Maximizing Benefit and Utilization of Compost in Vegetable Production

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Executive Summary

The purpose of this project was to determine the effects of using compost in the intensive vegetable production systems of the Salinas Valley, and examine factors that could influence the use of composts made with municipal organic materials. Our approach was to study responses of soil carbon and nitrogen availability in response to the addition of compost and cover crops to vegetable production fields, and to examine the effects on plant yield, nutrient content, and pests. An economic analysis of using cover crops and compost was also conducted. The project focused on fields that were in organic production, or in transition to organic production, because these are situations that typically utilize high organic matter inputs.

The focus of the project was on the combined use of compost and cover crops for two reasons:

1. The two sources of organic matter provide both readily-available and more degradation-resistant carbon compounds (plant residues and compost), which together were hypothesized to increase and sustain the soil microbial biomass and the capacity for retaining carbon in the soil.
2. Many organic and organic-transitional vegetable growers use both inputs in their crop rotations, and this research was aimed at providing information on these practices for this growing sector of the California agricultural industry.

The project supported three main studies, summarized as follows:

- A compost quality trial on a Salinas clay loam soil showed that compost derived largely from municipal yard waste increased lettuce yields after one year, compared to a compost made from manure and a lower percentage of yard waste. This was especially true in plots that had a small rather than large amount of cover crop biomass in the previous season. There were no effects on assays for soil carbon and nitrogen availability, including soil microbial biomass, potentially mineralizable nitrogen, ammonium, and nitrate. There were no effects of one vs. two applications of compost per year. The field was in transition to organic production and received cover crops and organic fertilizers in addition to compost. Soil microbial biomass and potentially mineralizable N increased across all treatments throughout the 1.5-year period.
- A second trial on a Metz silt soil comparing winter bare, cover crop, cover crop plus compost, and compost treatments showed higher lettuce yields in the treatments with compost. The data showed no consistent effect of these amendments on the soil assays for soil carbon and nitrogen availability. Since this trial was flooded temporarily, the experiment is being repeated on an Antioch loam soil. Preliminary results show that lettuce yields were similar in all three compost or cover crop treatments, and these were higher than the winter bare treatment.
- Economic analysis of cover crop plus compost use in relation to all other management costs for vegetable production on a Salinas silt loam soil showed that these amendments increased yield with acceptable net economic returns during a two-year period. The additional cost of cover crop plus compost treatments paid off in terms of net returns for a broccoli crop, due to a high-yield response. (The yields were lower for lettuce crops). Thus, use of cover crop plus compost inputs was economically viable when compared to non-amended soils. As determined in a previous study, these inputs also improved some aspects of soil quality, including increased soil microbial biomass and decreased leaching of nitrate.

The management implications of this project are that composts made of municipal yard waste are recommended for vegetable production to increase yield. This is especially true in circumstances where a cover crop is not possible, or where only a short-term cover crop can be accommodated due to scheduling. The role of compost in increasing yield was not clear and cannot be simply attributed to changes in soil carbon and nitrogen availability.

Field Trial on Compost Quality

The main field trial for the project has been an on-farm comparison of the effects of two composts on plant growth, soils, and pests. A major vegetable company in the Salinas Valley, Tanimura and Antle, Inc., is our cooperator. The 20-acre site on a Salinas clay loam soil is being transitioned to organic production from 2000 through 2003. In order to hasten the buildup of soil carbon and nutrients during this transition period, this company decided to utilize both compost and cover crops, as do many transitional organic growers. Our experiment was designed to determine if there were differences between two kinds of composts, and at two application amounts on a field that was cover-cropped every winter.

Four compost treatments were applied (7 yards per acre per application). The whole field is cover-cropped in the fall and/or winter. The treatments are:

1. Commercial grade compost once per year (C1).
2. Commercial grade compost twice per year (C2).
3. High-grade compost once per year (H1).
4. High-grade compost twice per year (H2).

The high-grade compost contains at least 30 percent municipal yard waste, 5 percent waste from salad packing plants, with the remainder composed of manure, clay, finished compost, and baled straw. It costs $28 per ton and weighs 1,400 lb per yard. On average it contained 12.85 percent C, 0.89 percent N, 2,395 μg Na^+/g, 7.6 μg NH_4^+-N/g, and 142 μg NO_3^--N/g. The commercial grade compost contains 75 percent municipal yard waste, along with horse manure, horse bedding, and lime. It costs $22 per ton and weighs 800 lb per yard. On average this compost contained 20.31 percent C, 0.93 percent N, 1133 μg Na^+/g, 22.42 μg NH_4^+-N/g, and 58.34 μg NO_3^--N/g. The composts were supplied by Cranford, Inc. of Spreckels, California.

Methods and Sampling for Compost Quality Trial

The entire block (20 acres) was farmed uniformly prior to the first sampling in 2000. At that time, no plants were present. The entire field then received compost application with either high-grade (H1 and H2) or commercial-grade compost (C1 and C2). The number 1 or 2 designated the number of times that compost was applied per year. Each application was 7 yards of compost per acre. The field was subsequently divided into two halves by the grower, designated (Storm 4 North and Storm 4 South). These two halves of the field have been managed with the same four treatments but with different crops and schedules. The original plot design specified managing the field as a 20-acre entity. By splitting the field in half, the number of sampling points doubled on each side of the field. Conducting two simultaneous experiments on both sides of the field is beneficial, because it allows for testing the effects of the composts in two slightly different contexts.

Both Storm 4 North and Storm 4 South are 10 acres. Each half contains two irrigation blocks for surface drip irrigation. Each irrigation block contains one plot of the four treatments, each with two sampling regions. Two samples were taken within each sampling region. Thus, there were 32 sampling points, that is, 8 sampling points for each of the four compost treatments, on each half of the field (Storm 4 North and Storm 4 South).

On the north half of the field, compost was applied in all plots in May 2000. Broccoli was harvested in September 2000, then compost was applied in two of the treatments (C2 and H2) in October. A grass plus legume cover crop then was planted across the whole area in the fall of

2000 and incorporated in February 2001. Compost was again applied in all plots in May 2001. Romaine lettuce was transplanted in the spring of 2001, and harvested in July. Another crop of transplant romaine was planted in August 2001. A fall cover crop was incorporated in November 2001, as well as additional compost in C2 and H2.

