High soil nitrate on most dates
- Cover crops decreased nitrate leaching potential
- Min Till decreased soil nitrate

Pests in Organic Matter/Tillage Study

- Few diseases; no significant difference between tillage (minimum vs. conventional) or OM inputs (+/- cover crops & compost) (Steve Koike)
- Leaf miners not affected by tillage or OM inputs (Bill Chaney)
- Weeds were affected by OM inputs but not tillage type (Steve Fennimore)
  - Lower weed densities with cover crops & compost additions
  - Burning nettle and shepherd's purse weed density was inversely correlated with soil microbial biomass C
  - No correlation between weed seedbanks and soil microbial biomass C
  - Hypothesis: Organic amendments may have resulted in lower weed seedling emergence due to enhanced soil microbial activity.

Lettuce Yield and Disease with Minimum Tillage on Semi-Permanent Beds

	Jul 1997*			Jul 1998				Sept 1999		
	Sun-dance only	Deep chisel		Sun-dance only	Deep chisel	4-step deep till		Sun-dance only	Deep chisel	4-step deep till
Fresh weight (g)	ND	ND		811^{a}	863^{ab}	943^{c}		873^{x}	939^{xy}	967^{y}
Dry weight (g)	21.30^{m}	22.56^{m}		36.44^{a}	37.81^{a}	39.24^{a}		36.46^{x}	38.85^{x}	39.01^{x}
Lettuce drop (%)	6^{m}	4^{m}		5^{a}	2^{b}	1^{b}		4^{x}	2^{y}	1^{z}
Corky root (% of taproot)	17^{m}	17^{m}		56^{a}	43^{b}	47^{b}		5^{x}	4^{x}	5^{x}

- Higher lettuce drop disease (*Sclerotinia minor*) with shallow minimum tillage

Lettuce: Economic Analysis (average of 3 lettuce crops)

	Min Till +OM	Min Till -OM	Conv Till +OM	Conv Till -OM
Returns per acre ($)				
Total returns	7709	7614	8017	7972
Total costs	7303	7003	7768	7423
Net returns	406	611	249	550
Fuel (Gallons per acre)				
Diesel used	33	31	93	76

Summary of Two-Year Experiment: Cover Crops, Compost, and Tillage Practices

- Total soil C and N were not affected by OM inputs or tillage treatments after two years.
- Soil microbial biomass increased and remained higher following fall treatment of compost + cover crop compared to fall fallow.
- Yield generally increased with fall compost + cover crop.
- Nitrate in the deep soil profile was removed by fall cover-cropping, reducing the potential for leaching loss.
- Diseases and insect pests were minor, but at a different site, minimum tillage increased *Sclerotinia minor*

Cont. Summary of Two-Year Experiment: Cover Crops, Compost, and Tillage Practices

- Weed densities often decreased with OM inputs.
- Economic returns were highest with minimum till w/o OM inputs, despite lower yields.
- Fuel savings with minimum tillage was 30-50% of conventional tillage.
- Implications for energy savings: Minimum tillage can save fuel, and organic matter additions can potentially save energy-intensive inputs, e.g., N fertilizer

Conclusions

- Minimum tillage, cover crops and compost are slow to sequester total soil C in these crop systems
- Minimum tillage offers large fuel savings, and is profitable despite lower yields, but can increase *Sclerotinia*
- Organic matter inputs have benefits for soil quality but cover crops increase fuel use
- Solution: intermittent minimum tillage with cover crops+compost balances tradeoffs of economic costs, disease, and soil quality

Three-Year Experiment: Effects of Deep vs. Shallow Minimum Tillage on Lettuce Yield, Disease, and Soil C

- **Goal:** Examine changes in yield, *Sclerotinia* and corky root levels, soil microbial biomass, and SOM under three types of tillage that retain semi-permanent beds for several years (American Farms)
- **Cropley silty clay:** sprinkler and furrow irrigation
- **Three treatments started in Oct 1994**
  - Shallow minimum till ("Sundance")
  - Deep minimum till ("Deep Chisel")
  - Deep minimum till ("4-Step Deep Till")
- **Lettuce crops every year (1995-1998)**
- **Sampling:** Re-sampled same points in strip plots across the field once each year

Four-Step Minimum Tillage for Retaining Semi-Permanent Beds (American Farms)

- Minimum-till chisel: Chisels furrows to approx. 20 inches and diskhills beds
- 'Sundance' system: Disks the top 6-10 inches of the beds
- Minimum-till ripper: Broad shanks with floating wings break the compacted layer at 15- 20 inches
- Rototill/mulcher: Smoothes surface and prepares seedbed

Summary of On-Farm Experiment: Effects of deep *vs.* shallow minimum tillage

- After two years of shallow minimum tillage ('Sundance'), yields decreased and lettuce drop disease increased.

