Mulch Demonstration Project,
Napa and Sonoma Counties:

Utilization of Composted Mulch for Erosion Control in Hillside Vineyards

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Executive Summary

In May 1999, a two-year project began to investigate the value of using composted yard trimmings as mulch on hillside vineyards for erosion control. Cooperators included the California Integrated Waste Management Board (CIWMB), the City of Napa, farm advisors from the University of California (UC) Cooperative Extension, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), the USDA Agricultural Research Service (ARS), the Resource Conservation Districts (RCD) in both Napa and Sonoma counties, Napa Garbage Service, Sonoma Compost Company, grape growers, and the City of Napa.

This project was a demonstration and research project designed to develop information and guidelines for the use of composted mulch for soil erosion management in vineyards. The project also aimed to open a new market for yard trimmings that have been diverted from landfills, thus reducing landfill space requirements.

Project demonstration sites were located in four vineyards, two each in Napa and Sonoma counties. Both counties are premium wine grape growing regions with approximately 100,000 acres in vineyard cultivation. Of that acreage, about 30,000 acres are located on hillsides. Both counties have very strict erosion control ordinances in place, and grape growers are very interested in exploring effective methods of soil erosion control.

At each vineyard, a block of vines located on a hillside that contained at least 27 vine rows was selected as the demonstration project site. Vine rows were planted up and down the slope, and the middle group of nine vine rows were equivalent in slope at each site. Slopes ranged from 7 to 31 percent, depending on site. The row middles (tractor drive area) contained either closely mown resident vegetation (weeds) or had been sown with winter annual cover crops such as blando brome and zorro fescue. Weed control practices under the vine rows had been performed by hand or with the use of post-emergent herbicides.

All four sites received identical mulch application regimes in 27 contiguous vine rows. Field-based activities were focused on only the middle group of nine vine rows; hence, all data and observations reported herein are from nine vine rows at each site. In that group of rows, three treatments were imposed—one treatment per row—and replicated three times in a randomized complete block design. In fall 1999, mulch was applied in 3 vine rows at a depth of 3 inches and reapplied an additional 1.5 inches to the same rows the next fall (Treatment 1). Three different rows only received a 3-inch layer of mulch in fall 1999 (Treatment 2). The remaining three vine rows did not receive a mulch application in either year (Treatment 3).

The mulch used in this project was generated from partially composted yard waste trimmings. The mulch was thermophilically treated to reduce pathogens. Mulch was deposited in a 24-inch wide strip along a 29-foot length of the vine rows in Vineyards 2, 3, and 4, and in an 18-inch wide strip in Vineyard 1.

At all four vineyard sites, a plot was established in each of the nine vine rows that allowed sediment to be collected from a uniform land surface area within each row. Plot dimensions were 24 inches wide (18 inches in Vineyard 1) and 29 feet long. A metal border was installed on the perimeter of each plot to contain the mulch. A sediment trap was located at the bottom of each plot.

Soil yield (sediment loss) data were collected from the nine plots in Vineyards 1, 2, and 3 after one to three rain events during the annual rainfall period from January to May 2000. Data were collected from plots in all four sites during the following rainfall period from November 2000 to May 2001.

The reduction of total sediment collected from vine rows that contained mulch relative to vine rows without mulch ranged from 98 percent (Vineyard 3) to 91 percent (Vineyard 1) over the five-month period that ended in May 2000. In contrast, over the seven-month rain period that ended the following May, the reduction of total sediment collected from vine rows that contained mulch relative to vine rows without mulch ranged from 98 percent (Vineyard 4) to 78 percent (Vineyard 3). Results indicate that composted mulch is an effective erosion control material for rainfall up to 40 inches annually.

In Vineyard 4 a rain simulator was used in March and April 2001 to produce a precipitation rate that enabled researchers to directly measure runoff volume and sediment yield. The relative average percent reduction in the amount of sediment generated over all Treatment 1 and Treatment 2 mulch plots by a 4-inch rainfall as compared to the sediment generated over control plots was 85.0 percent and 54.7 percent respectively. The relative average percent reduction in the amount of sediment generated over all Treatment 1 and Treatment 2 mulch plots by a 6-inch rainfall as compared to the sediment generated over control plots was 77.4 percent and 69.1 percent respectively.

