Compost Maturity and Nitrogen Release Characteristics in Central Coast Vegetable Production

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Table of Contents

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Executive Summary

Growers may have a number of reasons for using composts, but they often may not be able to determine the best product for meeting production requirements. In addition, agricultural users of compost produced from urban green waste continue to accept economic risks due to either inconsistent composition or quality.

Compost quality in relation to intended end use is a frequently discussed issue; however, rigorous definitions or standards for agricultural uses have yet to be established. Compost maturity is a critical factor affecting compost quality for specific agronomic objectives. Maturity has been a confusing and often subjective issue for producers and growers due to the lack of objective and quantitative methods to classify these products. Additionally, crop responses to compost applications may be affected by soil texture, timing, depth of incorporation in soil, and other cultural or management practices.

This project sought to quantify the effect of compost feedstocks (green waste and poultry manure), compost maturity, and soil texture on vegetable crops. All of the field work was conducted in cooperation with commercial vegetable growers in Santa Cruz, Santa Clara, and San Benito Counties. Initially, the intent was to work equally with conventionally and organically farmed crops. However, in the end, the majority of the field trials occurred on conventional farms. Efforts to match similar crops to trials performed on different soil textures (conventional and organic) were largely unsuccessful due to the inevitable complications inherent in on-farm studies.

Early in the course of this study, a method for quantitatively determining compost maturity was developed. With this method, maturity is not described by a single property, but a group of properties related to the state of organic matter decomposition, changes in forms of nitrogen (N) during composting, and/or plant performance in a lab environment. This maturity index was used to analyze most of the compost batches that were applied to grower fields. Therefore, the analysis and interpretation of the results of crop trials and field N-release tests in this study are based on the maturity rating of the composts applied.

Overall project objectives were as follows:

- Characterize a number of composts produced solely with green waste and blends of green waste and manure.
- Conduct field tests to evaluate the quantitative maturity index tests for composts.
- Evaluate the effect of compost characteristics and maturity on N release in soils of different textures.
- Compare crop performance and N uptake in response to compost type and maturity status.
- Attempt to link compost quality to potential agronomic/economic benefits on differing soil types.
- Evaluate if compost utilization can be considered as a soil conservation practice.

Methods

This study began in the fall of 1999 at two field sites on conventionally farmed blocks in the Gilroy (Santa Clara County) and Watsonville (Santa Cruz County) areas. Additional field sites in the San Juan Bautista (San Benito County) and Gilroy areas were established in the spring of 2000. Only one field trial was completed in a certified organic field. The fields used in this study were on coarse sandy loam, fine sandy loam, sandy clay loam, and clay soils. Most compost applications were made with commercial spreading equipment; however, some smaller trials were established following hand applications of compost that were then incorporated into the soil with field-scale equipment. A sample was collected from each compost load (25 samples total) and submitted to a certified commercial laboratory for either complete or partial physical, chemical, and maturity analysis.

Soil samples were collected from a number of field sites following compost incorporation. These samples were placed in thin plastic bags and buried in fields for up to 250 days. Routinely, sub-samples of soil were collected to estimate N release (NH_4- and NO_3-N) from soil and soil amended with compost in order to determine the relationship between maturity and potential N-supplying power of the composts.

Compost Maturity

The maturity of composts varied significantly between suppliers and different loads from the same source. This variability appears to explain some of the differences in soil and crop responses in the trials. The maturity index appears to be a useful diagnostic tool and a reliable indicator of compost quality. Fourteen of the 25 compost samples collected were analyzed with a complete physical and chemical properties, and maturity analysis package. The remaining samples were characterized with a modified “partial” version of the maturity index.

Generally project results suggest that there may be some gross predictive value provided by the maturity index evaluation, particularly when supplemented by some key compost chemical and physical parameters. In this study, mature and/or moderately mature (maturing) composts consistently released a greater percentage of their total N content, in comparison to immature or very mature materials. Therefore, total N content cannot be considered alone as an indicator of N-supplying power. Further, these maturity analyses also disprove prior assumptions about the interpretative value of the carbon/nitrogen (C/N) ratio as a measure of compost maturity. There was no correlation between C/N ratio and other maturity index parameters.

While the total N content of the composts is important to the overall N-supplying power of the materials (measured as pounds of N per dry ton of compost), the maturity status would appear to be a more important predictive property.

Crop Trials

Crop response to compost applications was variable. Yield increases were observed in early spring lettuce, winter cabbage, mid-season celery, and early- and mid-season baby greens. Blend composts tended to be superior to green-waste composts in most of these trials.

No yield differences were observed in a number of trials where immature (IM) or very immature (VIM) composts were applied either months or weeks prior to a crop planting. Reductions in yield were associated with the incorporation of immature and very mature composts into the soil, while yield increases tended to occur with the use of mature or maturing materials. In one trial in an organic field, where compost was the sole fertility input, an immature poultry-manure compost reduced crop stand and yields. This was likely due to extremely high free-ammonia (NH_3) levels in the material, limited depth of soil incorporation, and seeding too soon after incorporation.

In comparison, the mature green-waste and blend composts resulted in better yields in this organic field. A mature blend compost applied in the fall increased early-spring head lettuce stands and yields in one field in both growing seasons. This was apparently due to a reduction in disease loss caused by an unidentified soil fungus that results in damage similar to Fusarium wilt fungi. Reductions in the common soil disease causing lettuce drop (*Sclerotinia minor*) were also noted in two other spring lettuce crops.

In this study, researchers evaluated crop and soil response to fall, winter, spring, and summer application of composts. Even when immature compost was applied in October or November for an early February or even May planting, there was no positive yield response in the first or second crop rotation the following season.

Conversely, some trials resulted in positive response to mature composts applied one to two weeks prior to planting. Table 1 summarizes the results of crop trials in relation to compost type and maturity index rating. Crop trials that are noted as “?” are those for which the grower decided not to include a check (or no-compost) treatment.

Table 1. Summary of Crop Response to Composts of Varied Maturity Status on Different Soils

Compost Type	Maturity	Crop	Yield
Sandy Soil Class (Coarse Sandy Loam and Fine Sandy Loam Textures)			
Blend	VM	Baby Lettuce	o
	VM	Baby Lettuce	-
	VM	Baby Spinach	+
	VM	Baby Spinach	o
	M	Frisse	?
	IM	Baby Spinach	o
	IM	Baby Spinach	+
	IM	Baby Chard	o
	MM	Baby Mustard	+
Green Waste	MM	Baby Lettuce	+
	IM	Baby Lettuce	-
	IM	Baby Lettuce	-
	MM	Baby Spinach	+
	IM	Baby Spinach	o
	MM	Baby Spinach	o
	IM	Baby Spinach	-
	MM	Baby Spinach	-
	M	Baby Chard	o
	M	Frisse	?
	VIM	Baby Mustard	-
Loamy Soil Class (Sandy Clay Loam Texture)			
Blend	M	Lettuce	+
	MM	Lettuce	+
	MM	Celery	+
Green Waste	M	Lettuce	o
	IM	Lettuce	o
	M	Celery	+
Clayey Soil Class (Clay Texture)			
Blend	M	Cauliflower	?
	M	Romaine	?
	MM	Cabbage	+
	VIM	Lettuce	-
Green Waste	VM	Cauliflower	?
	VM	Romaine	?
	M	Cabbage	+
	IM	Lettuce	o

+ = Increased yield
O = No difference in comparison to check
- = Decreased yield
? = Check (no-compost) treatment not included

I: Immature
MM: Moderately mature or maturing
M: Mature
VIM: Very Immature
VM: Very Mature

Very immature or very mature composts may temporarily reduce or immobilize available soil N and have a negative impact on crop development and yield. The longest and greatest immobilization of available soil N occurred with an old, very mature green-waste compost. Timing and depth of compost incorporation can be important. Reductions in seedling emergence and N uptake were observed when immature green-waste compost was incorporated only to a depth of 3 to 4 inches.

Conversely, cabbage transplants responded significantly to shallow incorporation of mature composts. High NH_3-N levels associated with immature manure-based composts can reduce seed germination and crop productivity similar to raw manure when crops are planted soon after. Application of mature or maturing composts too early in the fall may result in leaching loss of much of the N released prior to crop establishment in late winter to early spring.

Soil texture likely has an effect on N-release characteristics of composts, as it does for decomposition of organic residues and the accumulation of soil organic matter. While attempts were made to conduct trials with similar crops on different soils, the realities of farming and on-farm research made it impossible to achieve this objective. However, based on the results of N-release tests, it appears that lighter (for example, sandy) soils allow for more rapid release of N from composts.

Costs and Returns

Simple cost analyses, based on compost input costs, observed yields, and a range of market prices suggest that mature composts provide the most reliable increase in gross revenues per acre. Many of the trials in which immature compost was incorporated resulted in no increases or, in some cases, reductions in per-acre yields. After accounting for compost and application costs in trials in which immature compost was used, researchers calculated substantial losses in potential net returns, compared to net returns without compost use. These calculated financial losses quantify the potential economic risk associated with purchase of poor-quality composts.

Nutrient Management

It is unclear if greater agricultural use of compost can provide tangible benefits to water quality objectives within the Pajaro watershed. This project found that immature compost incorporated in the fall can reduce soil NO_3-N during the winter. This would potentially reduce leaching and/or runoff losses during the rainy season. However, it was found that use of immature composts would not provide adequate economic returns. Conversely, early fall applications of maturing or mature composts (particularly blends) when soil is still warm will likely lead to rapid increases in soil NO_3-N that could increase leaching during the rainy season.

Conclusions

In summary, this study has provided new quantitative information regarding compost quality for vegetable crop production. Following are important project findings:

- Mature or maturing composts more consistently result in positive crop yield response in comparison to immature or very mature composts.
- Composts produced with chicken manure and green waste appear to provide more available N in comparison to green-waste composts.
- Manure blends may have a higher percentage of smaller-sized ‘reactive’ particles.
- Immature and very mature composts may reduce inorganic soil N long enough to have negative impact on production in conventionally farmed soils.

- High NH_4-N levels associated with immature manure-based composts can reduce seed germination and crop productivity under certain circumstances.
- Mature composts can provide significant N dependent on timing of applications.
- Timing and depth of incorporation of compost applications will have direct effect on crop response.
- The maturity index appears to be a useful tool to assess compost quality.
- Maturity status of compost is a significant predictor of compost quality for vegetable production.

Introduction

Growers may have a number of different reasons for using composts, but they often may not be able to determine the best product for meeting production requirements. In addition, agricultural users of compost produced from urban green waste continue to accept economic risks due to either inconsistent composition or quality.

Compost quality in relation to intended end-use is a frequently discussed issue; however, rigorous definitions or standards for agricultural uses have yet to be established. Compost maturity is a critical factor affecting compost quality for specific agronomic objectives. Maturity has been a confusing and often subjective issue for producers and growers due to the lack of objective and quantitative methods to classify these products. Additionally, crop responses to compost applications may be affected by soil texture, timing, depth of incorporation in soil, and other cultural or management practices.

This project sought to quantify the effect of compost feedstocks (green waste and poultry manure), physical and chemical properties, compost maturity, and soil texture on vegetable crops. Within the past few years, the traditional role of manures in soil fertility management for high-value vegetable and fruit crops has come into question. Many vegetable packing companies have become concerned with consumer perspectives related to food safety. Many have taken steps to more carefully monitor or forbid entirely the use of raw manures on produce handled by their facilities. These changes have led in part to an increased utilization of composts derived from municipal organics.

Additionally, in the Central Coast region of California there has been a rapid expansion of certified organically managed acreage. However, there are a number of specific concerns and questions still posed by growers and concern that the quality and consistency of these materials could be improved. These factors will continue to limit market expansion for compost, particularly given the current economic challenges facing producers of many agricultural commodities in California.

There continues to be little information that defines compost quality and how it may impact crop response and yield, particularly on different soil types. As a result, many growers continue to "shop around" for organic amendments which are of consistent quality and which meet their agronomic objectives.

On-Farm Field Research

Project work began in the fall of 1999 and crop trials were conducted on mostly conventionally farmed blocks in the Gilroy (inland), Watsonville (coastal), and San Juan Bautista (inland) areas. These areas are within the Pajaro River watershed region. Only one field trial was conducted in a certified organic field. These fields were on coarse sandy loam, fine sandy loam, sandy clay loam, and clay soils. Most compost applications were made with commercial spreading contractors and equipment, however some smaller trials were established following hand applications of compost that were incorporated with field-scale equipment.

Compost Maturity

Compost maturity is the degree or level of completeness of composting. In mature compost, raw starting materials have been sufficiently decomposed under controlled moisture and aeration conditions, resulting in a stable organic amendment product. "Stability" refers to a specific stage of decomposition or a state of organic matter during composting. The stage of decomposition or the state of organic matter, in turn, is determined by the increased complexity of organic compounds remaining, concurrent with decreases in microbiological activity in the material. The stability of a given compost is important in determining the potential impact of the material on N availability in soil or growth media and maintaining consistent volume and porosity in container growth media.