- Yields were highest when both chiseling and ripping were included in the operations for maintaining semi-permanent beds.

- Soil microbial biomass was often higher with shallow minimum tillage, but little change in total soil C occurred, even after 4 years.

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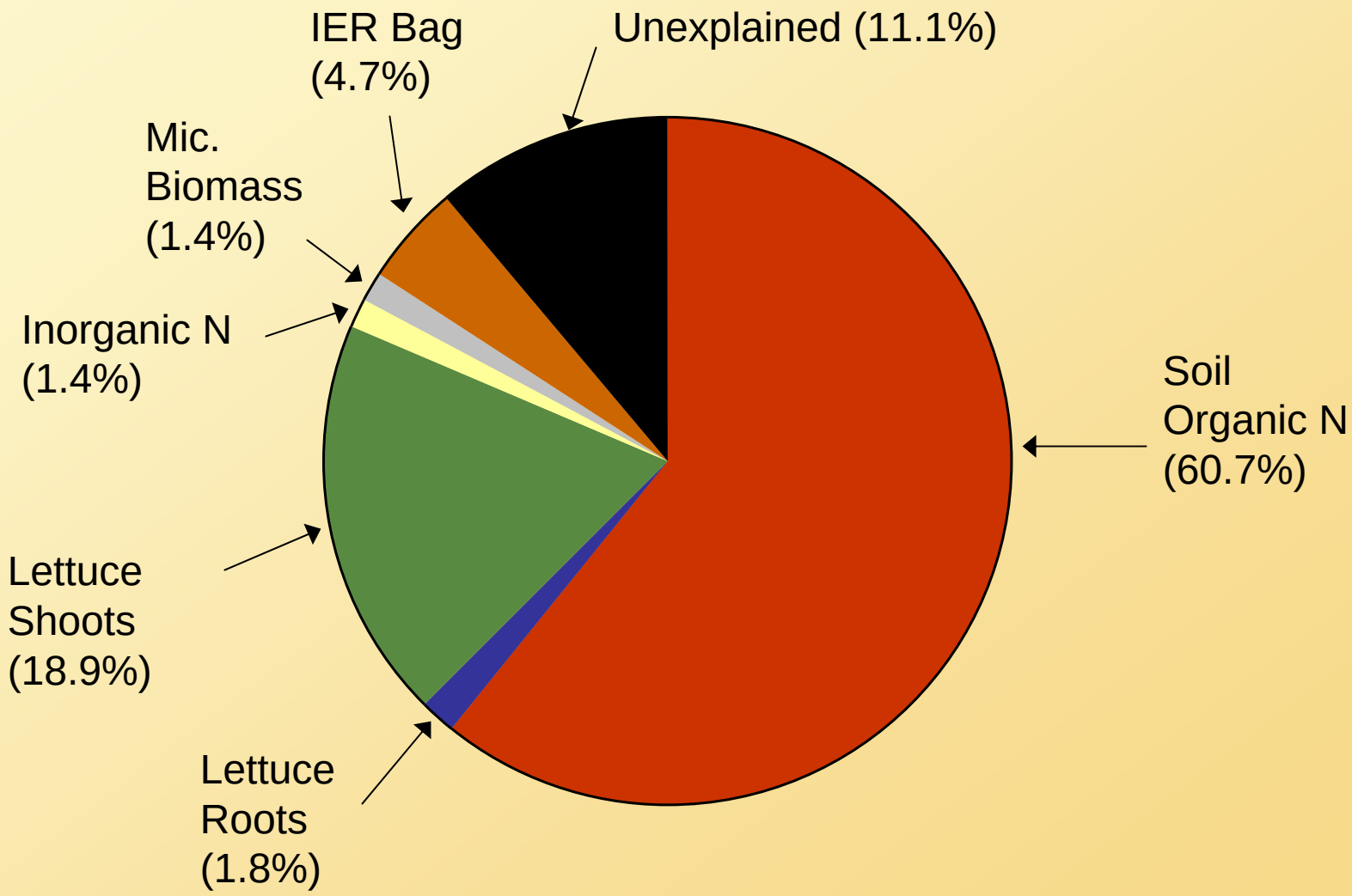
Fate of Cover Crop ^{15}N at Harvest of First Lettuce Crop

