A Practical Guide to the Application of Compost in Vineyards – Fall 2003

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This bulletin has been written to provide growers with very practical information on the use of compost in vineyards. It will focus on determining the correct rate of compost to use based on the nitrogen contained in the compost and the nitrogen needs of the vineyard. Although there are many potential benefits to the use of compost in vineyards, the greatest potential for the misuse of compost and long term negative impacts of compost in the vineyard is the over application of nitrogen through the use of compost. This bulletin is not intended to provide in depth information on making compost, evaluating compost quality or grape nutrition, although these subjects are addressed to a limited extent. These are all complex subjects that are covered more completely in other resources. The content of this bulletin will be expanded as grower experience and new research add to the knowledge of compost use in vineyards.

Part I. Introduction To Compost Use in the Vineyard

Compost can have many beneficial effects on the growth and health of grape vines. Growers have observed that compost treated vines "look" healthier. Compost treated vines grow well, have greener foliage, show fewer nutrient deficiencies in the leaves, and suffer less from drought. They may also resist disease better and have a longer productive life. However, compost can also be detrimental to grape vines. Composted vines may grow too vigorously resulting in problems with canopy management, disease management, reduced fruiting and increased cold injury to the vine or buds. Once compost is applied to the vineyard floor, its effects are difficult to undo either good or bad. Growers must determine how to use compost to their best advantage in the vineyard without causing long-term problems. The affects of compost will remain in the soil and be evident in the vine for 5 to 7 years after the compost has been applied.

Part II. Compost Application in the Vineyard:
Research Results on Use of Compost in Vineyards

When most people think of compost the first thing that comes to their minds is organic matter and nutrients, which is a correct way of viewing compost. The decomposition of organic matter in the soil releases nutrients such as nitrogen, phosphorus and potassium, which are taken up by plants thus reducing fertilizer requirements of the vine. Organic matter in the soil improves nutrient retention in available forms in the soil and reduces nutrient leaching. Organic matter also improves soil structure by reducing the potential for soil compaction, increases water retention and infiltration. Organic matter also improves the buffering capacity of the soil by increasing the total surface available for cation exchange sites. Organic matter also impacts soil microbial activity in a positive way. The organic matter in compost will increase biological activity in the soil once applied by supplying nutrient sources and habitat for beneficial microorganisms. However, the microorganisms in compost are key to the positive impacts compost has on the soil and vines. Most beneficial effects of compost are a result of the activities of microorganisms. Microorganisms produce plant growth regulators, stimulate plant growth and compete in the soil with disease organisms.

This research project was undertaken to study from a scientific perspective, the impacts compost has on vineyard soils, vine growth and juice quality. Three years of results will be presented in this bulletin as a preliminary summary of the impacts of compost on vineyards. It is well documented that compost has an impact on the soil and plant growth for 5 to 7 years after an application is made. This report presents only the first impacts of compost on the vines and grapes.

Vineyard Research Sites

Compost application is being studied at 3 vineyard sites. The first 2 compost test vineyards are commercial and located in southeastern Pennsylvania in Berks and Northampton counties. The first is a 4-year-old Chardonnay and Chambourcin vineyard that had received no previous fertilizer applications. The second vineyard is a mature 8-year-old Chambourcin vineyard that had received regular chemical fertilizer applications to maintain vine vigor and yield previous to compost being applied. The third site is in Erie County PA and includes a Concord vineyard and a mature Chambourcin and Vignoles vineyard.

Compost Types, Rates and Timing

The two southeastern vineyards used the same type and source of compost made from animal manure, mushroom substrate and yard trimmings. The rates of compost applied ranged from 7 T/A to 60 T/A applied in two consecutive seasons. The Erie County vineyard site utilized compost made from animal manure and yard trimmings from local suppliers. A wide range of compost rates were also applied to the research vineyards to evaluate the effect of low (7 T/A) and extremely high (100 T/A) rates of compost on grapevines in the short and long term. Most of the applications listed above were applied as broadcast applications that covered the entire vineyard floor. Band application rates would be equivalent to about 1/3 of the rates listed. Some of the rates listed above are higher than recommended since they are research trials and the extremes serve to define the optimal rates for vineyards. Based on these rates and soil and vine responses, we now recommend lower rates (7 to 10 T/A) applied over several seasons calculating nutrient impacts as described later in this bulletin.

Impact of Compost on the Vineyard – A Selected Summary of Results

Vineyard 1 – 4 yr, own rooted Chambourcin & Chardonnay,
Commercial Vineyard, Berks Co.

Compost made from animal manure, mushroom substrate and yard trimmings were tested on this site with broadcast applications occurring over two seasons. A rate of 20 T/A of each compost type was also applied in randomized plots throughout the vineyards in July 2001. The following summer (June, 2002), the vineyard received a follow-up application of each compost on the same treatment plots of 40 T/A, broadcast.

<u>Microbial Activity & Organic Matter</u>. Soil microbial activity increased in the first 2 seasons in all the compost treated plots as compared to the untreated plots. The increase in activity within the first 9 months ranged from 10 to over 20 % above untreated plots. In the first 9 months, yard trimmings compost appeared to have the greatest impact on microbial activity, however, by spring 2003 animal manure and mushroom substrate compost resulted in higher microbial activity levels. It was observed that perhaps the higher salts in animal manure and mushroom substrate compost may have an inhibiting effect on microbial activity in the first year only. In year 2 & 3 the higher nitrogen levels in animal manure and mushroom substrate compost may stimulate microbial activity. After an extremely dry 2002 season, microbial activity levels remained higher in the compost treated plots verses untreated plots. In spring of 2003, microbial activity levels in the Chambourcin block remained nearly 20 to 40% higher in composted plots than untreated plots with organic matter levels from 15 to almost 100% higher than untreated vines. There were also significantly higher organic matter and microbial activity in the Chardonnay compost plots but there was more variability perhaps due to high moisture levels at the time of sampling.

<u>Vine Response.</u> The pruning weights, after 2 seasons of compost reflected an improvement over non-treated compost plots. Compost treated Chardonnay had from 8 to 18 % higher pruning weights than non-treated vines. Compost treated Chambourcin vines had pruning weights 97% to 131% higher than un-treated vines. There was no significant difference in pruning weights between types of compost.

<u>Vine Response to Ozone.</u> Chambourcin vines were evaluated at harvest in 2002 for the impact compost has on ozone leaf symptoms. Yard trimmings, animal manure and mushroom substrate compost all significantly reduced the severity of ozone leaf symptoms. Ozone causes leaves to yellow prematurely. Leaves that stay green longer from compost applications are more effective in ripening grapes late in the season before harvest.

<u>Juice Measurements.</u> In 2002, juice was evaluated at harvest for Brix, pH and Total Acidity. There was not a significant difference between compost treated and untreated vines.

Vineyard 2 – Mature 8 yr, own rooted Chambourcin,
Commercial Vineyard, Northampton Co.

Compost made from animal manure, mushroom substrate and yard trimmings were tested on this vineyard over two seasons as a broadcast application. A low rate of 7 T/A and a high rate of 20 T/A were applied the first year (2001) in July as broadcast applications. In June, 2002, a low rate of 30 T/A, and a high rate of 60 T/A of each compost type was applied in randomized plots throughout the vineyard

Microbial Activity and Organic Matter. Organic matter increased in the first 3 seasons on all compost treated plots over a fertilizer/ no compost plot and a no fertilizer/no compost plot. Compost plots had from 15% to 34% increases in soil organic matter. In this vineyard, the mushroom plots resulted in the highest organic matter increase. There were no significant differences between low and high application rates of compost.

Vine Response. Pruning weights recorded in April 2003 were higher on all compost treated vines than either the fertilizer check or untreated vines. Pruning weights in compost plots were from 72% to 172% higher than the untreated compost plots and from 56% to 156% higher than the fertilizer check.

Vineyard 3 – Mature Concord, Chancellor & Vignoles,
Research Vineyard located at the
Lake Erie Grape Research and Extension Center, Erie County, PA

Research at the Lake Erie Regional Grape Research and Extension Center allowed us to try some compost experiments such as high compost rates and disease development that are not possible in commercial vineyards.