Most uses of compost require a stable to very stable product that will prevent nutrient tie-up and maintain or enhance oxygen availability in soil or growth media. Immature composts may contain high amounts of free NH_3, certain organic acids, or other water-soluble compounds that can limit seed germination and root development. While maturity is related in part to the stability of the material, the degree of maturity is also affected by the presence of chemicals such as those mentioned in the previous statement. All uses of compost require a mature product free of these potentially phytotoxic components.

Early in the course of this study, researchers developed a method or index for quantitatively determining compost maturity. This maturity index was used in analyzing most of the compost loads applied to grower fields. It thereby provides another way to present, interpret, and discuss data from field trials and the nitrogen release tests completed during this project.

Nitrogen Release From Compost

Many vegetable growers in this region accustomed to using raw or aged manures may prefer that compost be manure-based or at least a blend of manure and other feedstocks such as green waste. As a result, businesses that have typically produced compost solely from green waste have occasionally produced custom orders requiring the additional expense of purchasing and importing manures. Green-waste compost producers have not been convinced that these blend composts can be profitable, due to the added costs of purchase, transport, and additional composting and curing time. Certified organic vegetable growers face constant challenges in providing adequate N for double, triple, and even quadruple crop rotations within one season. Therefore, the N-release characteristics of a major production material such compost are critical.

Nitrogen supply for crops is determined by the processes related to the nitrogen cycle in soil, additional additions to the soil from fertilizers, bulk organic amendments, irrigation water, and, in some cases, liquid sprays on crop foliage. Most of the N absorbed by plants is in the inorganic forms, ammonium (NH_4) and nitrate (NO_3). These forms of N result from the conversion of more complex organic N compounds in soil organic matter and plant/animal residues to these simpler inorganic forms (a process called “mineralization”).[1]

A soil amendment such as compost has most of the N in organic form, and a mature compost will contain varying amounts of NH_4- and NO_3-N to soil. During composting, a wide range of microorganisms changes the composition of organic forms of N. The organic N in mature compost is more stabilized than that found in raw organic materials. This stabilization reduces the rate at which this organic N will be mineralized by soil microorganisms to NH_4 and NO_3 following compost incorporation.

Manure or blend composts tend to be higher in total N in comparison to green waste composts. However, there is little current data that contrasts these materials or provides some quantitative indication of the N release or N-supplying ”power” of these composts. This project has utilized field tests of soil and compost in order to characterize the N release of composts and link that to feedstock types, maturity, and crop response.

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[1] The glossary of this report contains definitions to other technical terms and concepts.

Compost and Nutrient Management

The Pajaro River watershed has been listed as an impaired water body by the California Regional Water Quality Control Board, due to excessive nitrates, occasional phosphorus (P), and sediment loads related to certain land uses. Agricultural crop production is identified as a contributor to degraded water quality, with local and watershed planning efforts citing the need to reduce nitrogen and sediment loading from croplands. In the past few years, there has been discussion about compost utilization as a conservation management tool or practice to protect water quality. A subjective and qualitative assessment of this subject is in the section on findings.

Project Objectives

Overall project objectives were as follows:

- Characterize a number of composts produced solely with green waste and blends of trimmings and manure.
- Conduct field tests to evaluate the quantitative maturity test for composts.
- Evaluate the effect of compost characteristics and maturity on N release in soils of different textures.
- Compare crop performance and N uptake on different soils in response to compost type and maturity status.
- Attempt to link compost quality to economic benefits on differing soil types.
- Evaluate if compost utilization can be considered as a soil conservation practice.

Methods

This study had a number of components. Sampling and analysis of compost characteristics and maturity was key to the analysis of field crop trial data. All crop trials were performed in growers' fields and timed according to their crop plans and schedules. In an ever-changing vegetable industry, this reliance upon growers' timetables creates inevitable challenges to the researcher, as weather and prices can often change crops and planting schedules with only a day's notice. A few crop trials were compromised by miscommunication, collapse of market prices, or poor weather.

The project successfully characterized 25 composts used in 15 vegetable crop trials located in different microclimates and soils in the Pajaro River watershed. Results of these trials are interpreted in light of compost maturity and N-release test results.

Maturity Analysis

Since compost maturity is not described by a single property, maturity is best-assessed by measuring two or more parameters. The maturity index uses widely used and commonly accepted laboratory methods. Compost stability is evaluated based on respirometry (the measurement of carbon dioxide evolved or oxygen consumed by microorganisms within the material), which provides an estimate of potential biological activity. Higher rates of carbon dioxide release or oxygen consumption will reflect less stable composts. Compost may then be rated as very mature, mature, and immature. Some of the composts described later in this report have also been classed as moderately mature or very immature, based on the presence of NO_3-N in the sample.

All of the compost maturity analyses (complete and partial characterizations) were performed at Soil Control Laboratory in Watsonville, California. A complete maturity index characterization first requires determination of the carbon-to-nitrogen (C/N) ratio and at least one of the tests from each group (A and B) below. Compost must have a C/N ratio of less than or equal to 25 before the application of the following stability and maturity criteria. The C/N ratio of most green waste feedstocks (unless exclusively grass) have a pre-composting ratio of greater than 25. As composting proceeds, the C/N ratio will decline, reflecting a greater loss of organic carbon (C) as carbon dioxide ($CO_{2)}$ due to microbial respiration in comparison to total N content.

Group A (tests to determine compost stability)

- CO_2 evolution or respiration
- Oxygen demand
- Dewar self-heating test

Group B (tests to further determine maturity in reference to potentially phytotoxic compounds)

- NH_4-NO_3 ratio
- NH_3 concentration
- Plant test (seed germination and growth)
- Volatile organic acids concentration

Compost is then rated as very mature, mature, or immature based on the rating criteria in Table 2. Note that some of the composts described later in this report have been rated as moderately mature or very immature, based on the presence or absence of -NO_3-N in the sample.

Table 2. Maturity Ratings Based on Test Results
(Source: Draft report for California Compost Quality Council by project leader/author: *A Maturity Index for Compost.* Excerpted from Tables 1 and 8 (pp. 8, 11), with some revision. Funded by CIWMB. Draft report submitted to CIWMB for review October 12, 2000. Final report: *Compost Maturity Index*, published June 2001)

Test	Rating		
	VIM	M	IM
CO_2 Test C / unit VSo / day	< 2	2 – 8	> 8
BIO-C CO_2 C / unit VSo / day	< 2	2 – 8	> 8
NH_4-/NO_3-N Ratio	< 0.5	0.5 – 3	> 3
NH_3-/NH_4-N Ratio ppm, dry basis	< 100	100– 500	> 500
Seed Germination % of control	> 90	80 – 90	< 80
Plant Tests % of control	> 90	80 – 90	< 80

BIO-C: Proprietary test for biologically available carbon that differs from a standard respiration test.

VSo: Volatile solids or organic matter. Draft document used the abbreviation “VS,” which has been changed in this report to “VSo,” since “VS” in this document is the abbreviation for “very stable.”

Following are characteristics for the three categories in the maturity index (“Immature,” “Mature,” and “Very Mature”), as well as the additional categories applied to some composts later in the report (“Moderately Mature” and “Very Immature”).

Immature
Unstable compost
Odors likely
High toxicity potential
Immobilization (tie-up) of available nitrogen

Mature
Cured compost
Odor production not likely
Limited toxicity potential
Positive impact on available soil nitrogen

Very Mature
Well-cured compost
No continued decomposition
No odors
No potential toxicity
Possible lower release of N than mature compost

Moderately Mature
Stability test result is greater than 6 and less than 8 and/or when nitrate is detected and is greater than 25 ppm N.

Very Immature
C/N ratio is greater than 25, and/or stability test is greater than 12, and/or NH_4 is greater than 500 and there is no nitrate present.

Crop Trials

Crop trials were conducted in fields with varying crop histories on coarse sandy loam, fine sandy loam, sandy clay loam, clay loam, and clay soils. In many cases compost was applied with commercial spreading equipment to replicate subblocks within an entire field. Incorporation of compost was done with the grower's typical equipment and production practices. There were always at least three replicated plots for each treatment, most often in a complete block design. One trial involved a split-plot design in which N fertilizer was varied. Some trials were conducted following hand application of compost to small (30- x 30-foot) or micro- (6.5- x 6.5-foot) plots. Incorporation was achieved with grower practice, or for some trials, compost was intentionally incorporated to a shallow depth with rakes or harrows.

Harvest plot size and configuration varied at each site. Generally, with crops grown on 40-inch beds, a 30-foot length of two beds in each treatment replicate were harvested and weighed fresh. For baby green crops grown on 80-inch beds, up to six separate 1-square-foot areas were cut per plot and weighed.

In-Field Nitrogen Release Tests

This research method involves placing field-moist soil in a partially sealed plastic bag, burying it, and then collecting subsamples at various time intervals. Soil or soil-compost mix was analyzed at the start of the test and at each time interval. In this study researchers have attempted to assess the pattern and magnitude of the release of inorganic N (NH_4- and NO_3-N) release with time. The method cannot assess mineralization perfectly, as water infiltration, drying of soil, and tillage disturbance cannot be simulated. In some cases, researchers added water during the test if soil that had initially been dry was rewet by rainfall or irrigation.

Generally, immediately after incorporation of compost, large soil samples (depth interval dependent upon incorporation depth) were collected with a shovel, homogenized, and then placed into thin (0.5 mil) plastic bags. A subsample was retained for analysis; three replicate bags were then buried either in listed or shaped beds or later in soil away from the field if there was a likelihood for tractor/cultivation damage. Bags were buried upright to simulate either a 0- to 6-inch or 0- to 12-inch depth interval. Soil from these bags was then usually sampled at the end of one week and then at monthly intervals as long as practical.

During the first round (fall 1999) of placing and monitoring these "mineralization bags," some problems were encountered. Occasionally a replicate was lost due to tearing of the bag, followed by water entry, which in some cases saturated the soil. As well, the initial sealing method allowed rainwater to enter into the tops of some bags, thus also saturating the soil. In the first year no bag was lost to tractor cultivation damage. However, a number of treatment replicates were lost in the spring of 2001, when a tractor operator failed to notice location flags.

Soil, Compost, and Plant Analysis

The following method was used for all field and mineralization bag soil samples:

After sampling and homogenization, a subsample was placed into a graduated conical extraction tube filled with either 30 milliliters (ml) of 0.01 molar calcium chloride ($CaCl_2$ [for NO_3]) or 30 ml of 2 molar potassium chloride (KCl [for NH_4]). Soil was added until the liquid line reached 40 ml. Each tube was next weighed and then shaken to extract the inorganic N forms. Following shaking, the tubes were placed in a refrigerator at 4 to 6 degrees Celsius to allow soil to settle, leaving a clear supernatant. The supernatant was then analyzed for NH_4- and NO_3-N with either a Cardy meter (NO_3) or an EM-Scientific reflectometer (NH_4). Additionally, at two times during this first year, replicate soil subsamples were submitted to a commercial analytical laboratory for a “quality control” check of our analytical methods. In all cases, researchers found quite good agreement (less than 5 percent difference) between analytical results.

Compost was sampled on the day of spreading and incorporation. Typically, subsamples were collected by digging 3 feet deep into piles in at least 10 locations. These subsamples were homogenized with a shovel, then redivided into subsamples and placed into plastic bags. If necessary, these bags were placed on ice prior to delivery to the laboratory. In the fall of 1999, all compost samples were simply analyzed for organic matter, organic C, total N, and NH_4- and NO_3-N. Beginning in 2000, all samples were submitted to the same laboratory for a complete characterization of nutrients, heavy metals, particle-size distribution, and the recently developed maturity index. In 2001, most of the samples were analyzed with a partial maturity package. The partial maturity analyses included total organic C, total N, pH, and NH_4- and NO_3-N.

Plant leaf samples were collected at harvest of most crops. Samples were dried, and in some cases weighed, to determine moisture content prior to fine grinding. Samples were analyzed for total carbon and nitrogen on a Leco CN analyzer at Soil Control Laboratory.

Costs and Returns Analysis

Accounting for costs and potential revenues provides a measure of the value and risks associated with the use of compost for short-term yield benefits. A simple analysis was done with selected example crop trials from both seasons, where either immature or mature composts were used. The costs of compost were assumed to range between $20 and $25 per ton delivered, with application costs of $8 to $10 per acre. A typical range for market prices was then applied to yield data from trials in order to assess the potential per-acre returns to a grower. It was not possible to assess the potential long-term positive or negative impacts of compost application in this study.

