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

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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

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**
- **Three lettuce crops (July 98, May 99, Aug 99); one broccoli crop (Apr 00)**

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

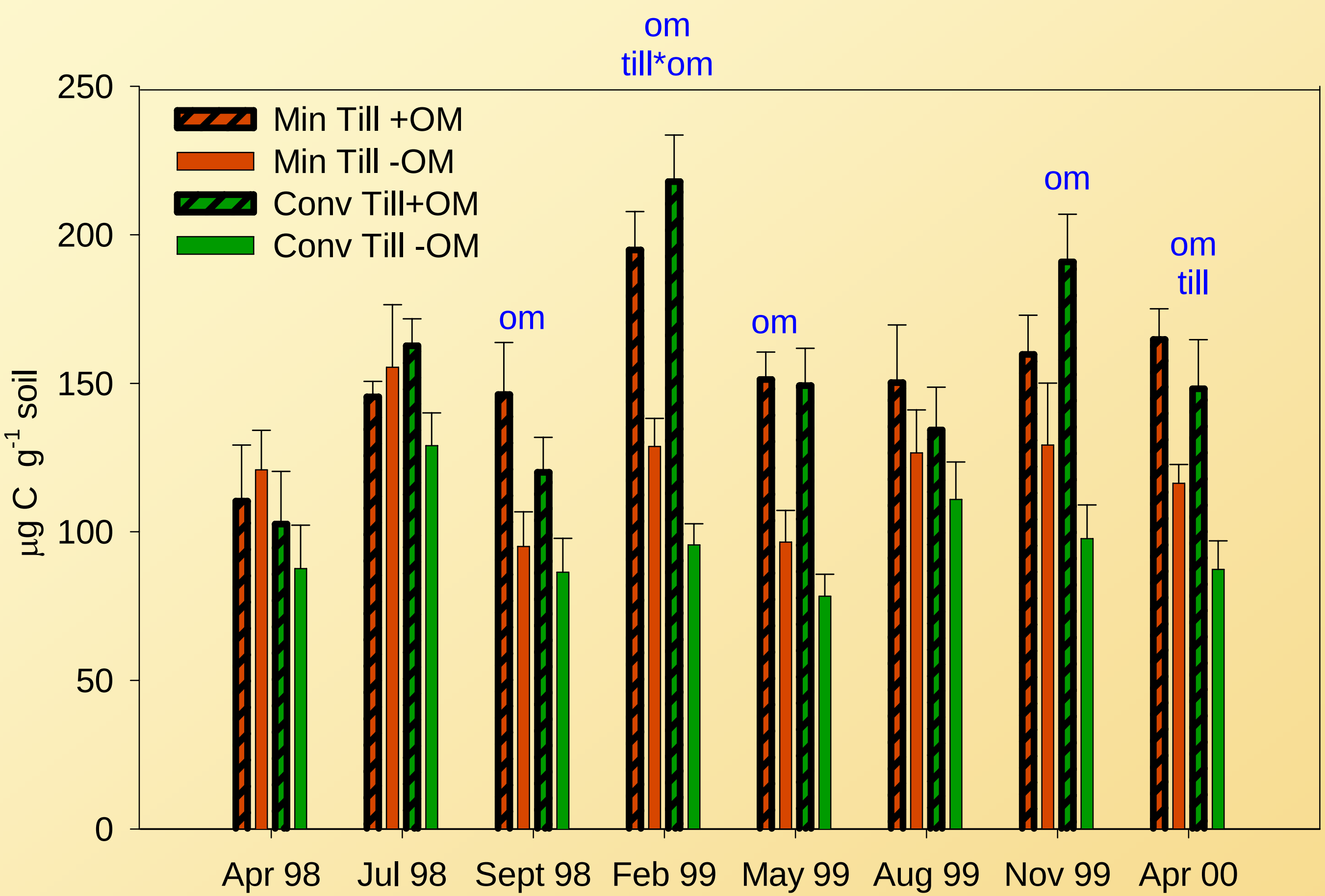

