Compost and Mulch Demonstration Project,
Mendocino County

Use of Compost and Mulches for North Coast Vineyards

January 2003

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Executive Summary

Phylloxera-Related Damage

Grape phylloxera is an aphid-like insect that is a pest of grapevines worldwide. In California it caused $1 billion damage in the 1990s. Root feeding by this insect allows entry of secondary, soil-borne pathogens into the grape roots. These pathogens cause root necrosis that eventually kills vines.

The damage is successfully controlled by the use of rootstocks resistant to the insect. However, in spite of widespread availability of these rootstocks, the pest remains a serious threat because of cost and availability of specific rootstocks, misinformation, virulent strains of the insect, and lack of backup technologies to ameliorate transition from self-rooted vines to rootstocks.

Previously, the University of California project team demonstrated in greenhouse trials that soil-borne fungal pathogens cause a large portion of the damage. The team also demonstrated that organically managed vineyards have less fungal pathogen damage than conventionally managed vineyards. Greenhouse tests and small field-plant experiments that demonstrated that compost in soils reduces root necrosis due to fungal pathogens.

Since these findings suggest that compost applied to infested vineyards may ameliorate phylloxera-related vine damage, researchers initiated research and demonstration plot studies in a mature vineyard to evaluate variables.

Erosion Potential

Soil erosion in vineyards planted on slopes is a critical problem, especially in the North Coast, where rainfall may exceed a meter per year (39 inches). Erosion starts when raindrops directly contact the soil and displace soil particles. Protecting the soil with either a living plant cover or mulch dissipates the energy associated with the raindrops and prevents direct contact between soil and raindrops. *Mulches* are ground or unground plant materials that protect the soil surface; they have not necessarily been subject to an intensive rotting process. Besides dissipating energy, mulches also create micro-ponds that retain small amounts of water, allowing more time for rainwater to infiltrate the soil. Consequently, runoff is reduced when soils are mulched. Presently, the most commonly applied mulch in new vineyards is straw.

Compost overs are ground, urban green trimmings that may be used as mulch, but many growers are unaware of this. Since straw is relatively expensive (around $75 per ton) and needs to be imported from distant growing areas, compost overs should be a feasible alternative. A demonstration using compost overs as mulch in a vineyard was initiated to exhibit the benefits of using compost overs. Straw was also included in the demonstration project.

Demonstration Objectives

1. Demonstrate control of phylloxera and associated grapevine root infections.
2. Determine the difference between surface and incorporated applications relative to phylloxera and related grapevine root infections.
3. Demonstrate erosion prevention with mulches, specifically compost overs and straw.

Plot Descriptions

Phylloxera Treatment Sites—Fetzer Vineyards, Hopland, California

First Trial: An initial trial was established in June 2000 at an organically managed site at Fetzer Vineyards that had been infested by phylloxera for at least seven years. While exhibiting damage, the site remains productive. In this trial, researchers used four treatments, with each replicated four times. Researchers initially applied compost at the rate of 2 tons per acre.

Evaluations of phylloxera, root health, and soil microbial ecology were periodic through the experiment. Vigor and yields were determined in fall 2000 and fall 2001. The last reported measurements occurred in May 2002.

Second Trial: When researchers observed difficulties in the summer of 2001, they instituted a second trial to correct problems. The site of this second trial, though in the same vineyard, was substantially less damaged. Researchers increased the application rate of compost to 8 tons per acre and added oat-hay treatments (tilled and nontilled plots).

Erosion Control Sites—Bonterra Vineyards, Butler Ranch, Mendocino County

An erosion control site was established at Bonterra Vineyards, Butler Ranch, a Mendocino County hillside vineyard, in fall 2000. The plots were seeded with cover crops before treatments. Treatments consisted of compost overs, straw, and a no-mulch control section. Each treatment was replicated randomly four times, with 10 vines per replicate. A new site was established in fall 2001. Plots in each site were evaluated periodically thereafter for visual signs of erosion and cover crop performance.

Results and Discussion

Phylloxera Sites

The data from the phylloxera treatment plots indicated that, individually, compost and tillage did not substantially decrease the insect's populations or associated root necrosis, nor did they increase vine productivity within the constraints of this project. Detrimental effects were seen on vine vigor, though a beneficial effect was seen with the compost-plus-tillage treatment. Soil fungal ecology was affected, though in no explainable way. Though the count of presumably pathogenic *Fusarium oxysporum* propagules in soil decreased (a beneficial effect), estimates of root necrosis did not significantly change. Researchers had expected that the additions of compost would change the soil microbiology sufficiently to decrease root necrosis associated with phylloxera feeding sites and thereby benefit vine vigor and productivity. They feel that these effects were not seen for the following reasons:

- The duration of the project was too short, having run for less than two years. As perennials with considerable potential for storage of photosynthates, grapevines may respond to management changes only after several years. Researchers see the work on this plot so far as the beginning. This and other trials will continue as research and demonstrations of compost treatments for several years to come, and researchers predict the trials will begin to show biologically and viticulturally significant differences in two or three more years.
- The initial site chosen was a severe test of the phylloxera demonstration objectives. It consisted of vines that were severely damaged by at least seven years of previous stress by phylloxera and necrosis when the researchers began. The plot was already under organic vineyard management, though compost had not been added for a number of years.

- The compost may not have been effective because of improper amounts applied or location of application (or the measurement of compost effectiveness correlated with necrosis may not be a valid indicator of damage).

The second phylloxera site has demonstrated to be unbiased by stress or yield clines within it. As expected, no treatment effects were seen during the first year. This site was designed to be available for demonstrations for five years.

Erosion Sites

The erosion control trial demonstrated the efficacy of compost overs for erosion control. Not only did the trial directly decrease erosion, but it enhanced cover crop germination and growth and provided extra nutrients and water, in comparison with the straw and no-mulch control treatments. The compost overs both protected the soil during cover crop establishment and also enhanced cover crops that additionally decreased erosion and benefited the vineyard.

Decreasing Green Material in Landfills by Composting Landscaping Waste for Vineyard Use

There are approximately 20,000 acres of vineyards in Mendocino County. The incorporated areas of Mendocino County generate landscaping waste sufficient to produce 8,000 tons of compost per year. If only this compost and no other were deployed in vineyards, only a small percentage of vineyards in the Mendocino County would have sufficient compost. Clearly, green material collected in highly urbanized counties could be imported for use in vineyards by other counties that have lower population or green material collection levels. Benefits of compost to agricultural soils are well documented, if not fully appreciated.

Project Benefits

This project has been beneficial in several ways, including those listed below.

- It clearly demonstrates the utility of compost overs for erosion control. Vineyardists of Mendocino County have seen these plots firsthand and are encouraged to increase their use of compost overs as mulch.
- The project established a long-term phylloxera management plot that will be available for researchers and vineyardists to see over the next four to five years.
- Researchers feel that this plot will encourage compost use as growers transition into strongly resistant rootstocks.
- In addition, the plots will encourage compost use for enhancing root health.

Introduction

Grape Phylloxera

Grape phylloxera, *Daktulosphaira vitifoliae* (Fitch), is an aphid-like insect that is a worldwide pest of *Vitis vinifera L.*, the European grape (Davidson and Nougaret, 1921, Ordish, 1982). The insect feeds on roots of this species of grape, eventually resulting in vine death. Phylloxera is a native herbivore of North American wild grape species, but does little damage to these plants, since the roots of these species of grapes are resistant to populations of the insect. Though phylloxera initiate formation of leaf galls and feed on leaves, they do little damage to vines of this species.

When this insect was introduced into Europe accidentally in the mid-19th century, it devastated vineyards. When the cause of the vine death was discovered, chemical treatment technologies were developed. Use of carbon bisulfide fumigants became widespread, and though treatments killed many phylloxera and saved some vines, treatments were dangerous to all animal life, including workers, had to be repeatedly applied, potentially harmed vines, and were expensive.

Discovery that native American species of grapes were resistant to the insect's root feeding allowed development of resistant rootstocks. Viticulturists collected plant materials from the southern and midwestern U.S. and produced resistant rootstocks from selections or hybrids of *V. riparia*, *V. rupestris*, *V. berlandieri*, *V. champinii*, and other wild grape species (Galet, 1979). Cuttings of European grape cultivars to be grown for wine were grafted onto these rootstocks either in nurseries or the field. These rootstocks have resisted grape phylloxera damage for more than 120 years and are the only consistently successful control method known for this insect in commercial grape producing vineyards. Since its introduction into Europe, phylloxera has spread to almost all parts of the world where wine grapes are grown, and rootstock technology has followed.

In addition to the strongly resistant and durable rootstock cultivars, there are also rootstock cultivars whose resistance to the insect is less durable. When the European grape, *V. vinifera*, is hybridized with one of the strongly resistant rootstock species, a rootstock results that may be sufficiently resistant for at least temporary use. Some of these less durably resistant rootstocks, when used intensively for 20 or 30 years, select for virulent phylloxera individuals (phenotypes or biotypes) and this selection results in the roots becoming overwhelmed and eventually dying (Granett, et al., 1985).

These weakly resistant rootstocks found viticultural use because they sometimes appear to have growth, qualities, and management advantages in comparison with the strongly resistant, pure American rootstocks. In California, the less durably resistant rootstock AXR#1 was intensively planted beginning in the 1960s. Populations of phylloxera phenotypes virulent to this rootstock selectively increased and became a major problem by 1984. Phylloxera caused $1 billion of damage and loss in the 1990s.

Vine damage by phylloxera is not due to removal of photosynthates (stored sugars used by the insect for growth). The phylloxera population on root systems can be large, in excess of 300,000 insects, including all life stages, on a single vine (Granett, et al., 2001). However, the insect is minute, so the total weight of insects on a vine never exceeds 10 grams (half an ounce). The amount of nutrients removed by these insects is inconsequential in comparison with the 1–5 kilograms (2–11 pounds) of grapes farmers remove from productive vines yearly. The damage therefore must be caused either physiologically by disruption of vital plant functions or pathologically by the introduction of natural, soil-borne fungi that can cause disease in roots.

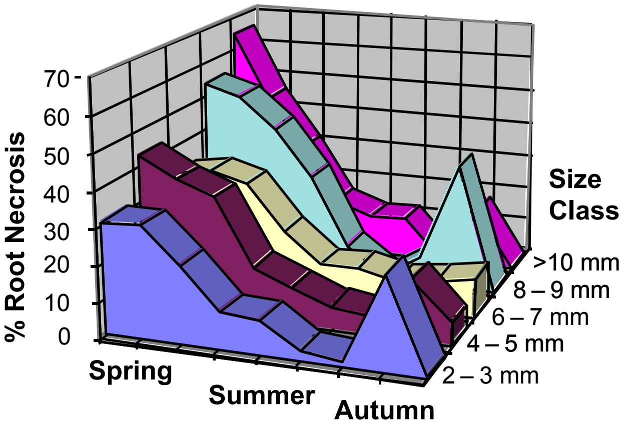
Though physiological damage decreases vine growth and production, it is not likely to kill a vine. On the other hand, soil-borne pathogens cause root necrosis that progresses completely around the root, killing the fluid-conducting phloem cells and the cambium that produces new cells. When a root becomes girdled by the necrosis, all root tissues on the side of the girdle opposite from the vine trunk dies for lack of cellular connection with the vine. When enough roots are thereby killed, the vine itself dies.