On the south half of the field, compost was applied in all plots in May 2000, followed by baby greens and a late summer grass plus legume cover crop and additional compost in two of the treatments (C2 and H2). A spring transplanted romaine lettuce crop was harvested in May 2001, and a second crop was harvested in late August 2001. A fall cover crop was incorporated in December 2001, as well as additional compost in C2 and H2.

All irrigation and fertilizer inputs have been recorded. Chicken pellets and Biolyzer-XN are the two sources of fertilizer used during this transition to organic production. As an example, approximately 150 lb N/acre were applied per romaine crop in these two forms of fertilizer.

Sampling occurred on 14 dates from May 2000, through December 2001 (Table 1). Soil samples were taken at two depths (0–15 cm and 15–30 cm). Total C and N was measured by combustion, pH by saturated paste, and cation exchange capacity (CEC) and EC by standard methods at the University of California Division of Agricultural and Natural Resources (DANR) Analytical Laboratory. All soil samples throughout the study were analyzed for moisture, and NH_4^+-N and NO_3^--N concentrations measured in 2N KCl extracts by analysis with a Lachat 8,000 ion analyzer. Soil microbial biomass C (MBC) was done by chloroform fumigation-extraction (Vance et al., 1987), and potentially mineralizable N by accumulation of NH_4^+-N after a seven-day anaerobic incubation (Waring and Bremner, 1964).

For each crop or cover crop, aboveground dry weight was measured in a 2-m^2 area in each sampling point. For romaine lettuce and broccoli crops, crop fresh weight was also measured. Subsamples were taken for nitrogen analysis by combustion.

Weed identity and density was measured at harvest of each crop and cover crop. Any pest damage on plant shoots and roots from pathogens (for example, botrytis, virus, sclerotinia, downy mildew) and insects was noted during the sampling at harvest times. For the spring romaine crops on Storm 4 South and Storm 4 North, insect activity was measured by destructively sampling in the field. Each week five heads per replicate (40 heads total) were cut and each leaf was stripped and inspected for insects, damage, and natural enemies, including leafminers, aphids, worms, and lygus as pests; and parasitic wasps, lacewings and others (syrphid flies, spiders, big-eyed bugs, etc.) as natural enemies.

The other measure of insect activity began in the weeks prior to harvest. This method measures leafminer and leafminer parasitoid populations in a plant at the time of sampling. The sampling frequency was the same as the field monitoring, five heads per replicate (40 heads total) every week. Whole plants are brought into the lab. These plant samples are placed into a 5-gallon plastic bucket fitted with a yellow sticky card and topped with floating row cover to create an emergence cage. “Bucket samples” detect the number of leafminers and leafminer parasitoids per plant. The buckets are left for 6–8 weeks and leafminers or leafminer parasitoids emerge, becoming trapped on the sticky card for counting.

Results for Compost Quality Trial

All crops produced high yields with very little disease incidence and little insect damage, except for leafminers in September 2001 on romaine. Weeds are not becoming a problem. The transition to organic production is going smoothly.

No differences between the compost treatments occurred in total soil nitrogen or soil carbon at 1.5 years after the experiment began (Table 2). Soil nitrogen increased slightly from a mean of 0.14 to 0.16 percent during this time, but soil carbon remained essentially equal, with a mean of 1.56 percent in 2000 and 1.53 at 1.5 years later. The field was uniform in terms of soil characteristics, as shown by the lack of significant differences and low standard error (SE) of the means on both sampling dates.

Soil parameters for nitrogen and carbon availability were not different between the compost treatments. From May 2000 through the summer crops of 2001, there were no treatment differences in soil microbial biomass C (Figures A and B), nitrate (Figures C and D), ammonium (data not shown), or potentially mineralizable N (data not shown). These results indicate that the compost treatments were not differentially affecting the readily available pools of nitrogen and carbon in this soil, which was also receiving other sources of nutrients via chicken pellets and Biolyzer fertilizer. It was surprising that one vs. two applications of compost per year had no effect on these parameters.

Microbial biomass and potentially mineralizable N did increase through the 1.5-year period on the field as a whole. Linear regressions of these variables through time were highly significant when conducted with the data from all dates with no distinction for compost treatment. For the north field, MBC=0.92* days + 93 ($P<0.0001$) and PMN=0.08*days + 4.3 ($P<00025$). For the south field, MBC=0.29*days + 100 ($P<0.0001$) and PMN=0.09*days + 2.0 ($P<00025$). These indicators of microbial activity increased more rapidly in the north field that had received a > four-month fall/winter cover crop in 2000–01, compared to the south field that had a two-month summer cover crop in 2000. The cover crop biomass in the north field was more than two times higher than in the south field (Table 3), and this seems to have been a key factor in increasing microbial biomass and N mineralization potential through time.

The most important effect of compost on crop fresh weight and dry weight was an increase due to commercial-grade composts during the second year of the study on the south side of the field (Table 3). This side of the field had accumulated less cover crop biomass in the previous season. In May 2001, romaine lettuce was 11 percent larger by fresh weight and 9 percent larger by dry weight in commercial grade than high-grade compost treatments, but there was no difference related to number of applications of compost per year. In August 2001, highest yield was in the commercial-grade compost applied twice a year (C2) followed by C1, with 25 percent lower fresh weight and 18 percent dry weight yields in the high-grade compost treatments.

Crop productivity was not as responsive to compost treatment on the north side of the field, to which a large amount of cover crop biomass had been added in the previous season. No significant difference was observed in romaine dry weight between compost treatments in the July 2001 crop, but the highest romaine dry weight in September 2001 was in the C2 treatment (commercial-grade compost twice per year). Fresh weight data for these crops is difficult to interpret because of lack of similarity with dry weight data. In the samples that have been analyzed so far, no differences in crop nitrogen have been observed. The comparison of the two fields suggests that the effect of compost may be higher in soils when lower amounts of other organic matter inputs, that is, cover crop residues, are applied.

No differences in leafminers, aphids, lygus, worms, or natural enemies were observed between compost treatments. There was very little pest pressure, except for one romaine crop in September 2001, where leaf miner pressure was high with a mean of eight live mined leaves per plant in the bucket cage assay. Data on incidence of diseases (Sclerotinia, botrytis, tomato spotted wilt) and insects is currently being analyzed. Analysis of the weed data shows no differences between compost treatments, but the field had few weeds. Typical biomass of weeds was < 0.2 g m^{-2}, except for cover crops, where means reached 1 to 4 g m^{-2}.