Minimum till beds
with cover crop
Minimum till be
without cover c

	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

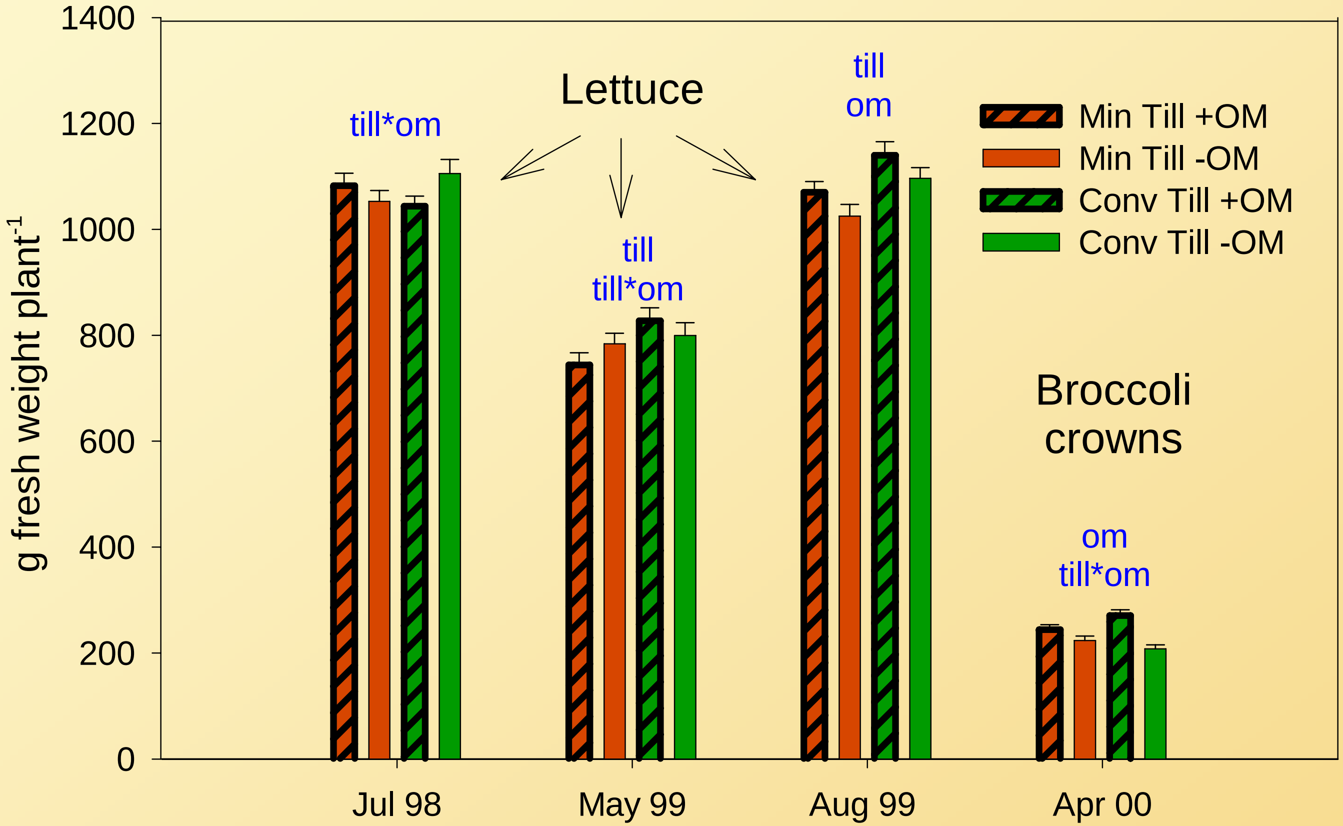
Soil Microbial Biomass Carbon



- 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

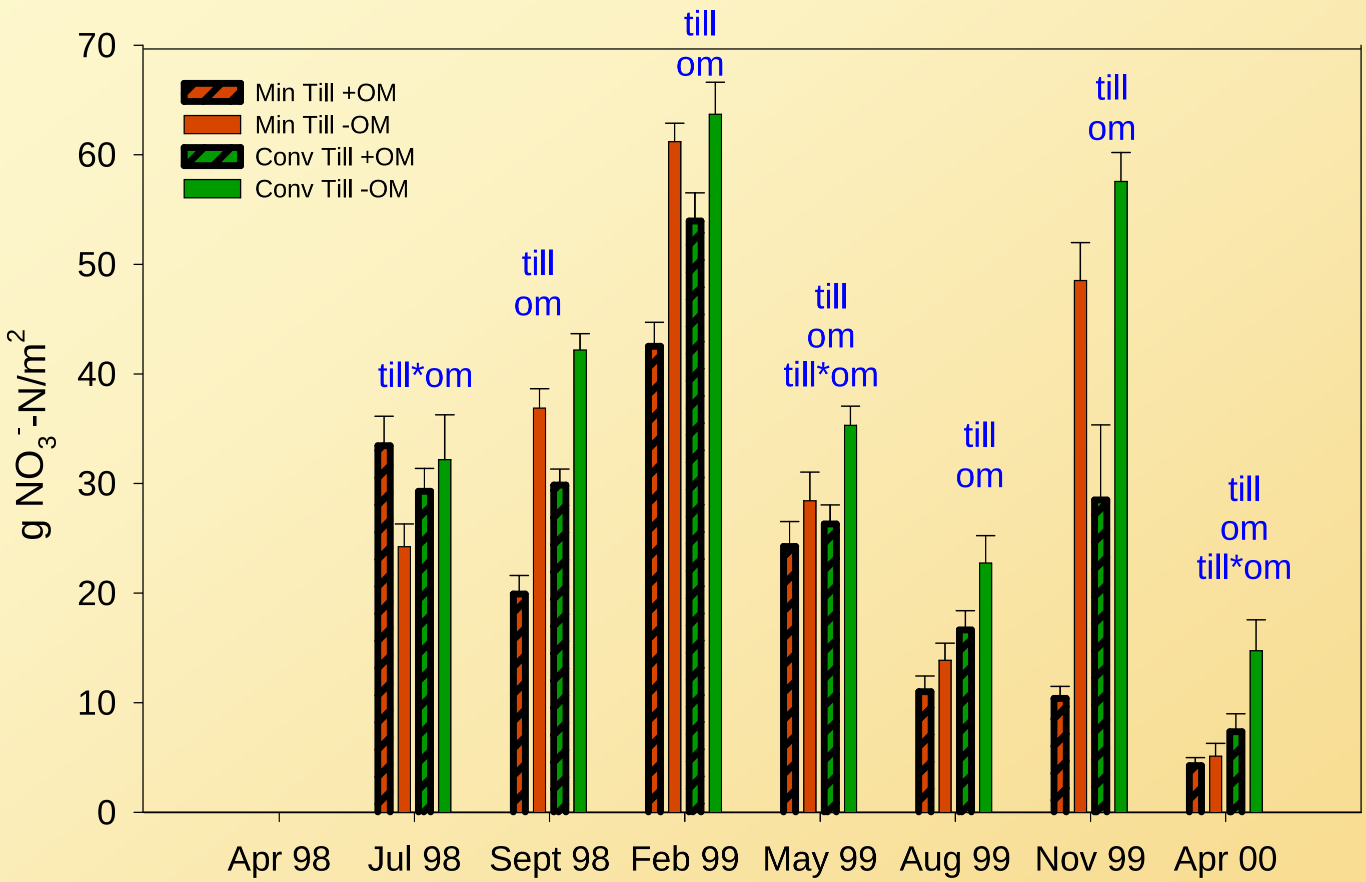
Crop Fresh Weight



- 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: 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

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

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.

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

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

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

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.