The damage is successfully controlled by the use of rootstocks resistant to the insect. The rootstocks prevent populations of phylloxera reaching a level that can harm vines. In addition, preliminary data suggest that rootstocks are also somewhat resistant or tolerant toward at least some of the facultative fungal pathogens that cause the root necrosis. But the pest remains a serious threat in spite of widespread rootstock availability because use of strongly resistant rootstocks is not universal. Use is not universal because of the higher cost of rootstock plants, occasional limited availability of specific rootstock cultivars, insufficient information on adaptability to all vineyard sites, problems of scion adaptability with specific rootstock cultivars, or misinformation on risk of damage to vineyards not using strongly resistant rootstocks. Phylloxera damage is also seen because of virulent phenotypes of the insect and because of a lack of backup pest- and damage-management technologies to ameliorate transition from the self-rooted vineyard situation to rootstocks.

It has been shown that soil-borne fungal pathogens cause a large portion of the phylloxera-associated vine damage (Omer, et al., 1997; Granett, et al., 1998. Figure A.).

Figure A. Root Necrosis Levels

Level of root necrosis as a percentage of root circumference in an array of size classes (by diameter) of roots in a phylloxera-infested vineyard (Granett, et al., 1998). The decrease in necrosis between spring and the end of summer represents the proportion of the total root biomass lost to necrosis. This level of loss accounts for the magnitude of above-ground damage seen.



Researchers demonstrated that phylloxera-infested vineyards that are organically managed have less fungal pathogen damage than conventionally managed vineyards (Lotter, et al., 1999. Figure B.). Researchers have also demonstrated in preliminary greenhouse tests with young potted plants that compost in planting soils reduces root necrosis due to fungal pathogens (Table 1).

Figure B. Root Damage Comparison

Data showing that root damage in a survey of organically managed vineyards was less than that observed in conventionally managed vineyards (Lotter, et al., 1999).

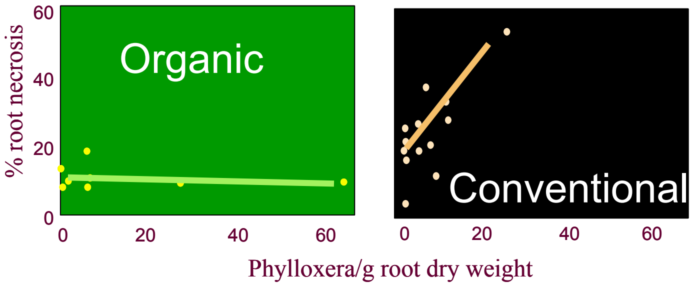


Table 1. Decrease of Root Necrosis Through Use of Compost

Greenhouse experiments with 1-year-old vines showing that compost mixed into soil of phylloxera-infested vines can decrease the root necrosis observed.

Treatment	Phylloxera Nymphs	Root Biomass (grams)	Percent Root Necrosis
Control	36 c	16 b	26 ab
Low Nitrogen	45 c	20 b	29 a
High Nitrogen	55 bc	26 a	26 ab
Sterile Compost	77 ab	28 a	17 bc
Live Compost	89 a	27 a	14 c

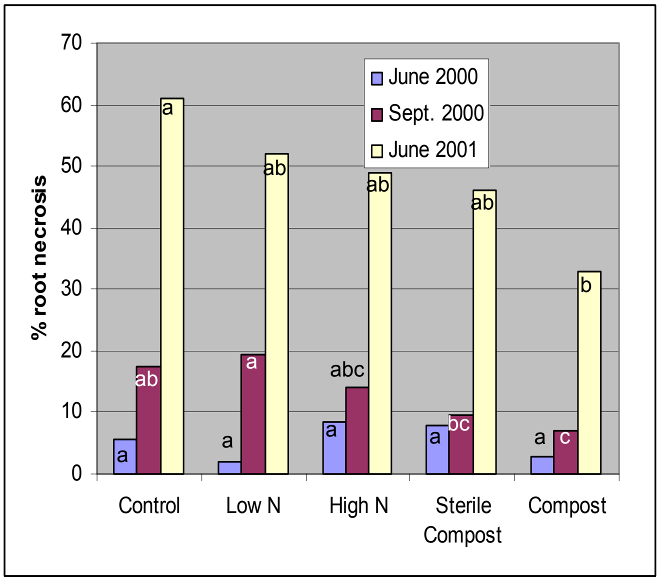
Note: Values followed by similar letters are statistically similar ($P < 0.05$).

Data presented in Figure C represent a phylloxera-infested field trial beginning with the planting of 1-year-old vines. In the second year it appeared as if damage in the compost plots had biologically and significantly reduced necrosis. By the third year, the statistical difference remained, but the biological significance was lost because of the high level of necrosis in all treatments. These findings suggest that compost applied to infested vineyards may ameliorate or slow development of phylloxera-related vine damage. Researchers therefore undertook this mature vine research and demonstration plot study to evaluate variables involved.

Soil Fungal Ecology and Organic Amendment Effects

The soil microbial community and the soil organic matter have major affects on soil structure, nutrient retention, and root-microbe interactions. An ideal soil has many soil aggregates and macro-pores that promote good drainage, aeration, and root penetration. Soil organic matter (primarily humic matter) along with an active soil microbial community support the formation and maintenance of the soil aggregates and macro pores. In addition, the organic matter contains plant nutrients both within its structure and at ion exchange sites. The humus also functions as a slow-release fertilizer. Due to its slow decomposition, nutrients are released and made available to plants. The soil microbial community is key to this decomposition and the benefits that flow from it. The microbes themselves, through their hyphal networks and slime production, further contribute to soil aggregate and macro-pore stability. Building up soil organic matter provides the food base for supporting a robust and active microbial community in the soil. This can be done by addition of organic matter such as compost, mulches, fresh manure or green plant materials, and cover crops.

Figure C. Three-Year Field Experiment With Young Vines, Davis, California



Composts have been used routinely by many gardeners and organic farmers to improve the soils. The properties of compost are similar to those of humus, and thus the addition of compost to soil contributes to all of the positive benefits described above: good soil structure, nutrient retention, slow release of nutrients, and supporting the development and maintenance of microbial communities. Compost used in the nursery trade can effectively suppress some root pathogens (Hoitink and Boehm, 1999). Incorporation of green plant residues has also been shown to significantly suppress the incidence and severity of *Verticillium* wilt as well as economic damage (Davis, et al., 1996, 1999, and 2001). This suppression was strongly correlated with increases in soil organic matter and in the soil microbial community, especially with that of root-colonizing fungi. These findings suggest that use of compost and other organic soil amendments could also have an impact on the pathogens of grape roots.

Plant roots growing through soil develop a microbial community on their surfaces that includes both beneficial microbes and potential pathogens. Soils with high microbial populations and activity support a more dense and diverse microbial population on the plant roots. Competition for limited resources and colonization sites on roots appears to be an important mechanism contributing to disease suppression. Huisman (1988) has found that the colony size of the wilt pathogen on potato roots is dramatically reduced when the population of saprophytic root colonizers is increased in soil and on roots by organic matter additions. This indicates that following the dynamics of root colonizing fungi in both the soil and on plant roots provides a measure of any changes in the soil microbial community that is most likely to affect pathogen interactions with plant roots.

Changes in the microbial community in soils take time to develop, since they are the result of complex processes and interactions in the soil. Three to six years are often needed to effect significant, visible changes. Davis, et al. (1996) found that three successive years of organic matter addition were needed to achieve significant disease suppression. A continuous program of organic matter build-up is essential for advancing significant changes in the soil microbial community. Fortunately, just as it takes time to change the soil structure and community, the benefits are long-lived, potentially lasting for years.

Soil Erosion

Soil erosion in vineyards is a critical problem, especially in the North Coast, where total rainfall frequently exceeds a meter per year (39 inches). Erosion starts when raindrops directly contact the soil and displace soil particles. Protecting the soil with either plant cover and/or organic matter mulches dissipates the energy, and prevents direct contact between soil and raindrops. Mulches also create micro-ponding that retains small amounts of water, allowing more time for infiltration into the soil compared to unprotected soils. Consequently, runoff is reduced when soils are mulched. Presently, the most commonly applied mulch in new vineyards is straw. Use of ground urban yard trimmings, termed “compost overs,” as a mulch, is also an option for vineyardists, but many are unaware of this resource. Since straw is relatively expensive (around $75 per ton plus application costs), and needs to be imported from distant growing areas, compost overs should be a useful alternative to straw to protect soil. A demonstration project was established to increase the use of compost overs for this purpose.

Objectives

1. Demonstrate control of phylloxera and related grapevine root infections.
2. Determine differences between surface and incorporated compost applications relative to phylloxera and related grapevine root infections.
3. Demonstrate erosion prevention with mulches, specifically compost overs and straw

Methods

Materials

Phylloxera Treatment Sites

Material used to make the composts (feedstock): Grape pomace consisting of fermented skins, seeds, and yeast residue following fermentation and pressing of red wine grapes.

In addition, composts were made from standard compost blends at Cold Creek Compost, Inc., near Ukiah, from about 30 percent manures, 35 percent grape and pear pomace, and 35 percent high carbon sources, including shredded yard trimmings and construction debris.

Processes: For the pomace compost, starting material is delivered to a composting site on the winery property where it is piled and allowed to decompose. It is turned at least three times, and then allowed to age until the following season, when it is spread on vineyards following harvest. Temperatures routinely exceed 140°F during the composting procedure. Cold Creek Compost uses a commercial composting process.

Estimated cost of production: The pomace process costs, including all hauling, turning, and spreading, are estimated at $10 per ton of finished material.

Average nutrient content: The nutrient composition of the compost is variable, but usually is about 1 percent nitrogen, 0.5 percent phosphorus, and 4 percent potassium. When applied at 1 ton per acre, the compost adds back about 20 pounds of nitrogen, 10 pounds of phosphorus, and 80 pounds of potassium. This would be a normal application. In the study, researchers started with a rate of 2 tons per acre and upon suggestion increased it to 8 tons per acre, the latter being considerably higher than usual. Eight tons per acre is equivalent to approximately 160 pounds of nitrogen, 640 pounds of potassium, and 80 pounds phosphorus per acre. Although these amounts are high in the context of inorganic fertilizer applications, the slow decomposition rate of compost will release these nutrients over an extended period of time.

It is important to note that materials were applied at a rate of up to 8 tons per acre that is greater than most grower applications. Such rates would cost growers approximately $80 per acre.

Oat-hay used as mulch was obtained from a commercial source.

Erosion Control Sites

Feedstock: The compost overs consisted of coarse materials—chipped and shredded landscape, "green material," and chipped lumber—between 0.375 and 2 inches. During processing, the coarse materials are run through the standard composting windrows and used as an aeration aid, and then subsequently screened out. A considerable amount of fines coating the particles gives the material meaningful nutrient content. Standard compost blends at the Cold Creek facility are made from about 30 percent manures, 35 percent grape and pear pomace, and 35 percent high-carbon sources, including shredded yard trimmings and construction debris.

Cost of production and application: Production costs for compost overs are not available, since this material is typically returned to compost piles for aeration instead of sold. Regular compost retails for about $20 per ton delivered to a vineyard site in the Ukiah area from the Cold Creek facility). In the study, researchers applied 8 tons of compost overs per acre. If compost overs were commercially available, the following costs could be expected to treat an acre of new vineyard, based on costs of regular compost:

Material:	8 tons @ $20/ton	$160
Spreading:	Approximately $5 per ton	$40
Total		**$200**

Vineyard managers indicate this expense is comparable to the $175 per acre cost of spreading 35 bales of straw by hand. The advantage of the compost overs is that the material can be spread by machine. Additionally, an additional pass of a disc or roller to “pin” compost overs to the soil is not needed, as would be with straw.