Findings

The primary project goal was to develop new information relating compost quality to crop response in different soil types. Unfortunately, the different locations of the fields, while providing the necessary variety of soil types, introduced some degree of microclimatic variability that influenced some of the data. Also, with on-farm trials the researchers are not able to control crop type and planting and fertilization schedules, a factor that also limits direct comparisons between soils and field sites. Given the differences in field location and crop rotation schedules, researchers were also unable to apply exactly the same compost material at all sites.

This was only a two-season study that mainly used compost from two regional producers. The data from 15 crop trials and 25 compost samples does not reflect the diversity of products, crops, and locations necessary for comprehensive conclusions. Generally, the researchers found that there may be some gross predictive value provided by the maturity index evaluation, particularly when supplemented by some key compost chemical and physical parameters. Researchers have identified some important chemical and physical differences between poultry manure-green waste blends and green-waste composts, which may influence their impact on soil N and crop productivity.

In this study, blend composts (poultry manure and green waste) consistently released more N than green-waste composts and more often resulted in improved crop yield in conventionally farmed systems. Table 3 summarizes important chemical and physical differences between the two compost types that may have influenced the impact of the two composts on soil Nand crop productivity. These results indicate that the blend composts generally had greater organic matter, total N and inorganic N, water-soluble nutrients, and finer particle size, all properties that may more positively influence crop production. An analysis of biological properties of the composts (likely important to some crop trial results) was beyond the scope of this project.

Table 3: Summary of Selected Compost Characteristics

Parameter	Green Waste	Blend
Organic Matter (%)	40.3 a[*]	49.5 b
Total N (%)	1.6 a	2.0 b
C/N Ratio	15	13
NH3-N (ppm)	231 a	734 b
pH	7.2 a	8.6 b
Soluble Salts (mmhos)	4.0 a	8.3 b
N+P+K	4.2 a	6.8 b
Moisture (%)	29.6	30.9
Particles < 2mm (%)	72.5 a	79.2 b

[*]Values with different letters indicate statistically significant differences between measured parameters for each compost type. For example, with the first parameter (“Organic Matter (%),” the “a” after the Blend value and the “b” after the Green Waste value indicate a statistically significant difference between the two compost types.

Compost Characterization

Typical laboratory analysis

Table 5 in Appendix A summarizes some key chemical and physical characteristics of all types of composts applied (including one 100 percent poultry-manure compost) in crop trials and used in-field N-release tests. Results reveal important differences that may influence the performance of these materials. The manure green-waste blends evaluated tended to have higher total organic matter, total N, macronutrient content (N+P+K), NH_4-N, soluble salts, and particle size fractions smaller than 2 mm. The higher average pH for blend composts indicates that many of the materials had substantial free-NH_3 fractions that can have a negative effect on soil microbes, germinating seeds, and seedlings.

Therefore, as many growers know, one would expect better overall macronutrient supplying power for blend composts in comparison to those produced solely from green waste. However, there may be more constraints on the amount of compost incorporated into the soil due to soluble salts that can reduce germination and vigor of plants. If a purchaser of compost hoped to maximize organic matter per unit volume, there was a substantial difference between the two compost types favoring blend composts.

The only poultry-manure compost assessed (see Table 5) shared characteristics of both green-waste compost and blends. While organic matter levels and fine fraction size were similar to green waste composts, the total and NH_4-N content, pH, and soluble salts were much higher than either green-waste or blend composts. This was a very unstable material (see NH_3/NH_4 content and pH) and was not properly composted or cured.

Maturity rating

Table 7 in Appendix A provides a summary of all the composts applied in the 1999–2001 seasons. The ID number for each compost sample will be used for reference throughout this report. As expected, there was a large variation in the maturity status of the composts. There was no initial expectation that one type of material would be on average more mature than another, as this is solely a function of processing by the compost producer.

Vegetable crop growers in the Central Coast region that use compost have felt that producers could/should do more to achieve consistent quality. While the general chemical and physical characteristics of composts supplied by any one producer for this study tended to have only small variations, the maturity status often varied dramatically. During this study, 7 composts were specifically selected at producer sites in order to include very immature or moderately mature composts in crop trials. Of the 18 other materials that were delivered without prior specification, only 9 could be considered mature or very mature.

Negative impacts from less than optimal processing will be particularly critical for poultry-manure composts. Three manure-based composts likely had very high levels of NH_3-N that likely caused poor germination and/or seedling vigor in laboratory tests. In at least three cases, researchers believe that these high levels of NH_3 also led to false results for the respiration/stability test due to inhibition of microbial activity.

In applying either a complete maturity index characterization or a partial one (C/N ratio, NH_4/NO_3 ratio), it was possible to select specific composts with different maturity status for use in some crop trials and the more controlled N-release tests. Table 6 in Appendix A shows six composts that were selected for specific field experiments in 2001 based on the partial maturity tests. Note the general trend of declines in NH_4-NO_3 ratio indicating increasing maturity. These data were, in part, used to rate the maturity of these composts.

One of the objectives in this study was to test how foolproof the maturity index approach can be by testing a variety of materials in which the conditions of composting and curing were known. It has been found that the multiple parameter test approach can reveal false positives that may be indicated by any one parameter. For example, a number of respiration test results (for stability) indicated that the composts were stable; however, testing for NH_4 (and indirectly NH_3) or the presence of NO_3 revealed that the materials were immature.

Due to weather and operational delays at one farm in the fall of 2000, researchers had opportunity to continuously evaluate a material during the composting, curing, and storage processes, where most of the conditions were known. Repeated samples were collected from this blend stockpile prior to application in four different crop trials. Table 8 in Appendix A summarizes the changes in selected compost characteristics and maturity status. Sample 1 was taken at the producer's site after four to five weeks of composting, while samples 3–8 were collected from the stockpile at the grower's field.

Note that there were few changes in the C/N ratio during an 8-month sampling period. Conversely, characteristics most indicative of the state of decomposition, reflecting increased maturity up to the 6-month sampling date, are as follows:

1. Decreasing carbon dioxide evolution as a measure of the quality and stability of organic matter.
2. Seed germination and vigor in relation to NH_4-NO_3 levels.
3. Decreased soluble salt levels.

At first, the 8-month sample analysis appears to be inconsistent when comparing the stability determination to the NH_4 levels and germination/vigor test results. Researchers assume that as the stability test indicates increased stability of organic matter with time, there would be a concurrent increase in NO_3-N and a decrease in NH_4-N. However, the results shown here demonstrate improper curing of this compost.

Optimal curing of compost requires occasional aeration and maintenance of adequate moisture (greater than 30 percent). During the winter, the stored compost continued to decompose and generate internal heat sufficient to drive off moisture. As the moisture content decreases to 25 percent, then to 15 percent, microbial activity is reduced. Additionally, there was no aeration of the stockpile during the winter, and that led to high NH_3 and reduced seedling vigor in the last sample.

These analyses disprove prior assumptions concerning the interpretative value of the C/N ratio and total nitrogen content of composts. In much of the past literature, the C/N ratio has usually been assumed to be an indicator of maturity. However, researchers found no correlation between C/N ratio and maturity as defined/assessed by the maturity tests and index used.

Nitrogen-Release Tests

These tests were carried out over differing time periods in seven fields between 1999 and 2001. Combined with the results from more 'controlled' tests they provide some preliminary insights as to how the initial feedstock and maturity of compost may impact N behavior in different soils. By burying soil with compost in plastic bags researchers were able to measure the inorganic N (as NH_4 and NO_3) that accumulates with time in due to mineralization, ammonification, and nitrification (see glossary for definition of terms). As discussed earlier, the majority of the N absorbed by plants is in the inorganic forms, NH_4 and NO_3. These forms of N result from the conversion of more complex organic N compounds in soil organic matter and plant/animal residues to these simpler inorganic forms (mineralization).

Generally, the manure-based blends were superior to green-waste compost in providing readily available N in all four soil types. Figures 1–6 in Appendix B demonstrate the patterns and quantity of N release from the longest field tests. Figure 3 shows that even when total N applied in composts was the same, the blend compost (#14) potentially provides more available N. The curved lines in these graphs represent the best mathematical fit between inorganic N release and time of test. Here the shape of the curves is used to suggest the potential pattern of N release as affected by compost characteristics and maturity. The pattern and magnitude of N release is also related to soil temperature, moisture, and tillage.

The field tests occurred during different times of the year and for differing lengths of time. Mature composts that had a higher NH_4-N content were generally the materials that caused the greatest increases in soil inorganic N in short-, medium-, and long-term tests. Figure 7 uses a straight-line depiction to show the magnitude of the increases from poultry-manure compost (NH_4-N = 5578 ppm) during the first week in the coarse sandy loam soil as compared with the blend (#18=240 ppm) and green-waste compost (#1= 22 ppm). Conversely, the blend (#14) used in the tests shown in Figure 3 had no measurable NH_4-N and did not cause rapid increases in soil inorganic N during the first week.

Early increases in available soil N are initially largely due to the NH_4- and NO_3-N content of the composts. After one week, much of the recovered inorganic N in soil samples was in nitrate- rather than NH_4-N form, suggesting the rapid conversion of the NH_4 contained in the composts. In most cases, continued mineralization of the organic N in these materials continued to increase the amount of inorganic N in the bagged and buried soils. However, there was no correlation or predictive relationship between either NH_4- or NO_3-N levels in the compost and the percentage of total N released.

Only one compost caused a long-term immobilization or reduction in available soil N based on N-release tests. This occurred with a green-waste compost (#2) that was rated mature by determination of the NH_4- to NO_3-N ratio. However, it was known that this was an old material that had been purchased at a discount and then stockpiled by the grower. This compost also had the lowest organic matter content (less than 30 percent) of any material tested during this study. Short-term nitrogen immobilization was also observed with a very mature blend compost (#14 shown in Figure 3). A controlled test (identical measured amounts of compost and soil held at 25 +/- 5 degrees Celsius) where the coarse (greater than 2mm) and fine (less than 2mm) fractions of this compost were added to soil found that the fine fraction caused most of the N immobilization. The coarse fraction contributed to available soil N initially, but there were no further increases or reductions during another 50 days of testing.

The results suggest that very well-cured or old composts, while perhaps an important source of humic substances and beneficial microorganisms, will have a lower N-supplying power. Immature green-waste compost can clearly immobilize variable amounts of N immediately following soil incorporation (#6 shown in Figure 2). This may have little significance when compost is applied in the fall prior to spring cropping. However, as shown in Figure 3, an immature green-waste compost (#4) did not provide more N than soil alone and substantially less than either a maturing green-waste material or a very mature blend.

Timing and magnitude of N release will be critical for the grower that purchases compost for some enhancement of N supply. While this may be primarily a concern for certified organic producers, this can be important for conventional growers attempting to increase N fertilizer efficiency. Table 9 in Appendix A demonstrates changes in the average daily N release rate for soil alone and soil with compost during the winter and the early- and late-spring periods. The influence of time and soil temperature are apparent as the N release rate declines due to lower soil temperatures in the winter, then increase later in the spring. Note that much of the N release occurred after the harvest of an early spring lettuce crop and prior to the planting of a second rotation crop. Typically a conventional grower would not account for this residual N in estimating N fertilizer needs for the following crop. In some cases, such as mature blends, this available N could be substantial.

Attempts to clearly distinguish the impact of composts on soils of different textures were less than successful for reasons discussed earlier. Differences in soil temperature between fields located in coastal and inland areas and the variable effect of decomposing crop residues were factors that confound the comparisons. Researchers were able to perform one more controlled comparison in which identical amounts of compost were added to three different soils and incubated in plastic bags indoors. A mature and an immature manure blend were each added to sandy loam-, loam-, and clay-texture soils, and the results suggest that after 90 days more nitrogen would be released from the loam soil (Figure 8). However, without more rigorous testing and comparisons, it is difficult to come to any conclusions concerning the influence of soil texture or type.

Figure 9 compares the differences in the percentage of compost total N released in the field tests, rather than the actual amount (as shown in Table 4). Both examples demonstrate not only the superior N-supplying power of the blends, but also show how maturity influences this characteristic. Manure blend composts typically had higher total N contents in comparison to green-waste composts. Therefore, mature blend composts will be the best choice for a grower seeking to increase short- and medium-term N availability in soil.

Table 4: Nitrogen Release in Relation to Compost Maturity Index Rating

Compost Maturity		Percent N Release	lb N/Ton
		Blend Composts	
VIM		21 a*	8.0 a
VIM		42 c	14.3 b
MM		56 b	22.5 c
M		41 c	23.8 c
M		42 c	15.1 b
M		35 c	9.5 b
VM		24 a	9.1 a
	Average	**37.3 A**	**14.6 A**
		Green-Waste Composts	
VIM		22 a	3.5 a
IM		18 a	4.7 a
MM		30 a	10.8 b
M		42 c	14.3 c
M		30 a	7.8 a
M		34 b	8.8 b
VM		(-)16 d	(-)4.5 d
	Average	**22.9 B**	**6.5 B**

VIM: Very Immature
MM: Moderately Mature
VM: Very Mature

*In the sections for each compost type, values with different lower case letters indicate statistically significant differences between measured compost parameters. (For example, there were three groupings indicating percent N release in the Blend category—a, b, and c. Statistically, each of these groupings differs significantly from the other two.) Within each parameter column, values with different upper case letters indicate statistically significant differences between compost types for the "Average" values.