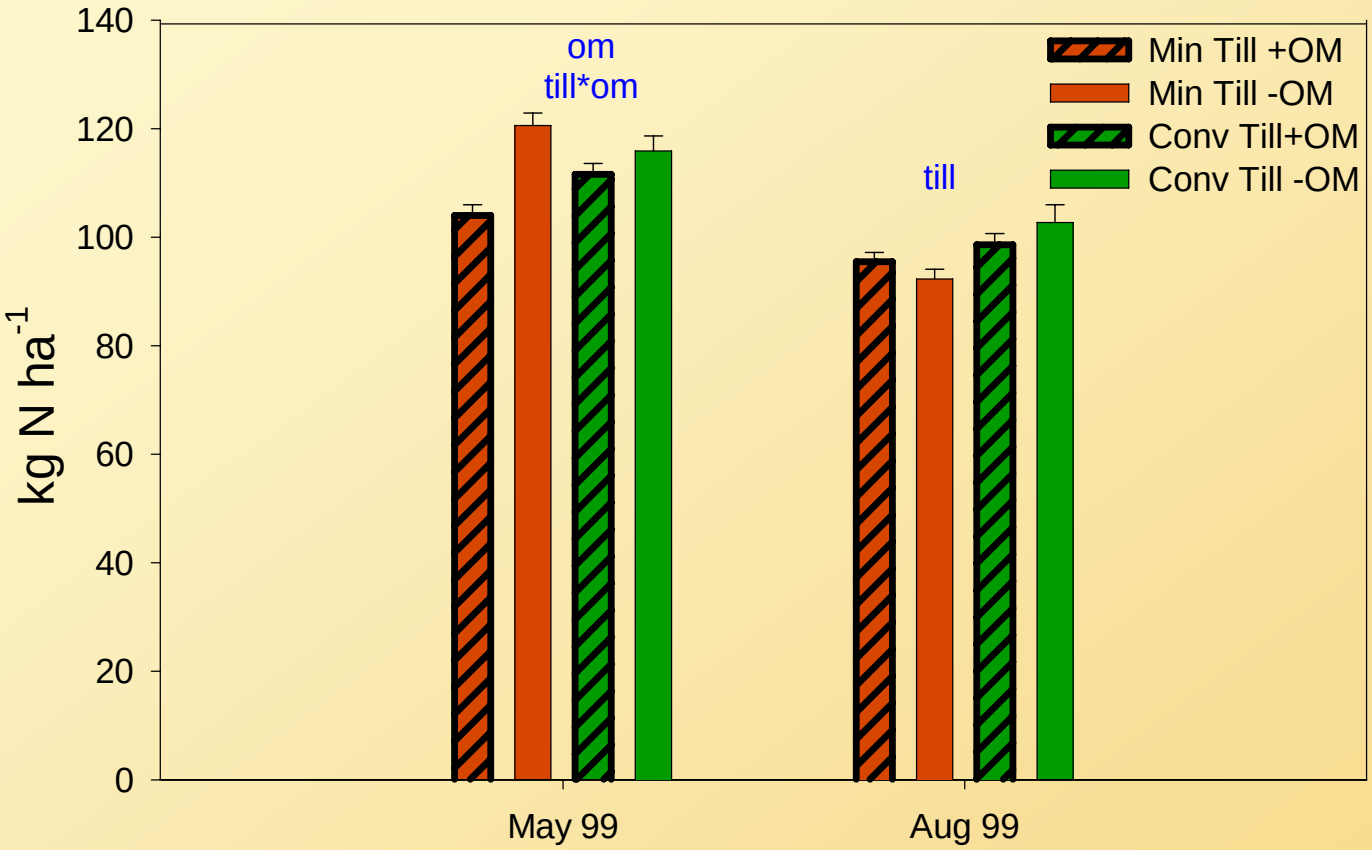


Soil Responses to Minimum Tillage on Semi-Permanent Beds

	Jul 1997			Jul 1998				Sept 1999		
	Sun-dance only	Deep chisel		Sun-dance only	Deep chisel	4-step deep till		Sun-dance only	Deep chisel	4-step deep till
Soil microbial biomass (μg C g^{-1} dry soil) in surface layer										
0-4 in	225^{m}	254^{m}		291^{a}	233^{ab}	182^{b}		355^{x}	343^{x}	330^{x}
Soil bulk density (g cm^{-3} dry soil) at 3 depths										
0-2.4 in	1.08^{m}	1.06^{m}		0.95^{a}	0.98^{a}	0.95^{a}		0.90^{x}	0.86^{x}	0.99^{x}
7.9-10.2 in	ND	ND		ND	ND	ND		1.09^{xy}	1.17^{x}	0.96^{y}
15.7-18.1 in	1.29^{m}	1.24^{m}		1.19^{a}	1.23^{a}	1.27^{a}		1.24^{x}	1.14^{x}	1.07^{x}
Soil total organic C and N (%)										
Org. C (0-4 in)	ND	ND		ND	ND	ND		2.01^{x}	1.94^{x}	1.93^{x}
Org. N (0-4 in)	ND	ND		ND	ND	ND		0.24^{a}	0.24^{a}	0.22^{b}

- Higher soil C at 0-4 inches with shallow minimum till after 4 yrs

Lettuce N Uptake (kg N ha^{-1})



- Lettuce N tended to be lower with Min Till

Note: om, till indicate significant treatment effects (P<0.05) by ANOVA

Management Sequence

+ OM treatments, 1998

- April 98: Apply compost (4 tons/acre)
- May 98: Plant lettuce
- July 98: Harvest lettuce
  Apply compost (4 tons/acre)
  Minimum or Conventional Till
- Aug 98: Plant Merced Rye cover crop
- Sept 98: Till cover crop into soil on beds or on flat
  Minimum or Conventional Till

+ OM treatments, 1999

- Jan 99: Plant lettuce
- May 99: Harvest lettuce
  Minimum or Conventional Till
- June 99: Apply compost (4 tons/acre)
  Minimum or Conventional Till