Soil movement was estimated at all four sites comparing the presence and absence of mulch in the vine rows using the Revised Universal Soil Loss Equation (RUSLE), a model that predicts long-term soil loss. The model was run using site-specific data collected from each vineyard. For each site, a term in the model was varied to reflect the presence or absence of mulch in the vine row. Given the differences in soils, rainfall and slope among all sites, the RUSLE predicted a consistent range of 90 percent to 90.4 percent reduction in soil loss when mulch was present.

Based on these results, project researchers recommend a 3-inch layer of mulch. In order to facilitate proper spreading, the mulch should be screened to no coarser than 2-inch minus with moisture content of 35 to 55 percent. Crop yield parameters and vine growth were measured in vines located inside and immediately adjacent to the plots in Vineyards 2 and 3. No significant differences were detected in yield or growth during the project. Berry samples collected by plot at both sites just prior to harvest each year also showed no effect of the presence of mulch on fruit composition (sugar, pH or titratable acidity).

In all four sites, soil samples were collected each year from the nine vine rows that contained the plots. Composite samples were taken outside the plots to prevent disturbing the soil within the contained area. The macronutrients (nitrogen, phosphorus and potassium) were not significantly different prior to the application of mulch, with the exception of sulfuric acid extracted potassium in Vineyard 1. In that site, potassium levels from a soil water extract were low (<100 ppm) and were not different in either 1999 or 2000. In Vineyard 3, the grower cooperator had applied phosphorus and potassium fertilizer equally across all rows each year, yet phosphate-phosphorus and potassium was significantly greater (p<05) in 2000 in rows that had received mulch.

Leaf samples were collected from all sites each year to determine if vine nutrient status was impacted by treatments. In Vineyards 1, 2, and 4, there were no significant differences in levels of the macronutrients in vines whether or not mulch was present in the vine rows in either year. In Vineyard 3, phosphorus levels were elevated (p<.05) in 2000 in leaves collected from vines grown in vine rows that had received mulch.

Variables such as soil moisture content, vine water potential, and weed control were not measured, but these may have been impacted by the presence of mulch in the vine rows. Visual assessments of the weed growth inside the plots indicated that the mulch had the potential to be an effective weed suppressant, but this effect was not quantified.

A market evaluation was conducted to determine whether the grape growing industry perceived the use of composted yard trimmings as a viable tool for erosion control in their vineyards. The market evaluation indicated that grape growers, vineyard managers, and consultants believed that the use of composted mulch for erosion control would be a beneficial management practice to be implemented on vineyards with erosion potential.

Furthermore, the response of the growers and vineyard managers at the compost site field days as well as during industry outreach events was that great economic gain could be achieved if the mulch could reduce the applications of herbicides for weed control. It should be noted that a substantial reduction in weeds was observed in the plots, but weed control was not quantified. The provision of an application service—for both equipment and labor—to apply the mulch for the vineyard operators would greatly increase the marketing potential of this product. Substantiation of the efficacy of the mulch for weed control would also benefit marketing efforts. Knowledge of the beneficial impacts of mulch applications on weed control would be extremely useful to end users, and it could likely increase the adoption of the practice of applying mulch in vine rows.

Additionally, growers farming in water-limited areas might also be motivated by the potential of mulch for conserving soil moisture.

Introduction

Soil conservation is a key component of sustainable agriculture systems. Environmental regulations require growers implement sustainable agricultural practices that minimize negative impacts on our water resources. Mulch aids in formation of soil aggregates. It is typically high in carbon, which promotes a fungal-dominated population of microorganisms. These fungi play a significant role in soil aggregate stability. Improved aggregation increases the infiltration rate of precipitation, thus decreasing runoff and associated soil transport.

Concerns regarding limited landfill space and increased interest in recycling has resulted in the objective of maximizing diversion of organic materials from landfills. In particular, reuse of yard trimmings in commercial agriculture could reduce the amount of waste going into landfills as well as reduce soil erosion in hillside vineyards and other crops. A void of pertinent information and guidelines for the application and use of organic material for erosion control in vineyards prevents many grape growers from using recycled yard trimmings in their vineyards.