Field Trial on Effects of Compost Vs. Cover Crops

A second field trial was established in November 2000 on an organically-managed field. The trial took place on a Metz silt soil in Chualar in a cooperative project with Israel Morales of American Farms. Six sampling dates have now been completed. There were four treatments:

1. Winter bare soil.
2. Winter grass plus legume cover crop.
3. Winter grass plus legume cover crop and spring application of compost.
4. Spring application of compost.

This trial was intended to determine the relative effects of adding organic matter as compost vs. cover crops. The trial also tested the hypothesis that beneficial plant-soil interactions result when compost is applied together with fresh plant residues, such as cover crops.

Methods and Sampling for Compost Vs. Cover Crop Trial

The plots were arranged in strips for each treatment to facilitate management for the grower. There were four strips, each with four 16m x 12m plots. On each date, samples for soil organic matter, nitrate, ammonium, moisture, potentially mineralizable N, and microbial biomass C were taken at the 0–15 cm and 15–30 cm depths. Plant samples were taken in 2 m^2 plots. Methods are described above.

The cover crop was grown on the bed tops and incorporated with minimum tillage equipment directly on the beds. The compost was applied in February 2001 at 4.5 tons/acre. It contained 21.27 percent C, 2.26 percent N, 6550 μg Na^+/g, 243 μg NH_4^+-N/g, and 5,900 μg NO_3^--N/g. The grower applied approximately 75 lb N/acre as fisholyzer fertilizer, and 25 lb N/acre as chicken pellets for the lettuce crop. Unfortunately, the field was flooded in February, which undoubtedly caused movement of soil and cover crop residue between strips.

Results for Compost vs. Cover Crop Trial

Lettuce yields were highest in the compost and cover crop plus compost treatments, and lowest in the winter bare treatments (Table 4). There are no clear explanations for these differences based on the soils data. Neither microbial biomass C or inorganic N were consistently higher in the plots to which compost had been applied. Nitrate and ammonium, however, were higher in the compost plots than winter bare plots in April.

This experiment is currently being repeated at the Hartnell College agriculture experimental area on an Antioch loam soil with a compost containing 13.1 percent C, 1.0 percent N, 52.6 mEq Na^+/L, 11 μg NH_4^+-N/g, and 219 μg NO_3^--N/g. Lettuce yield was not significantly different between the compost, cover crop plus compost, or cover crop treatments (0.98, 0.99, and 0.97 kg $head^{-1}$, n = 80 plants, respectively), but all these were different from the winter bare treatment (0.77 kg $head^{-1}$). Soil parameters are still being analyzed.

Economic Cost Analysis of Cover Crops, Compost, and Tillage Practices

To obtain a detailed economic analysis of the costs of cover crops and compost, and the proportion of these costs in relation to the entire vegetable production budget, we compiled all management information for a two-year trial (1998–2000) on cover crop plus compost amendments on a Salinas silt loam soil. The 1998–2000 trial compared four treatments:

1. Minimum tillage with added organic matter (that is, cover crops plus compost).
2. Minimum tillage with no added organic matter.
3. Conventional tillage with added organic matter.
4. Conventional tillage with no added organic matter.

During the two-year period, microbial biomass C increased with cover crops compost, and so did lettuce and broccoli harvestable yields (Jackson et al., 2002). Tillage treatments had less effect than organic matter additions, but lettuce yields were lower with repeated minimum tillage.

Conventional tillage followed the typical tillage method for vegetable production in this area, that is, disking, cultivating with a lilliston, subsoiling, and bed-shaping. The soil is disturbed to a depth of approximately 50 cm. Beds are re-made between every crop. By contrast, the minimum tillage treatments consisted of using the "Sundance" system, a liliston, rollers, and bed-shaping. The Sundance system utilizes disks and lister bottoms to incorporate crop residues and cultivate the tops and sides of the beds in a single pass. This method tills shallowly to approximately 20 cm in depth. No subsoiling was done in the minimum tillage treatments.

In treatments receiving added OM, compost was added two or three times per year, and a Merced rye cover crop was grown during the fall or winter. The compost had a low C/N ratio (approximately 15). Starting materials for the compost were municipal yard waste (30 percent), waste from salad packing plants (5 percent), with the remainder composed of manure, clay, finished compost, and baled straw. Four vegetable crops were grown during the course of the study.

Sprinkler irrigation was used during the germination and establishment stages of the crops and cover crops. After thinning the cash crops, surface drip irrigation was applied. After each crop, the tape was lifted, retrieved, spliced, and wound on reels to be used at a later date. Fertilizer inputs consisted of a banded pre-plant application of 300 lb/acre of 5-25-25 before each lettuce and broccoli crop, and one to four applications of 125–250 gals/acre of liquid 20 percent ammonium nitrate through the drip tape after thinning each crop. There was one 300 lb/acre application of ammonium sulfate prior to planting broccoli.

The "Budget Planner" software package was used to evaluate costs of all management operations at the field, and for determining the actual and relative costs of using compost in relation to other management practices during the two-year period. Economic analysis has focused on the tradeoffs between cover crop plus compost application costs and the increased yield of vegetables with these inputs.

The grower supplied information for each operation including the date, labor, and time required, and materials and equipment used. Yield data was also provided for the entire field. Costs and returns were then calculated from the baseline data and crop yields, using actual market prices and costs from local input suppliers. The Budget Planner program calculated total costs, gross returns, monthly cash flow and equipment schedules, and summaries of water, fertilizer, energy and labor use throughout each crop and cover crop season for each of the four management treatments. Rents were estimated to be \$1,000 acre^{-1} cash crop^{-1} in this district. Non-cash overhead included equipment costs. To convert yield data from the grower (boxes acre^{-1}) for the whole field to yield per treatment, project staff used the relative differences in harvestable yield in 1.67-yd^2 areas that had been obtained from the same crop.

Results of Economic Cost Analysis of Cover Crops, Compost, and Tillage Practices

Production costs differed with each management system, depending on the amount of tillage and land preparation, the use of a cover crop prior to planting, and the harvesting costs associated with differences in crop yield due to tillage or OM management (Tables 5 and 6). The costs of using a cover crop resulted in additional irrigation, seed, and tillage costs, averaging \$265 acre^{-1} for each cover crop. The costs of the four compost applications and two cover crops over the two-year study period averaged \$288 acre^{-1} cash crop^{-1} for the minimum till +OM system, and \$337 acre^{-1} cash crop^{-1} for the conventional tillage +OM system. The difference in management costs between minimum tillage and conventional tillage was \$575 acre^{-1} for the two-year study. Note that harvest costs were left out of all these calculations. Approximately half of the savings was in reduced fuel use with an average reduction of 32 gal per acre^{-1}. The rest of the savings was in reduced labor and equipment ownership costs.