Analysis of Crop Trials

Crop response to compost applications was variable. Yield increases were observed in early spring lettuce, winter cabbage, mid-season celery, and early- and mid-season baby greens. Table 10a shows selected characteristics of composts applied to a sandy loam soil in the fall of 1999 prior to planting of spring lettuce. Table 10b compares spring head lettuce yields following compost applications and two N fertilization levels. While weight per head was not affected by compost application, there were small increases in the percentage of marketable heads (cut percent) in both compost treatments at the lower N fertilizer level. There was significantly greater yield in the blend (#16) compost plots due to higher plant populations. This lettuce crop had large stand losses due to a currently unidentified fungal rot that affected a number of lettuce fields (primarily romaine) in the region in 2000. The damage resembled that caused by Fusarium wilt and suggests that the mature blend compost may have reduced infection of the crop. Table 11 shows that there was significantly less loss to this disease where the mature blend compost was applied in comparison to the immature green waste (#6) compost. The field N release tests (Figure 2 and Table 9) suggested that the blend compost could have supplied up to 65 pounds of N per acre between application and crop harvest.

Compost was incorporated to a 3-inch depth in small plots in the same field in late December 2000. Table 12a shows selected compost characteristics, and Table 12b gives the yields for the early spring lettuce crop. In this season there was consistent response to compost. The same fungal disease was apparent in this field and both compost treatments resulted in numerically, but not statistically, lower stand losses in comparison to the check (no-compost) plots. This crop was harvested for the export market. The lower cut percent in both compost treatments was due to a larger number of large “puffy” heads that did not meet the quality (small, dense) required for the export market.

Table 13a shows the characteristics of three composts applied two weeks prior to the planting of mixed baby greens in early summer 2000. The intent of this trial was to intentionally compare composts of different maturity. Table 13b shows the yields of baby lettuce on a fine sandy loam soil following compost applications of 8 tons per acre in early summer. All plots also received 101 pounds of fertilizer N per acre as pre-plant and top dressing. The best yields in this 30-day crop occurred in plots that received mature green waste (#3) compost, while the lowest occurred in plots where immature green waste (#4) compost was applied. Similarly, total N uptake by lettuce leaves was highest in the mature green waste plots and lowest with the immature material. The field N-release tests (Figure 3) suggest that the mature green waste may have increased soil inorganic N by as much as 30 pounds per acre over the check during the first 50 days following incorporation, while there may have been no net release from the immature material in the same time period.

Table 14 shows the yields of baby lettuce in a separate field strip trial where the equivalent of 5 tons per acre was applied and incorporated to a depth of 3 to 4 inches on shaped 80-inch beds. This was done at the interest of the grower to determine if these treatments would reduce soil crusting and improve germination and stand uniformity. Both compost treatments that used the same very mature blend (#14) and the immature green-waste material depressed yields of baby lettuce. The plants in the immature-compost (#4) treatment also had significantly lower N content in the leaves, which suggests immobilization of soil and fertilizer nitrogen. Conversely, the treatment did not reduce the leaf N content or total N uptake. The field N-release tests (Figure 3) from the trial shown in Table 13b suggest that there may have been reduced N availability in the early stages of crop development. Indeed, there was noticeably slower emergence and early growth of plants in both compost treatments.

Tables 15a and 15b compare baby spinach yields in a double crop in the same field as the above-mentioned baby lettuce trial. This crop was planted over three weeks after compost applications and the results were a bit different. Here, for the first crop, the greatest N uptake occurred in the blend (#14) and moderately mature green-waste (#3) treatments. Leaf N content was highest in the mature green-waste plots. The field N-release tests (Figure 3) suggest that after 50 days inorganic N release may have been highest in these two treatments during this period. The second crop growing in the plots had yields equivalent to the check and immature green-waste treatment. Again, the field N-release tests indicate a delayed, but significant increase in soil inorganic N in the soil with the immature material during the time of the second baby spinach crop.

Table 16a shows selected characteristics of compost that was applied in November 2000 to the same sandy loam field used for the previous baby green trials. Table 16b compares the yields for the two baby spinach crops in spring 2001 (immature blend #17 and moderately mature green waste #7). Figure 5 suggests that the green-waste compost did not begin to release N until mid-spring of 2001. Conversely, greater mineralization from the blend compost immediately after incorporation may have been lost to the crop due to leaching/denitrification during the winter. The blend compost significantly reduced total N uptake by the first crop (May 4, 2001), but did not reduce the yield in comparison to the check treatment. The following crop (June 21, 2001) had a significantly lower N concentration, but due to increased yield had total N uptake similar to that of the check plots. The green-waste compost increased the yield and N uptake by the first crop. However, the second-rotation crop yield was lower than other treatments, in part due to a poor stand due to seedling loss from *Pythium sp.*, or damping off disease. Researchers also noted that soil in two of the green-waste plots was compacted. The soil compaction was caused by worn knives in the rotovator (mulcher) used for minimum tillage soil preparation between crops.

Table 17a shows the characteristics of four composts incorporated to a 4-inch depth one week prior to planting mixed baby greens in the summer of 2001. The initial intent was to apply immature and mature composts of both types and measure response in the same crop. However, a change in crop planting plans resulted in two of our treatments in chard and the remaining in mazuna-type mustard. A very immature green-waste (#11) compost reduced the yield and total N uptake of mustard, while an immature blend (#22) compost actually increased N concentration and N uptake in baby chard (Table 17b). In comparison, the mature green-waste compost (#12) added about 110 pounds of N, while the immature blend (#22) added about 230 pounds of N per acre. However, the most important property may have been the NH_4-N content that was 27 ppm in the green waste compost and 2,477 ppm in the blend. This high inorganic N likely increased the early absorption of N by the chard crop.

Table 18a shows selected characteristics of composts applied at 5 tons per acre to clay soil in the fall of 1999. The grower did not want to leave an untreated section of this field, so only compost plots could be compared. Tables 18b and 18c give cauliflower and romaine yields in this double crop rotation. This is the field where an old (more than one year), mature green-waste compost (#2) with less than 30 percent organic matter was used. No differences were measured in yield of either crop, even where field N-release tests (Figure 1) suggested continued immobilization of soil inorganic N during the cauliflower crop sequence. Because the grower's field manager neglected to contact researchers, the romaine crop was harvested prior to final sampling. Therefore, only estimates of plant population, the percentage of marketable plants, and the incidence of lettuce drop (*Sclerotinia minor*) are given.

Table 19a shows selected characteristics of three composts applied at 8 tons per acre three days prior to planting in the spring of 2000. Table 19b compares the yields of blanched frisse yields in an organic field with coarse sandy loam soil where applications were 8 tons per acre. While the field N-release tests (Figure 4) included a check treatment, the actual field trial did not have such a treatment, as compost is the primary fertility input for this grower.

This is the field where the immature poultry-manure compost was applied four days prior to planting. Yields were depressed in this treatment in comparison to the plots receiving mature blend (#18) and green-waste (#1) compost. While the percentage of marketable plants was higher, the actual stands were dramatically lower in the poultry-manure compost treatment. Despite the clearly superior N-supplying power of the material (Figure 4), researchers believe that the extremely high levels of NH_3-N in this material reduced seed germination. The high NH_3-N occurrence was more likely in this production system than others because the materials were incorporated to only a depth of 5 to 6 inches prior to listing of beds. Additionally, seeds were planted within only three days of incorporation, probably before NH_3 was converted in soil. Subsequent probing of soil during this crop showed high concentrations of compost in soil. The best yields occurred with the two mature composts due to better stands, although the percentage of marketable plants was lower.

Table 20a shows selected characteristics of composts applied in early April 2001 to a new field converted from walnut production. Table 20b compares the yield of celery planted in May following the application of 8 tons of compost per acre. The blend (#21) and green-waste (#10) composts had been stockpiled at this ranch site over the winter prior to application. Yields and quality of celery were significantly higher following the application of these moderately mature to mature materials. While the crop was produced for a specific processed product market, it was noted that plants in the compost-amended plots had a greater crown diameter (greater than 3 inches on average) in comparison to the check treatment. There was no difference in crop height or plant populations.

Table 21a shows selected characteristics of composts applied at 5 tons per acre in early fall 2000. Table 21b compares yields for head lettuce harvested in July 2001. This field and crop were impacted by weather events during the winter due to its proximity to the mouth of the Pajaro River. A high runoff event occurred before the annual winter sandbar had been breached, causing salt water to inundate part of this field. The field could not be planted until May, and then subsequent germination and development of the crop was hindered in the areas where saltwater had infiltrated the soil. Harvest plots were located in areas of each replicate block that exhibited the least problems with plant populations or stand uniformity. Ultimately, only a portion of the field could be harvested for the fresh-wrap market, while the remainder of the field was harvested for the bulk-shred market.

The immature blend (#19) compost released a large (42 percent) portion of its total N content over a 210-day field N-release test. However, as compost was applied very early in the fall when soil temperatures were still warm, there was a significant amount of available N in soil prior to the rainy season. There was a reduction in plant loss from lettuce drop disease (*Sclerotinia minor*) in the blend compost treatment. Again, there was no apparent yield benefit for a crop following the incorporation of immature composts, even months prior to crop establishment.

Table 22a shows selected characteristics of composts applied at 5 tons per acre and incorporated to a 3-inch depth in December 2000, prior to transplanting the crop in January. Table 22b shows the yields from the first cut of the field in early May. Unfortunately, the second harvest was completed 20 minutes before researchers arrived at the field. Results from the first cut indicate increased yield due exclusively to a higher number of marketable heads in both treatments in which either moderately mature blend (#20) or mature green-waste (#14) compost was incorporated to a shallow depth prior to transplanting.

Costs and Returns

This study has addressed two important factors contributing to compost quality for vegetable production, maturity, and raw compost feedstocks. Historically, the variable and sometimes negative impacts of compost on crop production create a certain level and perception of significant economic risk for growers. While many growers will agree that the quality of compost must be high, fewer have been able to define the appropriate quality for their specific crop systems. In some cases, conventional growers may apply compost with the simple objective of returning organic matter “lost” during the season as a substitute for manure. This study has found that compost maturity is an important factor even for these conventional vegetable growers.

Costs for compost application include cost of the material, hauling costs to the field, and costs for spreading the material. Costs for compost delivered to growers’ fields ranged between $20 and $25 per ton, while spreading cost ranged between $8 and $10 per ton. Using the median cost for each, a 5-ton-per-acre application cost $157.50 per acre, and an 8-ton application cost $252 per acre. Table 23 in Appendix A shows some potential increases and decreases in revenues (after accounting for compost costs) based on the results of selected crop trials. This analysis assumes all other production input costs (for labor, fuel, fertilizer, etc.) to be fixed, while considering measured yields and a reasonable range of market prices. Revenue increases are related to higher yields in compost treatments in comparison to the check treatments in these crop trials. Decreases reflect results where crop yields were statistically identical or where compost treatments are associated with lower yields.

Results from the analysis of two baby spinach rotations are shown in Table 23. In both cases, a baby spinach crop was planted two to three weeks after one previously planted in the same field. Compost was applied prior to the first crop planting (in both cases two weeks prior to planting), but not for the second planting.

A potentially important difference (aside from different growing seasons) is the type of soil tillage that was used between crop plantings. In one case, conventional tillage was used (disking of crop residues, deep ripping, then disking two times, and bed preparation using mulcher);in the other, minimum tillage was used (special disk and chisel tool used, followed by mulcher). Conventional tillage breaks down the previous planting bed, while minimum tillage maintains the bed shape and location. Compost (small sticks) was visible on the surface of beds prepared with minimum tillage, but was not observed on beds following conventional tillage. The differences in yield results in this trial comparison hint at the importance of tillage method and the depth and placement of compost.

Generally, these and other data not shown in Table 23 (including the frisse crop in the only certified organic field trial), suggest that mature composts provide the most reliable return and therefore the lowest potential monetary risk to a grower. Many of the trials in which immature compost was incorporated resulted in no increased return or, at worst, reductions in per-acre revenues. In some cases, after accounting for compost and application costs, there were substantial gains in potential net revenue. However there were also significant reductions in potential revenues when immature compost was used.

Soil and Nutrient Conservation

During the planning stages of this project, one of the project partners noted that there are currently no federal, State, or local guidelines for compost specifications and use as a soil/nutrient conservation practice. At the conclusion of this study, the question remains unanswered as to whether municipal organics recovery and agricultural reuse could provide tangible benefits related to water quality objectives.