This demonstration and research project was designed to develop information and guidelines for the use of partially composted yard trimmings (mulch) for soil erosion management in vineyards. Another purpose of the project was to open a new market for mulched yard trimmings that has been diverted from landfills, thus reducing landfill space requirements.

A unique partnership was formed between compost producers, scientists, service providers, agencies, and grape growers (end users) of the product to provide oversight and input into the implementation of this project. This partnership held quarterly technical advisory committee meetings to review project status, plan field days, and evaluate any changes necessitated by actual field conditions.

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A total of four vineyard sites were selected in Napa and Sonoma Counties to demonstrate the effect of composted mulch applications on sediment production. Identical mulch applications were made at all sites. In each vineyard, one hillside block of vines was selected that had at least a five percent slope and minimal side slope. Vine rows were planted up and down the slope. Mulch was applied in a strip under all of the vines in the middle group of nine vine rows in a randomized and replicated manner to create two mulch application treatments and an untreated control.

Individual plots were established in each vine row and sediment was collected from each plot periodically during the rainfall months in the winters of 1999–2000 and 2000–2001. In addition, the impacts of the mulch applications on vine production and fruit composition was evaluated.

Whereas the four vineyard sites allowed us to collect field-based data on sediment that was not specific to individual rain events, a rain simulator was used on two occasions at one site to provide controlled, episodic rain events over all plots. This enabled us to calculate the average sediment yield in mulched vs. control plots in a managed storm event. In addition, an estimate of average long-term sediment yield with and without mulch was made with the RUSLE at all sites.

A comprehensive evaluation program was implemented throughout the two-year term of this contract utilizing data from monitoring, interviews, and questionnaires distributed at field day demonstrations to grape growers and end users who attended. The results of this project were disseminated through workshops, display boards at conferences and community events, field demonstrations, articles in newspapers and trade journals, and through fact sheets.

The main target group for the dissemination of written materials included grape growers, consultants, appropriate regulatory agencies, and compost producers. A mailing list for this target audience was compiled through the partners; for example, the lists of the Sotoyome RCD's Fish Friendly Farming program and the UC Extension's Erosion Control workshop. The Sonoma County Grape Growers Association, Napa Valley Grape Grower Association, Alexander Valley Winegrowers Association, and the North Coast Grape Growers Association also provided their member mailing lists and/or ran articles in their newsletters about the project's field days to ensure that the largest target audience could be reached.

Local grape growers were apprised of the use of mulch in vineyards for erosion control through presentations at erosion control workshops that were held in Sonoma County. The Sonoma County Farm Bureau hosted one workshop and the Napa County Grape Growers Association hosted another. Other events included two composting facility tours and a spreader demonstration at Sonoma Compost Company. An additional spreader demonstration was delivered to a workshop organized by the Sonoma County Grape Growers Association. The project was discussed on a KSRO 1350 AM Radio Farm Minutes radio broadcast, at the Napa County Viticultural Fair, and in a presentation to the California Association of Resource Conservation Districts' annual conference. Brochures on the use of composted mulch for erosion control were distributed to participants at several of these events. These brochures are available from the RCDs, the U.C. Cooperative Extension offices, the farm bureaus, the county agricultural commissioner offices, and the grape grower associations for distribution to growers that contacted these agencies with concerns about erosion control.

The partnership presented its findings at the Sonoma Grape Day on February 7, 2002.

Articles about the findings of this project will appear in *Practical Winery & Vineyard* magazine and other agricultural and wine industry publications in the future.

Project Tasks and Methodology

Organization and Administration

The Napa County RCD and Sonoma Compost Company convened the first organizational meeting of all partners in the project on May 27, 1999. During this meeting the partners reviewed an outline of the tasks to be accomplished over the course of this grant, assigned task leaders, confirmed timelines for implementation, and established a communication structure.