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

- **With help from:**
  - Tanimura and Antle
  - Ron Yokota
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  - Bill Chaney
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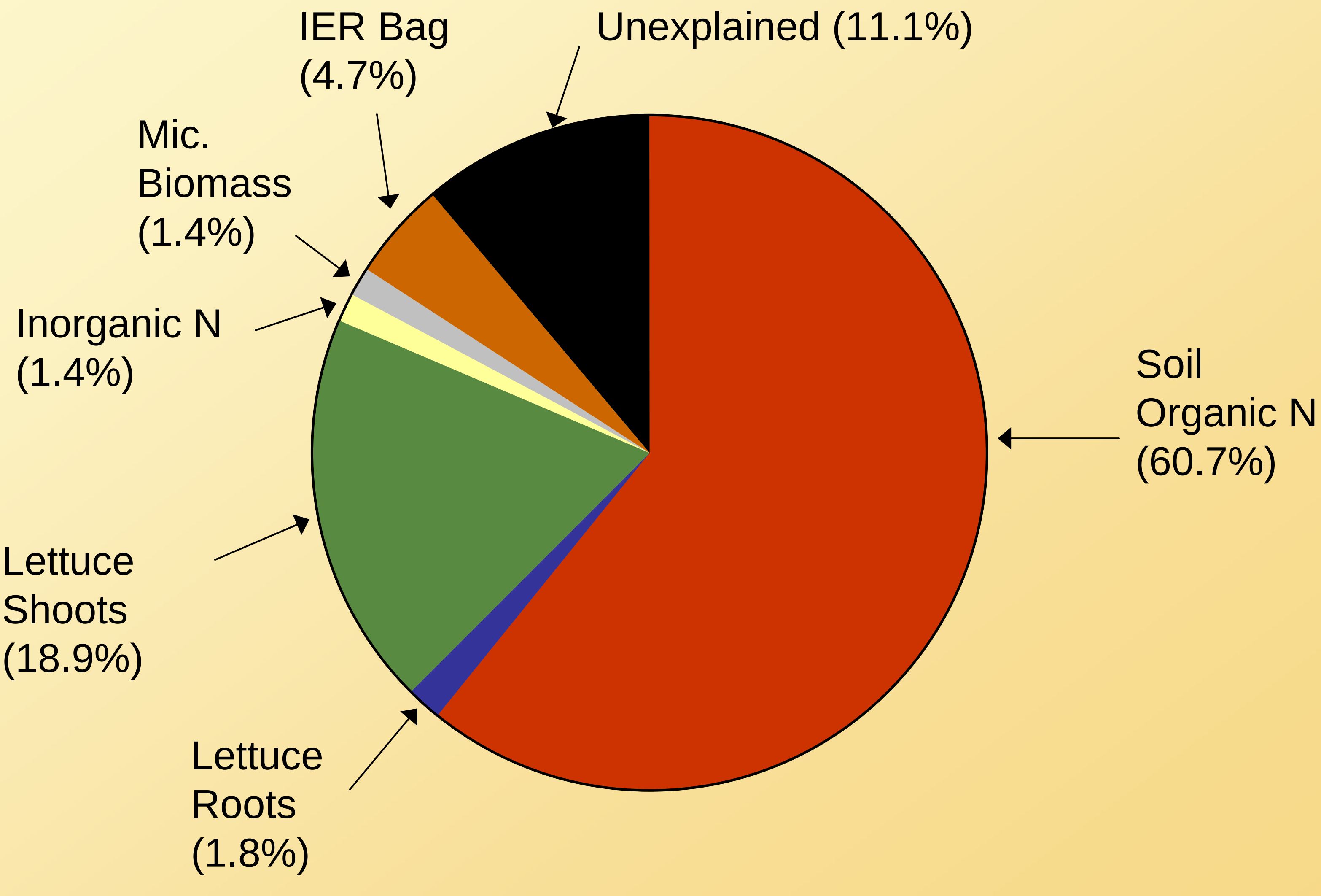
Fate of Cover Crop ^{15}N at Harvest of First Lettuce Crop