The Erie vineyard site utilized compost made from animal manure, and yard trimmings from local suppliers. In a Concord vineyard, a low rate of 7 T/A, and a high rate of 20 T/A were applied the first year (2001) in June as broadcast applications. In June 2002, a low rate of 30 T/A, and a high rate of 60 T/A of each compost type were applied in randomized plots throughout the Concord vineyard. An extremely application rate of 100 T/A, broad cast was applied to a Vignoles and Chancellor vineyard to evaluate the impact on the soil and vines.

Soil Chemistry & Microbial Activity
Organic matter, CEC levels in the soil were slightly elevated in compost treatments compared to chemical fertilizer and non-compost treatments. The pH was variable across plots with no clear change after compost application. Nitrogen and phosphorus levels were not different in compost plots while potassium levels were slightly higher after compost was applied.

The increase in microbial activity in the soil was from 10% to 20% in compost treated plots about 1 ½ years after the first compost application. The animal manure compost had lower microbial activity levels than the yard trimming compost. This may have been due to higher salt levels in the animal compost, which would suppress microbial activity. In other trials it has been observed that the microbial activity in the soil after animal compost treatments reaches the same level as other compost types in years 2 and 3.

Vine Response
Shoot lengths were longer in 2002 after compost treatments as compared to no compost and fertilizer check plots. Pruning weights were also slightly elevated in compost plots the first and second years after compost application.

In 2002-2003, bud survival was slightly better on Concord vines treated at recommended compost levels. Winter bud survival was not different in Chancellor but slightly better in Vignoles after compost was applied at 100T/A two years earlier.

Juice Analysis (Concord)
Juice analysis resulted in no significant difference of pH, total acidity and Brix after compost application in years one and two.

Disease Development, Downy Mildew on Chancellor (100 T/A, broadcast)
On Chancellor grape there were was slightly lower levels of downy mildew after compost application in year two. This may have resulted from more rapid degradation of over-wintering leaves in compost plots.

Botrytis on Vignoles (100 T/A, broadcast)
Over-wintering clusters under compost on the ground had fewer berries still intact by spring. Of the clusters under compost, 28% fewer produced spores and of the clusters that did produce spores, the sporulation was reduced by 42% as compared to clusters on bare soil.

Botrytis can infect berries with no evidence of infection. This is known as latent infections. The first year after the compost was applied (2002-dry season), compost plots had significantly less latent infection of berries at fruit set. However, by veraison, the latent infection levels between compost treated and non-treated plots was not different. In 2003, during very wet conditions, there were more latent infections of berries at fruit set in compost plots but by veraison there was no difference between compost and non-compost treated vines.

Powdery Mildew on Concord
Powdery mildew was higher on Concord clusters in plots treated with compost. Higher disease levels may be due to a denser canopy and higher humidity levels in compost plots

Weed Control
The number of weed species and growth of the weeds was higher in compost plots. In addition, there were a greater number of grape seedlings that germinated under Chancellor vines. The seedling grapes were often infected by downy mildew early in the season.

Graduate Student Research on Compost

Suppresssion of *Cylindrocarpon destructans* utilizing composted soil amendments.

Beth K. Gugino, Dept. of Plant Pathology, Penn State University

Introduction

Mature grapevine decline is an increasingly serious problem for vineyards in Pennsylvania. The symptoms of decline include reduced shoot growth, sparse yellow foliage, necrosis and stunting of the roots, reduced yield and inferior fruit. A recent study that surveyed Pennsylvania vineyards found that *Cylindrocarpon destructans* was isolated repeatedly from the roots of declining grapevines. In an effort to evaluate environmentally sustainable management practices, the efficacy of several types of compost on the suppression of *Cylindrocarpon destructans* was examined. In growth chamber studies, the population of *C. destructans* was monitored over time in soil-less mixes amended with 0, 10, 25 and 50% composted animal manure (CAM) using serial soil dilution plating. The preliminary results indicated an increasing reduction in the *C. destructans* population as the amount of compost increased from 0 to 50%. Several microorganisms isolated from these composts have also demonstrated antagonism toward *C. destructans* in vitro.

Results

Between 24 hours and 54 days there was a significant reduction in the *C. destructans* population within individual treatments (Figure 1). After 54 days there also was a significant reduction in population between the unamended control and 10 and 25% amended with CAM and 50% amended with CAM.

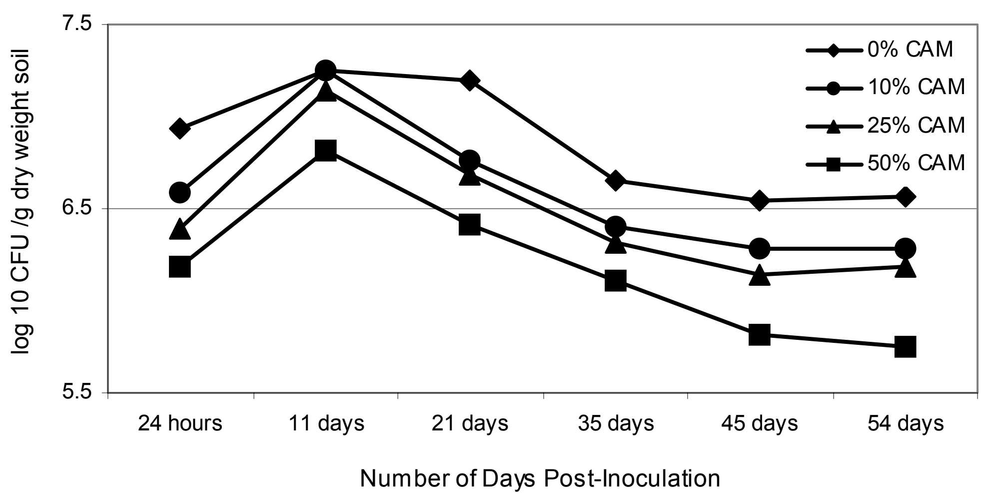

Figure 1. The population of *C. destructans* ($\log_{10}$ CFU/g dry weight soil) in soil-less mix amended with 0, 10, 25, and 50% composted animal manure as determined using soil dilution plating. Pots were maintained in a growth chamber at 21C under a 12-hour photoperiod and over 90% relative humidity.

Diverse bacterial populations were able to be isolated from composted yard trimmings, composted poultry manure and vermicompost using soil dilution platings on a variety of media. Several bacterial isolates from composted animal manure, yard trimmings, poultry manure and vermicompost have demonstrated antagonism towards *C. destructans* in vitro including *Bacillus subtillis*, B. *amyloliquefaciens, B. lentimorbus, and B. pumilus* GC subgroup B which have been identified using FAME analysis.

Investigation for biological nature of grape replant problems in Pennsylvania and the effect of compost on root health, Fritz Westover, Department of Plant pathology, Pennsylvania State University

The term "replant disease" or "replant disorder" has been used to describe the poor growth of fruit trees after replanting on a site that had previously been planted to the same or closely related species. Apple replant disease (ARD), for example, is well documented in numerous orchards worldwide. Although the etiology of ARD is not conclusive, research has demonstrated that both biotic and abiotic factors are involved and that these factors often may vary from one location to the next.

Grapes are susceptible to numerous biotic pathogens including fungi, bacteria and viruses. In established vineyards, grapevine decline is commonly associated with symptoms including delayed and weak seasonal vine growth, sparse yellow foliage, shortened internodes, uneven wood maturity, reduced yields, root rot and reduced feeder roots, often resulting in death within a few years. These symptoms have been observed in mature vines in Pennsylvania vineyards and also in young vines (1-4yr) that were planted directly into soils where declining vines had been removed. The cause of these replant problems is not fully understood.

Numerous studies investigating compost treatments on agricultural crops have demonstrated disease suppression of specific root and foliar pathogens. The effect of compost in replant soils was also evaluated in the bioassay. This soil treatment incorporated either composted municipal yard waste or composted animal manure from Pennsylvania producers at a rate of 15% total volume. The compost was homogenized, incorporated into the replant soils from Pennsylvania vineyards and incubated in a greenhouse for 9 days prior to planting with grapes.

Results of this project are currently in progress.

Future Research

Future updates to this bulletin will contain specific recommendations for the use of compost in replant situations to prevent young vine death and promote the long-term productivity of the vineyard. It will also provide information for the use of compost to suppress both soil and fruit diseases and reduce ozone injury to grape leaves. The publication of a bulletin with expanded recommendations for compost use in vineyards awaits only additional experience by growers and new research findings.