Average nutrient content: Nutrient content in the compost overs is surprisingly high, considering the coarseness of the material. The following data were supplied from an analysis by A & L labs: 1.6 percent nitrogen; 2.46 percent phosphorus; and 2.0 percent potassium. At our rate of 8 tons per acre, applications were at 240 pounds nitrogen, 400 pounds phosphorus, and 376 pounds potassium.

Procedures

First Phylloxera Treatment Site (Pertaining to Objectives 1 and 2)

Establishment: Researchers identified a phylloxera-infested site at Fetzer Vineyards, Hopland, California. An examination of roots determined the site was relatively evenly infested. The vines of the site initially appeared relatively healthy and, according to the manager, were productive. This assurance was necessary to predict viability through the duration of the project and to assure researchers that the vines were healthy enough to respond to the treatments.

The treatment plot is on Fetzer property on Eastside Road just outside of Hopland. The soil type is Russian River loam. Researchers used vines in rows 275 to 288 in the vineyard with Chardonnay on AXR#1 rootstock cultivar; this site is easy for visitors to locate, just opposite the winery. Appendix A provides the site layout and indicates placement of tape ribbons designating certain plots. The plots were laid out and ribbons placed on June 23, 2000 after a joint discussion of all cooperators. On this date, researchers took soil and root samples to ascertain infestations of phylloxera, lack of significant geographical variability in populations and damage, and nature of soil microbes.

To test the feasibility of the proposed work, researchers applied a grape pomace compost and till treatments on July 20, 2000. This exercise revealed that tilling the berms required hand equipment rather than the tractor that was used to till the middles. Researchers also realized that watering the plots to “jumpstart” the process of integration of compost with the soil would be needed.

Researchers laid out four replicates of four treatments, shown in Table 2.

Table 2. Phylloxera Treatment Variables (First Trial, 2000)

	Objective 1	Objective 2	
Treatment	**Compost***	**Cover Crop****	**Tillage**
1	Yes	No	Yes
2	No	Yes	No
3	Yes	Yes	No
4	No	No	Yes

* Two tons per acre.

** Mixed burr clover, subterranean clover, and rose clover commercial mix.

These treatments were carried on for the full two years of the study. Since Fetzer Vineyards already used organic management, the first year of the study was used to establish the "control" (no compost, treatments 2 and 4) conditions. Treatments were made to two vineyard rows and the medians on either side of the two rows. One of the rows was used for below ground samples and the other for above ground viticultural measurements. Twenty vines were in each treatment in each replicate.

Populations and necrosis: Below-ground samples were taken periodically. The soil surface under each sample vine within 0.5 m of the trunk was divided into four quadrants. Each quadrant overlaps a portion of the berm and row middle, and therefore all quadrants were considered comparable to one another. A root sample consisted of roots from an excavation of the soil in a volume of 30 (high) x 30 (wide) x 40 (deep) centimeters within one of the four quadrants. For each treatment and sampling dates, researchers selected 10 quadrants to sample. They exposed the roots and determined phylloxera population and demography by examining the roots under a microscope (Omer, et al., 1997). Researchers determined the percent of root necrosis by estimating the percent of the root diameter in which there was necrosis in the region of the phloem parenchyma (Granett et al. 1998). They determined which fungal pathogen species caused that necrosis by plating surface-sterilized root sections that exhibit necrosis on appropriate nutrient agar (Omer, et al., 1999).

Soil microbiology: Soil samples, collected by coring each quadrant on scheduled sampling dates, were used to evaluate microbial populations in the soil and on the grape roots (Huisman 1988). Researchers determined population densities in non-rhizosphere soils by dilution plating on appropriate media (Dhingra and Sinclair, 1985).

Soil samples were collected at periodical intervals (June 23, August 2, and October 5 in 2000 and April 26, May 21, July 2, and September 28 in 2001). Samples were collected with a soil corer near drippers where soil remained moist from irrigation. Soils were stored for later analysis of microbial populations and root densities.

The samples collected in 2000 were examined for the population density of selected fungi (*Fusaria, Ulocladium, Penicillium* and *Aspergillus spp.). Fusari*a species were evaluated since these are the principle colonizers of plant roots and thus may serve as competitors to other microbes. The other fungi are typical saprophytes, which are influenced by the availability of organic matter and have weak root colonization ability.

In addition, plant roots were recovered from the soil samples with a flotation procedure. Total root length was estimated with a statistically based procedure in order to obtain root densities. Almost all roots obtained by this method were small feeder roots with over 80 percent having diameters of less than one millimeter. Simultaneously, the nodosities (small galls on the feeder roots induced by phylloxera) were counted in order to get a quantitative estimate of the impact of phylloxera on small roots. The nodosities represent feeding sites established some time before the sampling date. For the 2001 samples, fresh roots were isolated shortly after collection. Using a plating procedure, the density of microbes well established on or in the root cortex was measured. These data can be used to evaluate whether the treatment had any effect on the colonization of grape roots by soil microbes.

Second Phylloxera Treatment Site, (Pertaining to Objectives 1 and 2)

After the first complete year of the project, researchers became concerned at not seeing treatment trends in phylloxera populations, root necrosis, or soil microbiology, and that the high level of necrosis might be beyond “repair” by the treatments. They therefore decided to set up a second treatment site in July 2001 in the same vineyard but in a portion that exhibited less necrosis. The randomized plot diagram is shown in Appendix B. Treatments were compost, tilled or nontilled; oat-hay, tilled or nontilled; and the control treatment with no added materials, tilled or nontilled. Each of the six treatments (Table 3, four vines per treatment) was replicated four times.

Table 3. Phylloxera Treatment Variables (Second Trial, 2001)

Treatment	Compost*	Oat-Hay**	Cover Crop	Tillage
1	Yes	No	No	No
2	No	Yes	No	No
3	No	No	Yes	No
4	Yes	No	No	Yes
5	No	Yes	No	Yes
6	No	No	Yes	Yes

*Compost was made from a mixture of commercial green compost and grape pomace and applied at a rate of 8 tons per acre.

Rate of Compost Application: Under two drippers per vine (96), a pile 5 centimeters deep x 30 centimeters wide by 60 centimeters long = 9000 cm^3 (about 2 gallons).

**Oat hay is high in nitrogen. Same application rate as with compost.

Viticultural Measurements for Both Phylloxera Treatment Sites

In each treatment replication, 10 vines were selected for gathering viticultural data. At harvest, researchers measured total yield, bunch weight, and berry weight. When the vines were dormant, pruning weights and cane lengths were determined for the same vines. Vigor ratings were based on the following scale:

1 = Poor growth, shoots less than 12 inches long, no grapes.

2 = 12- to 18-inch shoots, few grapes.

3 = 18- to 30-inch shoots, light crop.

4 = 30-to 48-inch shoots, good crop.

5 = Shoots greater than 48 inches, good crop, healthy vigorous vines.

All data were analyzed statistically to determine mean differences based on $P < 0.05$.

Erosion Control Site (Pertaining to Objective 3)

Researchers identified a phylloxera-free, recently planted Mendocino County vineyard site located on sloping ground likely to erode. Plots were established on October 17, 2000 at Bonterra Vineyards, Butler Ranch, southwest of Ukiah, at an elevation of approximately 1900 feet. The vineyard had been staked and planted earlier, in the spring. At that time, Zinfandel on St. George rootstock, head pruned on an 8 x 8-foot spacing, was planted. The site is moderately sloped, at an approximate 20 percent grade. The soil is a Josephine loam. Soil preparation included liming, light ripping, disking three times, seeding cover crops, and harrowing to lightly cover the seed. The non-tillage, self-reseeding cover crop mix included (by percent weight) 40 percent Juan triticale, 40 percent common rye grass, and 20 percent Nitro Persian clover.

Treatments were applied following seeding of the cover crop mix. A randomized complete block design was chosen with the three treatments replicated four times, as shown in Table 4 below.

Table 4. Erosion Control Treatments

Treatment	Number of Replicates	Number of Vines per Replicate
Compost Overs	4	10
Straw	4	10
No-Mulch Control	4	10

The treatments consisted of compost overs, applied at 8 tons per acre (approximate cost, $160); straw, hand-applied at 1.3 tons per acre (approximate application cost, $175); and a no-mulch control with no cover over the seeded bare soil. Plot size per treatment was 10 x 70 feet (approximately 700 square feet per plot); and the total experiment size was 120 x 70 feet. The plot design, material details, and dates are presented in Appendix C.

Erosion was evaluated by using protocol developed by the Natural Resource Conservation Service (NRCS). Erosion monitoring was conducted by visual evaluations with the staff of the NRCS, in which soil surface disturbance was inspected for rills, exposed aggregates, or other signs of soil displacement.

Light rains in late fall ensured adequate germination, and a cover crop stand was successfully established. Plant stand and density was estimated visually in January following seeding. Erosion was visually evaluated in December, January, and February, using the NRCS soil loss estimation protocol. Cover crop yields were measured by harvesting one square meter from each replication when the cover crops were blooming in the spring.

This first erosion plot was terminated after winter because of loss of the plot due to equipment failure (blocked irrigation lines). A second erosion plot, similar to the first one, was established in fall 2001. The new trial was established at Bonterra Vineyards, Butler Ranch, in a different location at the crest of the slope, and designed to avoid the problems seen the first year.

The same treatments and rates were used as in the first experiment, and the plot was seeded November 2, 2001. Data were collected on this plot May 24, 2002.

Results

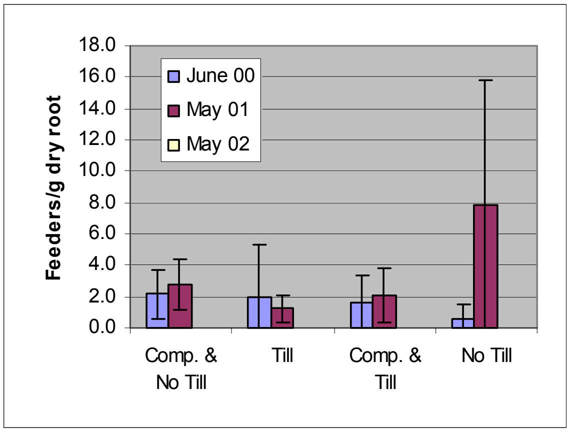
Phylloxera Sites (Pertaining to Objectives 1 and 2)

Populations

Populations of grape phylloxera feeders (first instars through adults) were variable into the second year of the project, but mean populations did not differ by treatment at the time of the first treatments in summer 2000 or during the course of treatments **(**Figure D). Researchers expect population measurements to be highly variable because the insects are not evenly distributed within vineyards or on the root system of any given vine, and as a result sampling displays highly variable outcomes.

Figure D. Populations of Phylloxera Feeders

Nymphal instar 1 through the adult stage observed on lignified roots (2 to 15 millimeters in diameter). Bars are 95 percent confidence limits. *Note:* May 2002 population data not comparable because soil temperature was below the 18ºC threshold for gall formation.