Site Selection

A site layout team consisting of representatives from both UC Cooperative Extension offices, Sonoma Compost Company, and the USDA-NRCS in Napa developed the criteria for site selection in each of the four vineyards. They were based on information collected from the Napa County and Sonoma County soil surveys and vineyard records to ensure that similar soil types would be found within each vineyard site. One criterion for all sites was that the vineyard rows had been planted in a vertical pattern (up and down the slope) as opposed to a contour pattern (across the slope). Although the practice of laying out vine rows in the direction of the slope is common since it tends to maximize yield per acre, this vineyard design is also prone to erosion problems. Finally, it was important that the slope at any given site was consistent across all of the rows designated to be included in the demonstration project. Slopes ranged from 7 to 31 percent over all four vineyard sites.

The project proposal called for the selection of two-acre demonstrations at each vineyard; however, site visits revealed that there was too much soil variability within an area of that size. Within each site, however, nine contiguous rows could be identified that were relatively uniform in soil type and percent slope.

Several USDA scientists including Donald McCool, Walter Bunter, and David Howell visited the sites and were consulted on issues of site layout, size, and specific soil parameters related to the use of the RUSLE. Slope measurements were taken and soil was collected and sent to the USDA-NRCS laboratory for measurement of organic matter and to determine the soil "K" factor in each row. The "K" factor is a site-specific term in the RUSLE. According to David Howell's preliminary report, the rows selected in each of the four vineyards "are located on soils similar enough within each monitoring site to allow for comparisons between the nine rows at each site." He determined that within a site, the "K" factor was nearly identical across all nine rows. Because of the need to minimize variability within a vineyard site, it was decided that at each vineyard, all field data were to be collected from the nine contiguous vine rows that had been evaluated by the USDA researchers.

Vineyard Site Design

Each vineyard site consisted of 27 contiguous vine rows; however, field-based activities were focused on only the nine vine rows that had been selected by USDA researchers. Nine additional vine rows, on either side of those selected, received mulch applications in a different pattern than the center group. Although they were assigned plot numbers, no data were collected from them (Appendix B).

Three treatments were imposed in the nine selected rows using the same experimental design at each site. The experimental unit was the entire vine row, thus one treatment was applied to one row. Treatments were replicated three times in a randomized complete block design.

Mulch Treatments

Treatment 1—a layer of three inches of composted material was applied the first year (December 1999) and an additional 1½ inches of material was reapplied the second year of the project (November 2000).

Treatment 2—a layer of three inches of composted mulch was applied in December 1999 and no additional treatment was applied in the second year.

Treatment 3—is the control and no mulch was applied either year.

Mulch was deposited in a 24-inch-wide strip along the entire length of the vine rows in Vineyards 2, 3, and 4, and in an 18-inch wide strip in Vineyard 1.

In each site, the row middles (the drive space located between vine rows) had been previously planted in a cover crop or maintained as "resident" vegetation (weeds). The vegetation in the row middles was not altered during the course of the project.

Plot design

At all sites, a plot was established in each vine row that allowed sediment to be collected from a uniform land surface area within each row. Plot dimensions were 24 inches wide (18 inches in Vineyard 1) and 29 feet long. A metal border was installed on the perimeter of the plot. The border consisted of metal strips hinged at 2-foot intervals. The strips were 6 inches in height. Sections of the metal strips overlapped each other, thereby eliminating the risk of water passing in or out of the contained area.

Also included in each plot was a sediment trap that was located on the downslope end of each bordered area (Appendix E). The sediment traps were 8 inches deep, 24 inches wide (18 inches wide in Vineyard 1) and 6 inches long. The back and sides of the trap were raised 1 inch to accommodate the metal strip around the sediment plots. The traps were fitted to match the degree angle of the slope of each of the vineyards (3 to 15 degrees). On the downslope side an overflow pipe was installed to allow water to flow out of the trap. The overflow pipe was fitted with a 90 degree 2-inch diameter elbow to prevent debris from clogging the opening. A small hole was drilled in the top of the elbow to prevent an air trap from developing.

Overflow socks were installed on all sediment traps during the second year of the project. (The socks were not fabricated in time for use during the first year of the project.) The sock was attached to the overflow pipe to collect suspended sediment in the water that flowed through the pipe and entered the sock. An overflow sock measuring 18 by 48 inches was constructed so that the seam was on the outside to ease recovery of sediment as well as to provide space for the grommets to secure the socks to the sediment trap and soil. Three overflow socks were made for each trap so that replacements were available when sediment was collected.