Part III. Compost Application in the Vineyard: Compost and Composting

Maybe a good way to begin this discussion is to state what compost is not. It is not animal manure, or mushroom substrate, either fresh or aged. It is not mulch such as shredded leaves, straw or wood chips. Quality compost contains these elements, but they must be combined in the proper ratios and undergo the process of composting to produce quality compost. There can be several detrimental effects on the soil and grapevines if these materials are used without composting. Animal manure and mushroom substrate often contain high nitrogen levels and salts that will disrupt the nutritional balance in the soil and even inhibit the beneficial microbial activity in the soil. Mulch (shredded leaves, straw and wood chips) will extract nitrogen from the soil during the degradation process potentially resulting in poor vine growth and reduced yield.

Composting is a controlled process where nitrogen-containing materials (manure, yard trimmings/kitchen waste) are mixed with a carbon containing source (corn stalks, cobs, straw, wood chips) to produce a substance preferably in a carbon-to-nitrogen ratio (C:N) of less than 20 :1. Compost with high ratios of C:N may actually not add any nitrogen to the soil during the first year. When C:N ratio of organic matter inputs exceeds 30:1, there isn't enough nitrogen for microbes and they begin removing it from the soil to survive. At that point, microbes can and do out-compete plants for nitrogen, resulting in plants becoming starved for nitrogen (immobilization). With a compost C:N ratio of less than 20:1, there is plenty of nitrogen for microbes and microbial decomposition results in release of nitrogen into the soil.

Active composting generates heat, CO_2, and water vapor. Composting is the aerobic decomposition of organic materials by microorganisms. During composting, the microorganisms consume oxygen while consuming organic matter. Mechanical agitation or turning of composting materials is required for good aeration to start the microbial degradation process. In the process of composting, the mixture must reach a temperature of 140 degrees F for at least 3 days. Temperature is a good process indicator since the heat produced is related to the microbial activity level. A rapid increase in temperature (120 to 140 degrees F) can occur within the first few hours and be maintained for several weeks. Compost contains 50% water to maintain microbial activity. Water and CO_2 losses can equal ½ the weight of the initial materials. Composting is most rapid under conditions that favor the microorganisms. As active composting slows, temperatures drop to 100 degrees F and finally ambient air temperature. Compost is "done" or mature based on C:N ratio, oxygen level, temperature and odor. After the compost is mature it continues to break down until the last remaining nutrients are consumed by the last remaining microbes and until nearly all of the available carbon is converted to CO_2. Factors that affect the final quality of the compost include include, oxygen, aeration, nutrients (C:N ratio), moisture, porosity, structure, texture, particle size, pH, temperature and time.

The final compost produced is variable due to the variety and ratio of the inputs and the environmental conditions that existed during the composting process. Growers can have the compost analyzed to determine the level of the critical factors listed above.

To get your compost tested, send samples, properly labeled and identified to:

The Agricultural Analytical Services Laboratory (http://aasl.psu.edu)
Penn State University, University Park PA 16802
(814) 863-0841 Fax (814) 863-4540
Cost: $30-$60.00

Determining Compost Quality

How To Read a Compost Analysis Report – What is Important?

When observing your compost analyses report, certain key components (analytes) are important to the overall health of your compost. They can affect the quality, stability and maturity of your compost product. These components are listed below followed by a brief description:

pH: pH is a measure of acidity in the compost. Most finished composts have a pH range of 5.0 to 8.5. A neutral pH (7.0) is desirable for most applications.

Soluble Salts (SS): Composts have a typical SS range of 1 to 10. A general recommendation is for the SS concentration to be less than 5. High salinity levels (when SS concentrations are greater than 10-15) can be toxic to plants. Mushroom substrates are typically high in SS, therefore, care must be taken when using and applying mushroom composts. If the compost analysis shows high levels of SS, it is advisable to follow up with a soil test to confirm if these salts remained in the soil. In a wet season, they may have leached out and toxicity may not be a problem.

% Moisture: The moisture content of compost will depend on the water holding capacity of the original materials. Materials that are high in organic matter hold more water and will have a higher moisture content. A starting compost will have a range of 40-65% and a finished compost should have a range of 50-60%. Microorganisms will not be active if the moisture content is too low. If the moisture content is too high, then anaerobic regions within the compost may form which can affect beneficial microorganisms as well as reduce porosity.

% Organic Matter (OM): There is no ideal level of OM for finished composts. The OM of a finished compost will range from 30-70% (dry weight basis). An OM content of greater than 60% is recommended for most compost usage.

% Total Nitrogen (N): Total N includes N in all its forms which include ammonium, nitrate and organic N. In a finished compost, the total N will range from 0.5-2.5% (dry weight basis). In a stable, finished compost, most of the N should be in the organic form. Organic N is not immediately available to plants (about 15% the first year), however, this depends on other factors such as temperature, soil moisture and the C:N ratio.

Carbon:Nitrogen Ratio (C:N): The C:N ratio is an indicator of compost stability and N availability. It is the ratio of total carbon to total nitrogen in the sample. Composts with a high C:N ratio (>25) will tie up the available nitrogen, making it unavailable. Composts with a low C:N ratio (<20) will release organic N making it available to the plant.

Physical Properties: Just looking, touching and smelling a finished compost can tell you a lot. Is it uniform in color and particle size? Is it dry or moist? Does it smell? If the compost has an odor, it probably is becoming anaerobic which is not a desirable trait?

Agricultural Analytical Services Laboratory
The Pennsylvania State University
University Park PA 16802

Analysis Report For:	Copy To:
YARD TRIMMINGS COMPOST	

LAB ID:	SAMPLE ID:	REPORT DATE:	DATE SAMPLED:	SAMPLE TYPE:	COUNTY:
C00156	CYT	05/23/2003	5/14/03		

COMPOST ANALYSIS REPORT

Compost Test 1C

Analyte	Results (As is basis)	Results (Dry weight basis)
pH	7.8	—
Soluble Salts (1:5, w:w)	2.49 mmhos/cm	—
Solids	46.7 %	—
Moisture	53.3 %	—
Organic Matter	19.9 %	42.6 %
Total Nitrogen (N)	0.8 %	1.8 %
Organic Nitrogen[1]	0.8 %	1.8 %
Ammonium N (NH_4-N)	2.1 mg/kg	4.5 mg/kg
Carbon (C)	12.3 %	26.3 %
Carbon:Nitrogen (C:N) Ratio	14.5	14.5
Phosphorus (as P_2O_5)[2]	0.30 %	0.65 %
Potassium (as K_2O)[2]	0.68 %	1.45 %
Calcium (Ca)	2.07 %	4.43 %
Magnesium (Mg)	0.44 %	0.94 %
Sulfur (S)	0.14 %	0.29 %
Sodium (Na)	153 mg/kg	327 mg/kg
Aluminum (Al)	6005 mg/kg	12857 mg/kg
Iron (Fe)	5729 mg/kg	12267 mg/kg
Manganese (Mn)	346 mg/kg	741 mg/kg
Copper (Cu)	22 mg/kg	48 mg/kg
Zinc	81 mg/kg	174 mg/kg

[1]See comments on back of report .

[2]To convert phosphorus as (P_2O_5) into elemental phosphorus (P), divide by 2.29. To convert potassium (as K_2O) into elemental potassium (K), divide by 1.20.

Agricultural Analytical Services Laboratory
The Pennsylvania State University
University Park PA 16802

Analysis Report For:	Copy To:

ANIMAL MANURE COMPOST

LAB ID:	SAMPLE ID:	REPORT DATE:	DATE SAMPLED:	SAMPLE TYPE:	COUNTY:
C00012	animal compost	02/06/2003	1/22/03	Finished Compost	

COMPOST ANALYSIS REPORT

Compost Test 1C

Analyte	Results (As is basis)	Results (Dry weight basis)
pH	7.8	—
Soluble Salts (1:5, w:w)	3.15 mmhos/cm	—
Solids	62.1 %	—
Moisture	37.9 %	—
Organic Matter	16.3 %	26.3 %
Total Nitrogen (N)	0.9 %	1.4 %
Organic Nitrogen[1]	0.9 %	1.4 %
Ammonium N (NH_4-N)	2.8 mg/kg	4.5 mg/kg
Carbon (C)	8.9 %	14.4 %
Carbon:Nitrogen (C:N) Ratio	10.2	10.2
Phosphorus (as P_2O_5)[2]	0.71 %	1.15 %
Potassium (as K_2O)[2]	1.21 %	1.94 %
Calcium (Ca)	2.03 %	3.27 %
Magnesium (Mg)	0.56 %	0.90 %
Sulfur (S)	0.17 %	0.27 %
Sodium (Na)	448 mg/kg	721 mg/kg
Aluminum (Al)	16480 mg/kg	26528 mg/kg
Iron (Fe)	17321 mg/kg	27882 mg/kg
Manganese (Mn)	489 mg/kg	787 mg/kg
Copper (Cu)	29 mg/kg	46 mg/kg
Zinc	104 mg/kg	167 mg/kg

[1]See comments on back of report.