Net returns for the lettuce crops were lowest in the conventional tillage +OM system (Tables 5 and 6), despite the tendency for higher harvest yields in this treatment. The total returns from higher yields were offset by the costs of the OM inputs and increased harvest costs compared to the conventional tillage treatment that did not receive compost and cover crops.

For the broccoli crop in 2000, net returns were highest in the conventional tillage +OM system, which produced higher yields than the other treatments (Table 6). The high management costs of this treatment were compensated by a much greater yield increase for broccoli than for lettuce. These results must be taken cautiously, however, because the grower harvested the broccoli crop on three separate dates. The small plot data that were used to assign treatment differences are for only the second harvest date, at which time the grower made the single largest harvest of the crop.

The ranking of net returns for the entire two-year study is as follows, from lowest to highest: minimum tillage +OM inputs (\$1,732 acre^{-1}) < conventional tillage -OM inputs (\$2,008 acre^{-1}) < minimum tillage -OM inputs (\$2516 acre^{-1}) < and conventional tillage +OM inputs (\$3,008 acre^{-1}). The typical practice, conventional tillage without OM inputs, was not the most economically advantageous for either lettuce or broccoli.

Fuel use was 2.2- to 3.8-fold greater with conventional tillage than minimum tillage (Tables 5 and 6). Fall tillage operations to disk, chisel, and shape beds accounted for the largest difference between conventional and minimum tillage operations. Incorporation of the cover crop and compost utilized 10–30 percent of the fuel used for the spring crop seasons.

Monitoring Long-Term Soil Changes with Cover Crops Plus Compost During Organic Transition

Compost and cover crops are integral components of the conventional-to-organic transition at the Storm and Daugherty Ranches of Tanimura and Antle, Inc. that began in June 2000. We are repeatedly sampling 81 points on the two ranches two or three times per year. This data on time courses of soil quality parameters and plant yield and nutrient content will be used to corroborate information obtained from the compost quality trial. Funding for this project also comes from a University of California Department of Agriculture and Natural Resources (DANR) work group grant. A proposal to the USDA-SARE (Sustainable Agriculture and Research Education) program began in October 2001 to further support this project. Both of these grants also provided some matching funds toward the Storm 4 compost quality project.

Outreach

A field day was conducted on September 8, 2000, at the Storm Ranch, Lot 4 study site to introduce the project to the public. Speakers included: Louise Jackson, Ron Yokota (Tanimura and Antle, Inc.), Don Cranford (Cranford, Inc.), and Richard Smith, Steve Koike, Marita Cantwell and Karen Klonsky (UC Cooperative Extension). A four-page handout was distributed. Approximately 30 people attended. A summary of the meeting was published in *Ag Alert*.

In February 2001, an internship program began with undergraduate students at California State University Monterey Bay with Dr. Liese Schultz, who was hired as the project manager and post-doctoral researcher on the project. Two or three undergraduate students from the Earth Systems and Policy Dept have assisted with sampling, sample processing and data analysis each summer. Another 20 students have helped with sampling. This is an excellent opportunity for education and public outreach.

Louise Jackson described aspects of this project at the following meetings: February 23, 2001, at a Merced workshop, “Soil Fertility and Pest Management;” February 27, 2001, at a Watsonville workshop, “Compost Maturity-Quality Analysis and Recent Trial Findings;” November 1, 2001, at a Davis meeting of the DANR Organic Farming work group on “Salinas Valley Organic Strawberries and Vegetables: Research Results and Implications for Production;” December 4, 2001, at a Salinas Entomology meeting (Chaney and Smith) on “Transition to Organic—A Multidisciplinary Approach;” January 16, 2002, at a Salinas meeting on “Organic Matter Management, and Soil and Plant Health;” August 19, 2001, at the Ecological Society of America National Meeting in Madison, Wisconsin, on “Effects of Organic Amendments and Tillage Practices on Soil Microbial Biomass, N Availability and Crop Yield in Intensive Agriculture;” December 5, 2001, at a Davis DANR Vegetable Crops Continuing Conference on “Soil Aspects of the Transition to Organic;” and March 12, 2002, at a Davis DANR Conservation Tillage work group on “Minimum Tillage and Organic Matter Management.”

Table 1: Sampling Dates at Storm 4 Field for Compost Quality Trial

Date	Day of Study	Storm 4 South (S) or North (N)	Sampling
5/10/00	1	S + N	Soil characteristics
7/7/00	59	S	Soil + baby lettuce
9/19/00	133	S	Cover crop biomass (no soil)
9/19/00	133	N	Soil + broccoli
11/6/00	181	S	Soil only (no plants)
12/19/00	224	N	Cover crop biomass (no soil)
¼/01	240	S	Soil only (no plants)
2/1/01	268	N	Cover crop biomass (no soil)
5/10/01	366	S	Soil + romaine
7/5/01	422	N	Soil + romaine
8/15/01	463	S	Soil + romaine
9/17/01	496	N	Soil + romaine
11/13/01	553	S	Cover crop
12/19/01	589	N	Cover crop

Table 2: Soil Characteristics at the Compost Quality Trial at Storm 4 in Salinas

Soil Characteristic	High-Grade Compost 1x Per Year	High-Grade Compost 2x Per Year	Commercial-Grade Compost 1x Per Year	Commercial Grade Compost 2x Per Year
	H1	H2	C1	C2
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
May 2000				
pH	7.4 ± 0.2	7.4 ± 0.1	7.5 ± 0.1	7.45 ± 0.09
EC (mmhos cm^{-1})	0.98 ± 0.08	0.98 ± 0.08	0.94 ± 0.05	1.00 ± 0.07
CEC (meq 100 g^{-1})	28.0 ± 0.9	28.9 ± 0.6	28.8 ± 1.0	28.6 ± 1.1
Total soil N (g kg^{-1})	0.14 ± 0.005	0.14 ± 0.005	0.15 ± 0.005	0.14 ± 0.007
Total soil C (g kg^{-1})	1.55 ± 0.072	1.55 ± 0.1	1.61 ± 0.08	1.55 ± 0.13
August 2001 (Storm South)				
Total soil N (g kg^{-1})	0.16 ± 0.007	0.17 ± 0.008	0.16 ± 0.007	0.15 ± 0.006
Total soil C (g kg^{-1})	1.52 ± 0.07	1.69 ± 0.04	1.51 ± 0.06	1.40 ± 0.07
September 2001 (Storm North)				
Total Soil N (g kg^{-1})	0.17 ± 0.002	0.15 ± 0.004	0.18 ± 0.004	0.17 ± 0.006
Total Soil C (g kg^{-1})	1.54 ± 0.04	1.40 ± 0.06	1.72 ± 0.13	1.45 ± 0.11

Table 3: Plant Biomass at the Storm 4 Compost Quality Trial in Salinas
Significant differences ($P \leq 0.05$) between treatments on a given sampling date are indicated by different letters. NS indicates no significant differences.