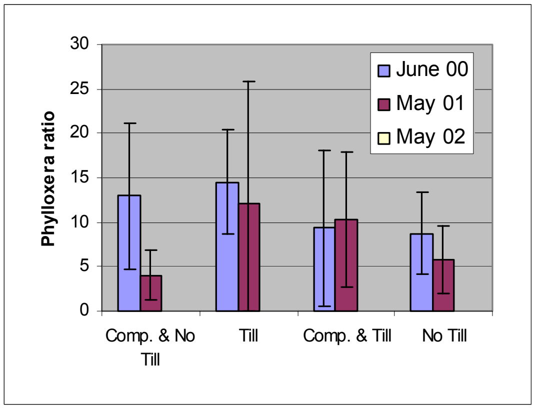
In addition, population size is influenced by the health of roots. On individual roots that have been infested a long time and show damage, populations will decline, whereas roots with newer infestations tend to be healthier and more supportive—this then increases observed population variability, since the several roots sampled from each vine will appear to decline at different rates. The high variability in populations can mask subtle trends. The fact that the populations did not observably decline over time is therefore only a crude indication that vine health was unchanged. However, the fact that all vines began the experiment infested and remained infested suggests that this was an appropriate site for evaluating benefits of compost.

Population ratio is the sum population of eggs, first instars, and second instars as a proportion of the sum population of third instars through adults. This value can be considered an index of relative vigor of a population. If the ratio is greater than 1, it indicates that the population is actively reproducing, while values less than 1 indicate a senescing population. When the ratio is in the range of 10 to 20, the bulk of the population is generally in the egg stage and the fecundity of each reproducing female is high. Having sampled the population in spring 2000 and 2001 of the project, researchers found that the ratios were comparable. This suggests possible population trends and infers health of the supporting roots.

The ratio averages were highly variable and in all treatments and dates not statistically differentiable (Figure E). The 95 percent confidence limits bars were large, suggesting that researchers would not detect any but the most severe differences between measures. However, the data do reveal that almost all averages were statistically above 1, suggesting that root quality was uniformly sufficient to support growing populations. The lack of change in the ratio between the pretreatment measurements in June 2000 and the 2001 sampling suggests that the overall root quality did not substantially decline.

Figure E. Ratios of Populations
(Eggs and 1st and 2nd Instars/3rd and 4th Instars and Adults)

Bars are 95 percent confidence limits. *Note:* May 2002 population data were not comparable because the soil temperature was below the 18°C threshold for gall formation.

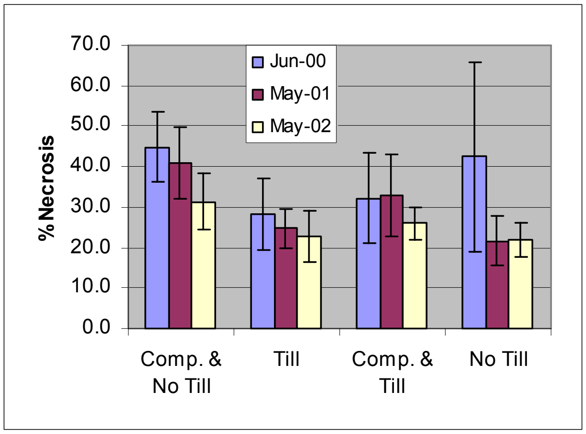


Necrosis Associated With Phylloxera

Root quality can be measured directly by evaluating the percent of the root circumference that exhibits fungal necrosis—the more necrosis, the less root tissue is available for absorption of water and minerals and storage of photosynthates, and the more likely it is that root biomass will be lost through girdling. Figure F shows that necrosis did not change appreciably during the course of the project. Though quality of roots was marginal from the beginning, pretreatment differences in the blocks were not present, and neither treatment nor time statistically changed this measurement of necrosis. Though researchers had hypothesized that compost treatments would ameliorate development of new necrosis, this was not observed during the two-year course of the project.

Figure F. Percent Fungal Necrosis of Lignified Roots (2—15 mm Diameter) as a Percent of Circumference at 4-cm Intervals By Treatment and Date

Bars represent 95 percent confidence limits.



The lack of a treatment effect with regard to root necrosis could mean that (a) compost and tillage are not components of the necrosis ecology, (b) they are components, but not enough time had elapsed to see the effect clearly, or (c) this particular vineyard block was not appropriate for the study because it already had near maximal necrosis—researchers had never seen a productive vineyard with more than about 40 percent necrosis. The second trial block was set up as an adjustment to account for the third explanation.

Microbial Ecology

Soil fungal populations: The populations of soil fungi were fairly consistent over the different sampling dates (Table 5). For most of the *Fusarium spp.*, there were no significant differences among treatment plots within any sampling date. *F. equiseti* had essentially the same population density at all dates. The small increase in *F. oxysporum* and the larger increase in *F. solani* in the spring are consistent with the expected effects of the winter cover crop—mostly grasses. The saprophytic fungi exhibit more variable densities over time. With the August 2000 sample, there is an indication that the compost prevented the normal summer decline of the *Penicillium spp.* However, by autumn, this effect was no longer evident as populations of this fungus exhibit a general increase.

Table 5. Summary of Soil Populations of Selected Fungi in the Fetzer Vineyard Treatment Blocks

Treatments with significant differences ($P < 0.05$) are indicated with letters.

Treatment	Colony-Forming Units Per Gram of Soil					
	Fusarium equiseti	***Fusarium oxysporum***	***Fusarium solani***	***Ulocladium spp.***	***Penicillium spp.***	***Aspergillus spp.***
June 2000 Pretreatment Soil Samples						
Compost, No Tillage	140	960	180	750	190	90
No Compost, Tillage	150	1180	180	690	180	70

Treatment	**Colony-Forming Units Per Gram of Soil**					
	Fusarium equiseti	***Fusarium oxysporum***	***Fusarium solani***	***Ulocladium spp.***	***Penicillium spp.***	***Aspergillus spp.***
Compost, Tillage	140	1000	140	840	360	120
No Compost, No Tillage	130	950	160	870	220	360
August 2000 Soil Samples						
Compost, No Tillage	130	790	320	370	410	100
No Compost, Tillage	130	980	320	350	25	32
Compost, Tillage	120	890	270	400	440	240
No Compost, No Tillage	150	870	240	280	50	200
October 2000 Soil Samples						
Compost, No Tillage	160	790	140	570	670	140
No Compost, Tillage	140	970	190	570	430	60
Compost, Tillage	200	900	180	640	2340	140
No Compost, No Tillage	120	1110	200	490	1160	95
April 2001 Soil Samples						
Compost, No Tillage	200	1320 b	690			
No Compost, Tillage	160	1670 a	660			
Compost, Tillage	180	1460 ab	780			
No Compost, No Tillage	180	1490 ab	720			
July 2001 Soil Samples						
Compost, No Tillage	135	970 c	500	150	200 a	90
No Compost, Tillage	124	1670 a	740	220	60 b	100
Compost, Tillage	123	1460 ab	800	200	200 a	130
No Compost, No Tillage	123	1250 bc	520	210	60 b	320
September 2001 Soil Samples						
Compost, No Tillage	160	1670	1160			

Treatment	Colony-Forming Units Per Gram of Soil					
	Fusarium equiseti	***Fusarium oxysporum***	***Fusarium solani***	***Ulocladium spp.***	***Penicillium spp.***	***Aspergillus spp.***
No Compost, Tillage	180	1680	870			
Compost, Tillage	180	1860	1090			
No Compost, No Tillage	110	1590	820			
April 2002 Soil Samples						
Compost, No Tillage	204	1550	430	790	680	560
No Compost, No Tillage	140	1650	320	620	650	640

Species of *Penicillium* exhibit a significant difference between compost treated and untreated plots in the July 2001 sample. Thus far, the data show that the treatments have had little impact on the soil populations of the main root-colonizing fungi. The early 2001 data indicated that there might be a treatment difference developing for the soil populations of *F. oxysporum*. Tilled plots had slightly higher levels of this fungus and some of the differences were significant. The differences may result from the accelerated rates of decomposition of organic matter (especially roots, the primary site of inoculum buildup of *F. oxysporum*) that often accompanies mixing of the soil profile. However, by autumn, the differences were no longer significant, reflecting the fact that organic matter decomposition in the other treatments had time to catch up. The populations of the *Fusarium spp.* all exhibited increases by the autumn.

Densities of roots and nodosities: The root densities exhibited little change between the summer of 2000 and the spring of 2001—especially for the untilled plots (Table 6).

Table 6. Densities of Small-Diameter Live Roots (Feeder Roots) of Grapes and of Nodosities on Small Roots in the Fetzer Vineyard Treatment Blocks

Treatments with significant differences ($P < 0.05$) are indicated with letters.

Treatment	Root (Centimeters) Per 100 Grams of Soil				
	August 2000	**April 2001**	**May 2001**	**July 2001**	**September 2001**
Compost, No Tillage	10.2	11	24 a	34	43
No Compost, Tillage	5.6	15	20 b	27	29
Compost, Tillage	8.1	13	16 b	27	32
No Compost, No Tillage	12.6	13	28 a	36	38

	Nodosities Per Meter Root (< 1 mm diameter)				
	August 2000	April 2001	May 2001	July 2001	September 2001
Compost, No Tillage	23	33	18 b	24	34
No Compost, Tillage	34	35	28 a	21	48
Compost, Tillage	29	33	37 a	23	48
No Compost, No Tillage	33	34	15 b	34	61

In the May 2001 sample, an increase in the density of the small roots is evident. A further increase in root densities was observed in the July 2001 sampling; a flush of growth in the spring is typical for perennial plants.

The root density data indicate that tillage has a negative influence. In the spring of 2001 and 2002, root densities in the tilled plots were significantly lower than in the untilled plots. The August 2000 sample (taken after the initial tillage) exhibited slightly lower densities in the tilled plots, but the difference is not significant at the 5 percent level. By April 2001, though, this effect was gone. However, in the May sampling (shortly after the spring 2001 tillage) the tilled plots again had lower densities.

By July, the untilled plots still exhibited higher root densities than the tilled plots; however, the difference was no longer significant at the 5 percent confidence level. Root densities in the autumn were similar to those in the summer and did not exhibit a significant difference between treatments.

The density of nodosities on small roots was constant over both treatments and most sampling dates, and averaged about 33 nodosities per meter of root. The untilled plots exhibited a significant drop in density between the end of April and the end of May. This might be explained by the flush of new root growth. A doubling of small roots would be expected to drop the overall density of nodosities to half the initial values. Even if new roots support new feeding sites for phylloxera, there might not have been enough time for the galling reaction to show. Results of the mid-summer sampling indicated this was probably the case.

Among the treatments, nodosities per meter of root were similar to the levels observed earlier, and there were no significant differences. The nodosity density continued to increase during the summer and, at the end of September, was almost double the July values (Table 5). Again, no significant treatment differences were evident.

Colonization of roots by fungi: The data indicated that by the summer of 2001 no real differences were evident in the colonization of the grape roots by the *Fusarium spp*. or by *Penicillium* (Table 7).