Mulch Specifications and Application

The composted mulch was made from yard trimmings that were thermophilically processed (see Appendix A for specific details of mulch processing). The original plan was for both Napa Garbage Service and Sonoma Compost to produce similar mulch products so that material applied in all four vineyard sites would be consistent. However, due to different feedstock composition and processing equipment, the mulch created by the two facilities was found to be significantly different. To insure that a uniform mulch product could be applied at all four vineyard sites, composted mulch from Sonoma Compost was used in the nine plots at all four sites. The rows on either side of the center nine rows received mulch produced from either Napa Garbage Service or Sonoma Compost, depending on location.

A demonstration of three types of mulch spreaders was conducted to determine which was most suitable to apply mulch in the vineyard sites. The three pieces of equipment demonstrated were a Millcreek Row Mulcher, Whatcom Northwest Mulch Spreader, and Finn Bark Blower. For the purpose of this demonstration, the spreader had to be equipped to deliver 2-inch minus material in the vine row on a 5 to 30 percent slope. Evaluation of each piece of equipment was based on productivity, accuracy of delivery, and economics.

The mulch was applied to the vineyard sites with a Mill Creek Row Mulcher and a Whatcom Northwest Mulch Spreader. The mulch was applied by hand with 5-gallon buckets inside the plots (see Appendix E for plot schematic) to the depth specified by the assigned treatment. The separation of contact between the vine and the composted mulch and the overall fine-tuning of the application inside the plots was accomplished manually.

Erosion Control Assessment

Erosion control was assessed through three separate means:

Field data—monitoring of sediment in water runoff during the rainy season.

Rain simulator—monitoring of sediment in water runoff induced by storm-specific rain simulation.

Computer modeling soil loss assessment using RUSLE.

Field Data

Hobo dataloggers were installed in each vineyard to monitor precipitation.

In the winter of 1999–2000 sediment was removed and collected from individual sediment traps after a variable period of time that spanned one to three rainfall events. In the following rainy season, sediment was also collected from overflow socks. These were replaced on the same date that sediment was removed and collected from the traps. Sediment and overflow socks were air-dried and the net weight of sediment collected per plot recorded. The percent reduction of sediment yield over a given time period, as compared to the control, was calculated using the following formula:

% reduction of sediment yield in a mulch plot as compared to a control plot = [control plot yield (oz)—mulch plot yield (oz)]/ control plot yield (oz) x 100

Plot fabrication was delayed and not all were completed in time for placement in the vineyards before significant rainfall events had occurred in winter 1999–2000. Therefore, no sediment data were collected in Vineyard 4 the first winter. All plots were in place the following year in Vineyard 4.

The percent reduction of sediment collected in treatments 1 and 2, as compared to the control plots, is reported for each site for each rain season (Appendix D, Figures 1a and 2a).

Rain Simulator

The purpose of the rain simulator was to assess sediment yield under controlled storm-specific conditions.

It was originally planned to use a portable Wilcox rain simulator programmed to deliver a specific precipitation rate at each of the demonstration sites to project how the mulch would behave during various types of rainstorms. However, because two of the vineyards have bearing vines, the use of the rain simulator in those sites might have caused fruit rot. As a result, the simulator was used at Vineyard 4, which did not have bearing vines.

Rainfall Simulator Trial

A simulator was installed and tested at Vineyard 4 in the summer of 2000, adding to erosion observations that were being conducted on the four vineyards. Although sediment yield was quantified for all four vineyards, overflow of sediment traps during winter storms did not allow for observations of total runoff yield vs. rainfall.

The simulator consisted of pressure compensating microsprinklers attached to poly tubing secured to the upper foliage catch wire on the trellis. NRCS scientists designed the system to provide precipitation rates equivalent to the two-year six-hour storm event for the area where Vineyard 4 was located (2.4 inches). A single row of Agrifim MFA adjustable microsprinklers were set up at a 4-foot spacing for all nine plots. During each storm run, four collection cans were randomly set about each plot to measure precise rainfall amounts and to account for the variable effects of wind on output of sprinklers. Covers were placed over each sediment trap so that sprinkler output would not affect runoff yield measurements.