It was found that immature compost incorporated in the fall can reduce soil nitrate-N during the winter. This situation could reduce leaching and/or runoff losses during the rainy season. However, it was found that immature composts would not provide adequate economic returns to a grower.

Conversely, early fall applications of maturing or mature composts (particularly blends) when soil is still warm typically lead to rapid increases in soil NO_3-N that could increase leaching during the rainy season. Further, the higher phosphorus content of blend composts may be a new challenge for growers as new efforts and “rules” to control phosphorus levels in surface waters are implemented. Therefore, the potential role of compost use for soil and nutrient conservation is not clear at this time.

Conclusions

In summary, this study has provided new quantitative information regarding compost quality for vegetable crop production. Following are important project findings:

- Mature or maturing composts more consistently result in positive crop yield response in comparison to immature or very mature composts.
- Composts produced with poultry manure and green waste appear to provide more available N in comparison to green waste composts.
- Manure blends may have a higher percentage of smaller-sized ‘reactive’ particles.
- Immature and very mature composts may reduce inorganic soil N long enough to have negative impact on production in conventionally farmed soils.
- High NH_3-N levels associated with immature manure-based composts can reduce seed germination and crop productivity under certain circumstances.
- Mature composts can provide significant N dependent on timing of applications.
- Timing and depth of incorporation of compost applications will have direct effect on crop response.
- The maturity index is a useful tool to assess compost quality.

Matching the right compost quality for specific agronomic objectives remains a challenge to vegetable growers in this region. This study has successfully linked an objective quantitative method for assessing the maturity status with traditional chemical and physical properties analysis to characterize the potential N release from composts. As growers and producers become more attentive to compost quality, there should be a concurrent reduction in the economic risk that has been associated with compost use for vegetable crop production.

Abbreviations and Acronyms

Compost Maturity and Stability Ratings

VIM	Very immature
IM	Immature
M	Mature
MM	Moderately mature or maturing
MS	Moderately stable
S	Stable
US	Unstable
VM	Very mature
VUS	Very unstable
VS	Very stable

Units

ppm	Parts per million
ml	Milliliter
mm	Millimeter
mmhos	Millimhos
µm	Micron

Other Terminology

BIO-C	Proprietary test for biologically available carbon that differs from a standard respiration test.
C	Carbon
$CaCl_2$	Calcium chloride
CO_2	Carbon dioxide
KCl	Potassium chloride
N	Nitrogen
nd	Not determined
NSD	No statistical difference in yields in comparison to check
P	Phosphorus
K	Potassium
VS	Volatile solids
NH_3 –N	Ammonia nitrogen
NH_4 –N	Ammonium nitrogen
NO_3-N	Nitrate nitrogen

Glossary of Terms

40- or 80-inch bed – The distance between the centers of raised planting beds in a field that allows for efficient, repeated, controlled equipment operations for tillage, weeding, spraying, and harvest.

Ammonia – A volatile gaseous form of inorganic nitrogen.

Ammonium – A water-soluble form of inorganic nitrogen created by the reaction of ammonia with water at a pH lower than 8.2. A building block for amino acids, proteins, and DNA.

Ammonification – The conversion of simple organic nitrogen compounds (such as amino acids) to ammonium by soil microorganisms.

Available soil nitrogen–Largely the inorganic forms of nitrogen both soluble and bound to soil particles.

Baby greens – Leafy greens (such as lettuce and spinach) planted densely (greater than 1 million seeds per acre) and harvested at very young growth stage, largely for pre-packaged consumer salad markets.

Biologically available carbon (BIO-C) – This refers to the portion of organic carbon in a compost sample that is readily available to microorganisms. The respiration test involves additions of inorganic nutrients to ensure that the only limiting growth factor is easily decomposable carbon.

Biological properties – Properties of soil and compost that reflect the presence, type, activity, and/or by-products of microorganisms, insects, worms, and animals.

C/N ratio – The percentage of organic carbon to total nitrogen in soil and compost.

Cardy meter – A hand-held device that allows for the analysis of nitrate or potassium in water or a liquid extraction of soil or compost.

Check – Field trial treatments where no compost was applied.

Chemical properties – Soil and compost properties based on the quantity and types of elements (such as sodium and chloride) and compounds (such as organic and inorganic) found in each.

Complete block design – A type of experimental design that groups that arranges various “treatment” replicates into discrete groups to control for effects other environmental or physical factors and to enhance the “strength” and validity of statistical analysis.

Compost quality – The sum of compost physical, chemical, and, in some cases, microbiological properties that provide the best performance for a specific end use (for example, soil conditioning, turf topdressing, and container mix).

Conventional farming - The production of food and fiber crops using synthetically produced inorganic and organic chemicals for soil fertility enhancement and pest control. Habitat manipulation (for pest control) and the use of bio-engineered materials may also be used.

Cured compost – A stabilized and mature compost. Following the high temperature (thermophillic) and rapid decomposition phase of composting, the material is then allowed to continue decomposing at a slower rate until internal pile temperatures approach air temperature and odors are absent.

Damping off disease – A common soil microbial infection of germinating seeds that results in plant loss.

Fusarium wilt disease – A common soil fungus that can infect the roots and water conducting tissue of many crop plants causing growth reduction or death.

Heavy metals – Metallic elements that have a high atomic weight and are known to be potentially toxic to plants and animals (such as cadmium and lead). These elements are regulated by the U.S. Environmental Protection Agency.

Humic substances – Complex organic compounds formed by microbial and inorganic chemical reactions in soil and compost that are resistant to further rapid decomposition. Humic substances contribute to the nutrient-holding capacity of soils and compost and include humic acids, fulvic acids, and humans.

Lettuce drop disease – A soil fungus that infects the water and nutrient-conducting tissues of many types of lettuce causing the plants to wilt or ultimately drop after the root connections are severed.

Minimum tillage – Equipment and methods that prepare soil for planting with a reduced number of tractor operations as compared to conventional plowing, deep ripping, and disking of soil.

Mineralization – The conversion of more complex organic compounds to simpler inorganic forms.

Nitrogen cycle – Describes the complex interactions and movement of nitrogen between the atmosphere, soil, and water. Nitrogen undergoes many changes in form (organic to inorganic) and *oxidation state* (see definition), and many of these changes are caused by the actions of microorganisms. In soil the important processes are nitrogen mineralization, immobilization, ammonification, and nitrification (see definitions).

Nitrogen immobilization – The reduction in plant available forms of soil nitrogen (ammonium, nitrate, and simple organic nitrogen compounds) due to absorption and use by soil microorganisms.

Nitrogen mineralization – Nitrogen occurs in many different organic and inorganic forms in soils and compost. Microorganisms control this conversion of organic forms to inorganic or mineral forms.

Nitrogen release – Refers to the total amount of inorganic nitrogen appearing (mostly due to mineralization) in soil with time. This occurs in soils with and without the addition of compost.

Nitrification – The conversion of ammonium-nitrogen to nitrate-nitrogen by a specific group of soil microorganisms.

Nitrogen uptake – The root or leaf absorption of inorganic and organic forms of nitrogen by plants.

N immobilization – The absorption of inorganic forms of nitrogen in soil and compost by microorganisms, thereby preventing loss and/or absorption (uptake) by plants. Typically resulting in the reduction or elimination of available nitrogen in soil.

Organic amendments – Organic materials (such as compost and raw waste materials) that may be applied soil to enhance physical, chemical, and/or biological properties (fertility) for crop/plant production.

Organic carbon – A specific form of carbon defined by its oxidation state or charge based on balance of protons and electrons.

Organic farming – The production of food and fiber crops largely without synthetically produced chemicals but with approved naturally occurring inorganic and organic materials for soil fertility enhancement and pest control. Habitat manipulation maybe used for pest control, but bio-engineered materials are not allowed by law.

Organic matter – Any compound containing organic carbon (such as sugars, humic substances, and DNA).

Organic matter decomposition – Similar to mineralization, the microbial or chemical conversion of organic compounds to energy, microbial cells, and carbon dioxide resulting in a reduction of total organic matter in soil or compost.

Oxidation state – Many elements (such as nitrogen or carbon) undergo changes related to the number of electrons associated with each atom. This alters how they react with other elements.

Physical properties – Soil and compost properties such as texture, structure (shape and arrangement of particles), air spaces, and moisture.

Particle-size distribution – The measured percentages of sand-, silt-, and clay-size solid particles in soil (see soil texture).

pH – A measure of the relative acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing (7–14) with increasing alkalinity and decreasing (1–7) with increasing acidity.

Phytotoxic – A chemical or element toxic to plants.

Plant crown diameter – The diameter at the base of a plant (such as celery) just above the soil surface.

Reflectometer – A device that measures a variety of elements and compounds by measuring and comparing the refraction of light from a liquid or solid sample in comparison to a ‘zero’ standard.

Residual soil nitrogen – The available soil nitrogen remaining following a crop or prior to the fertilization and establishment of a crop.

Respiration – The biological conversion of organic compounds to energy and carbon dioxide.

Soil texture – A physical property of soil determined by the range and distribution percentage of solid particles, where a size less than 2 μm = clay, 2 to 50 μm = silt, and 50 μm to 2 mm = sand. Major soil texture classes may be described as sandy, loamy, or clayey (for example, sandy loam or clay loam). Clay soils have at least 40 percent of clay-size particles, silt soils have 80 percent silt-size particles, and sandy soils have at least 40 percent sand-size particles.

Soluble salts – Those largely inorganic compounds (such as sodium chloride) that are water-soluble and, therefore, dissolved in soil and compost.

Split-plot design – A type of experimental design where the main treatment units or plots are physically split to allow for further comparison of additional “sub-treatments”.

Stand – Plant population (number of living heads per acre).

Statistically significant – A specific mathematical test to determine a true numerical difference between experimental “treatments” based on the average on replicated measurements.

Supernatant – The clear liquid solution that forms above settling soil or other particles in a tube or other container.

Total nitrogen - The combined quantity of all organic and inorganic forms of nitrogen found in soil or compost.

Volatilization – Conversion of a solid or dissolved form of an element or compound (such as. ammonium) to a gaseous form (such as ammonia) that can escape to the atmosphere. Or any loss of a soil gas to the atmosphere.

Volatile organic acids – Weak acids containing carbon that may volatize under certain conditions.

Appendix A
Tables 5–23

General Table Notes:

(1) For Tables 5, 10b, 12b, 13b, 14, 15a, 15b, 16b, 17b, 19b, 21b, and 22b, values followed by different lower-case letters indicate statistically significant differences between measured compost parameters.

(2) Legend for Maturity Levels:

VIM: Very immature
MM: Moderately mature or maturing
M: Mature
VM: Very mature

Table 5. Comparison of Selected Properties of Blend, Green-Waste, and Poultry-Manure Composts (25 Samples)

Sample	Organic Matter (%)	Total N (%)	C/N	NH_4 (ppm N)	pH	Salts (mmhos)	N+P+K (%)	Moisture (%)	<2mm (%)
Blend	49.5 a	2.0 a	13	734 a	8.6 a	8.3 a	6.8 a	30.9	79.2 a
Green Waste	40.3 b	1.6 b	15	231 b	7.2 b	4.0 b	4.2 b	29.6	72.7 b
Poultry Manure	40.0	3.9	7	5578	9.2	14.1	7.6	37.5	71.4

Table 6. Partial Maturity Characterization of Six Composts Used in Crop Trials and Nitrogen-Release Tests in 2001

Compost	NH_4:NO_3	Total N (%)	C/N	pH	EC (mmhos)
Blend					
VIM	130.4	1.7	18	8.6	8.9
MM	20.0	2.3	14	9.3	5.8
M	0.83	2.0	11	8.4	5.4
Green Waste					
VIM	4.2	1.2	29	5.3	3.4
M	0.31	1.3	17	7.5	2.3
VM	0.03	1.6	10	7.8	3.4

Table 7. Comparison of Maturity Index Results for Composts

Compost	C/N Ratio	Stability		Germination	Vigor	NH_4-N	NO_3-N	Ratio
		Respiration Test	BIO-C	(%)		(ppm)		
Green Waste								
1-00	12	S	S	88	75	22	436	0.05
2-00	10	nd	nd	nd	nd	260	300	0.87
3-00	11	S	S	93	90	232	142	1.6
4-00	12	US	US	93	91	211	38	6.0
5-00	19	S	US	89	96	552	0.0	nd
6-00	23	nd	nd	nd	nd	480	0.0	nd
7-00	14	S	US	96	100	485	4	122
8-00	7	VUS	US	85	75	579	0.0	nd
9-01	14	nd	nd	nd	nd	61	159	0.38
10-01	10	VS	VS	100	100	96	784	0.12
11-01	29	nd	nd	nd	nd	139	33	4.21
12-01	17	nd	nd	nd	nd	27	88	0.31
13-01	11	nd	nd	nd	nd	25	876	0.03
Blend								
14-00	8	VS	VS	95	94	0	219	0.0
15-00	15	nd	nd	nd	nd	56	63	0.89
16-00	18	nd	nd	nd	nd	23	74	0.31
17-00	12	US	US	85	83	1306	0.0	nd
18-00	8	S	S	88	84	240	364	0.66
19-00	14	VUS	VUS	22	0	326	0.0	nd
20-01	12	VS	VS	81	25	618	110	5.6
21-01	10	VS	S	20	2	2082	339	6.14
22-01	18	nd	nd	nd	nd	2477	19	130
23-01	14	nd	nd	nd	nd	660	33	20
24-01	11	nd	nd	nd	nd	405	485	0.84
Poultry Manure	7	S	S	0	0	5578	0.0	nd

Table 8. Changes on Maturity Index Parameters During Storage of a Manure Blend Compost

Parameter	Sample (months)				
	1	3	4	6	8
Moisture (%)	32.6	25.5	25.0	15.8	25.5
Total Nitrogen (%)	1.9	1.7	1.9	2.3	2.0
C/N Ratio	13	14	12	12	10
NH_4-N (ppm)*	2106	1326	306	618	2018
NO_3-N (ppm)	0.0	0.0	0.0	110	339
Stability (mg CO_2/day)**					
Respiration	S	VUS	US	VS	VS
BIO-C	VUS	VUS	MS	VS	VS
Soluble Salt (mmhos)	11.4	10.3	8.2	5.9	5.8
pH	8.6	8.6	8.8	8.5	8.6
Germination (%)***	0	22	85	84	20
Vigor (%)	0	0	83	21	2

* Critical values for NH_4 are <100 ppm = very mature, 100-500 = mature, > 500 ppm = immature.
**Table 2 contains maturity ratings based on CO_2 tests (< 2 = very mature, 2 – 8 = mature, > 8 = immature).
***Table 2 contains maturity ratings based on seed germination (percentage based on control where >90% = very mature, 80-90% = mature, < 80% = immature).