Table 7. Colonization of Grape Roots by Selected Fungi in the Fetzer Vineyard Treatment Blocks (Summer 2000)

Treatment	Colonies Per Meter of Root			
	Fusarium equiseti	*Fusarium oxysporum*	*Fusarium solani*	*Penicillium spp.*
April 2001 Soil Samples				
Compost, No Tillage	20	74	40	11
No Compost, Tillage	30	80	27	16
Compost, Tillage	30	70	38	13
No Compost, No Tillage	36	80	50	19
May 2001 Soil Samples				
Compost, No Tillage	12	26	14	68
No Compost, Tillage	24	56	24	52
Compost, Tillage	36	48	22	14
No Compost, No Tillage	12	36	20	20
July 2001 Soil Samples				
Compost, No Tillage	23	70	48	110
No Compost, Tillage	21	59	47	130
Compost, Tillage	35	82	47	92
No Compost, No Tillage	30	86	38	67
September 2001 Soil Samples				
Compost, No Tillage	5	86	112	16
No Compost, Tillage	11	78	102	21
Compost, Tillage	8	99	89	13
No Compost, No Tillage	6	82	92	5

Colonization rates by other fungi were well below 10 colonies per meter of root. Again, there was an indication that tillage may effect the colonization rate by *F. equiseti* and *F. oxysporum*. The lower values observed on May 23 could be related to the new root growth. Preliminary data indicated that the density of these fungi was lower on very young feeder roots as compared to the older small roots. Again, the results of the mid-summer assay showed that this decrease in density appears to be temporary, since colonization levels in July and September are similar to those observed the previous summer. Colonization rates of roots by *F. oxysporum* and *F. solani* exhibited only small seasonal variations while those of *F. equiseti* and *Penicillium* had larger variations.

Vine Vigor and Productivity

During the course of the project, researchers were able to collect data on cane pruning weights (winter 2000–2001), vigor rating (summer 2001), and yields at harvest in autumn 2001. Lastly, researchers collected vigor information in May 2002.

Canes, winter 2000–2001: Cane weights and lengths for winter 2000–2001 are shown below as averages (±95 percent confidence limit) (Table 8). Essentially these are pre treatment since the compost and tillage done mid season could not affect cane growth that had already been completed by the time applications were applied and were not likely to affect grape harvest. The data showed no treatment effects confirming that the plots started the project essentially equal.

Table 8. Pruning Data From Winter 2000–2001 (First Phylloxera Treatment Trial)

Values in parentheses are 95 percent confidence limits.

Treatment	Cane Weight in Kilograms	Cane Length in Centimeters
Compost, No Tillage	0.79 (0.32)	813 (86)
No Compost, Tillage	0.97 (0.34)	833 (80)
Compost, Tillage	1.11 (0.38)	874 (106)
No Compost, No Tillage	1.18 (0.33)	947 (58)

Vigor rating, summer 2001: The vigor ratings during summer 2001 showed treatment differences (Table 9).

Table 9. Vigor Rating on a 1–5 Scale (July 2001)

Values in parentheses are 95 percent confidence limits.

Treatment	Average
Compost, No Tillage	3.1 (0.3) a
No Compost, Tillage	3.9 (0.2) b
Compost, Tillage	4.1 (0.4) b
No Compost, No Tillage	3.6 (0.2) ab

Viticultural Measurements:

1= Poor growth, shoots less than 12 inches long, no grapes.

2=12- to 18-inch shoots, few grapes.

3=18- to 30-inch shoots, light crop.

4=30-to 48-inch shoots, good crop.

5=Shoots greater than 48 inches, good crop, healthy vigorous vines.

Unexpectedly, the compost-treated plants were less vigorous than the plants treated with tillage alone, or compost plus tillage. Tillage clearly appears to make a difference, though the reason is not evident from the phylloxera or necrosis data presented. The difference may have to do with nutrient availability as a result of the tillage, soil aeration, or possibly a combination effect of increased nutrient availability and root stimulation by the cutting of surface roots that occurs with tillage.

Yields at harvest, autumn 2001: Harvest data for autumn 2001 are shown in Table 10. There were no berry weight or overall yield differences between treatments, nor were there chemistry differences as measured by degree Brix (sugars), pH, or total acids (factors important for berry quality).

Table 10. Berry Weight and Chemistry for Harvest (September 2001)

Values in parentheses are 90 percent confidence limits.

Treatment (except last row)	Berry Weight (grams)	Percent Brix	pH	Total Acidity	Yield Per Vine (kilograms)
Compost and No Tillage	137.6 (6.9)	24.0 (0.9)	3.48 (0.01)	0.52 (0.01)	4.97 (0.82)
Tillage	150.2 (6.7)	24.0 (0.6)	3.52 (0.06)	0.56 (0.04)	6.21 (0.62)
Compost and Tillage	157.2 (23.7)	24.0 (0.6)	3.48 (0.09)	0.53 (0.01)	6.17 (0.70)
No Tillage	151.6 (9.4)	23.9 (9.4)	3.49 (0.04)	0.60 (0.08)	5.68 (0.66)
Entire Vineyard	149.1 (6.8)	24.0 (0.3)	3.50 (0.03)	0.55 (0.02)	

Second Phylloxera Treatment Site

Necrosis and populations: Pretreatment populations of grape phylloxera and necrosis in the second treatment site were evaluated July 11, 2001 by sampling 10 buffer-position vines. These data were then segregated by compass direction, first on the east-west axis and then again on the north-south axis. The data are presented in Table 11 below. These data suggest no population or necrosis decline through the site.

Table 11. Necrosis and Phylloxera Feeder Populations for the Second Phylloxera Treatment Site (July 11, 2001)

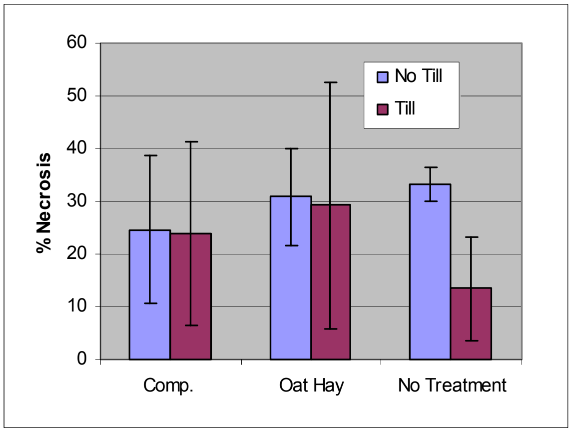
Values in parentheses are 95 percent confidence limits.

	Percent Necrosis	Phylloxera Feeders
East	10.2 (4.8)	35.6 (15.1)
West	11.5 (6.3)	19.2 (8.4)
North	13.1 (7.0)	26.4 (25.1)
South	8.7 (2.7)	28.4 (14.3)
Overall	10.9 (3.4)	27.4 (14.0)

Plot sampling was done for the first time May 22, 2002 (Figure G). Necrosis was not statistically higher than it was mid-summer the previous year. Even though the oat hay had greater necrosis, it is too early to expect treatment effects that are not artifacts. A second treatment (till, no-till) was superimposed onto the compost, oat hay, and control on the date that these data were collected.

Figure G. Percent Fungal Necrosis of Lignified Roots (May 2002)

Lignified roots are between 2 and 15 millimeters in diameter, and measured as a percent of circumference at 4-centimeter intervals. Averages are based on arcsine square root transformed data. Bars represent 95 percent confidence limits.



Soil microbiology: At the second treatment site, initial soil and root samples were collected in July 2001 to serve as a baseline for subsequent evaluations. Analysis of the samples showed that the densities of soil fungi were similar to those of the first site. Population densities for *F. equiseti, F. oxysporum, F. solani, Ulocladium, Penicillium* and *Aspergillus* were, respectively 105, 950, 350, 260, 30, and 90 colonies per gram soil. Equivalent values for July at the first site were 130, 1200, 600, 200, 100, and 150, respectively. In contrast, the nodosity density on small roots (12 nodosities per meter root) was about half that observed for the first site (25 nodosities per meter root). These results were consistent with the higher vigor of the vines at the new site. No significant differences in values were observed for any of the above data with respect to row or treatment plot sites.

The spring 2002 assays presented in Table 12, show only minimal changes in the soil populations of the *Fusaria*. The saprophytic fungi exhibit the significant increases in population densities expected from favorable conditions (moist, cool spring) for organic matter decomposition. Results of the May 22 assay indicate that changes in the soil microbial community are beginning to show up in the upper layer of soil (up to 1 inch) directly under the oat-hay. The population densities of *F. equiseti, Ulocladium, Penicillium,* and *Aspergillus* are higher under this treatment.

Table 12. Summary of Soil Populations of Selected Fungi in the Fetzer Vineyard Treatment Blocks at the Second Phylloxera Treatment Site

No significant differences ($P < 0.05$) were seen.

Treatment	Colony-Forming Units Per Gram of Soil					
	Fusarium equiseti	***Fusarium oxysporum***	***Fusarium solani***	***Ulocladium* spp.**	***Penicillium* spp.**	***Aspergillus* spp.**
July 2001 Pretreatment Soil Samples (0- to 12-inch depth)						
All Plots	105	950	350	260	30	90
April 2002 Soil Samples (0- to 12-inch depth)						
Compost	120	970	300	160	1000	520
Oat Hay	200	1140	340	430	250	1080
No-Mulch Control	100	1180	300	220	130	290
May 2002 Soil Samples (0- to 1-inch depth)						
Compost	340	3760	2560	750	680	880
Oat Hay	890	4050	1710	2980	1390	1760
No-Mulch Control	260	3850	2060	940	810	1100

Vine Productivity: The pretreatment grape yield data for the second treatment site are shown in Table 13. Here again, no statistical differences between plots were seen.

Table 13. Pretreatment Grape-Yield Data for the Second Treatment Site as Means (95 Percent CL).

Treatment	Pretreatment Yield (Kilograms Per Vine)	
	No Tillage	**Tillage**
Compost	5.12 (0.65)	5.58 (0.81)
Oat Hay	6.87 (0.79)	6.64 (0.89)
No-Mulch Control	6.57 (0.96)	5.73 (1.04)

Erosion Control

Year 1, Starting Fall 2000

Successful stands of cover crops were established following autumn seeding and light rains. The winter of 2000–2001 was a relatively dry season. Initial observations were made in March 2001. The plots were harvested April 30, 2001.

The compost overs performed the best of the three treatments (Table 14). With the compost overs, the cover crops emerged strongly, covering about 95 percent of the soil. The color of the cover crop was the deepest green, and there was little evidence of exposed aggregates on the surface of the soil.

The straw treatments did not perform as well. The cover crops were a lighter shade of green, and the stand density was about 60 percent of the area. The straw plots visibly lagged behind the compost overs plots for much of the season, although the grasses eventually grew well and provided considerable biomass. The soil was well-protected, and there was little evidence of exposed aggregates on the surface of the soil.

The no-mulch control portion of the experiment had a good cover crop stand, covering about 75 percent of the area, but there were obvious exposed aggregates and micro-rilling of the soil surface.

Table 14. Cover Crop Yield and and Surface Erosion, Bonterra Vineyards, Butler Ranch Erosion Site (April 2001)

Treatment	Cover Crop Yield (tons/acre)	Percent Grass	Percent Legume	Surface Erosion (1–5)*
Compost Overs	4.6	44	56	2.5
Straw	2.8	82	18	1.5
No-Mulch Control	3.4	70	30	3.5

*Ranking of surface erosion was by visual evaluation: 1: Little surface erosion noted. 5: Numerous exposed aggregates and gravel, obvious surface erosion, and movement of soil particle fines.

Overall, cover crop yields differed among the three treatments. Plots protected by compost overs yielded 4.6 tons per acre and by straw yielded 2.8 tons per acre. The no-mulch control plots yielded 3.4 tons per acre.

