SW96-016

Research Progress Report
to the
California Iceberg Lettuce Advisory Board's Research Program
for the period
April 1, 1997 - March 31, 1998

PROJECT TITLE: **Plant-Soil Relationships in Lettuce**

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OBJECTIVES:

The general objectives of this project are to understand how biological and physical processes control plant-soil relationships in lettuce production systems. Improved understanding of the plant-soil relationships provides a basis for developing management practices for growing lettuce with higher nutrient uptake, lower additions of water and fertilizer, long-term soil quality, and reduced loss of nutrients to the environment.

This year's proposal has two central goals. One is a focus on improving soil quality by management of tillage practices. Projects deal with short- and long-term issues related to tillage practices by: 1) examining the annual changes that occur under two types of minimum tillage; and 2) following the daily responses of soil to a tillage event. Second, a strong emphasis was placed on determining the genetic basis for root architectural characteristics in iceberg lettuce that increase the depth of the taproot and lateral production at the tip of the taproot, and water extraction from the lower zones of the soil profile. These are traits that are beneficial for the efficient utilization of water and nutrients.

A. Assess the short-term and long-term effects of tillage practices on soil microbial activity, nitrogen cycling, lettuce productivity, and pests.

B. Conduct genetic analyses to assess if a few major genetic determinants exist for root morphological traits.

PROCEDURES AND RESULTS:

A. Assess the short-term and long-term effects of tillage practices on soil microbial activity, nitrogen cycling, lettuce productivity, and pests.

Soil organic matter plays an important role in regulating the flow and retention of nutrients in crop systems, and it declines steadily in intensively managed soils. Research in other crop production systems has shown that tillage causes net mineralization of soil organic matter, promotes nitrate production, and decreases soil nitrogen retention and nitrogen cycling. Also, the active fraction of the soil organic matter, which is composed of decaying plant material and microbial cells, is the fraction that is most critical to nutrient cycling, and is the fraction most subject to degradation as a consequence of long-term tillage practices (1). Joint funding for this work came from grants from the USDA-NRI, USDA-SARE, and the Kearney Foundation of Soil Science.

Tillage practices also impact soil compaction. Compaction occurs when heavy equipment is used on moist or wet soils, and a compaction layer often occurs in Salinas Valley soils at about 12 to 18 inches (30-45 cm) depth. In lettuce, decreased rooting depth (2) and increased corky root severity (3) result from compaction, but these problems have not been well-studied. Some minimum tillage practices retain semi-permanent beds, and may reduce compaction in the beds. A contrast can be made between 'surface' and 'deep' minimum tillage practices. 'Surface' minimum tillage refers to operations such as the 'Sundance System' that utilizes disks and lister bottoms to incorporate crop residues and till the beds. It is specifically designed for shallow tillage, so that it can be used with subsurface drip irrigation. 'Deep' minimum tillage also is used to retain semi-permanent beds, but in contrast, is being practiced on sprinkler/furrow-irrigated fields, and uses deep ripping and chiseling to reduce soil compaction, increase aeration, and decrease the amount of time needed for tillage between vegetable crops.

Project 1. There are several phases of the project on minimum tillage practices: 1) describe the changes in soil properties that affect water movement, aeration and root growth when a field managed with 'deep' minimum tillage practices is conventionally prepared using a caterpillar and disk, laser planing and reshaping of the beds (see 1995-96 annual report); 2) after conventional tillage in the fall, compare the effects of 'surface' ('Sundance' system) and 'deep' (see operations listed below) minimum tillage on soil properties, lettuce dry weight, and insect pests and diseases during the subsequent years (1996-98); and 3) compare bulk density on conventionally-tilled and 'deep' minimum tillage fields on similar soil types.

The study site is situated at American Farms in Chualar on a Salinas clay loam, on a field that was under 'deep' minimum tillage on semi-permanent beds for several years, and was disked and land-planed in the fall of 1995. Israel Morales has designed equipment for 'deep' minimum tillage on fields under sprinkler/furrow irrigation. There are five operations (totaling 1.5-2 hours per acre) which each require one pass:

- mow/chop crop residues
- minimum-till chisel which simultaneously chisels furrows and disk hills beds
- 'Sundance'
- minimum-till rip which utilizes angled, broad shanks with floating wings to break the compacted layer at depth in the beds
- mulch to till the top 12 inches of the beds and furrows

In the first phase of this study (1995-96) that monitored the effect of disking and planing (conventional tillage) on soil that had been 'deep' minimum-tilled for several years, bulk density was low and saturated hydraulic conductivity (K_{sat}) was high and both showed little change after conventional tillage (4, 5). Thus, conventional tillage did not eliminate the advantages of 'deep' minimum tillage on reducing soil compaction.