Table 9. Timing of Nitrogen Release in Relation To Spring Lettuce Schedule in 2000 Season

Material	85 Days (Planting)		190 Days (Harvest)		240 Days		Post-Harvest (190 to 240 Days)	
	N Release		N Release		N Release		N Release	
	lb/Acre	lb/Day	lb/Acre	lb/Day	lb/Acre	lb/Day	lb/Acre	% Total Release
Sandy Loam Soil	13	0.15	75	0.39	110	0.46	0.84	38
Green Waste (VIM)	2	0.02	90	0.47	140	0.58	1.16	41
Blend (M)	45	0.53	110	0.59	188	0.78	1.70	45

Table 10a. Compost Characteristics for Spring Head Lettuce (Fall 1999)

Compost	C/N	Total N (%)	Stability	NH_3 (ppm)	NH_3:NO_3-N
Blend (M-16)	18	1.5	nd	23	0.31
Green Waste (VIM-6)	23	0.9	nd	480	nd

Table 10b. Spring Head Lettuce Yields Following Fall 1999 Application of Composts

Treatment	Stand	Cut %	Cartons 1st Cut	Cartons Total	Tons	Weight/Head (lb)
	---(per Acre)---					
None						
1N*	24,061 a	86.8 a	484 a	786 a	21.0 a	1.9 a
2N**	24,061 a	88.0 a	502 a	794 a	19.5 a	1.8 a
Blend (M)						
1N	25,536 b	91.7 b	590 b	879 b	23.0 b	2.1 a
2N	25,536 b	90.8 a	529 a	869 b	23.7 b	2.1 a
Green Waste (IM)						
1N	24,081 a	92.4 b	561 b	835 a	22.6 a	2.1 a
2N	24,081 a	87.0 a	463 a	786 a	21.0 a	1.9 a

Compost applied at 8 tons/acre. Blend = 210 lb N/acre. Green waste = 127 lb N/acre.
* 1N = 181 lb Fertilizer N
**2N = 203 lb Fertilizer N

Table 11. Dead or Dying Lettuce Plants Due to Unidentified Rot

	Replicate 1	Replicate 2	Replicate 3	Mean
	(per 3 beds at 290-ft length)			
None	152	248	147	182.3 a
Blend	55	114	83	83.0 b
Green Waste	117	274	152	181.0 a

Table 12a. Compost Characteristics for Spring Head Lettuce (Winter 2000-2001)

Compost	C/N	Total N (%)	Stability	NH_3 (ppm)	NH_3:NO_3-N
Blend (MM-20)	12	2.0	S	618	5.62
Green Waste (M-9)	14	1.3	nd	61	0.38

Table 12b. Spring Head Lettuce Yields Following Winter 2000-2001 Application of Composts

Treatment	Stand	Cut %	Cartons	Tons	Weight/Head
	-------------------------(per Acre)---------------------------				(Lb)
None	28,342 a	80.7 a	956 a	17.9 a	1.6 a
M. Blend (MM)	29,650 b	75.6 b	939 a	19.6 b	1.7 b
Green Waste (M)	28,560 a	74.5 b	887 b	15.9 a	1.5 a

Compost applied at 5 tons/acre. Blend = 200 lb N/acre. Green waste = 130 lb N/acre. Fertilizer = 167 lb N/acre.

Table 13a. Compost Characteristics for Mixed Baby Greens (Summer 2000)

Compost	C/N	Total N (%)	Stability (ppm)	NH_3	NH_3:NO_3-N
Blend (VM-14)	8	1.9	VS	0	0.00
Green Waste (MM-3)	11	1.8	S	232	1.63
Green Waste (IM-4)	12	1.6	US	211	5.56

Table 13b. Baby Lettuce Yields After Summer 2000 Conventional Incorporation of Composts

Treatment	Total N (%)	Harvest Weight	N Uptake
		----------------------(Lb/Acre)----------------------	
None	5.4 b	13,721 b	93 b
Blend (VM)	5.5 a	13,632 b	95 b
Green Waste (MM)	5.6 a	14,810 a	100 a
Green Waste (IM)	5.2 c	12,255 c	83 c

8 tons compost per acre. Blend = 184 lb N/acre. Green waste (MM) = 208 lb N/acre. Green waste (IM) = 190 lb N/acre.

Table 14. Baby Lettuce Yields Following Summer 2000 Surface Application of Composts

Treatment	Total N (%)	Harvest Weight	N Uptake
		---------------------(Lb/Acre)---------------------	
None	5.3 a	18,464 a	117 a
Blend (VM)	5.4 a	16,438 b	115 a
Green Waste (IM)	4.9 b	14,296 c	95 b

5 tons compost per acre. Blend = 115 lb N/acre. Green waste (IM) = 119 lb N/acre.

Table 15a. Baby Spinach Yields Following Pre-Crop Incorporation of Composts

Treatment	N %	Yield	N Uptake
		-------------- (Lb/Acre)-------------	
None	5.3 b	15,816 b	101 b
Blend (VM-14)	5.4 b	18,567 a	118 a
Green Waste (MM-3)	5.8 a	18,230 a	114 a
Green Waste (IM-4)	5.4 b	16,880 b	109 b

8 tons compost per acre. Blend = 184 lb N/acre. Green waste (M) = 208 lb N/acre. Green waste (I) = 190 lb N/acre.

Table 15b. Baby Spinach Yields Following Incorporation of Composts and First Baby Spinach Crop (2nd Rotation)

Treatment	Total N (%)	Petiole NO_3-N (ppm)	Yield	N Uptake
			------------(Lb/Acre)------------	
None	5.6 a	6,350 a	19,580 a	132 a
Blend (VM)	5.3 b	4,750 b	20,087 a	126 a
Green Waste (MM)	5.5 a	5,750 a	19,411 a	128 a
Green Waste (IM)	5.2 b	5,100 b	18,736 b	105 b

8 tons compost per acre. Blend = 184 lb N/acre. Green waste (M) = 208 lbs N/acre. Green waste (IM) = 190 lb N/acre.

Table 16a. Compost Characteristics for Spring Baby Spinach (Fall 2000)

Compost	C/N	Total N (%)	Stability	NH_3 (ppm)	NH_3:NO_3-N
Blend (IM-17)	12	1.9	US	1306	nd
Green Waste (MM-7)	14	1.4	US	485	121

Table 16b. Baby Spinach Response to Composts Applied in Fall 2000

Treatment	Total N (%)	Yield	N Uptake
		--------------------(Lb/Acre)--------------------	
Baby Spinach (5/4)			
Typical	4.31 a	10,551 a	66.1 a
Blend (IM)	3.61 b	10,194 a	52.0 b
Green Waste (MM)	4.18 a	13,346 b	81.0 c
Baby Spinach (6/21, post minimum tillage)			
Typical	5.22 a	13,974 a	87.5 a
Blend (IM)	4.29 b	14,581 b	82.8 a
Green Waste (MM)	5.06 c	12,320 c	74.8 b

Table 17a. Compost Characteristics for Mixed Baby Greens (Summer 2001)

Compost	C/N	Total N (%)	NH_3 (ppm)	NH_3:NO_3-N
Blend (IM-22)	18	1.7	2477	130.4
Blend (MM-23)	14	2.3	660	20
Green Waste (VIM-11)	29	1.2	139	nd
Green Waste (M-12)	17	1.1	27	0.31

Table 17b. Baby Spinach Response to Composts Applied in Summer 2001

Treatment	Total N (%)	Yield	N Uptake
		---------------Lb/Acre----------------	
Baby Chard (8/28)*			
No Pre-Plant N	4.02 a	9,430 a	45.5 a
Blend (IM)	4.84 b	9,320 a	58.6 b
Green Waste (M)	4.70 b	9,776 a	55.1 b
Baby Mustard (8/28)			
No Pre-Plant N	7.10 a	10,794 a	84.3 a
Blend (MM)	7.28 b	11,158 b	89.4 b
Green Waste (VIM)	6.62 a	9,320 c	67.9 c

*5 tons compost incorporated to 3-inch depth one week prior to planting of baby chard and baby mustard.
Blend (IM) =170 lb N/acre. Blend (MM) =230 lb N/acre. Green waste (VIM) =120 lb N/acre. Green waste (M) =110 lb N/acre.

Table 18a. Compost Characteristics for Cauliflower and Romaine Lettuce (Fall 1999)

Compost	C/N	Total N (%}	Stability	NH_3 (ppm)	NH_3:NO_3-N
Blend (M-15)	15	1.8	nd	56	0.89
Green Waste (VM-2)	10	1.4	nd	260	0.87

Table 18b. Spring Cauliflower Yields Following Fall 1999 Application of Composts

Compost	Cut %			Stand	Harvest Weight	
	First	Second	Third	(per Acre)	(lb/Head)	(Tons/Acre)
Blend (M)	43.4	63.1	85.1	15,246	1.5	11.43
Green Waste (VM)	40.7	62.1	82.1	14,810	1.4	10.38

5 tons compost/acre. Blend = 180 lb N/acre. Green waste = 140 lb N/acre.

Table 18c. Romaine Lettuce Yields Following 2000 Cauliflower Harvest and Fall 1999 Application of Composts

Compost	Cut %	Stand	Sclerotinia Loss
		---------------------- (per Acre)	---------------------
Blend (M)	71.8	52,423	230
Green Waste (VM)	70.2	52,550	361

Table 19a. Compost Characteristics for Blanched Frisse (Spring 2000)

Compost	C/N	Total N (%)	Stability	NH_3 (ppm)	NH_3:NO_3-N
Poultry (VIM)	7	3.9	S*	5578	nd
Blend (M-18)	8	2.9	S	240	0.66
Green Waste (M-1)	12	1.7	S	22	0.05

* False positive due to microbial toxicity from NH_3, etc.

Table 19b. Blanched Frisse Yields Following Spring 2000 Incorporation of Composts

Treatment	Stand	Cut%	Total Weight	N uptake
	-------------(per Acre)-------------		------------------(Lb/Acre)---------------	
Poultry (VIM)	12,052 b	87.0 a	7,549 b	nd
Blend (M)	18,731 a	73.0 b	11,212 a	nd
Green Waste (M)	16,843 a	75.8 b	9,575 a	nd

8 tons compost incorporated to 6-inch depth one week prior to planting.
Poultry = 390 lb N/acre. Blend = 256 lb N/acre. Green waste = 164 lb N/acre.

Table 20a. Compost Characteristics for Summer Celery (Spring 2001)

Compost	C/N	Total N (%)	Stability	NH_3 (ppm)	NH_3:NO_3-N
Blend (MM-21)	10	2.3	VS	2082	6.14
Green Waste (M-10)	10	1.4	VS	96	0.12

Table 20b. Summer Celery Yield in Response to Spring 2001 Compost Applications

Treatment	Yield	
	Lb/Plot	**Lb/Acre**
Typical N Program	110.1	87,303 a
Blend (MM)	136.3	118,898 b
Green Waste (M)	129.8	113,160 b

8 tons compost/acre. Blend = 274 lbs N/acre. Green waste = 147 lbs N/acre.