[2]To convert phosphorus as (P_2O_5) into elemental phosphorus (P), divide by 2.29. To convert potassium (as K_2O) into elemental potassium (K), divide by 1.20.

Agricultural Analytical Services Laboratory
The Pennsylvania State University
University Park PA 16802

Analysis Report For:	Copy To:

POULTRY/MUSHROOM SUBSTRATE COMPOST

LAB ID:	SAMPLE ID:	REPORT DATE:	DATE SAMPLED:	SAMPLE TYPE:	COUNTY:
C00121	Roth	05/07/2003	4/24/03		

COMPOST ANALYSIS REPORT

Compost Test 1C

Analyte	Results (As is basis)	Results (Dry weight basis)
pH	7.2	—
Soluble Salts (1:5, w:w)	4.96 mmhos/cm	—
Solids	35.9 %	—
Moisture	64.1 %	—
Organic Matter	18.9 %	52.8 %
Total Nitrogen (N)	1.0 %	2.7 %
Organic Nitrogen[1]	1.0 %	2.7 %
Ammonium N (NH_4-N)	3.9 mg/kg	10.8 mg/kg
Carbon (C)	11.4 %	31.7 %
Carbon:Nitrogen (C:N) Ratio	11.7	11.7
Phosphorus (as P_2O_5)[2]	1.03 %	2.88 %
Potassium (as K_2O)[2]	0.51 %	1.43 %
Calcium (Ca)	3.46 %	9.63 %
Magnesium (Mg)	0.26 %	0.73 %
Sulfur (S)	0.26 %	0.73 %
Sodium (Na)	271 mg/kg	755 mg/kg
Aluminum (Al)	2077 mg/kg	5788 mg/kg
Iron (Fe)	2503 mg/kg	6976 mg/kg
Manganese (Mn)	260 mg/kg	726 mg/kg
Copper (Cu)	53 mg/kg	147 mg/kg
Zinc	118 mg/kg	329 mg/kg

[1]See comments on back of report .

[2]To convert phosphorus as (P_2O_5) into elemental phosphorus (P), divide by 2.29. To convert potassium (as K_2O) into elemental potassium (K), divide by 1.20.

Agricultural Analytical Services Laboratory
The Pennsylvania State University
University Park PA 16802

Analysis Report For:	Copy To:
VERMICOMPOST	

LAB ID:	SAMPLE ID:	REPORT DATE:	DATE SAMPLED:	SAMPLE TYPE:	COUNTY:
C00155	Vermi	05/23/2003	5/14/03		

COMPOST ANALYSIS REPORT

Compost Test 1C

Analyte	Results (As is basis)	Results (Dry weight basis)
pH	7.8	—
Soluble Salts (1:5, w:w)	6.96 mmhos/cm	—
Solids	30.4 %	—
Moisture	69.6 %	—
Organic Matter	17.7 %	58.1 %
Total Nitrogen (N)	0.7 %	2.3 %
Organic Nitrogen[1]	0.7 %	2.3 %
Ammonium N (NH_4-N)	2.8 mg/kg	9.2 mg/kg
Carbon (C)	9.1 %	29.8 %
Carbon:Nitrogen (C:N) Ratio	12.7	12.7
Phosphorus (as P_2O_5)[2]	0.54 %	1.77 %
Potassium (as K_2O)[2]	0.90 %	2.94 %
Calcium (Ca)	0.67 %	2.21 %
Magnesium (Mg)	0.27 %	0.87 %
Sulfur (S)	0.15 %	0.49 %
Sodium (Na)	778 mg/kg	2557 mg/kg
Aluminum (Al)	5300 mg/kg	17414 mg/kg
Iron (Fe)	4296 mg/kg	14115 mg/kg
Manganese (Mn)	277 mg/kg	911 mg/kg
Copper (Cu)	20 mg/kg	67 mg/kg
Zinc	94 mg/kg	308 mg/kg

[1]See comments on back of report .

[2]To convert phosphorus as (P_2O_5) into elemental phosphorus (P), divide by 2.29. To convert potassium (as K_2O) into elemental potassium (K), divide by 1.20.

Part IV. Compost Application in the Vineyard: Compost Selection, Rate, & Timing

Type of Compost to Apply. To some extent the type (animal manure, yard trimmings, etc) of compost that is applied may depend on what is available and cost. Each type of compost can produce a quality material for application in vineyards. However, if several types of compost are available to the grower, then choices may be made based on nitrogen content, salts, microbial activity, presence of weed seeds, hauling considerations, texture and moisture levels which affect ease of application. The existing soil nutrient levels and pre-application vine growth are also factors in considering the best type of compost. For example, if vines are growing well, with adequate nitrogen already in the soil then yard trimmings based compost may be most appropriate to avoid over charging the soil with nitrogen. On the other hand, if nitrogen and soil organic matter are low and plants are growing poorly, then animal based compost is an acceptable choice. However, yard trimmings compost can also be used in a low nitrogen/weak growth vineyard since amount of compost applied can be adjusted to meet the needs of the vines. The key is to know the nitrogen content of the compost you intend to use through a laboratory analysis and know how much nitrogen you want to apply to the vineyard.

Another consideration involved in compost application is the introduction of non-biodegradable trash (plastic, glass, metal) to the vineyard. Yard trimmings compost is most likely to contain this type of material.

Rate of Compost to Apply

The nutrient and chemical properties of compost and their contribution to soil nutrient levels and vine growth are complex. This bulletin will focus on determining the appropriate amount of nitrogen to apply to the vineyard. However, it is acknowledged that there are several other important chemical factors of compost that can also affect the soil and vine growth. For example, compost normally has a pH of about 7.0. In eastern vineyards where there is a low pH, compost may have a beneficial effect of slightly raising the pH.

Soil nutrient analysis and petiole analysis are critical guides to how much compost to apply. It is also essential to test the nutrient and chemical properties of the compost. These tests should be taken prior to any compost application to the soil. If these tests indicate low nutrient and nitrogen levels in the soil and the vine, then compost can be applied in low to moderate amounts (based on compost nutrient and nitrogen levels) observing vine growth and productivity to determine the amount of follow-up applications.

Vineyard Nutrient Management

Dr. Terry Bates of Cornell University has provided vineyard nutrient management information, which has been included as the last section of this bulletin for easy reference in the future. This section discusses nitrogen cycles in the vineyard and recommendations for soil tests, petiole analysis and vine fertilization. Please read and study this information carefully before applying compost to your vineyard.

Nitrogen
Nutrients in compost are in a complex organic form and must be mineralized in the soil before they become available to plants. Not all the nitrogen in the compost becomes available to the vines. About 15% of the total nitrogen in compost is typically available in the first cropping season. Another 20% of the nitrogen is released over the next 4 to 5 years. Compost can be used effectively in vineyards if care is taken to limit the amount and frequency of applications. Determining the appropriate rate of compost application based on existing soil and plant nitrogen requirements, and nitrogen level of the compost, is complex but some helpful rules that will be presented later will assist in the decision process. After application of compost, the nitrogen in the compost is released slowly into the soil through further degradation of organic matter by microorganisms and from the microorganisms themselves. The effects of compost application in the vineyard is minimal the first year, noticeable the second year and is most pronounced in the third and fourth seasons. For this reason, growers are cautioned in making a decision to repeat compost application based on the vine response over the first two seasons. Once compost is applied in the vineyard it cannot be taken back even if vine growth is excessive from high nitrogen levels in the soil. As stated earlier, high nitrogen levels can result in very vigorous vines resulting in problems with canopy and disease management, cropping levels, and vine and bud winter injury due to a delay in hardening off for the winter.