	High-Grade Compost 1x yr^{-1}	High-Grade Compost 2x yr^{-1}	Commercial-Grade Compost 1x yr^{-1}	Commercial-Grade Compost 2x yr^{-1}
Storm 4 South	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Baby Lettuce 7/7/00				
Total g dry wt m^{-2}	100.5 ± 23.3^{a}	23.7 ± 3.0^{c}	92.9 ± 20.7^{a}	49.4 ± 6.6^{b}
Grass + Legume Cover Crop 9/19/00				
Total g dry wt m^{-2} (NS)	311.5 ± 20.5	363.5 ± 23.9	297.6 ± 21.5	295.4 ± 25.8
g N m^{-2} (NS)	11.6 ± 0.7	12.8 ± 0.9	9.5 ± 0.7	10.1 ± 0.9
Romaine Lettuce 5/10/01				
Total g fresh wt m^{-2}	5900.9 ± 118.5^{b}	5911.7 ± 117.0^{b}	6534.9 ± 110.0^{a}	6793.42 ± 144.4^{a}
Total g dry wt m^{-2}	257.2 ± 5.4^{b}	244.3 ± 5.5^{b}	278.6 ± 4.6^{a}	276.6 ± 4.7^{a}
g N m^{-2}	8.1 ± 0.4^{ab}	7.6 ± 0.4^{b}	8.7 ± 0.3^{a}	8.4 ± 0.3^{a}
Romaine Lettuce 8/15/01				
Total g fresh wt m^{-2}	2829.0 ± 72.9^{c}	2929.8 ± 63.6^{c}	3352.5 ± 70.7^{b}	3848.1 ± 73.8^{a}
Total g dry wt m^{-2}	145.9 ± 2.8^{c}	145.5 ± 2.8^{c}	164.1 ± 3.1^{b}	177.8 ± 3.3^{a}
Cover Crop 11/19/01				
Total g dry wt m^{-2} (NS)	525.2 ± 13.6	495.2 ± 16.4	472.2 ± 16.3	543.6 ± 57.4
Storm 4 North	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Broccoli 9/19/00				
g fresh wt m^{-2} (NS)	1624.7 ± 96.4	1590.3 ± 93.7	1541.7 ± 107.1	1717.81 ± 109.5
g dry wt m^{-2} (NS)	634.7 ± 37.3	627.2 ± 38.2	663.1 ± 36.9	657.3 ± 34.2
# plants m^{-2} (NS)	7.71 ± 0.78	8.5 ± 0.56	8.43 ± 0.42	8.75 ± 0.59
g N m^{-2} (NS)	28.0 ± 2.0	25.9 ± 2.0	29.0 ± 1.1	27.5 ± 1.9
Grass + Legume Cover Crop 1 Harvest 12/19/00				
Total g dry wt m^{-2} (NS)	363.8 ± 14.1	327.0 ± 19.6	327.6 ± 14.2	353.2.0 ± 15.5
g N m-2 (ns)	16.2 ± 0.6	14.4 ± 0.7	14.8 ± 0.5	14.3 ± 0.7
Grass + Legume Cover Crop 2 Harvest 2/1/01				
Total g dry wt m^{-2} (NS)	621.0 ± 49.1	734.3 ± 22.8	661.9 ± 33.4	706.4 ± 33.5
g N m^{-2} (NS)	17.2 ± 1.0	18.5 ± 0.8	17.2 ± 1.0	16.6 ± 1.1
Romaine Lettuce 7/5/01				
Total g fresh wt m^{-2}	8071.6 ± 155.1^{ab}	7727.4 ± 131.8^{bc}	8414.1 ± 195.0^{a}	7435.7 ± 156.6^{c}

	High-Grade Compost 1x yr^{-1}	High-Grade Compost 2x yr^{-1}	Commercial-Grade Compost 1x yr^{-1}	Commercial-Grade Compost 2x yr^{-1}
Total g dry wt m^{-2} (NS)	275.0 ± 4.4	272.9 ± 4.0	282.0 ± 4.9	271.6 ± 6.2
Romaine Lettuce 9/17/01				
Total g fresh wt m^{-2}	4969.0 ± 51.1[a]	5034.7 ± 69.0[a]	4528.6 ± 77.3[b]	4890.6 ± 74.4[a]
Total g dry wt m^{-2}	169.8 ± 2.2[ab]	165.5 ± 2.4[b]	163.2 ± 3.3[b]	175.4 ± 2.9[a]
Cover Crop 12/19/01				
Total g dry wt m^{-2} (NS)	502.9 ± 23.2	494.7 ± 20.2	482.2 ± 23.9	469.8 ± 27.7

Table 4: On-Farm Field Trial on Effects of Compost Vs. Cover Crops at American Farms in Chualar
Data were analyzed with t-tests. For each date, means with the same letter are not significantly different; different letters indicate significant differences ($P < 0.05$)