Table 21a. Compost Characteristics for Summer Head Lettuce (Fall 2000)

Compost	C/N	Total N (%)	Stability	NH_3 (ppm)	NH_3:NO_3-N
Blend (VIM-19)	14	1.7	VUS	326	nd
Green Waste (IM-5)	19	1.3	US	552	nd

Table 21b. Summer Head Lettuce Following Fall 2000 Application of Composts

Treatment	Stand	Cut %	Tons	Weight/Head	Sclerotinia
	---------------- (per Acre)	-------------------		(Lb)	(%)
None	27,865 a	90.6 a	20.2 a	1.6 a	3.9 a
Blend (VIM)	26,904 a	95.4 b	20.5 a	1.6 a	1.0 b
Green Waste (IM)	27,865 a	86.9 c	19.4 a	1.6 a	3.6 a

Both composts applied at 5 tons/acre

Table 22a. Compost Characteristics for Spring Cabbage (Winter 2000-2001)

Compost	C/N	Total N (%)	Stability	NH_3 (ppm)	NH_3:NO_3-N
Blend (MM-20)	12	2.0	S	618	5.62
Green Waste (M-14)	14	1.3	nd	61	0.38

Table 22b. Spring Cabbage Yields Following Winter 2000-2001 Application of Composts

Treatment	Stand	Cut %*	Tons	Weight/Head
	----------------------(per Acre)------------------------			(Lb)
None	22,649 a	55.9 a	17.9 a	2.8 a
Blend (MM)	23,061 a	71.4 b	23.6 b	2.9 a
Green Waste (M)	23,473 b	68.1 b	20.8 b	2.6 a

Composts applied at 5 tons/acre and incorporated to 3-inch depth.
Only first cuts were sampled.

Table 23. Returns Associated With the Use of Mature and Immature Composts

Cropping Details			
Price per Carton/Weight	**$5/Carton**	**$10/Carton**	**$20/Carton**
		Revenues	
Lettuce (8 tons/acre)*			
Blend (Mature)	$465	$930	$1860
Green Waste (Very Immature)	NSD	NSD	NSD
Lettuce (5 tons/acre)			
Blend (Immature)	NSD	NSD	NSD
Green Waste (Immature)	-$345	-$690	-$1035
Price per Carton/Weight	**$0.25/Lb**	**0.50/Lb**	**0.75/Lb**
		Revenues	
Baby Spinach (8 tons/acre)			
Blend (Very Mature)	$688	$1376	$2063
Green Waste (Mature)	$604	$1208	$1811
Green Waste (Immature)	NSD	NSD	NSD
Baby Spinach (2nd rotation)			
Blend (Very Mature)	NSD	NSD	NSD
Green Waste (Mature)	NSD	NSD	NSD
Green Waste (Immature)	NSD	NSD	NSD
Baby Spinach (5 tons/acre)			
Blend (Very Immature)	-$94	-$188	-$281
Green Waste (Moderately Mature)	698	1396	2096
Baby Spinach (2nd rotation)			
Blend (Very Immature)	$152	$304	$455
Green Waste (Moderately Mature)	NSD	NSD	NSD
Baby Lettuce (5 tons/acre)			
Blend (Very Mature)	NSD	NSD	NSD
Green Waste (Mature)	$272	$545	$817
Green Waste (Immature)	-$367	-$733	-$1100

*Compost costs assumed to range between $20 to 25/ton delivered, application $8 to 10 per acre.

NSD = no statistical difference in yields in comparison to check

Appendix B
Figures

Figure 1. Nitrogen Release in Clay Soil During Winter and Spring 2000

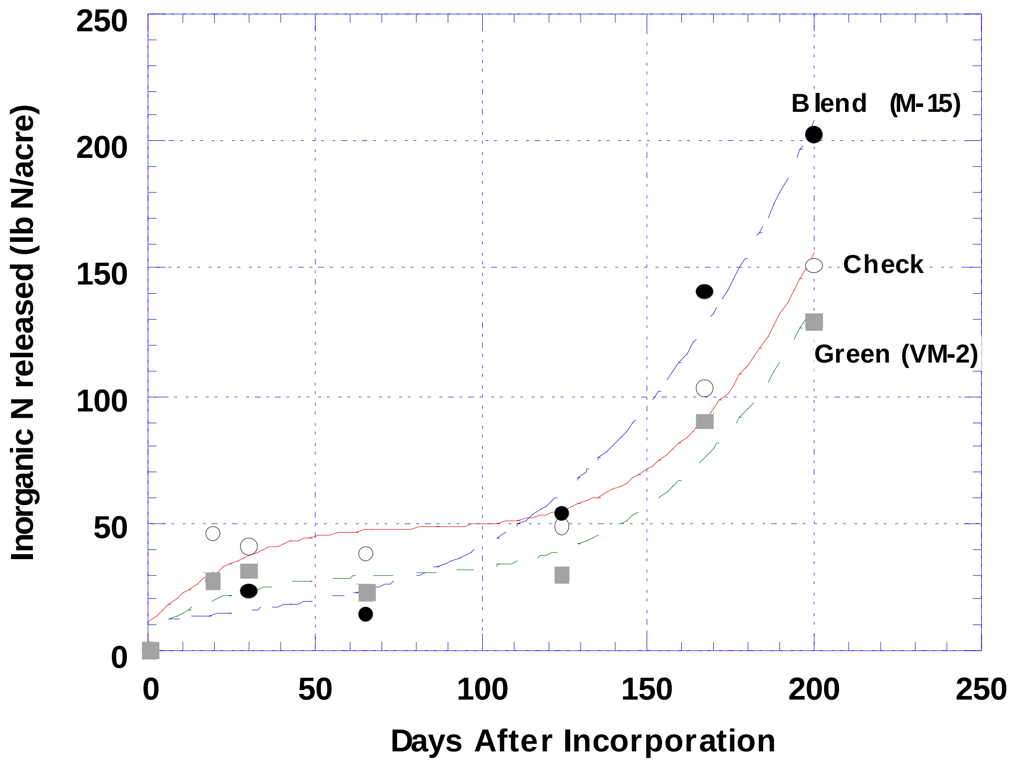

Figure 2. Nitrogen Release in Sandy Clay Loam Soil During Winter and Spring 2000

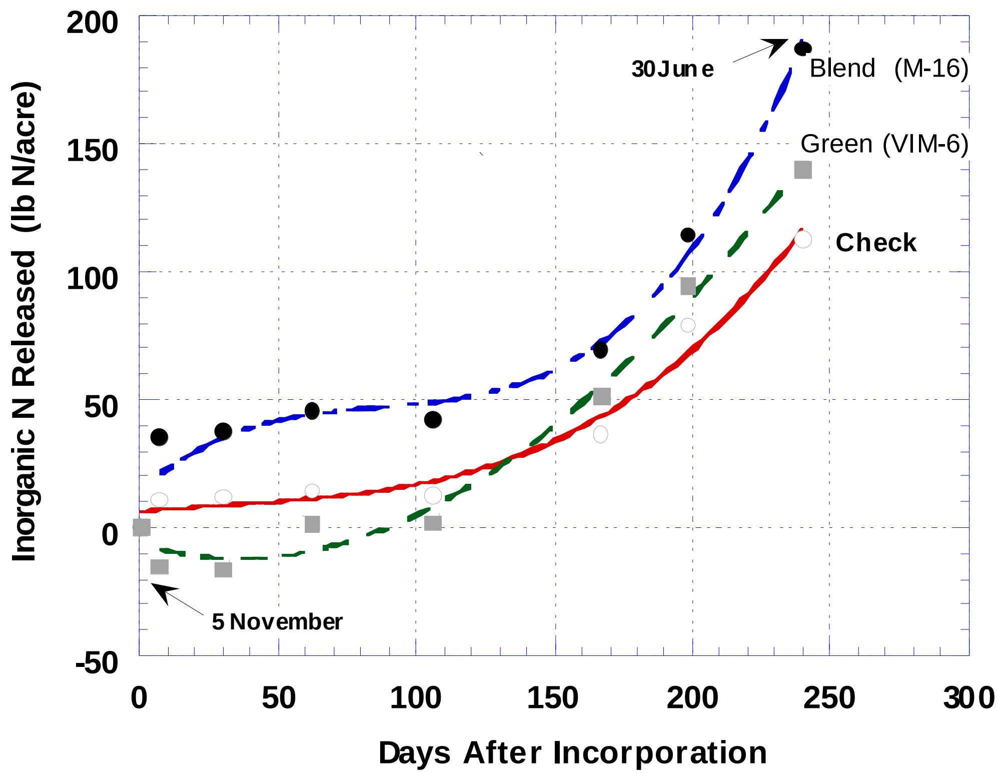

Figure 3. Nitrogen Release in Sandy Loam Soil During Spring and Summer 2000

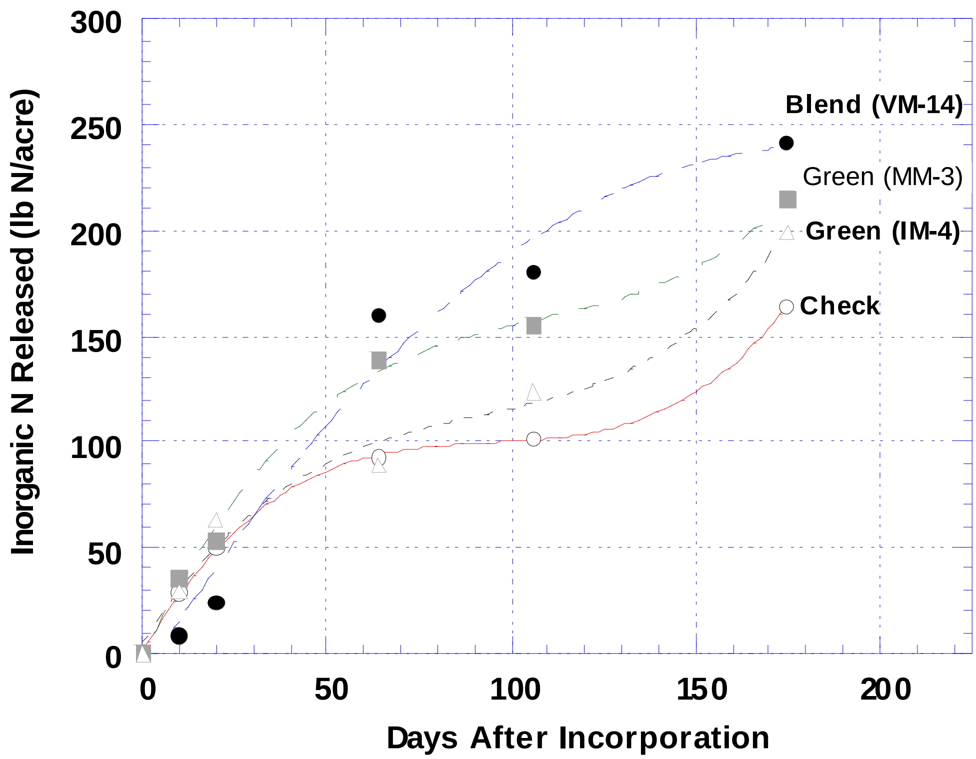

Figure 4. Nitrogen Release in Coarse Sandy Loam Soil During Spring and Summer 2000