Soil profiles were wetted to field capacity approximately 24 hours prior to simulations to develop required antecedent soil moisture conditions. This allowed for direct comparison of storm simulation output with soil loss models, which estimate erosion under assumed prior conditions.

A comparison of the relative percent reduction of sediment collected in Treatments 1 and 2 as compared to the control plots in a four- and six-hour rain simulation is reported for Vineyard 4 in Appendix D, Figure 3.

Computer Modeling: Revised Universal Soil Loss Equation

The RUSLE is a soil erosion model created to predict long-term average annual soil loss due to detachment and movement of soil particles resulting from raindrop splash and runoff under site-specific cropping management systems. Soil loss is computed-based upon a rainfall regime, soil erodibility factor, slope length factor, slope steepness factor, cover management factor, and support practice factor for the site. The widespread use of RUSLE has substantiated its reliability and accuracy. It was anticipated that the input from this two-year project would illustrate the long-term potential of the proposed practice of applying mulch in the vine rows.

The UNIXWARE version of RUSLE 3.4.0 was used for the calculations. Specifically, the model consists of the equation **A = RK (LS) CP**. The factors are defined as:

"A"—The computed soil loss per acre per year. This value is a long term (about 20 years) average and does not represent soil loss from a single storm event or a single season.

"R"—The intensity of the mechanism responsible for the detachment of soil particles by rainfall.

"K"—Is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff.

"LS"—Describes the combined effect of the geometric features (slope percent and length of slope) of the site.

"C"—Is used to reflect the effect of cropping and management practices on erosion rates and is the factor most often used to compare the relative effects of management options on conservation plans.

"P"—Is the support practice factor that represents the ratio of soil loss with a specific support practice to the corresponding loss with upslope and downslope tillage.

The RUSLE was used to compare the existing cropping system—the control in this project, referred to as the "benchmark"—and the proposed cropping and management system, which has mulch in the vine rows.

For this demonstration project, the benchmark crop system was defined as an existing three-year-old vineyard with 10 percent ground cover in the vine row, which is non-tilled, and a 30 percent raised canopy. The proposed management system is a three-year old vineyard with 85 percent ground cover in the vine row and a 30 percent raised canopy. The benchmark was used for all vineyards to enhance consistency.

The RUSLE factors used in each of the four vineyards are presented in Appendix C, Table 1.

The sites were also evaluated visually after major storm events for signs of both soil and mulch erosion; all observations were written down and documented through photographs. General observations were made for evidence of weed suppression, disease suppressant qualities, moisture conservation benefits, material dispersal through rodent activity or bird scratching, and overall health of the vines inside each of the mulch plots at each of the vineyards. Of particular concern to grape growers was the risk of a fungal pathogen causing disease in the vines and an induced nutrient deficiency caused by the microorganisms decomposing the mulch and reducing nutrient availability.

Baseline and Comparative Sample Analysis Protocols: Protocols for soil and plant tissue samples were developed to study the impact of treatments on vine nutrient availability. Samples were collected in the same manner at all sites.

Composite soil samples were taken from each vine row that contained the plots. Leaf blades were also collected from the same rows in late summer. Soil and plant tissue samples were collected in 1999 prior to the mulch application. Samples were collected in the same manner the following year after the mulch had been applied to the vine rows. Analyses were conducted on the soil and plant tissuesamples (see pages 19 and 20).

In Vineyard 2 and Vineyard 3, data vines were selected in 1999 in each row in which plots were to be established. In Vineyard 2, nine contiguous vines were chosen as data vines in each row. Plots were installed in late 1999 that included the center seven vines of each data vine set. In Vineyard 3, 12 contiguous vines were selected as data vines and the plots were installed in each row so that the center eight data vines fell inside each plot.

Grapevine yield and growth parameters were monitored in the same manner at both sites in 1999 and 2000. Data were collected by vine. In addition, each year a composite sample of berries was collected over all data vines immediately prior to harvest to assess fruit maturity indices.

The proposal called for training of the partners in sampling and data collection techniques. Renee Hendry, a student intern from California State University at Sonoma, was hired to perform all rainfall and sediment data collections at all demonstration plots. Dellavalle Laboratory, Inc. was hired to perform the soil and plant tissue sampling and analyses.