	Winter Bare	Cover Crop Only	Cover Crop + Compost	Compost Only
Lettuce Fresh Weight (g plant-1)				
Jun. 2001	824.8^{a}	903.8^{ab}	934.1^{b}	944.5^{b}
Microbial Biomass C (μg g-1 soil)				
Nov. 2000	160.4^{a}	203.6^{b}	164.7^{ab}	218.7^{b}
Jan. 2001	207.2^{a}	193.5^{a}	179.9^{ac}	237.2^{ab}
Feb. 2001	185.4^{a}	No data	No data	181.9^{a}
Mar. 2001	147.1^{a}	No data	No data	191.5^{a}
Apr. 2001	167.2^{a}	No data	No data	174.9^{a}
Jun. 2001	235.3^{a}	245.8^{a}	240.0^{a}	245.9^{a}
Inorganic N (μg N g-1 soil)				
Nov. 2000, 0–15 cm				
NH_4^+ - N	0.41^{ab}	0.04^{ab}	0.01^{ac}	0.17^{ab}
NO_3^- - N	26.54^{a}	47.44^{a}	24.03^{a}	37.62^{a}
Nov. 2000, 15–30 cm				
NH_4^+ - N	0.21^{a}	0.02^{a}	0^{a}	0.10^{a}
NO_3^- - N	23.27^{a}	41.68^{a}	26.01^{a}	32.13^{a}
Jan. 2001, 0–15 cm				
NH_4^+ - N	0.01^{a}	0.08^{a}	0.44^{a}	2.35^{a}
NO_3^- - N	42.86^{a}	16.74^{b}	13.48^{bc}	49.74^{ade}
Jan. 2001, 15–30 cm				
NH_4^+ - N	0.10^{a}	0.13^{a}	0.30^{a}	3.41^{a}
NO_3^- - N	31.91^{a}	11.91^{b}	9.72^{bc}	42.93^{ade}
Feb., 2001, 0-15 cm				
NH_4^+ - N	0.01^{a}	No data	No data	0.06^{a}
NO_3^- - N	10.94^{a}	No data	No data	25.40^{b}
Feb. 2001, 15–30				
NH_4^+ - N	0.21^{a}	No data	No data	0.29^{a}
NO_3^- - N	31.42^{a}	No data	No data	34.12^{a}
Mar. 2001, 0–15 cm				
NH_4^+ - N	0.04^{a}	No data	No data	0^{a}
NO_3^- - N	10.63^{a}	No data	No data	23.31^{a}
Mar. 2001, 15–30 cm				
NH_4^+ - N	0^{a}	No data^{a}	No data	0^{a}
NO_3^- - N	26.44^{a}	No data^{a}	No data	40.36^{a}

	Winter Bare	Cover Crop Only	Cover Crop + Compost	Compost Only
Apr. 2001, 0-15 cm				
NH_4 + - N	1.88[a]	No data	No data	12.12[b]
NO_3^- - N	9.04[a]	No data	No data	16.27[b]
Apr. 2001, 15–30 cm				
NH_4 + - N	0.71[a]	No data	No data	2.87[a]
NO_3^- - N	8.40[a]	No data	No data	8.68[a]

Table 5. Economic Analysis of All Management Costs and Returns, First Two Crops
Includes fuel use for the first two vegetable crops in the on-farm field experiment on minimum and conventional tillage with (+OM) and without cover crops and compost (-OM). Costs for the cover crop and its incorporation are included with the subsequent vegetable crop. In calculating returns, project staff used the figure of $7.50 per box of lettuce—the Monterey County average for the sampling times of the study.

	Lettuce Crop Harvested Jul. 1998				**Cover Crop + Lettuce Crop Harvested May 1999**			
	Min. Till +OM	**Min. Till +OM**	**Conv. Till +OM**	**Conv. Till -OM**	**Min. Till +OM**	**Min. Till -OM**	**Conv. Till +OM**	**Conv. Till -OM**
Management costs per hectare ($)								
Fuel, lube, repair	183	183	333	333	371	289	924	627
Machine labor	200	200	252	252	371	331	580	442
Non-machine labor	1,228	1,228	1,228	1,228	1,161	1,077	1,161	1,077
Harvest costs	11,332	10,996	10,885	11,557	8,949	9,426	9,996	9,616
Irrigation	245	245	245	245	220	183	217	180
Compost	437	0	437	0	437	0	437	0
Seed	247	247	247	247	309	247	309	247
Fertilizer	294	294	294	294	373	373	373	373
Herbicide	59	59	59	59	64	64	64	64
Other pesticide	469	469	469	469	368	368	368	368
Application fees	235	235	235	235	235	235	235	235
Cash overhead	10	10	17	17	22	17	54	37
Non-cash overhead	128	128	195	195	274	205	625	425
Interest on capital	170	153	175	165	240	175	314	215
Land rent	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470
Total costs	17,707	16,917	17,541	17,766	15,864	15,460	18,127	16,376
Returns per hectare ($)								
Total returns	20,096	19,498	19,298	20,494	14,783	15,571	16,514	15,885
Total costs	17,707	16,917	17,541	17,766	15,864	15,460	18,127	16,376
Net returns	2,389	2,581	1,757	2,728	-1,081	111	-1,613	-491
Fuel (L per hectare)								
Diesel used	261.8	261.8	570.4	570.4	486.2	402.1	1514.7	1037.9

Table 6. Economic Analysis of All Management Costs and Returns, Second Two Crops
Includes fuel use for the second two vegetable crops in the on-farm field experiment on minimum and conventional tillage with (+OM) and without cover crops and compost (-OM). Costs for the cover crop and its incorporation are included with the subsequent vegetable crop. $7.50 (lettuce) and $9.00 (broccoli) per box was used in the calculation of returns, which was the Monterey County average for the sampling times of the study.

	Lettuce Crop Harvested Aug. 1999				Cover Crop + Broccoli Crop harvested Apr., 2000			
	Min Till +OM	Min Till -OM	Conv Till +OM	Conv Till -OM	MinTill +OM	MinTill -OM	Conv Till +OM	Conv Till -OM
Management costs per hectare ($)								
Fuel, lube, repair	143	143	346	346	311	207	773	679
Machine labor	180	180	301	301	284	217	506	454
Non-machine labor	1,087	1,087	1,087	1,087	1,161	993	1,153	986
Harvest costs	14,237	13,662	15,102	14,526	8,857	8,149	14,906	8,489
Irrigation	326	326	326	326	262	205	259	200
Compost	437	0	437	0	437	0	437	0
Seed	247	247	247	247	309	247	309	247
Fertilizer	351	351	351	351	593	593	593	593
Herbicide	96	96	96	96	264	264	264	264
Other pesticide	425	425	425	425	0	0	0	0
Application fees	257	257	257	257	77	77	77	77
Cash overhead	7	7	20	20	20	12	47	42
Non-cash overhead	96	96	222	222	227	143	553	487
Interest on capital	185	168	203	185	237	170	326	212
Land rent	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470
Total costs	20,544	19,515	21,890	20,859	15,509	13,747	22,673	15,200
Returns per hectare ($)								
Total returns	22,247	21,348	23,593	22,694	16,781	15,440	28,244	16,085
Total costs	20,544	19,515	21,890	20,859	15,509	13,747	22,673	15,200
Net returns	1,703	1,833	1,703	1,835	1,272	1,693	5,571	885
Fuel (L per hectare)								
Diesel used	205.7	205.7	570.4	570.4	402.1	280.5	1,206.2	1,075.3

Figure A. Soil microbial biomass C (0–15 cm depth) during the compost quality trial on Storm 4 South.
No significant differences were observed between treatments on any of the sampling dates.