The grass/legume composition of the cover crop swards differed greatly. The cover crop seeded was a mix of triticale and Persian clover. In the compost overs treatment, the ratio of grasses to legumes was 0.8:1. In the straw treatment, the ratio was 4.7:1. The ratio of grasses to legumes in the no-mulch control treatment was 2.3:1. The legumes grew better with the compost overs, possibly due to better germination of seed and nutrition received. A denser stand of legumes is a favorable viticultural outcome because it contributes nitrogen to the soil and because the high legume cover crop degrades more easily, leaving less residue to manage in the vineyard. How beneficial these outcomes will be depends on the management objectives for the cover crop planting.

Two unfortunate events unrelated to treatments occurred to the plots. One was a clogged drain above the plot that allowed a deep rill to develop across the southeastern portion of the plot. The other was a slump in the northeast portion of the plot from a buried seep. These events sent water cascading through the east side and middle of the plot. Serious rilling occurred, rendering erosion measurements useless.

Visual examination of the soil were based on a ranking scale of 1 to 5, with 1 indicating few observed aggregates on the surface of the soil and very little erosion, and 5 indicating many aggregates visible and active erosion. This visual ranking showed that compost overs provided intermediate soil protection at 2.5, straw protected the soil the best with an average rating of 1.5, and the no-mulch control had the most erosion at 3.5. (Table 14).

Results from year 1 showed that use of compost overs is beneficial in erosion prevention on hillsides because of ease of spreading, higher nutrient value due to promotion of legume growth, and favorable cost. Another plot was planned for autumn 2001, following repairs to the slope where the trial was situated.

Year 2, Starting Fall 2001

Seed germinated in the plots, and a satisfactory cover crop stand formed. By December, the bare soil treatment was showing significant erosion, expressed as small rills and exposed pediments. Estimated soil losses already exceeded 5 tons per acre. Once again, germination and early growth looked best in the compost overs plots.

In all treatment blocks, cover crop wet weight averaged 2.24 kilograms for an area of 110 square feet. Table 15 displays the wet weight of the cover crop per plot. The compost overs plots averaged 161 percent of the control plot, which was significantly higher at α=0.05. The straw plot was 123 percent of the control, but this was not statistically higher than the control plot at α=0.05.

Table 15. Plant Coverage of Erosion Site and Index of Erosion, Bonterra Vineyards, Butler Ranch (May 2002).

Treatment	Cover Crop Yield (kilograms per plot)	Percent Ground Covered	Erosion Index*
Compost Overs	2.65	95 c	1.2 c
Straw	2.14	79 b	2.1 b
No-Mulch Control	1.95	51 a	3.2 a

* Ranking of surface erosion was by visual evaluation: 1: No obvious displacement of soil. 3: Aggregates exposed above the soil. 5: Aggregates exposed; also, rills and obvious erosion evident.

As Table 15 also indicates, the percent of ground surface covered by the plants was highest in the compost overs plot and intermediate in the straw plot. Erosion was negligible in the compost overs plots but significantly higher in the control and straw-treated plots. These data confirm the results of the first erosion control experiment indicating that compost overs is superior to straw for erosion control.

Discussion

Phylloxera

The data from the phylloxera plots indicated that compost and tillage individually did not substantially decrease the insect's populations, associated root necrosis, or increase vine productivity within the constraints of this project. Detrimental effects were seen on vine vigor, though a beneficial effect was seen with the compost-plus-tillage treatment.

Soil fungal ecology was affected, but not to a degree indicating a beneficial effect to the vine.. Though the count of presumably pathogenic *F. oxysporum* propagules in soil decreased (a beneficial effect), counts on roots did not significantly change. At the initiation of this project, researchers expected that the additions of compost to vineyards would change the soil microbiological community sufficiently to decrease root necrosis associated with phylloxera feeding sites and thereby benefit vine vigor and productivity. These outcomes were not seen for a number of possible reasons:

1. The experiment was conducted for a relatively short period of time, having run for less than two years. The experiment was originally designed to extend from May 2000 through May 2002 with treatments applied early, thereby providing for three May evaluations during the two years. However, delays in establishment of the project prevented early treatments.

   As a perennial plant with considerable potential for storage of photosynthates, the grapevine sometimes responds to management changes only after several years. Researchers therefore suggest that two years is too short a time for significant differences to develop. They suggest that a minimum of three years is needed to obtain pertinent data. Researchers predict that the treatments within this time period will begin to show biologically and viticulturally significant differences possibly in year 3 but more likely in year 4 or 5.

   From a management perspective, this delay in treatment effects is interesting. It supports a basic contention of "sustainable agriculture" and organic farming—that conditions must be in place for at least three years to show benefits. The effect of the conditions that researchers are observing are likely to be complex and possibly even involve natural selection of microbial communities. Such processes may not exhibit gradual or graded responses in the vineyard measurements being made, but exhibit more of a threshold response. Therefore, much more time is needed in this project before conclusions can be made. Should differences between treatments not show up as expected during the three-to-five-year timeframe, researchers may then interpret results and conclude that the treatments are or are not effective and to what extent.

2. The plot chosen was a severe test of the concept that compost applications would beneficially (from an agricultural perspective) affect a complex biological interaction. The plot consisted of vines that were already severely damaged by at least seven years of stress by phylloxera and necrosis when researchers began. The plot was already under organic management, though compost had not been added for a number of years. Implications of the proposed treatments were complex. Researchers were not only asking about stopping new damage, but reversing old damage.

   Previous work with an insecticide in phylloxera-damaged vineyards (Weber, et al., 1996) shows that removal of the pest does not mean that decline is stopped or reversed for a short- or long-term period. Insect and surface wounds are aboveground evidence of vine damage. In addition, vine damage is also caused by the presence of the pathogens deep within the root tissue, which result in loss of root biomass. To reverse damage, new wounding must be slowed or stopped, new infections must be stopped, old infections must run their course, and replacement root tissue must develop to replace all that has been lost.

Researchers hypothesize that compost treatments will change the microbial community in the rhizosphere to slow or prevent new infections. Possible mechanisms for slowing or preventing infections may be competition between pathogens and nonpathogens for attachment sites on the root surface, presence of beneficial microbes in the compost, inducement of plant defenses, and selection of nonpathogenic or low-pathogenic microbial phenotypes or communities.

In addition, nutrients in compost may enhance root growth to replace lost root biomass. However, mechanisms to speed up disposal of damaged roots are not apparent at this time. Replacement of those lost roots with new root growth certainly should be accelerated by good soil nutrition augmented by composts.

3. The quality and quantity of composts used or the location of the application may have been inappropriate, leading to lack of strong treatment effects.

    (a) Compost used in the initial experiment was mature, having gone through the complete microbial digestion process. Such composts are likely to influence the soil microbial community differently from composts that are less mature, or which have not completed their initial microbial digestion process. If the beneficial effects from the compost were dependent on enhancement of specific species of fungi or bacteria in the compost or on concentrations of a chemical product, then researchers' choice of mature compost was correct. On the other hand, if the effects expected were dependent on increased soil nutrition, so that resident soil microbes played the major role in the viticultural changes, then use of a less mature compost may have been more appropriate.

    (b) Similarly, the question of quantity of compost was one researchers pondered at the beginning of the project. They chose to use 2 tons of compost per acre, based on existing practices where long-term, not immediate, results are sought. This quantity may have been insufficient for the rapid changes that they were seeking to induce.

    (c) Compost was applied to the soil surface and researchers trusted that the active components would percolate to the root zone, or in the case of the tillage-plus-compost treatments, would be incorporated near, if not in, the root zone. However, percolation during the growing season only occurred beneath the irrigation drippers. In addition, incorporation by tillage is not possible on the berms under the drippers using disking equipment. Therefore, more attention may need to be given to where the compost is applied in the vineyard and the means by which the active components reach the roots.

    Conditions at the second phylloxera treatment site will address some of these issues in the next three to five years. Researchers made provision for both oat hay and compost at application rates of 1.3 tons per acre and 8 tons per acre respectively. In addition, researchers have an experiment planned to test the role of incorporation.

4. It may be that measures of necrosis and phylloxera population are not most relevant to extended vine life and productivity in organically managed vineyards. Researchers have measured factors of phylloxera population, vine necrosis, soil microbial community, root growth, vine vigor, and vine productivity. These seem the logical factors to measure, since they cover not only the presumed mechanisms of damage but also the viticultural bottom line—production quality and quantity. Although no alternative to the production measures are likely to be found, other mechanisms of damage might be. For example, it may be that the damage is caused by *Fusarium* toxins released into the vine, rather than by loss of root

biomass because of necrosis. Such mycotoxins have been studied extensively in other systems, but not in grapes. If these played a small or large role in causing damage, then our measures of phylloxera populations, necrosis, and soil communities would be correlations and effects rather than causal. In addition, infection by *Fusarium* may not be simply a matter of virulence of the isolate or community present in the soil, but may be a function of vine loss of resistance to the pathogens when under stress (as might be caused by phylloxera populations). Other mechanisms of virulence and damage can be hypothesized as well.

Erosion

The erosion plots demonstrated efficacy of compost overs as a mulch for erosion control. Not only did compost overs directly decrease erosion, but surface coverage by them also provided a superior setting for cover crops to establish, providing additional water percolation as well as extra nutrients in comparison with the control and the straw treatment. As a result, the compost overs mulch decreased erosion and also fostered cover crops that additionally decreased erosion and benefited the vineyard in other ways. Lastly, compost overs applied at 8 tons per acre are more cost-effective than are straw applications.

Decreasing Green Material in Landfills by Composting Landscaping Waste for Agricultural Use

There are approximately 20,000 acres of vineyards in Mendocino County. The towns of Mendocino County produce 8,000 tons of compost per year. If all the yard trimmings in Mendocino County were turned into compost for use in vineyards, the compost would meet the needs of only a small percentage of vineyards in the county. Clearly, the state's agricultural counties can act as importers of compost produced by predominantly urban counties, thus reducing green waste sent to landfills and benefiting agricultural efforts.

Conclusions and Recommendations

Phylloxera

This project established a long-term phylloxera management plot that will be available for observation over the next four to five years. Researchers feel that results to date are neither encouraging nor discouraging to compost use and that the time for the project has been insufficient. However, researchers believe in the validity of the project because it puts the question of compost use relative to phylloxera problems in a scientific context that they believe will eventually be quantified. Based on surveys and previous information, researchers see less damage to vineyards using compost and cover crops. They cannot yet understand mechanisms but can recommend these practices as part of a soil management program.

Other recommendations are:

- That the project's other funding agencies allow continuation of the plots as established for three to five years.
- That farmers be encouraged to visit the phylloxera plots and engage in similar experimentation with organic farming practices.

Erosion

This project has had a number of beneficial effects. It clearly demonstrates the utility of compost overs as a superior erosion-controlling mulch. Vineyardists of Mendocino County have seen these plots firsthand and are encouraged to use compost overs in this way. Researchers have and will continue to recommend:

- Applying compost overs as mulch at a rate of 8 tons per acre yearly during establishment of the vineyard and cover crops. (In absence of compost overs, straw will also be helpful.)
- Using a mixed grass-and-legume cover crop.
- Exploring the use of compost overs as an alternative to herbicides.

Bibliography

Davidson, W. M. and R. L. Nougaret, *The Grape Phylloxera in California*. USDA Bulletin 903, 128 pages, 1921.

Davis, J. R., O. C. Huisman, D. J. Westermann, S. L. Hafez, D. O. Everson, L. H. Sorensen, and A. T. Schneider,.“Effects of Green Manures on *Verticillium* Wilt of Potato, *Phytopathology* 86 (1996): 444–453.