Nitrogen availability
The total nitrogen reported in the compost analysis does not all become available to the vines. About 30% of the total nitrogen becomes available and this value varies based on compost composition, application method, soil conditions and microbial activity of the soil and environmental conditions after application. The actual percentage of the total nitrogen released will vary with each application based on the above factors. It is recommended that grape growers utilize the 30% nitrogen availability factor (.3) to reduce the risk of applying too much nitrogen to the vineyard in the form of compost. The amount of nitrogen that will be available to the vines over several seasons from one application is determined by multiplying the total nitrogen value from the compost analysis (lbs/T) by (.3). For example, if the total nitrogen in the compost is 20 lbs/T then 6 lbs of actual nitrogen will be available for vine use with each ton applied over 5 seasons. This does not sound like much but it adds up very quickly.

Potassium/Magnesium
Most of the potassium in compost becomes available to the plant in the first year, potentially resulting in competition for magnesium uptake in vines and a reduction in magnesium in composted vines. In the compost research trials conducted by Penn State University over the last two years, levels of phosphorus, calcium, and magnesium in petiole samples were generally slightly lower in composted vines, most notably magnesium. However, magnesium levels were still within the recommended range of 0.35-0.5 % in all compost treatments except the composted Vignoles (0.3 %). In these trials, phosphorus and calcium levels were very similar between composted and non-composted vines.

Some practical methods to evaluate how much compost to apply.

Once the grower has selected quality compost, the necessity to apply the appropriate amount of nitrogen in the vineyard takes priority in calculating compost application rates.

1. First observe vine growth. If vines are growing well from existing natural nutrient levels in the soil then a compost application may not be needed. If vines are growing well utilizing a nitrogen fertilizer then compost may be used to substitute for the nitrogen fertilizer applications and increase microbial activity and organic matter in the soil.
2. Mature Vineyards - Determine how much actual nitrogen is applied per year to the vineyard as a fertilizer. Next use the compost nutrient analysis to determine the total amount of nitrogen in the compost. Use the general rule that the nitrogen in the compost becomes available based on a release rate of **15%** - first year, **8%** - second year, **4%-** third year, **2%** - fourth year, **1 %** - fifth year. Of the total nitrogen contained in the compost about 30% becomes available to the vine over 5 years. Determine how much compost must be applied to equal the yearly nitrogen rate.

   An example: Normal soil nitrogen application rate = 30 lbs actual N/A
   Compost analysis nitrogen level = 20 lbs Total N/Ton of compost

Compost applied one time in year one contributes nitrogen to the soil for next 5 years

	1st applic. 10 T/A
1st year - 20 lbs N/T X **.15** = 3 lbs N / T	
10 Tons applied/acre X 3 lbs N/T =	30 lbs N/A
2nd year- 20 lbs N/T X **.08** = 1.6 lbs N/T	
10 Tons applied/acre X 1.6 lbs N/T =	16 lbs N/A
3rd year- 20 lbs N/T X **.04** = .8 lbs N / T	
10 Tons applied/acre X .8 lbs N/T =	8 lbs N/A
4th year- 20 lbs N/T X **.02** = .4 lbs N / T	
10 Tons applied/acre X .4 lbs N/T =	4 lbs N/A
5th year- 20lbs N/T X **.01** = .2 lbs N/T	
10 Tons applied/acre X .2 lbs N/T =	2 lbs actual

From this example it is apparent that there is a significant nitrogen contribution to the vineyard in years following the initial application. In follow-up years, vine growth and the amount of nitrogen released from previous applications should be used to calculate the amount of compost needed to maintain optimal vine growth. From the previous example, if in year 2 the grower wished to maintain a 30 lb/A rate of nitrogen then 5 tons of compost should be applied. Nitrogen from the previous year and the current year both contribute the nitrogen available to the vine in year 2.

(3 lbs N/T X 5 T = 15 lbs nitrogen added from current season's application to 16 pounds contributed from the previous year's compost application = 31 lbs N from previous year and current years application).

Some interesting values are observed if one carries this calculation for several seasons of compost application.

	Year 1 1^{st} applic.	Year 2 2^{nd} applic.	Year 3 3^{rd} applic.	Year 4 4^{th} applic.	Year 5 5^{th}applic.
	Application Rate				
Nitrogen Available	10 T/A	5 T/A	5T/A	5 T/A	5 T/A
1^{st} year 30 lbs N =	30 lbs N/A	--			
2^{nd} year 31 lbs N =	16 lbs N/A +	15 lbs N/A			
3^{rd} year 31 lbs N =	8 lbs N/A +	8 lbs N/A	+ 15 lbs N/A		
4^{th} year 31 lbs N =	4 lbs N/A +	4 lbs N/A	+ 8 lbs N/A	+ 15 lbs N/A	
5^{th} year 32 lbs N =	2 lbs actual +	2 lbs N/A	+ 4 lbs N/A	+ 8 Lbs N/A	+ 15 lbs N/A

If a grower applies 10 T/A the first year and 5 T/A for years 2 through 5, there is about 30 lbs of nitrogen available each season to the vines based on the nitrogen availability values provided earlier.

These values will become more surprising to growers once they realize that 10 T/A compost applied in a 3 foot band under the vines does not provide a complete cover on the soil surface (average compost depth is about ½”) and 5 T/A is barely visible. Our intuition tells us to apply 2 to 3 inches of compost to have some impact but it is apparent from the above calculations that 2 to 3 inches of compost would provide far too much nitrogen to the vines and raise concerns about the other nutrient effects of high compost rates on vine health and productivity.

Compost does not have to be applied each season. Based on the grower’s management practices for optimal vine growth, compost may be applied on alternating years or only when vines indicate a need (petiole analysis, shoot length, foliage color) for further compost.

Compost Application

Research on several crops indicate that compost is most effective when applied to the soil surface. There are several factors that affect the degradation process which contribute to the detrimental effect incorporation has on compost. It is recommended that compost applications in vineyards be applied to the soil surface.

Hand Application

Some growers apply compost to their vineyard using a scoop shovel. Although labor intense, it is an effective means to distribute compost throughout the vineyard. Normally, the compost is placed on the crown of each vine. There are some questions about impact on the total root system but research literature on other perennial crops does indicate that the positive influence of compost on vine health will be transported through out the vine. However, the primary concern is again how much is being applied. Growers who use this method should take care to calculate how much compost they are applying per acre and calibrate their individual vine treatment to match their per acre nitrogen goals. This can be done by weighing the compost in a bucket and then calculating how much compost to apply to each vine based on the yearly nitrogen availability calculations provided above.

Compost Spreader Application

Compost Spreader Application

Several commercial models of compost application equipment are available to growers in the eastern U. S. This equipment assists growers in obtaining optimal distribution and the desired rate of compost applied to the vineyard. Growers must decide whether to broadcast the compost or apply the compost in a band under the vines. Some machinery may be better equipped to make applications in band or broadcast applications. Although broadcast application will provide a more uniform impact of compost across the vineyard, band application allows growers to concentrate the compost in the area of most roots. Band application also requires less compost per acre which may be particularly important to growers who are just beginning to use compost and want to cover as many acres as possible with the compost they have available. If band applications are made, growers can make applications to row middles in alternate years (but don't loose sight of how much nitrogen is being applied to the vineyard).

Calibration of Compost Application

Some general 'rules-of-thumb' are helpful in calibrating a piece of equipment for compost application. The actual volume/weight ratio of the compost you plan to use depends on type of compost, water content and texture. So the following values will vary with different types of compost and moisture content but they are helpful as you begin to think through compost calibration.

For discussion making several assumptions,

a. If a compost contained 2 cubic yards/T (normally there is 1.5 to 2 yards/T)
b. and 132 cubic yards was applied per acre broadcast, it would result in 1" of compost across the acre, at a rate of 66T/A
c. If this compost were applied in a vineyard (9 feet between rows) in a 3 foot band under the vines, 1" thick = 22 T/A, or ½" thick = 11T/A.

To calibrate a spreader one needs to know,

1. Number of yards per ton of the compost.
2. The volume of a tractor bucket used to load the spreader.
3. The time it takes to fill the bucket with compost from the spreader which is stationary.
4. Distance the spreader will travel in the time it takes to fill the bucket.

Position the bucket in front of the stationary spreader. Begin discharging the compost into the bucket. Calculate the amount of compost discharged (bucket full) in a given time. Determine how much distance the spreader will travel in the same time period. Since you know the amount of compost discharged (bucket size) and the distance traveled, you can calculate the amount of compost that would be discharged in an acre. One can increase or decrease the amount of compost applied per acre by increasing or decreasing the spreader output or tractor speed.