Vineyard Soil Fertility and Plant Tissue Nutrient Analyses

A soil amendment applied to the vine row or a management practice that directly impacts the area directly under the vines may potentially affect nutrient uptake and plant water status, among other things. To determine the effects of mulch applied in the vine row on soil and vine nutrient levels, soil and plant tissue samples were collected in 1999 and 2000 from all four of the vineyards.

Nine soil samples were collected from each vineyard in August and September 1999 and in August 2000. One sample consisted of a composite of 12 soil cores taken from one vine row. Each of the nine rows was sampled in the same manner both years. Soil was collected with a ¾-inch diameter soil probe that collected soil from a 1- to 12-inch depth. Cores were taken from the vine row, in the area wetted by the drip emitter—approximately 12 to 18 inches from the base of the vines. To avoid disturbing the soil and impacting soil movement and runoff data, cores were not taken from inside the plots.

Soil samples were collected from nine rows in Vineyard 1 and Vineyard 2 on August 25, 1999, and in Vineyard 3 and Vineyard 4 on August 18 that year. This was prior to the first application of mulch in all vineyards in December 1999, at which time 3 inches of mulch was applied to vine rows designated as Treatment 1 and Treatment 2. The following year, soil samples were collected on three dates in August and on September 1, 2000. In November 2000, vines rows designated as Treatment 1 received an application of an additional 1.5 inches of mulch. As a result, the second and final set of soil samples was collected after mulch had been in the vine rows for eight months and before it had been re-applied in Treatment 1.

Soil fertility analyses are presented in Appendix C, Tables 2–5.

Leaf blades were collected in August 1999 and 2000 from all vineyards in the same nine rows in which soil was sampled. Leaves were sampled at veraison (see Glossary for definition). A composite sample of 40 to 50 most-recently expanded leaves was collected from as many vines in each vine row for a total number of nine samples from each vineyard.

Nutrient status of leaf blades is presented in Appendix C, Tables 6–9.

Vine Yield and Growth Analyses

To determine if vines responded differently when grown in vine rows that had received mulch applications compared to vines grown in rows that had not received mulch, several parameters were monitored to assess vine yield, fruit maturity, and growth.

Data vines were selected in Vineyard 2 and Vineyard 3. These two sites contained vines of crop-bearing age. Yield and growth parameters were collected on a per-vine basis from nine vines in each row in Vineyard 2, five of which were contained in the plots in each row. In Vineyard 3, twelve data vines were selected—eight of which were located inside the plots of each row. Data were collected from the same vines each year.

The grower cooperator chose the harvest date each year to optimize fruit quality. At that time, the number of clusters per vine was counted and the total crop produced per vine was weighed (Appendix C, Tables 10 and 11). Just prior to harvest each year, a composite sample of 100 berries was collected from all data vines in each row resulting in nine 100-berry samples. Berry samples were weighed to find average berry weight and then crushed with a fruit press to obtain the juice. Brix, pH, and titratable acidity were found on the juice (Appendix C, Tables 12 and 13). In the dormant season, vine pruning weights were found for each data vine at the time it was pruned (Appendix C, Tables 10 and 11).

Market Evaluation

The purpose of the market evaluation was to determine if the end users, grape growers, and vineyard managers would be willing to use composted mulch that had been produced from yard trimmings as part of erosion control management of hillside vineyards. This determination would enable the cooperators to decide if this would open a new market for yard trimmings, thus diverting it from the waste stream and reducing landfill space requirements.

The project was presented to grape growers, vineyard managers, and consultants at numerous events. These included project field day demonstrations, erosion control workshops, and other wine industry events. In general, the end users believed that the composted mulch had a place in vineyard management.

Findings

Erosion Control Assessment

A summary of rainfall totals collected in each of the vineyards is presented here. See Appendix D, Figures 4 and 5 for monthly totals by site:

	First year	Second year
Vineyard 1 =	38.46 inches	22.04 inches
Vineyard 2 =	31.98 inches	19.93 inches
Vineyard 3 =	20.77 inches	16.96 inches
Vineyard 4 =	29.41 inches	20.37 inches

An overall reduction in sediment yield occurred in the mulched plots as compared to the non-mulched control plots. In addition, there was a marked reduction in sediment yield in most control plots from year one to year two, which could be attributed to the presence of loose soil created when the plots were installed. Three out of four vineyards had significantly less rainfall in year two, which may have also contributed to lower sediment yields.