———, O. C. Huisman, D. O. Everson, D. O., L. H. Sorensen, and A. T. Schneider, “Control of *Verticillium* Wilt of the Russet Burbank Potato With Corn and Barley,” *American Journal of Potato Research* 76 (1999): 367.

———, O. C. Huisman, D. O. Everson, D. O., and A. T. Schneider, “*Verticillium* Wilt of Potato: A Model of Key Factors Related to Disease Severity and Tuber Yield in Southeastern Idaho,” *American Journal of Potato Research*. 78 (2001): 291–300.

Dhingra, O. D. and J. B. Sinclair, “Soil Microorganisms,” *Basic Plant Pathology Methods*, CRC Press Inc., Boca Raton, Florida <www.crcpress.com>, 1985.

Flaherty, D. L., and L.P. Christensen, et al. (eds), *Grape Pest Management*, 2nd Edition, Division of Agriculture and Natural Resources, University of California, Oakland, California, 1992.

Galet, P., *A Practical Ampelography Grapevine Identification*. Cornell University Press, Ithaca, New York, 1979.

Granett, J., P. Timper, and L. A. Lider, “Grape Phylloxera (*Daktulosphaira vitifoliae*) (Homoptera: Phylloxeridae) Biotypes in California,” *Journal of Economic Entomology*, 78: 1463–1467, 1985.

———, A. D. Omer, P. Pessereau, and M. A. Walker, “Fungal Infections of Grapevine Roots in Phylloxera-Infested Vineyards,” *Vitis*, 37, no. 1 (1998): 39-42.

———, M. A. Walker, L. Kocsis, and A. D. Omer, “Biology and Management of Grape Phylloxera,” *Annual Review of Entomology*, 46 (2001): 387–412.

Hoitink, H. A. J. and M. J. Boehm, “Biocontrol Within the Context of Soil Microbial Communities: A Substrate-Dependant Phenomenon,” *Annual Review of Phytopathology*, 37 (1999): 427–446.

Huisman, O. C., “Colonization of Field Grown Cotton Roots Infected With *Verticillium dahliae* Using an Immunoenzymatic Staining Technique,” *Phytopathology*, 78 (1988): 1174–1178.

Lotter, D. W., J. Granett, and A. D. Omer, “Differences in Grape Phylloxera-Related Grapevine Root Damage in Organically and Conventionally Managed Vineyards in California,” *HortScience*, 34 (1999): 1108–1111.

Omer, A. D., J. Granett, J. A. De Benedictis, and M. A. Walker, Effects of Fungal Root Infections on the Vigor of Grapevines Infested by Root-Feeding Grape Phylloxera,” *Vitis* 34 (1995): 165–170.

Omer, A. D., J. Granett, D. A. Downie, and M. A. Walker, “Population Dynamics of Grape Phylloxera in California Vineyards,” *Vitis* 36 (1997): 199–205.

Omer, A. D., J. Granett, and R. J. Wakeman, “Pathogenicity of *Fusarium oxysporum* on Different *Vitis* Rootstocks,” *Journal of Phytopathology* 147 (1999): 433–436, 1999.

Ordish, George, *The Great Wine Blight*. Sidgwick & Jackson Limited, London, 1987.

Weber, E., J. De Benedictis, R. Smith, and J. Granett, “Enzone Does Little to Improve Health of Phylloxera-Infested Vineyards,” *California Agriculture* 50, no. 4 (1996):19–23.

Glossary of Acronyms and Jargon Terms

Aggregate—The accretion of particles of sand, silt, and clay to form larger particles. In soil literature, the term “ped” is sometimes used.

Berm—The portion of the vineyard row line in which the trunks are found. This portion of the land is usually slightly higher than the middles that are between vineyard rows. Because the berm is not as accessible to cultivation as are vineyard middles, weed management is often more difficult here than in the middles.

Biomass—The weight of living plant or animal tissue.

Biotype—A collection of animals with a common genetic trait that makes them biologically different from some other individuals of the same species. In this document, the term is used to describe phylloxera that have host feeding abilities different from those of other individuals.

Cambium—A layer of plant cells that produces other cells. In the roots, concern is with the cambium situated between the phloem and xylem. When it is harmed by a pathogen, the root is doomed.

Clines—Gradual change in characteristics.

Compost—Product produced by the mostly aerobic, microbial decomposition of plant and animal materials.

Compost overs—Material greater than 3/8 of an inch in diameter left in the screening of finished compost. These are generally recycled back into compost windrows still being actively processed to improve aeration.

Cover crop—Plants grown in vineyard middles during winter to provide green mulch, increase soil nitrogen, and possibly prevent erosion and provide habitat to beneficial arthropod species. The mustards grown in vineyards in spring are a cover crop.

Cultivar—A cultivated variety of a plant species. In grapes, this is a type of vine that has specific characteristics in growth and berries. As examples, Cabernet Sauvignon, Chardonnay, and Thompson seedless are all scion cultivars. AXR#1, 5C, and St. George are all rootstock cultivars.

Cutting—Grapes are propagated by cutting portions of canes, inducing root growth at one end, and then planting them in the ground. In this way, cuttings are all genetically identical to the parent plant.

Daktulosphaira vitifoliae**—**Scientific name for grape phylloxera.

Feedstock—Materials used to make compost or mulch.

Fusarium—A genus of soil-borne fungi that has both pathogenic and nonpathogenic species. *Fusaria* are the most common fungal colonizers of the plant root system. After first use, the genus name is often abbreviated using the first letter along with the full species name. See below.

Fusarium oxysporum (or ***F. oxysporum***) and ***Fusarium solani*** (or ***F. solani***)**—**The scientific names for the most common of root-colonizing fungal species. These species are pathogens to some plant species causing symptoms of wilting and cortical root rot. In grapes they are not known to attack healthy roots but can enter and infect roots when phylloxera cause a wound by insect feeding.

***Fusarium equiseti* (or *F. equiseti*)—**Scientific names for a soil-colonizing fungal species. This species is not pathogenic but feeds on root exudates or other organic matter in the soil.

Gall—Some insect species induce swellings, galls, on plants as they feed. The swellings can be so formed that they enclose the insect, or they may be simple in structure with the insect feeding on their surface. Gall formation is induced by physical disruption by the insect or chemically by components of the insect's saliva. For phylloxera, root swellings are fed upon externally by the insect and serve to mobilize stored nutrients for uptake by the insect. On leaves, the gall encloses the feeding insect and protects it from drying and predators. Gall formation is a limiting step in the insect life cycle, and poor gall formation results in substantial insect mortality and poor nutrition.

Girdle—For the purposes of this document, refers to an object or process that goes completely around a plant part. Researchers observed that the process of pathogenesis goes around the circumference of the root, thus killing cells. When a root has been completely girdled by necrosis, the portion of the root that is farther from the trunk will die.

Grape phylloxera—An aphid-like insect species that takes nutrients from various grapevine tissues. This species is restricted to feeding on plants of the genus *Vitis*. With some *Vitis*, it is commonly found on leaves, but rarely on roots. With the European grape, *Vitis vinifera*, grape phylloxera, are commonly found to feed on roots but not leaves.

Hybrid—An individual whose two parents are of different species. Phylloxera-resistant rootstocks are commonly hybrids of two American *Vitis* species.

Isolate—An isolate is a selection of a fungal genotype isolated from a culture grown in a Petri dish on special media.

Micro-rilling—Formation of a very small rivulet or stream (see *Rilling*)

Mulch—Plant materials that are coarsely ground but not subject to an intensive rotting process. In contrast, compost has been subject to an intensive rotting process.

Necrosis—Rotten tissue, in the case of our work caused by fungal pathogens in roots.

Nodosity—Swelling on the rootlets of grapevines induced by grape phylloxera activity that serves as a feeding site for the insect.

Organically managed—a method of growing crops without synthetic chemical pesticides or fertilizers that works by encouraging "natural" biological processes. It often includes use of composts and cover crops without tillage. A certifying organization must provide organic certification.

Parenchyma—Undifferentiated cells associated with the root just beneath the root bark near the phloem tissue. Phylloxera feed in this parenchyma and it is these parenchyma cells that enlarge and increase in number as the root gall is formed. It is this tissue that is initially subject to pathogenic necrosis when made susceptible by wounding caused by phylloxera feeding.

Penicillium—A genus of saprophytic soil-borne fungi that have been used commercially for antibiotics and cheese-making. For the purposes of this study, researchers were concerned only with their role in the soil microbial community.

Phenotype—A group of individuals that are within the same species and are additionally morphologically or behaviorally similar, differing from other groups of individuals within that species. Researchers for this project use this term to describe phylloxera that have similar feeding traits, though their genetic traits may or may not suggest that they are all derived from the same founder.

Phloem—The plant tissue through which soluble photosynthates and leaf-produced plant hormones move downward, from leaves to the rest of the plant.

Photosynthates—The sugars and other compounds produced in leaves using solar energy and chlorophyll. Photosynthates provide structural and energy compounds for plants.

Resistance—The ability of a plant to remain relatively uninfested or undamaged in the presence of a harmful agent. For the purposes of this study, resistance is a characteristic of certain rootstock roots to grape phylloxera.

Rhizosphere—The soil found in a narrow layer around roots. Microorganisms in the rhizosphere can be different from those found in the bulk of the soil because of organic compounds exuded by the roots and because of the pathogen propagules released here.

Rilling—Formation of a small rivulet or stream.

Rootstock—A plant cultivar that is grown in the ground as the roots of the plant. A scion is grafted onto the rootstock to grow the portion of the plant important for grape production. There are many cultivars of phylloxera-resistant rootstocks. Some important ones are 5C, 3309 C, AXR#1, St. George, 1103 P, and others.

Saprophytic—Feeding on nonliving organic matter such as dead plant tissues (noun form = saprophyte).

Scion—Plant material that is grafted onto a rootstock to produce the plant tissues that produce trunks, canes, leaves, and grapes above ground. Important grapevine scion cultivars include Cabernet Sauvignon, chardonnay, and Thompson seedless.

Seep—As a noun, the extrusion of water under the soil surface.

Slump—As a noun the collapse of the soil surface because of removal of soil or rock substrate below the soil surface by a seep.

Species—A group of individuals having a common genetic ancestor and that generally can mate successfully with other individuals of the same group but not of other groups.

Spp.—"Species." Used in association with the name of a taxonomic genus (for example, *Fusarium spp.*, which is used to indicate several species of *Fusarium*).

Strain—A group of individuals within a species that have a common genetic ancestor.

Sward—A grassy surface of land, though for the purposes of this study the land surface may be covered by herbaceous plants other than grasses.

Triticale—A grass plant that is a hybrid of wheat and rye plants and can be used for grain forage, silage, or as a cover crop.

***Vitis berlandieri*—**A grape species native to the southern U.S. Its roots are highly resistant to grape phylloxera, though its leaves can harbor leaf galls. This species is in the parentage of a number of important phylloxera-resistant rootstocks, though these rootstocks are generally hybrids with other species (for example, Teleki 5C, Teleki SO4, 41B, 140R, 1103P, 110R).

Vitis champinii**—**A grape species native to the southern U.S. Its roots are highly resistant to grape phylloxera, though its leaves can harbor leaf galls. This species is in the parentage of a number of important phylloxera-resistant rootstocks (for example, Dog Ridge).