Useful Numbers to Know

1. If there are 9 feet between rows, there are 4,840 feet of row in an acre of vineyard.
2. 1 cubic yard (yd^3) = 27 cubic feet (ft^3). If you know how many ft^3 your tractor bucket holds you can calculate how many yd^3 the bucket holds. (ft^3 of the bucket divided by 27 ft^3/yd^3 = yd^3 of bucket).

Example: Spreader delivery and tractor speed calibration

a. if the tractor bucket is ½ yd^3 ($13.5\ ft^3$),
b. and the spreader fills the bucket in 60 sec
c. and the tractor travels 242 feet in 60 sec (2.75 mph)
d. then the spreader is delivering
   4840 ft/242 ft =20 (1/2 yd volumes/A)
   20 X .5 yd^3 = 10 yd^3s
   10 yd^3/2 yd^3 per T = 5 T/A

3. New vineyards – the best measure of appropriate nitrogen levels for a vineyard is through vine growth. It is recommended that young vines are not fertilized the first season of growth. Therefore, it is recommended that compost not be applied to vines during the first season.

The Best Time to Apply Compost.

The best time to apply compost is in the fall after harvest but before the ground freezes. The nutrients and soil microbes contained in the compost will have time to be incorporated into the soil before winter and will be available to the vine in the spring. However, compost can also be applied in early spring, just before budbreak until about pea-size fruit form. It is not recommended that compost be applied from pea-size fruit until harvest. There is some risk that nitrogen that is quickly leached from the compost after application could stimulate late season growth, slowing down hardening off of the vine. Stimulated late season growth may result in vine or bud damage if an early cold period occurs.

Part V. Cpmpost Application in the Vineyard: Nutrient Considerations

The application of compost to a vineyard impacts the nutrients in the soil and the vines. An understanding of the nutrient balance in the soil and the vines will be useful to the growers in making decisions on the application of compost in vineyards.

Nitrogen Cycles in the Vineyard
Dr. Terry Bates
Cornell University, Fredonia Vineyard Lab
10/3/2003

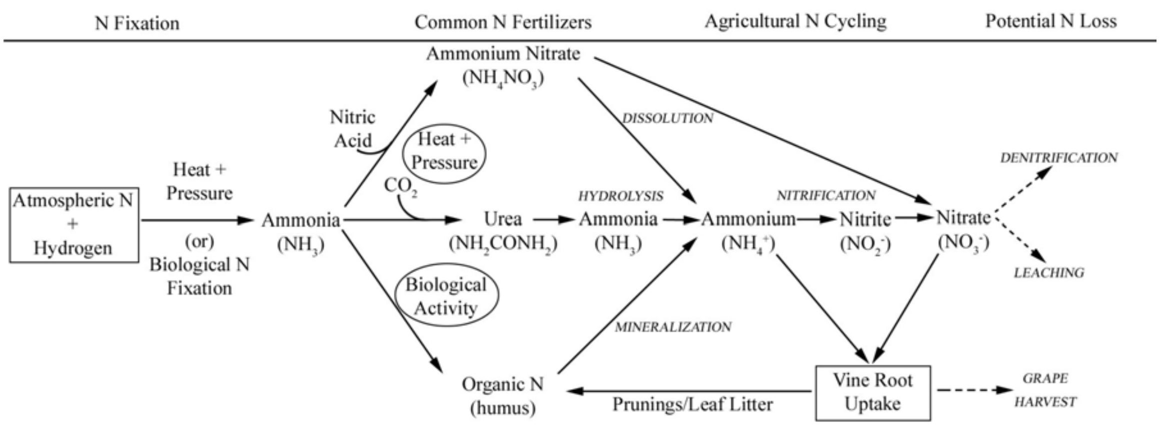

Figure 1: The synthesis and agricultural cycling of three commonly used nitrogen fertilizers in the eastern, United States.

Nitrogen Fixation

Atmospheric nitrogen is by far the largest pool of nitrogen on the planet; however, this molecular form of nitrogen is unavailable for plant uptake. Ultimately, both natural and industrial nitrogen fertilizers are derived from the fixation of atmospheric nitrogen into forms usable by plants. In industrial nitrogen fixation, nitrogen and hydrogen are combined under high temperature and pressure to form ammonia, otherwise known as the Haber process. Hydrogen in this reaction is derived from natural gas, petroleum, or coal, which makes the fertilizer industry dependent on the availability and cost of fuel sources. Industrial nitrogen fixation accounts for only a small fraction of world-wide nitrogen fixation. Biological nitrogen fixation, the dominant fixation process, takes place though the action of microorganisms. Free-living bacteria and bacteria that have symbiotic associations with certain plant species contain enzymes that harvest molecular nitrogen into ammonia. Agriculturally, biological nitrogen fixation is important because it is difficult and expensive to satisfy vineyard nitrogen requirements through industrial fertilizers alone.

Formation of Nitrogen Fertilizers

Nitrogen sources can be supplied to vineyards through both inorganic and organic nitrogen fertilizers. There are several commercially available nitrogen sources that supply ammonium, nitrate, or both to the soil solution for plant uptake. When ammonia is combined with nitric acid under heat and pressure, ammonium nitrate fertilizer is formed. Similar reactions with sulfuric and phosphoric acids produce ammonium sulfate and ammonium phosphate, respectively. Urea, a common inorganic nitrogen fertilizer, is formed from the reaction of ammonia and carbon dioxide under heat and pressure. Since industrial nitrogen fertilizers require high temperatures during the formation of both ammonia and ammonium, the cost of fertilizers are dependent on the cost and availability of fuel sources. Therefore, inorganic nitrogen fertilizers that cost the least per unit of nitrogen are preferred.

There are many sources of organic fertilizers because once nitrogen is fixed by bacteria and incorporated into organic compounds; nitrogen can enter any number of biological pathways in microorganisms, plants, and animals. Organic nitrogen incorporation and organic matter decomposition are also energy intensive processes; however, the energy is derived from biological activity and not the burning of fossil fuels. Ultimately, the breakdown of organic matter releases free ammonium ions and the build up of humus acts as a soil reserve of nitrogen.

Decomposing organic matter and humus are the largest pools of nitrogen in most agricultural systems and represent slow release nitrogen sources given the correct biological and environmental conditions. During periods of rapid vine growth, the release of nitrogen from organic stores can be too slow to meet vine demand. Although inorganic nitrogen fertilizers are only supplemental to organic nitrogen sources, properly timed inorganic nitrogen fertilizers can be essential to desired vineyard production during periods of peak vine nitrogen demand.

Agricultural Nitrogen Cycling

Inorganic and organic fertilizers, through a variety of chemical and biochemical reactions, supply ammonium and nitrate ions to the soil solution for plant uptake. Plants assimilate nitrogen into organic compounds for growth and reproduction. Cane prunings, leaf litter, and dead root tissue are eventually recycled into an organic nitrogen source. Vineyard nitrogen cycling is dependent on several factors such as temperature, moisture, oxygen, organic matter, soil pH, and microbial activity.

Nitrogen fertilizer salts such as ammonium nitrate, ammonium phosphate, and calcium nitrate when applied to the vineyard floor are dissolved into the soil solution and dissociate into their component ions. For example, ammonium nitrate (NH_4NO_3) dissolves into the ammonium cation (NH_4^+) and nitrate anion (NO_3^-). Ammonium cations can absorb onto soil clay particles and the degree of absorption is dependent on the cation exchange capacity and the competition from other cations. Ammonium can be converted to nitrate through the process of nitrification (discussed later). Nitrate anions, preferentially absorbed by grapevines, are a quick source of nitrogen but they are also subject to leaching. Both ammonium and nitrate make up a small percentage of the total nitrogen in agricultural nitrogen cycles; however, they are the nitrogen forms taken up by grapevines. It is estimated that 70% of all mineral nutrient ions taken up by plant roots are in the form of ammonium or nitrate.

Urea is converted to ammonia and then to ammonium through hydrolysis with the urease enzyme. Urea hydrolysis is a biochemical reaction influenced by several factors such as temperature, moisture, and enzyme concentration. Strongly acidic soils and soils with low clay content slow the rate of urea hydrolysis. Urease activity is optimum between a soil pH of 6.5-7.0. The intermediate step in the conversion of urea to ammonium is the formation of ammonia which can be lost from the system through volatilization. Sandy, alkaline soils, high temperature, wet soils, as well as high and unincorporated urea applications increase ammonia volatilization.