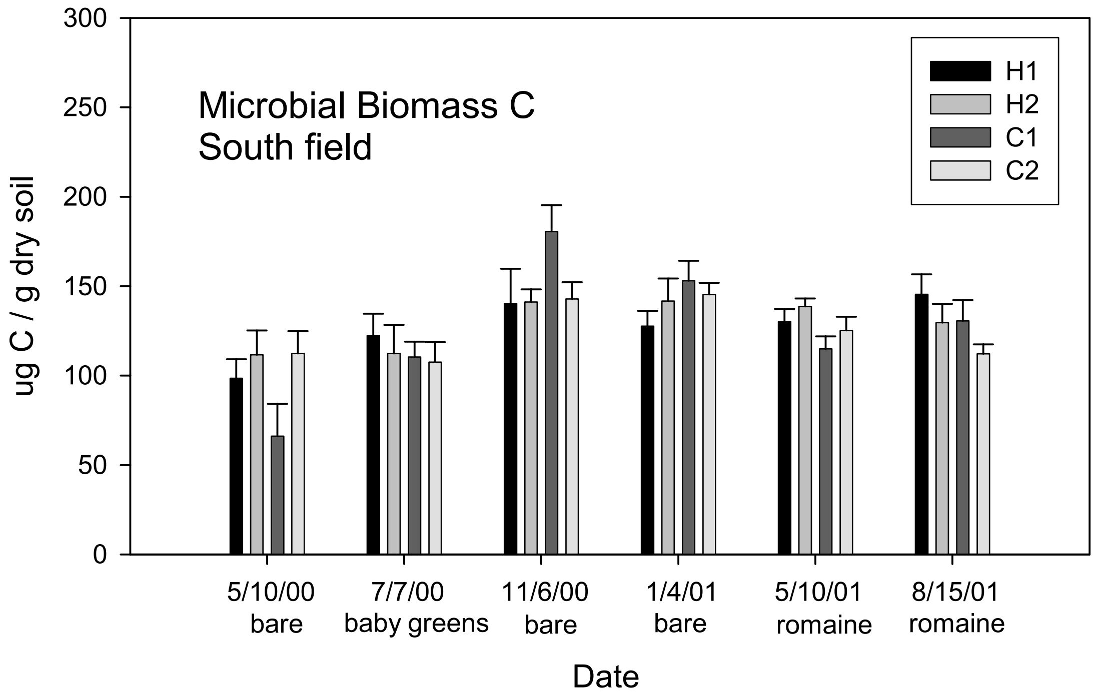


Figure B. Soil microbial biomass C (0-15 cm depth) during the compost quality trial on Storm 4 North.
No significant differences were observed between treatments on any of the sampling dates.

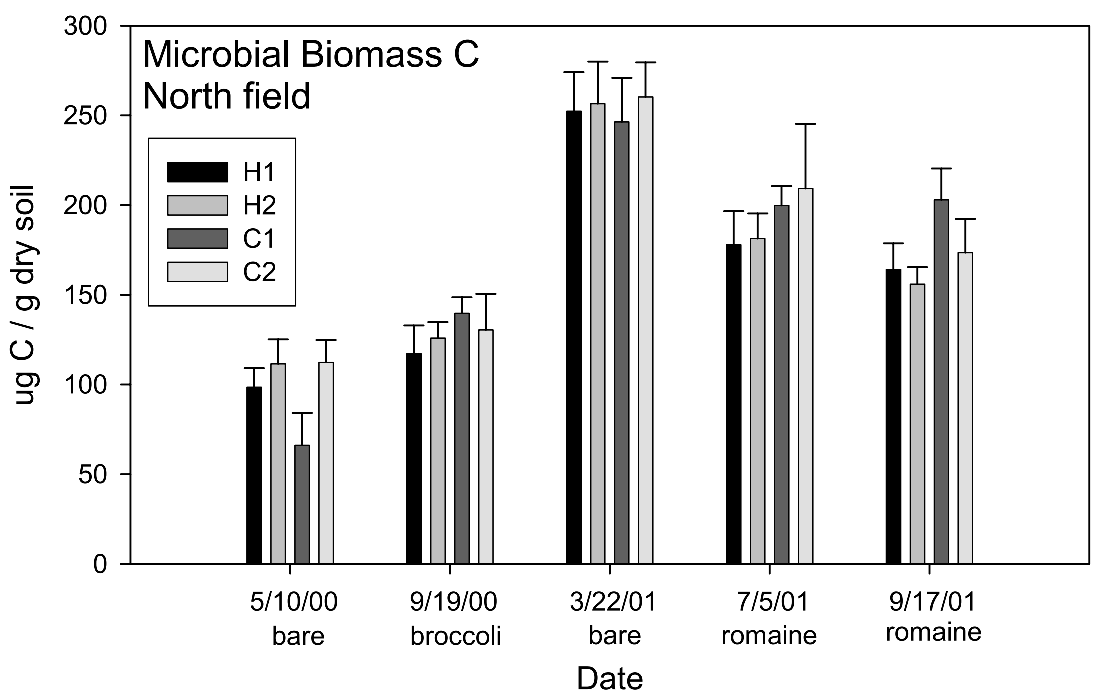


Figure C. Soil nitrate (0-30 cm depth) during the compost quality trial on Storm 4 South
No significant differences were observed between treatments on any of the sampling dates.