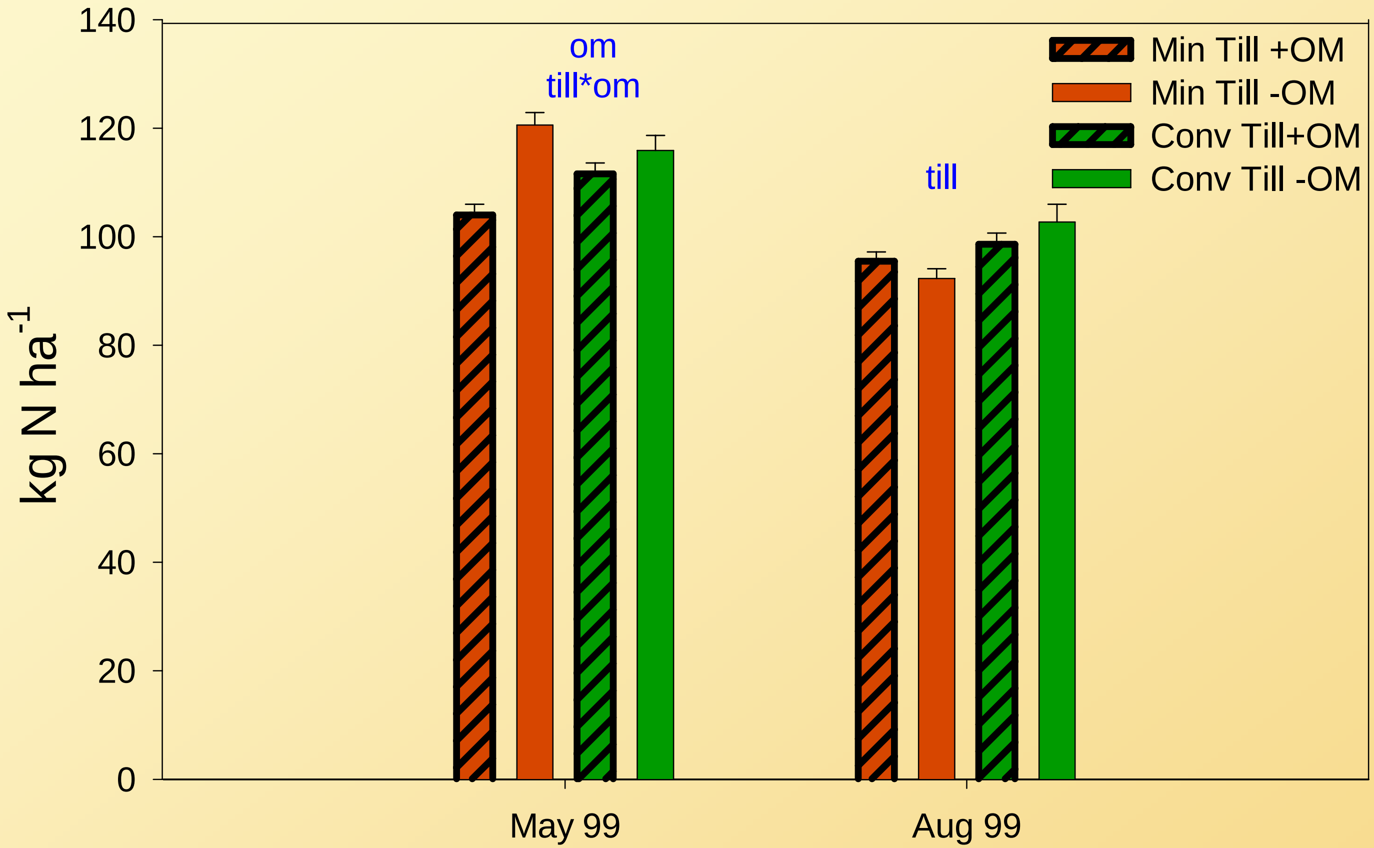


Soil Responses to Minimum Tillage on Semi-Permanent Beds

	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