Mineralization, the release of ammonium from decomposing organic matter, is also dependent on several environmental and biological factors. In general, warm, moist, well drained soil conditions with reasonable soil pH (4.5-9.0) and low C/N ratio substrate material increases the mineralization rate.

Dissolution of ammonium based fertilizers, hydrolysis of urea, and mineralization of organic matter all generate ammonium ions in the soil solution. Ammonium can be converted to nitrate through the process of nitrification. In nitrification, ammonium is oxidized to nitrite by one group of bacteria and then further oxidized to nitrate by a second group of bacteria. Hydrogen ions are released during nitrification which leads to potential soil acidification. If all the nitrate ions produced through nitrification were absorbed by plant roots, ion excretion by roots would neutralize the reaction. However, plant roots absorb only a fraction of the total nitrate produced and the leaching nitrate leads to soil acidification. Therefore, the addition of ammonium based fertilizers tends to acidify vineyard soils.

Nitrogen Loss

Nitrogen can be lost from the vineyard system through erosion, denitrification, harvesting plant tissues (grapes), and leaching. Erosion leads to the physical removal of organic nitrogen in the upper soil profile. Denitrification is the conversion of nitrate back to atmospheric nitrogen. Grapes and sometimes wood infected with disease removed from the vineyard also removes organic nitrogen from the system.

Nitrate leaching is an agricultural concern because excess leaching leads to soil acidification and potential groundwater pollution. Industrial and organic fertilizers both provide ammonium to the soil where the ammonium is oxidized to nitrate and potentially leached. Efforts should be made to make the most efficient use of nitrogen fertilizers by using the appropriate material, rate, and timing for the individual vineyard goals.

Vineyard Nutrient Management **©2001**

Dr. Terry Bates (10/31/01)

Vineyard fertility management is part of an overall vineyard management program where nutrient supply (soil availability, soil pH), nutrient demand (vine vigor, crop load), and nutrient uptake (root growth, rootstock) interact. In addition to the gaseous elements of carbon, hydrogen, and oxygen, grapevines require several essential mineral elements to grow and produce fruit (Table 1). Although the mineral elements are needed in different quantities, each one plays an essential role in completing the vine's life cycle. Most vineyard soils in New York and Pennsylvania contain sufficient amounts of most of these elements; however, they may not always be readily available. It is the grower's objective**:**

1. to increase the availability of naturally occurring soil nutrients and
2. to supplement deficient nutrients when needed.

The intention of this section on vineyard nutrient management is not to identify each essential element and its role in vine function. Rather, the goal is to characterize common conditions that cause low or imbalanced nutrient availability, identify petiole values that indicate a nutrient disorder, and provide recommendations for avoiding or correcting vineyard nutrient disorders.

***Table 1**. The 13 essential mineral nutrients required by grapevines and the amounts required each season by 3-year-old Concord grapevines as determined by destructive harvesting at the Cornell Vineyard Laboratory, Fredonia, NY. Mature Concord vines would require significantly more of each element. For example, Michigan research indicates that mature Concord requires approximately 70 pounds nitrogen per acre.*

Element	Symbol	Pounds/Acre used by 3-year-old Concord
Nitrogen	N	36.7
Potassium	K	31.2
Calcium	Ca	18.6
Phosphorus	P	7.2
Magnesium	Mg	5.7
Sulfur	S	not measured
Iron	Fe	0.7
Manganese	Mn	0.7
Copper	Cu	0.7
Zinc	Zn	0.2
Molybdenum	Mo	not measured
Chlorine	Cl	not measured
Boron	B	0.1

Nitrogen and Organic Matter: Eastern US trials investigating nitrogen fertilizer and organic matter effects on the growth and production of American grape varieties date back to the 1890's. Holladay in Virginia; Partridge, Kenworthy and Larson in Michigan; Holland in Ohio; Fleming in Pennsylvania; Childs in West Virginia; Upshall in Ontario; as well as Gladwin, Shaulis, and Kimbal in New York conducted similar nutrition field trials through the late 1960's (for a review see J. Cook, 1966). Although the results from these fertilizer trials were often conflicting based on location, variety, soil characteristics, soil organic matter, or production level, some general themes emerge regarding vine nitrogen nutrition.

1) When low soil nitrogen is the limiting factor to vine growth and production by inhibiting canopy fill (sunlight interception) and chlorophyll production (photosynthetic capacity), the addition of nitrogen fertilizer improves vine growth and production. This makes common sense but the same statement is not necessarily true for other nutrients under certain soil conditions.

2) When nitrogen is not limiting, the addition of nitrogen fertilizer can be detrimental to quality fruit production. Excessive nitrogen through either organic or inorganic sources can produce vines that are overly vigorous, which leads to internal canopy shading, reduction in fruit quality, and reduced bud

fruitfulness. In addition, excessive nitrogen leaching into water sources can be hazardous to the environment.

3) The major nitrogen source for vine uptake comes from the natural decomposition of organic matter in the soil and nitrogen fertilizers are supplemental to this. Additional organic matter can improve soil physical properties, increase water-holding capacity, and improve soil exchange capacity through the production of humus. In many of the early nitrogen studies, organic matter in the form of hay, grape pomace, or farm yard manure was equal to or better than inorganic nitrogen fertilizers in improving the long term grapevine nitrogen status.

Table 2*. Mean vine size and yield of Catawba grapes as affected by nitrogen and straw treatments from 1946-1951. Both nitrogen fertilization and addition of straw to the vineyard floor were needed to achieve greater vine size and yield in this vineyard plot. Reproduced from Shaulis (1956).*

Annual Treatment				
Actual N (lbs./acre)	straw (tons/acre)	pruning weight (pounds/vine)	Yield (pounds/vine)	% soluble solids (^{o}brix)
0	0	1.0	5.9	19.5
32	0	1.2	8.6	19.2
64	0	1.6	11.3	18.4
32	2.5	2.1	16.6	17.7
64	2.5	2.0	16.8	17.7

Determining the Need for Nitrogen Fertilization: Bloom time petiole samples from the most recently mature leaf in Concord are directly related to vine size, percent trellis fill, and production. In 1956, Shaulis and Kimbal showed "that the nitrogen content of the leaf blade is more than twice that of the petioles; that the nitrogen percentage decreases as the season advances; that the basal leaves contain less nitrogen than younger leaves; and that a wide difference in potassium concentration does not affect the nitrogen percentage." Tissue nitrogen concentration is high during the spring and quickly decreases during the period of rapid vine and shoot growth (Figure 1). Shaulis and Kimbal showed that bloomtime petiole samples for nitrogen were more closely correlated with vine production than samples in July or August. However, the rapid decline in tissue nitrogen through the bloom period makes designating recommended tissue values problematic. Shaulis and Kimbal add, "With the knowledge that the nitrogen analysis-vine growth relationship is not precise, one is certain that, for late-June petiole samples, a nitrogen percentage less than 1.5 is almost always associated with low vine vigor; and that values over 2.0 are almost always associated with high vine vigor."

Despite the relationship between bloom nitrogen samples and vine growth, bloom tissue samples are not widely used in New York, for several reasons. 1) Fall petiole samples are recommended for determining deficiency of other nutrients, especially potassium. 2) Maintenance nitrogen applications are used in many New York vineyards despite either quantitative (petiole values) or qualitative (canopy fill) analysis. 3) Observations of vine growth, leaf color, and trellis fill are arguably as accurate as bloomtime tissue samples given the rapid flux of tissue nitrogen concentration during bloom.

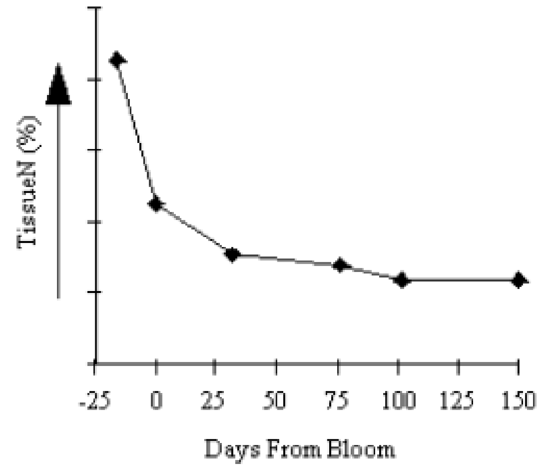

Figure 1. *The growing season pattern of petiole nitrogen concentration in Concord. Rapid vine growth during the bloom period is matched by rapid reduction in shoot tissue nitrogen concentration. Although bloom petiole samples are superior to fall petiole samples in indicating Concord nitrogen status, the rapid change during bloom makes sampling problematic.*

Suggested Recommendations for Soil Tests, Petiole Values, and Common Fertilizers in New York and Pennsylvania Vineyards.