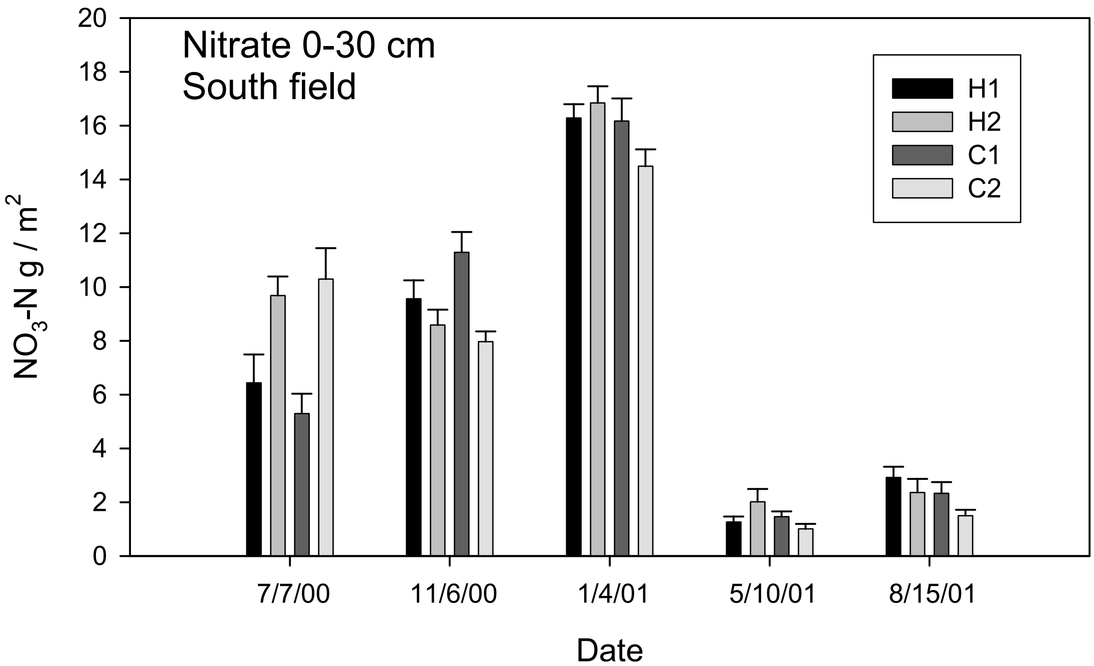
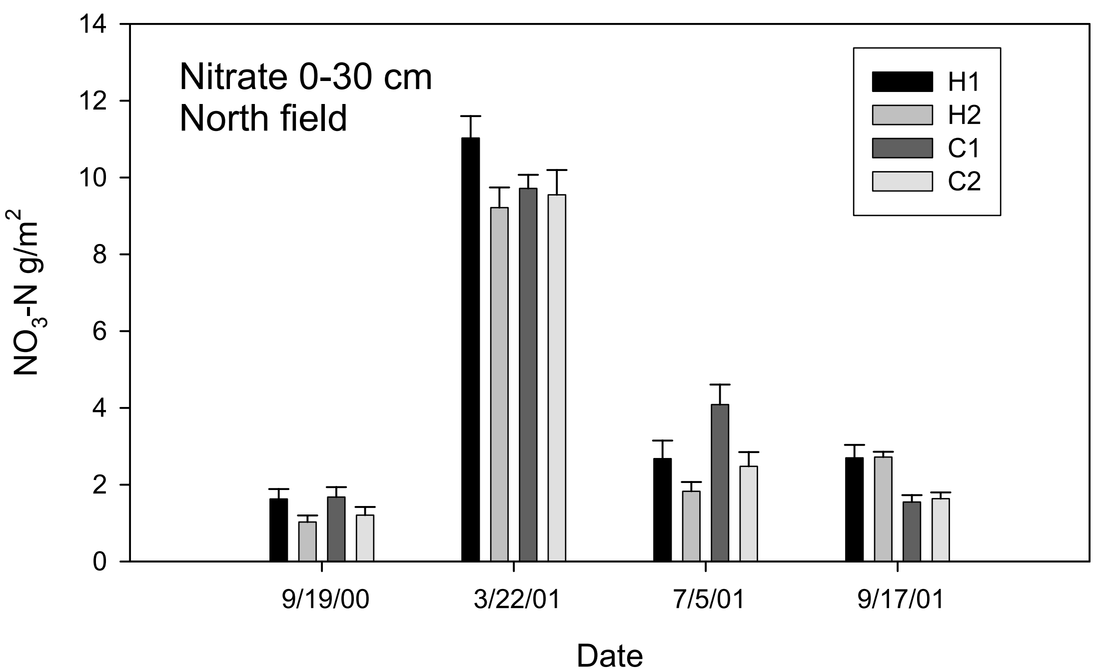


Figure D. Soil nitrate (0-30 cm depth) during the compost quality trial on Storm 4 North.
No significant differences were observed between treatments on any of the sampling dates.



Glossary of Terms

∗: Universal symbol for multiplication

μg: microgram

2N KCl 2: Normal potassium chloride

$acre^{-1}$: per acre

C: carbon

C1: compost treatment C1 (see text)

C2: compost treatment C2 (see text)

cash $crop^{-1}$: per cash crop

CEC: cation exchange capacity

cm: centimeter

cm^{-1}: per centimeter

DANR: Division of Agricultural and Natural Resources

EC: Electrical conductivity

emergence cage: sampling method for insects

fisholyzer: fertilizer type

g^{-1}: per gram

gal: gallon

H1: compost treatment H1 (see text)

H2: compost treatment C2 (see text)

$head^{-1}$: per lettuce head

hectare: metric measure of area

kg: kilogram

kg^{-1}: per kilogram

L: liter

Lb: pound

Liliston: tillage method

M: meter

m^2: square meter

m^{-2}: per square meter

m-2: per square meter

MBC: microbial biomass carbon

MEq: milliequivalents

Mmhos: electrical conductivity measurement

N: nitrogen

N: number in a sample

Na^+: per square meter

NH_4^+-N: ammonium nitrogen

NO_3-N: nitrate nitrogen

NS: statistically non-significant

OM: organic matter

P: phosphorus

Parasitoids: insects that parasitize other insects

PH: acid/base measure

PMN: potentially mineralizable nitrogen

Subsoiling: tillage of deep soil

yd^2: per square yard

Bibliography

Jackson, L. E., et al., “On-Farm Assessment of Soil Quality: Impacts of Cover Crops, Compost, and Tillage Practices on Vegetable Yield, Soil, Weeds, Pests, and Economics,” manuscript submitted to *Agricultural Ecosystems and Environment*, 2002.

Vance, E. D., et al., “An Extraction Method for Measuring Soil Microbial Biomass Carbon,” *Soil Biology and Biochemistry,* Vol. 19, No. 6, 1987, pp. 703–708.

Waring, S. A., and J. M. Bremner, “Ammonium Production in Soil Under Waterlogged Conditions as an Index of Nitrogen Availability,” *Nature*, Vol. 201, No. 4922, February 29, 1964, pp. 951–952.