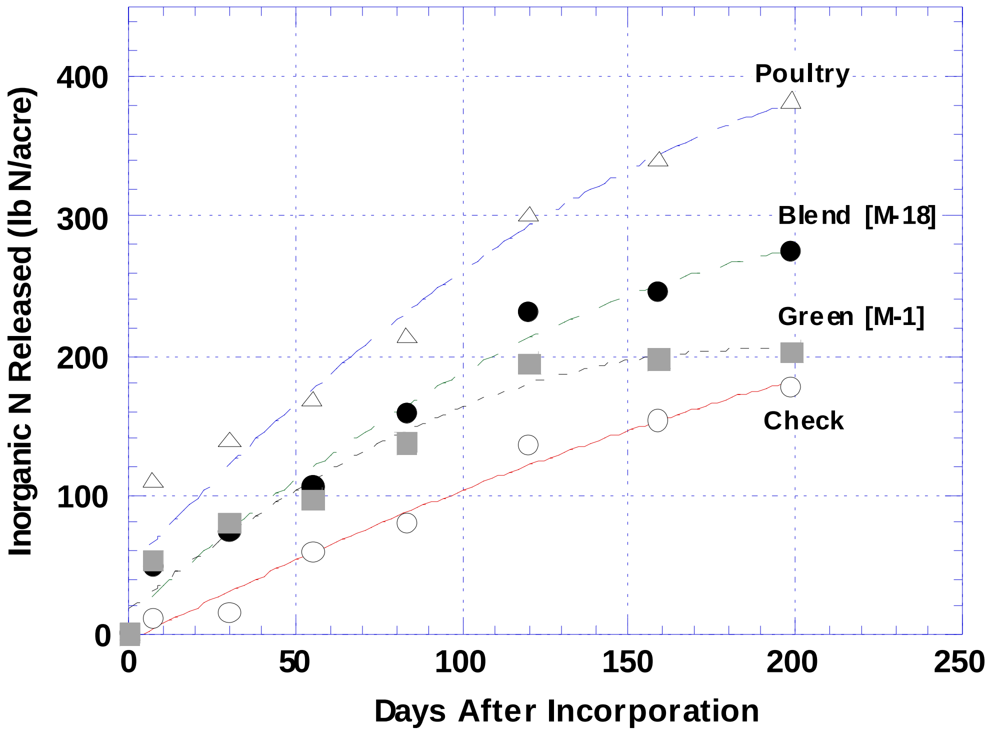

Figure 5. Nitrogen Release in Sandy Loam Soil During Winter 2001

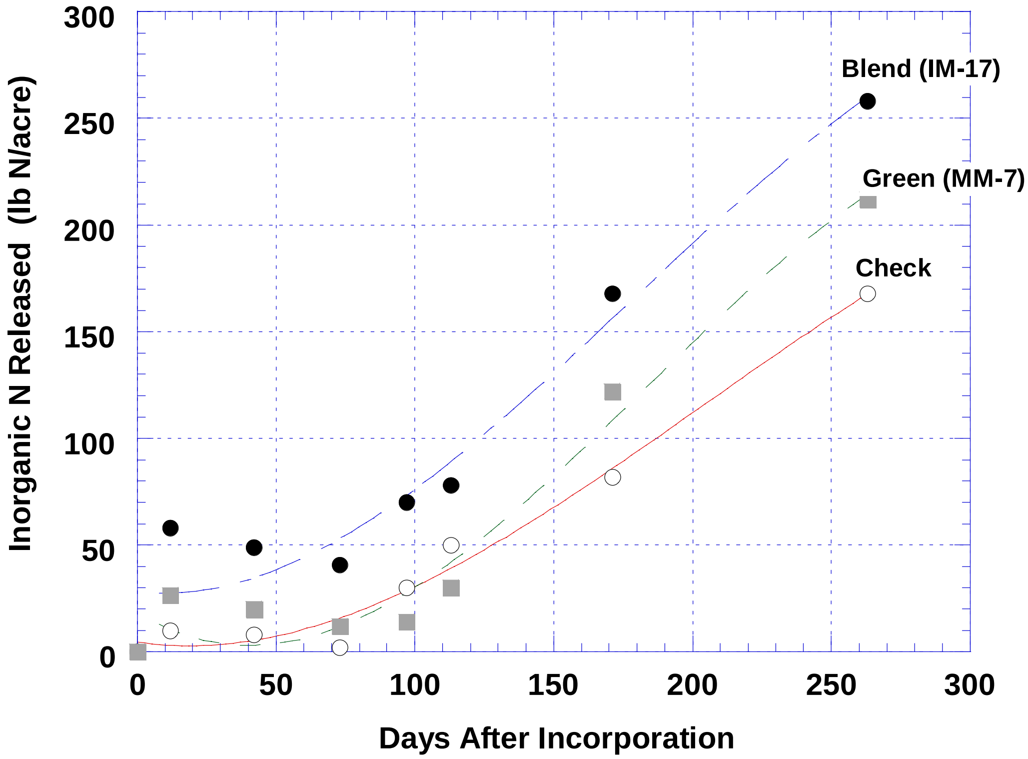

Figure 6. Effect of Compost Incorporation Timing on Nitrogen Release (Fall 2000 and Winter and Spring 2001)

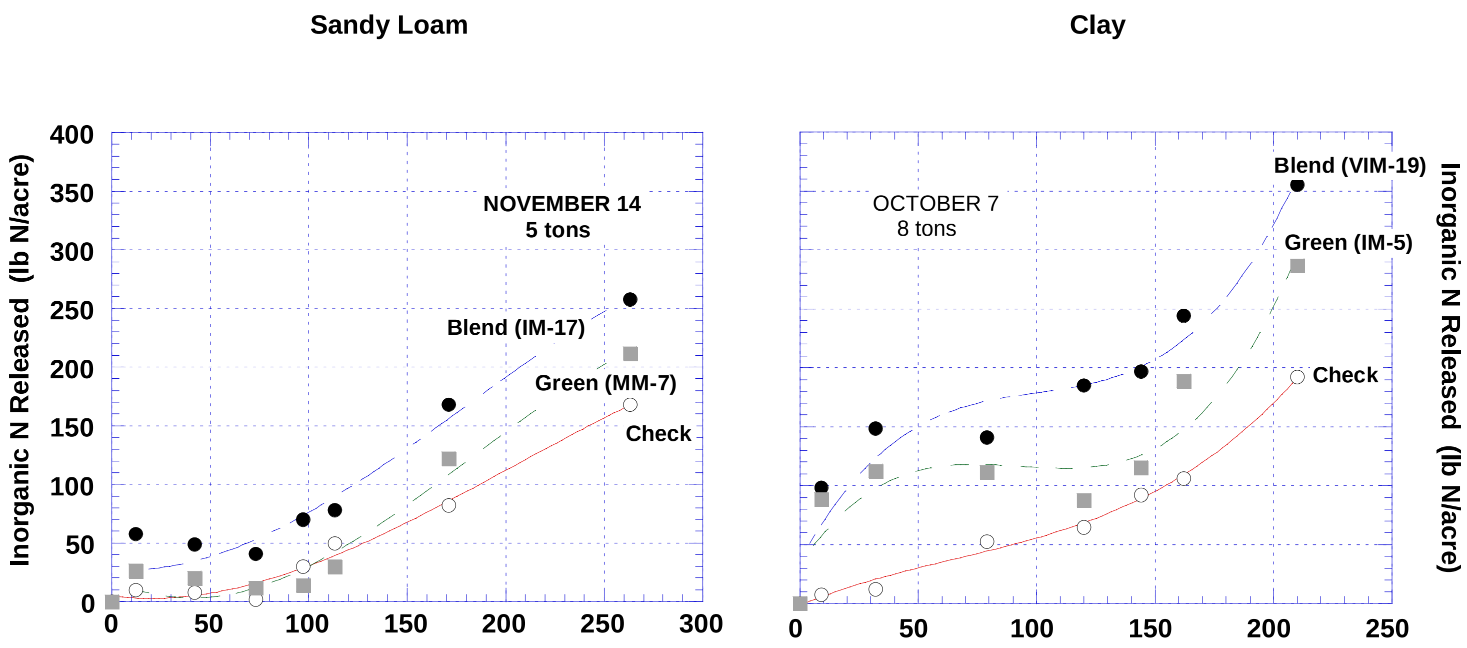

Figure 7. Increase in Available Soil Nitrogen Due to Ammonium After Compost Incorporation

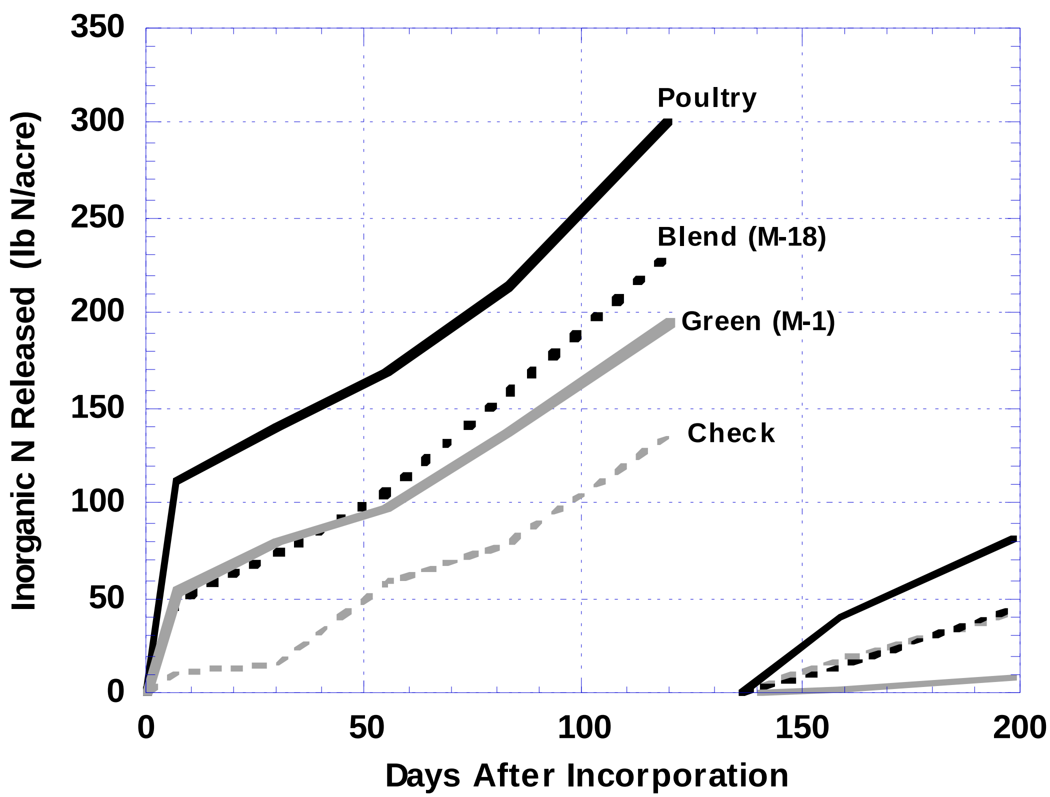

Figure 8. Comparison of Nitrogen Release From Mature and Immature Blend in Different Soils

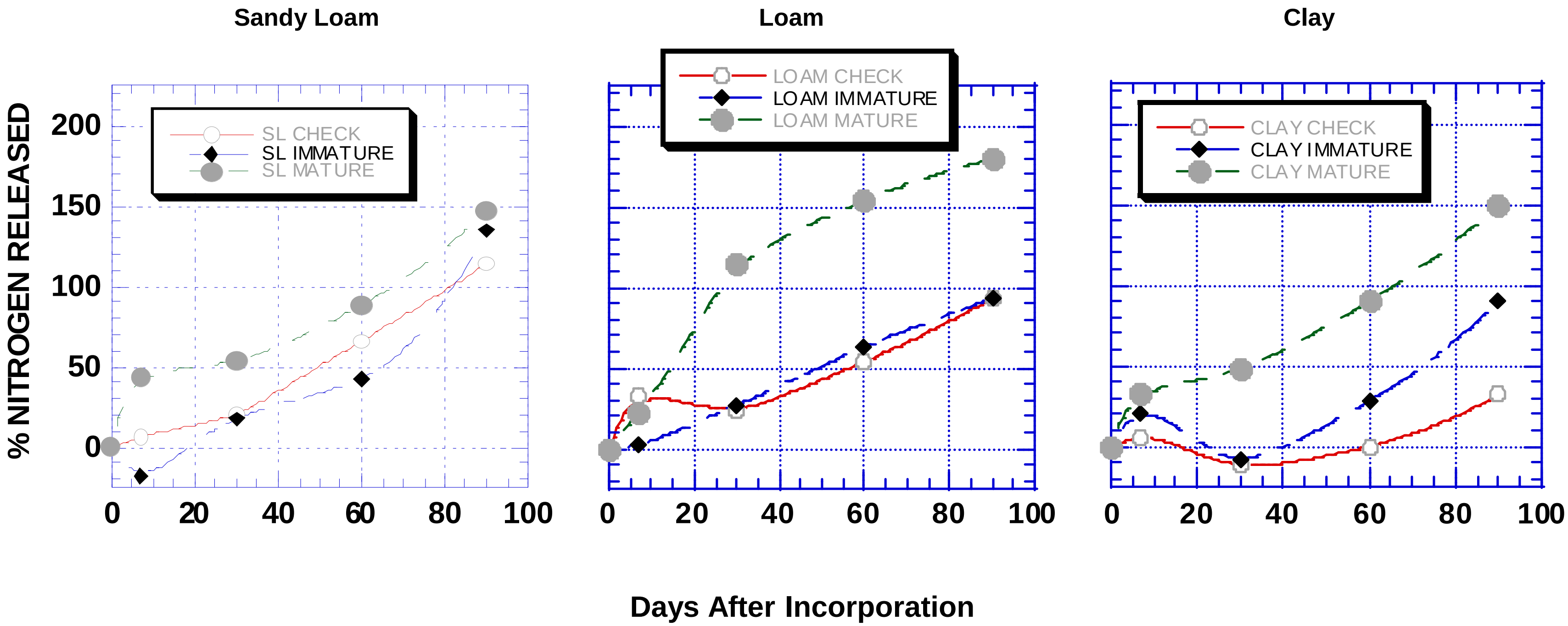

Figure 9. Percentage of Total Compost Nitrogen Released in Relation to Maturity