Vitis riparia**—**A grape species native to the southern U.S. Its roots are highly resistant to grape phylloxera, though its leaves can harbor leaf galls. This species is in the parentage of a number of important phylloxera-resistant rootstocks (for example, 3309C, 101-14 Mgt, Teleki 5C, Teleki SO4, Riparia Gloire).

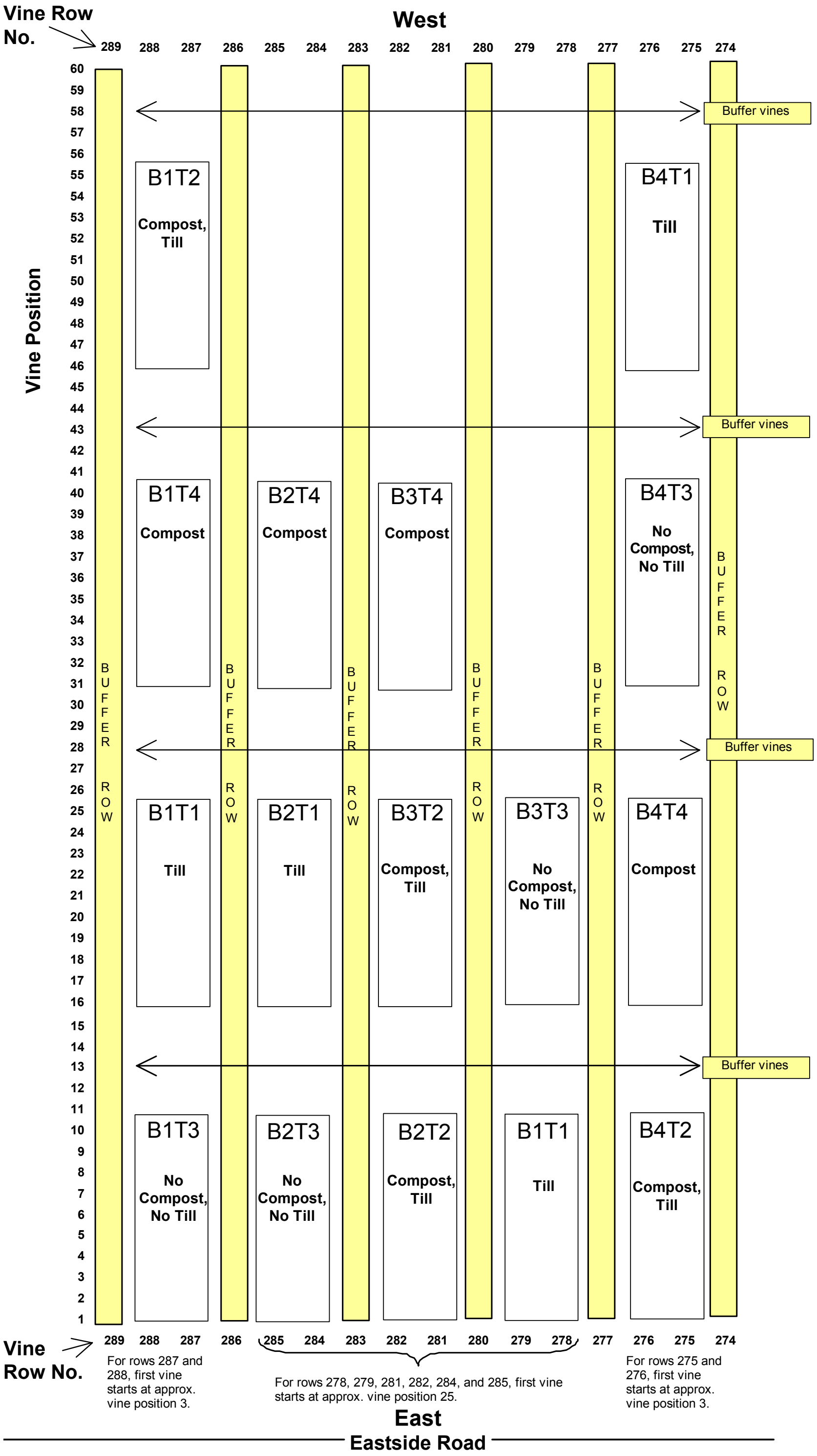
Vitis rupestris**—**A grape species native to the southern U.S. Its roots are highly resistant to grape phylloxera, though its leaves can harbor leaf galls. This species is in the parentage of a number of important phylloxera-resistant rootstocks (for example, 3309C, 101-14 Mgt, Dog Ridge, AXR#1, 140 R, 1103 P, 110 R, St. George).

Vitis vinifera**—**A grape species native to eastern Asia that is commonly grown worldwide for wine, table grapes, and raisins. Its common name is "European grape."

Windrow—Compost is produced in long piles wide at the base and narrow at the top (for example, one producer uses piles that are about 15 feet wide at the base,7 feet high, and 200 feet long). These are called "windrows."

Appendix A—Layout of First Phylloxera Treatment Site

Established June 2000



For rows 287 and 288, first vine starts at approx. vine position 3.

For rows 278, 279, 281, 282, 284, and 285, first vine starts at approx. vine position 25.

For rows 275 and 276, first vine starts at approx. vine position 3.

Appendix B—Layout of Second Phylloxera Treatment Site

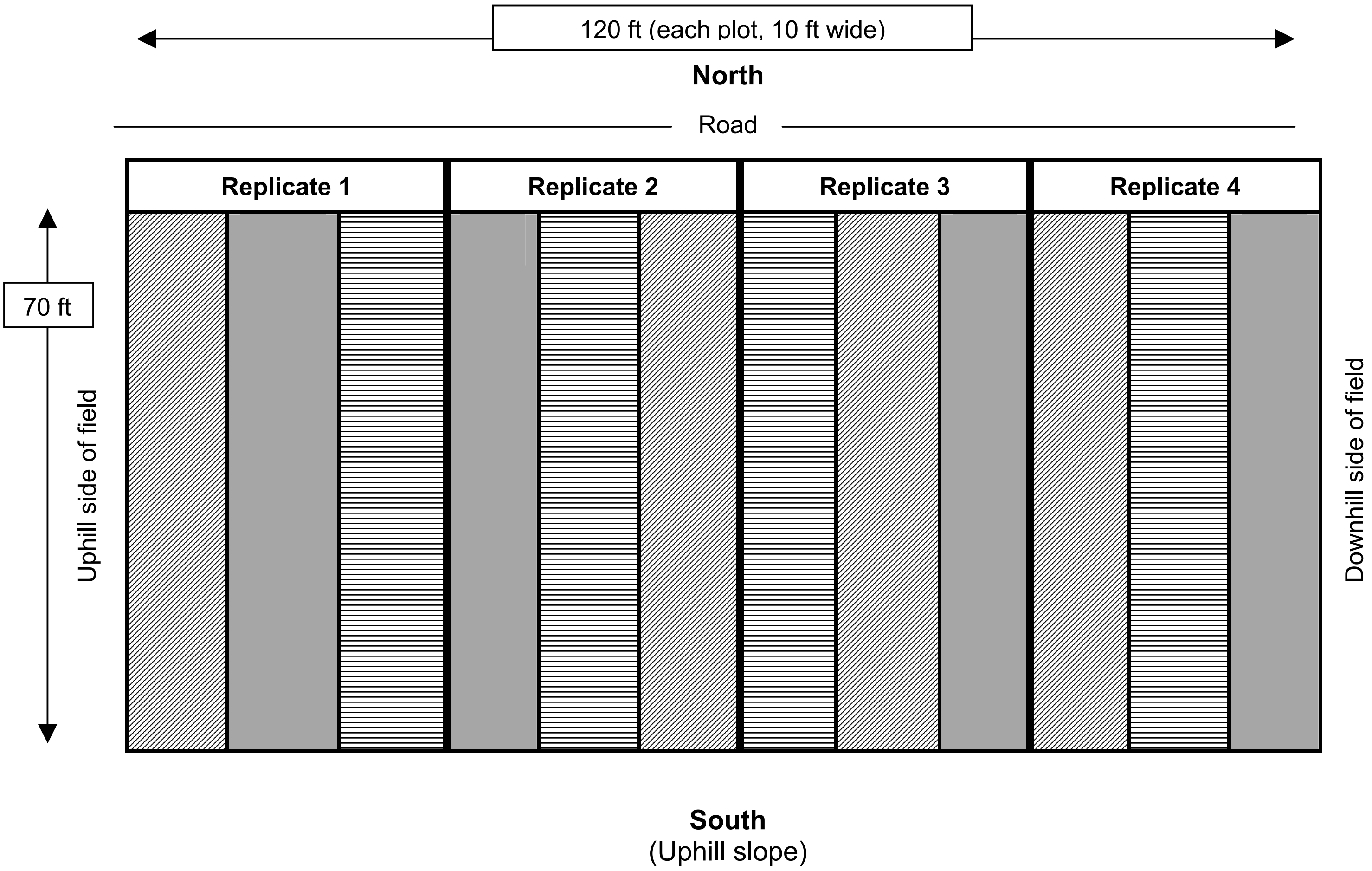
Treatments applied in July 2001. Cane weight and lengths measured during fall 2001. Phylloxera, necrosis, and soil ecology measured during spring 2002. Cane growth and root density measured during summer 2002.

Vine	Row 320	Vine	Row 319	Vine	Row 318	Vine	Row 317
34	Oat hay,	32	Oat hay,	34	No compost,	35	Compost,
33	Till	31	No till	33	No Till	34	No Till
32	(4 vines)	30	(4 vines)	32	(4 vines)	33	(4 vines)
31		29		31		32	
30		28		30		31	
29	No compost,	27	No compost,	29	Compost,	30	Oat-hay,
28	Till	26	Till	28	Till	29	Till
27	(4 vines)	25	(4 vines)	27	(4 vines)	28	(4 vines)
26		24		26		27	
25		23		25		26	
24		22	Compost,	24	Compost,	25	
23	Oat hay,	21	Till	23	No till	24	
22	No till	20	(4 vines)	22	(4 vines)	23	
21	(4 vines)	19		21		22	Oat hay,
20		18		20		21	No till
19		17	Compost,	19	No compost,	20	(4 vines)
18	Compost,	16	No till	18	Till	19	
17	No till	15	(4 vines)	17	(4 vines)	18	
16	(4 vines)	14		16		17	No compost,
15		13		15		16	Till
14		12	No Compost,	14	Oat hay,	15	(4 vines)
13	No compost,	11	No till	13	No till	14	
12	No till	10	(4 vines)	12	(4 vines)	13	
11	(4 vines)	9		11		12	No compost,
10		8		10		11	No till

Vine	Row 320	Vine	Row 319	Vine	Row 318	Vine	Row 317
9		7	Oat hay, No till (4 vines)	9	Oat hay, Till (4 vines	10	(4 vines)
8	Compost, Till (4 vines)	6		8		9	
7		5		7		8	
6		4		6		7	Compost, Till (4 vines)
5		3		5		6	
4		2		4		5	
3		1		3		4	

Appendix C—Layout of First Erosion Control Site

Established 2000



Notes

1. Site was flagged with 12-inch wooden stakes on October 17, 2000.
2. Site was preseeded, smoothed, and harrowed after seeding. Seeding rate was 100 pounds of seed per acre. Seed mix included Triticale (40 percent), Common Rye Grass (40 percent), and Nitro Persian Clover (20 percent).

Legend

▨	Control, cover crop seed only.
■	Straw—1.3 tons per acre (applied October 21, 2000).
▤	Compost overs—Coarse urban waste, ground, partially composted, 8 tons per acre.