  Plant lettuce
- Aug 99: Harvest lettuce
  Minimum or Conventional Till
- Sept 99: Apply compost (4 tons/acre)
  Plant Merced Rye cover crop
- Nov 99: Till cover crop into soil on beds or on flat
  Minimum or Conventional Till
  Plant broccoli

Lettuce + Cover Crop Harvested May 1999: Economic Analysis

- Much higher fuel and labor costs with Conv Till +OM; produced very negative returns

	Min Till +OM	Min Till -OM	Conv Till +OM	Conv Till -OM
Management costs per acre ($)				
Fuel, lube, repair	150	117	374	254
Machine labor	150	134	235	179
Non-machine labor	470	436	470	436
Harvest costs	3623	3816	4047	3893
Irrigation	89	74	88	73
Compost	177	0	177	0
Seed	125	100	125	100
Fertilizer	151	151	151	151
Herbicide	26	26	26	26
Other pesticide	149	149	149	149
Application fees	95	95	95	95
Cash overhead	9	7	22	15
Non-cash overhead	111	83	253	172
Interest on capital	97	71	127	87
Land rent	1000	1000	1000	1000
Total costs	6423	6259	7339	6630
Returns per acre ($)				
Total returns	5985	6304	6686	6431
Total costs	6423	6259	7339	6630
Net returns	-438	45	-653	-199
Fuel (Gallons per acre)				
Diesel used	51	42	159	109

This talk

- **Basics of Soil Organic Matter (SOM)**: What is it? What does it do? Why build SOM?

- **Cover Crops, Compost, and Tillage Practices (Salinas)**: 2-year study on soil microbial biomass, SOM, N cycling, yields, weeds, diseases, pests & economics

- **Alternative Tillage Practices to Maintain Semi-Permanent Beds (Chualar)**: 3-year study on effects of deep *vs.* shallow minimum tillage on lettuce yield, disease, and SOM