After conventional tillage, the one-acre plot was divided into two treatments, that received either 'deep' or 'shallow' minimum tillage. In 1996 and 1997, measurements of physical properties (bulk density, and K_{sat} (6, 7)) were made at two depths (0-4 and 16-20 inches; 0-10 and 40-50 cm) at 6 sampling points per treatment. Measurements of biological properties (soil microbial biomass (8), net mineralizable N (9) and inorganic N (10, 11)) were mainly done in the surface layer due to lack of activity at the lower depth. Preliminary data from 1996 show a very slight trend to higher microbial biomass, net mineralizable N, and inorganic N in the 'shallow' minimum tillage treatment.

There were, however, no significant differences between the two types of minimum tillage methods at approximately two weeks before harvest of iceberg lettuce in July, 1997 (Table 1). Bulk density and K_{sat} indicated less compaction and higher infiltration rates in the surface soil compared to deeper soil, but no difference could be attributed to tillage treatment. In the surface layer, soil microbial biomass was similar in both tillage types. Data on net mineralizable N and inorganic N from this layer were disregarded due to high variation as a result of recent fertilizer application. Plant dry weight and root distribution were also not affected by tillage treatment, and there were no significant differences in corky root score, incidence of lettuce drop disease or leaf miner damage (Tables 2 and 3). These results indicate that the two types of tillage methods could be used interchangeably, at least in a time frame of one or two years. Measurements will be continued for at least one more year.

A survey of soil bulk density (0-18.5 inches deep; 0-47 cm deep) was conducted to compare conventionally tilled soils with soils under 'deep' minimum tillage. Fields were chosen that were in adjacent blocks on the same soil type. Each pair of sampling points was less than 91 yards (100 m) apart. Four soil types were compared just before the first spring tillage event in 1998, as a means to eliminate the effect of recent management practices. The soil types were: Pico fine sandy loam, Mocho silt loam, Cropley silty clay, and Salinas clay loam. For two of the soil types, Pico and Salinas, bulk density was significantly lower in the blocks receiving minimum tillage, and for the other two soil types, no significant difference was observed (Figure 1). These data indicate a general trend towards less compaction with 'deep' minimum tillage than with conventional tillage.

Table 1. Comparison of mean values of soil properties under two types of minimum tillage. No differences were found between tillage treatments (t-tests, P<0.05, n=6).

	Bulk density g/cm^3	K_{sat} cm/sec	Mic. Biomass C µg/g soil	g H_2O/ g soil	NO_3^-- and NH_4^+-N µg/g soil
Top Depth (0-4 inches)					
Sundance	1.08	0.046	224	0.27	___
Deep Till	1.06	0.038	254	0.31	___
Lower Depth (16-20 inches)					
Sundance	1.29	0.004	No data	0.29	24.5
Deep Till	1.24	0.002	No data	0.31	42.0