(Tissue values for petioles collected 60-70 days after bloom from the most recently mature leaf)

Factor	Soil	Petiole	Common Materials/Notes
Soil pH	5.5 American 6.0 Hybrids 6.5 Vinifera		Calcitic Limestone (<5% $MgCO_3$ - rest $CaCO_3$) Dolomitic Limestone (15-45% $MgCO_3$ - 55-85% $CaCO_3$) Not all liming materials are the same. The effective calcium carbonate equivalent (ECC) or effective neutralizing value (ENV) considers limestone chemistry and particle fineness. For total rate, divide recommended rate by ENV. Ex: 2 tons per acre recommended / 0.9 (90% ENV) = 2.2 tons per acre applied. Dolomitic limestone is a source for both Mg and Ca. Watch for Mg-K competition as the soil pH increases.

			Low soil mobility. Deep incorporation suggested at pre-plant. No more than 2-3 tons/acre/year suggested for established vineyards. Relatively slow reacting. Apply anytime of year.
Nitrogen (N)		0.8-1.2%	Ammonium nitrate (32% N), most common, acidic soil reaction Urea (46% N), economical N source, acidic soil reaction Calcium Nitrate (15% N), more expensive, basic soil reaction. Organic matter decomposition, variable low % N, long-term, slow-release N. Rate depends on N need and desired vine size. Vineyards rarely require more than 50 lb. actual N/acre/year. 0-30 lb. actual N common for vinifera. 50-100 lb. actual N common for hybrids and labrusca. Apply between bud burst and bloom. Split applications may improve efficiency on coarse or sandy soils and may reduce the incidence of oxidant stipple. Little difference recorded between banded and broadcast applications, especially with high rainfall in NE.
Phosphorus (P)	10-50ppm	0.14-0.30%	Monoammonium phosphate (MAP) (48% P_2O_5), also contains 11% N, acidic soil reaction. Diammonium phosphate (DAP) (46% P_2O_5), also contains 18% N, acidic soil reaction. Vineyard P disorders commonly associated with low soil pH. In established vineyards, raise soil pH with low annual limestone applications. Supplement with P fertilizer until desired soil pH and phosphorus availability is achieved.
Potassium (K)	75-225ppm	1.5-2.5%	Murate of Potash (52% K, 62% K_2O), most common Sulfate of Potash (44% K, 53% K_2O), use if chloride toxicity is a potential problem.

			Sulpomag (22% K2O, 11% Mg), has both K and Mg, more expensive Murate of Potash (KCl) typically applied in the fall to allow K movement into the root zone and chloride leaching out of the root zone. Caution must be used on soil with a salinity problem (not common in the Northeast) or on shallow or poorly drained soils where the chloride cannot leach from the root zone. Potassium is typically banded; however, broadcasting in vineyards with spreading root systems and no-till row-middle management is an option. Factors to watch: 1. K-Mg competition, especially with changes in soil pH. 2. K demand, especially in high cropping systems. 3. K soil mobility, it decreases with decreasing soil moisture
Calcium (Ca)	1000-2000ppm	1.2-2.0%	Limestone (variable % Ca) Gypsum (calcium sulfate, 22% Ca), not used to adjust soil pH. Low calcium availability typically associated with low soil pH. Adjust with limestone.
Magnesium (Mg)	150-250ppm	0.35-0.5%	Dolomitic limestone (variable % Mg), most common Epsom salts (magnesium sulfate, 10% Mg) Sulpomag (22% K2O, 11% Mg), has both K and Mg, more expensive Low magnesium availability typically associated with low soil pH. Can be aggravated in acid soils with high K application. Adjust with dolomitic limestone in low pH vineyards. Use Epsom salts in neutral and high pH soils.

			Excessive soil Mg (either natural or fertilizer applied) may cause K deficiency and vine size reduction. Monitor petiole K and Mg.
Boron (B)	2ppm	25-50ppm	Solubor (20% B), most common. Borax (11% B) Borate-46 (14% B) Borate-65 (20% B) Soil application rates of 1 lb.B/acre in medium to coarse textured soils to 2 lb.B/acre on heavy clay soils are recommended. Blending with other fertilizers (such as N) for broadcast application is suitable. Soluble B products can also be applied to the soil with a herbicide sprayer. Calculate sprayer rate based on actual acres covered, as opposed to acres sprayed (i.e. 1 lb.B/acre = 5 lb. Solubor/acre. If only covering 1/3 of an acre with a 36 inch herbicide band on 9 foot rows, use 15 lb. Solubor/acre). Foliar application of 0.2 lb B/acre. (1 lb. solubor) are recommended and no more than 0.5 lb. B/acre (2.5 lb. solubor) in one application. Spring foliar sprays are timed at 6-10 inch shoot growth and 14 days later. In California, fall (immediate post-harvest) foliar sprays have been more effective than spring foliar application in eliminating cluster and berry disorder. To reduce the risk of foliar burn, do <u>not</u> apply boron sprays at less than 14 day intervals or tank-mixed with water-soluble packages, oil, or surfactants.
Iron (Fe)	20-50ppm	30-100ppm	Iron deficiency is often associated with calcareous soils (high soil pH), low soil oxygen (waterlogging), and variety (native more susceptible). Common deficiency treatments: Lower soil pH by trenching in soil sulfur or using

			acidifying nitrogen fertilizers. Improve soil drainage Apply foliar iron sprays (only good for existing foliage) Apply iron chelates (expensive and short lived) Excessive iron availability at lower soil pH may limit phosphorus availability.
Manganese (Mn)	20ppm	50-1000ppm	Manganese sulfate (32% Mn), Foliar spray Manganese-containing fungicides, Foliar spray Manganese deficiency rare. Manganese toxicity a potential problem at low soil pH.
Copper (Cu)	20ppm	10-50ppm	Deficiency rare. Apply foliar copper - Bordeaux mixture or other copper fungicide. Copper sulfate also available. Potential toxicity reported when copper sprays repeatedly use leading to copper accumulation in low soil pH vineyards. Symptoms similar to lime-induced chlorosis (iron deficiency).
Zinc (Zn)	2ppm	30-60ppm	Zinc chelates, foliar sprays Zinc sulfate, foliar sprays Zinc sulfate should be applied with equal amounts of hydrated spray lime (1-4 lbs./100 gal) at the 3 to 5-inch shoot stage. Repeat in 14 days as needed.
Aluminum (Al)	>100 high		Aluminum solubility and potential toxicity is common when the soil pH drops below 5.0. Toxicity affects root growth, which inhibits water and nutrient uptake. Adjust with lime.
Organic Matter	3-5%		The most common organic mulches used in the Lake Erie region are hay, pomace, and leaves. However, non-plant sources such as farm yard manure have also been effective. When increased root growth, more efficient nutrient uptake, improved water relations,

			decreased soil erosion, and increased vine size are desired, the use of organic mulch is strongly recommended. Even a thin layer of mulch in the month after bloom acts as a barrier to soil water evaporation, suppresses weed competition, and increases vine size. The breakdown of organic mulch to humus acts as a slow release fertilizer for continuous nutrient uptake and promotes beneficial macro and micro-organisms in the soil. Micronutrient deficiencies are rare where organic matter is applied to the vineyard floor. Because of its effect on vine growth, excessive soil organic matter can cause excessive vine size, internal canopy shading, decreased fruit quality, and decreased fruitfulness.

Compost in Vineyards References

Suggested Readings:

For an in-depth, detailed description of compost maturity and physical properties see:
Compost Science & Utilization, Vol.11, No.2, Special Focus: Compost Maturity
Compost Science & Utilization, Vol.11, No.3, A Literature Review: Physical properties of Compost pp.238-264.

Compost on grapevines by Johannes Biala, http://www.elspl.com.au/abstracts/D18.HTM