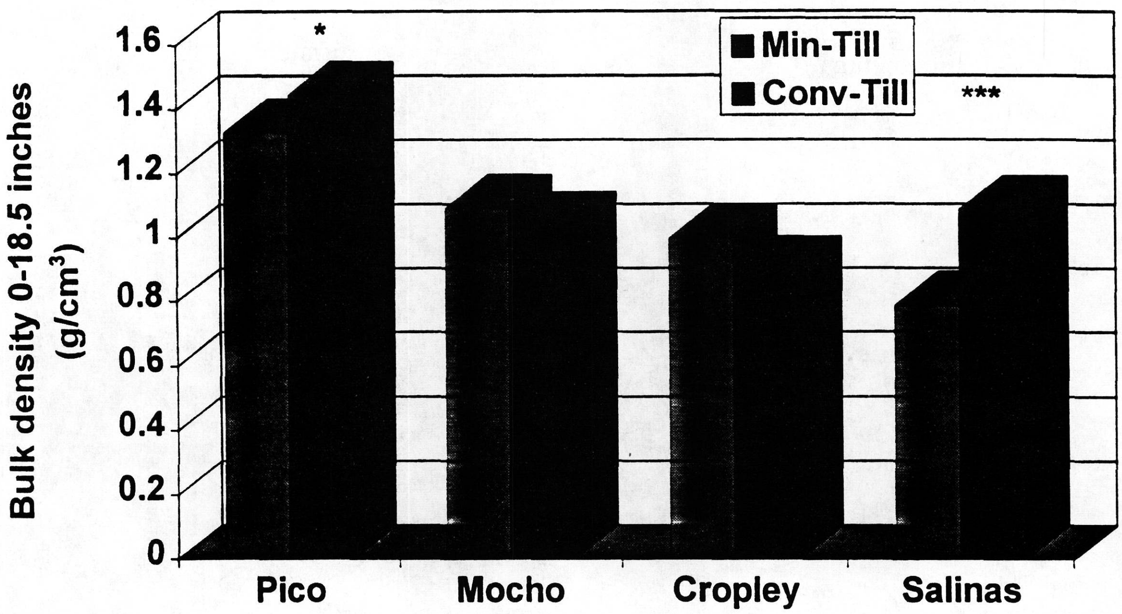
Table 2. Comparison of mean root length density under the two types of minimum tillage. Samples were taken midway between two lettuce plants at approximately two weeks before harvest. No differences were found between tillage treatments (t-tests, P<0.05, n=6).

	Soil Depth					
	0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm	50-60 cm
	cm root length / g soil					
Sundance	0.19	0.24	0.19	0.16	0.16	0.12
Deep Till	0.18	0.27	0.18	0.19	0.15	0.11

Table 3. Comparison of mean plant aboveground dry weight and incidence of lettuce pests and diseases under two types of minimum tillage. Corky root severity was assessed by a 9-point scale (12). Corky root severity and presence of root aphid was evaluated on 15 plants per treatment. Approximately 3000 plants per treatment were evaluated for lettuce drop.

Treatment	Dry Weight g dry wt/plant	Corky Root Score	Lettuce Drop	Leaf Miner	Root Aphid
Sundance	21.3	4.5	6%	T	___
Deep Till	22.5	4.5	4%	T	___

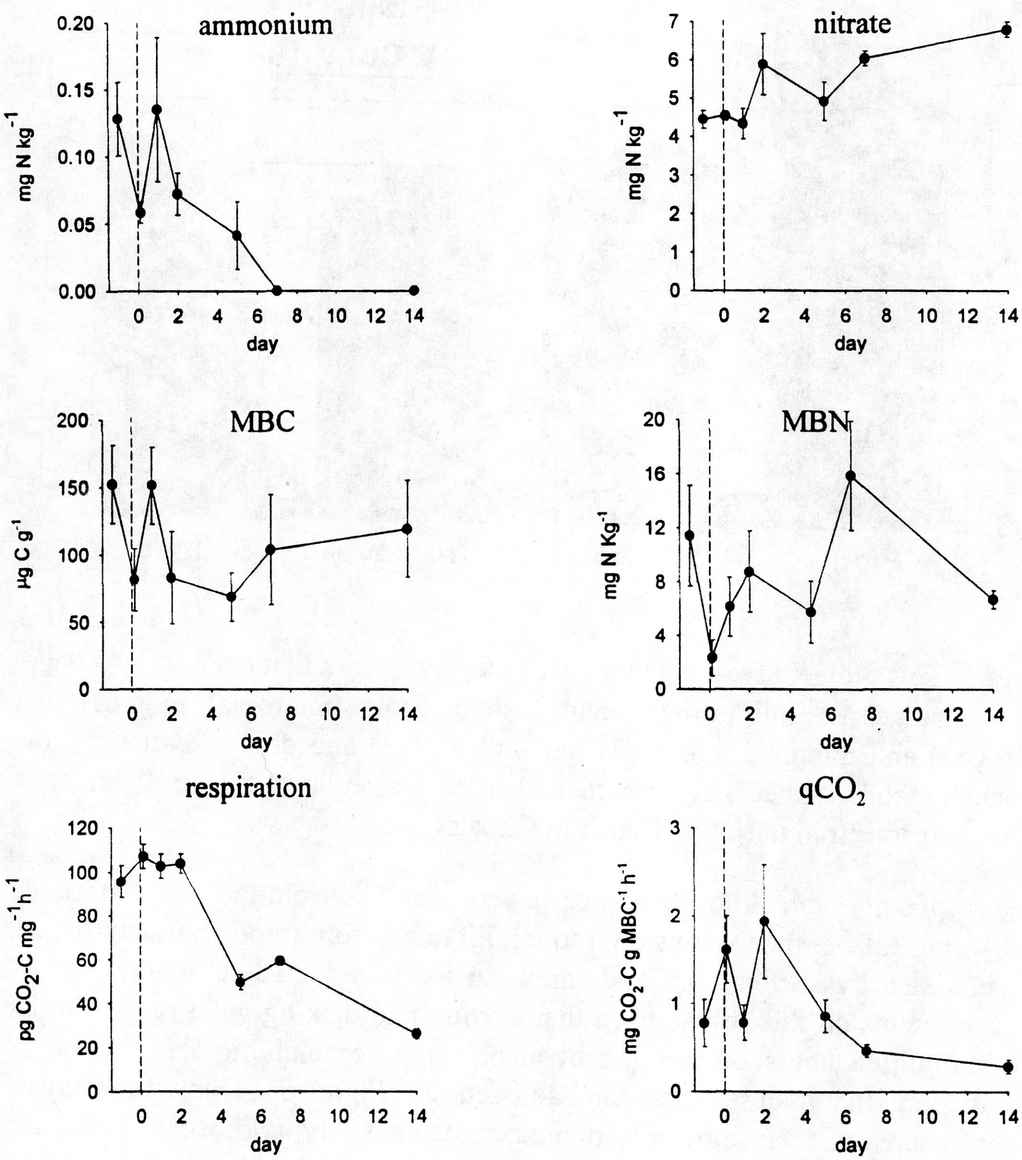
Figure 1. Bulk density (0-18.5 inches deep) under conventional tillage and 'deep' minimum tillage in four soil types. Each value is the mean of three measurements per treatment using 4 inch dia. PVC cores. Soils are ordered along a gradient of increasing clay content. *=t-tests with P<0.05; **=t-tests with P<0.01.



Project 2. This project investigated the short-term changes that occur after tillage. We monitored changes in soil nitrogen and carbon pools (microbial biomass and inorganic nitrogen) and microbial processes (respiration (13) and denitrification by the acetylene block method) immediately before and after a simulated tillage event on a Chualar sandy loam soil from the Wing Ranch in Chualar.

Cylinders of soil (9 cm dia. x 30 cm deep) were removed from the field before the growers' first spring tillage, then were stored to equilibrate before imposing disturbance. Tillage was simulated by sieving soil, and sampling was conducted frequently for 14 days. Later experiments on this soil showed that sieving and disking gave fairly similar responses. Within three hours of soil disturbance, soil microbial biomass C and N plummeted, indicating that intense disruption had occurred (Figure 2). This was followed by a temporary increase, then another pronounced decline. By two weeks after the disturbance event, microbial biomass had returned to pre-disturbance levels. Respiration and metabolic quotient (rate of CO_2 production/microbial biomass) also showed substantial fluctuations during the first five days after disturbance. Virtually no denitrification was measured (data not shown). Nitrate increased gradually during the two-week period after disturbance. Phospholipid fatty acid (PLFA) analysis, which uses biomarkers to identify microorganisms and their response to stress (14), confirmed the fluctuations in microbial biomass immediately after disturbance (data not shown). This method also indicated the predominance of bacteria over fungi in this soil. Markers indicative of microbial stress gradually increased after the disturbance event.

Figure 2. Short-term changes in soil carbon and nitrogen pools following simulated tillage in a Chualar loam soil. The dashed line shows the time of disturbance. MBC and MBN=microbial biomass carbon and nitrogen, respectively. qCO_2=metabolic quotient (see text).



This is one of the few studies that has ever been conducted to examine the rapid succession of events following soil disturbance. The data indicate that tillage creates a huge disruption for microorganisms, leads to a period of inefficient respiration (high metabolic quotient), and causes nitrate to gradually increase. When nitrate accumulates after tillage, and no plants are present to take it up, it can be very susceptible to loss by leaching.