The average relative reduction of sediment collected in the Treatment 1 mulch plots as compared to the controls in January through May 2000 in Vineyard 1, Vineyard 2, and Vineyard 3 was 91 percent, 97 percent, and 98 percent respectively. The average relative reduction of sediment collected in the Treatment 2 mulch plots as compared to the controls in the same period in Vineyards 1, 2 and 3 was 92 percent, 97 percent, and 98 percent respectively (Appendix D, Figure 1a).

The following year, all four vineyard sites were monitored for sediment yield during the rainfall period November 2000 to May 2001. The average relative reduction of sediment collected in the Treatment 1 mulch plots as compared to the controls in November through May 2001 was 91 percent, 90 percent, 81 percent, and 98 percent respectively (Appendix D, Figure 2a). The average relative reduction of sediment collected in the Treatment 2 mulch plots as compared to the controls in the same period in Vineyard 1, Vineyard 2, Vineyard 3, and Vineyard 4 was 91 percent, 88 percent, 78 percent, and 98 percent respectively.

These field observations provide an overall assessment of the impact of the use of mulch in vineyard vine rows on sediment yield. Such field-based observations cannot be compared to the sediment data collected from the rainfall simulator or the long-term soil movement estimated by the RUSLE, but general trends did emerge in the data.

Sediment yield in actual field conditions was measured after a discernable amount had moved into the sediment traps and overflow socks, which generally occurred after one to three rain events. The collection timing was dependant on the relative storm intensity. For example, sediment was collected after a series of “small” storms when each had very little precipitation. It was also collected after a “large” storm that lasted several days. As a result, data were not collected on a rain event basis.

Many of the variables associated with naturally occurring rain events were eliminated with the use of rain simulations in Vineyard 4, which were controlled events. For example, prior to the simulations, all plots were wet to field capacity but were not saturated. Thus, simulation data were collected from plots with a soil moisture content that may have differed significantly from soil moisture conditions that existed in plots over the course of the annual rainfall period.

The RUSLE is an estimate of long-term soil loss over an extended (20-year average) period. Thus it cannot be compared to sediment data collected over the course of individual annual rainfall periods. However, to illustrate the similarities in the data, they are presented together in Appendix D, Figure 6.

Figure 6 presents a side-by-side comparison of the percent reduction in soil loss predicted by the RUSLE under the cropping and management system that utilizes mulch in the vine rows and the average percent reduction of sediment collected in each mulch treatment as compared to the controls over the 2000–2001 rainfall period for Vineyard 1, Vineyard 2, Vineyard 3, and Vineyard 4. Actual trends were generally in keeping with RUSLE data, with the exception of Vineyard 3. Field observations noted that sidehill slope in that site increased concentrated flow on most plots (thus more sediment was collected from the sediment traps). For Vineyard 1, Vineyard 2, and Vineyard 4, actual erosion reduction vs. RUSLE-predicted annual soil loss varied from 0.7 percent to 7.7 percent.

Visual Observations of the Vineyards

Water runoff from the control plots in all vineyards was murky and contained sedimentary materials, whereas water runoff from the mulched plots in vineyards ran clear. A few days after storm events water runoff ceased in the mulched plots, while there was a small but noticeable drainage into control plot sediment traps. Gopher activity was absent in the mulched plots with the exception of plot 203 in Vineyard 4. Mulch did not show any signs of movement.

Rainfall Simulator, Vineyard 4

The March 2001 simulation was run for a four-hour period, and the April 2001 simulation was a full six-hour run.

Sediment yield totals for both the four-hour and the six-hour storm simulation were for the most part higher in the controls. In the four-hour simulation, soil loss per inch of rain in controls ranged from over two times to more than 40 times the rate of mulched plots (with the exception of mulch plot 302, which was just slightly higher than soil loss in the control). The six-hour storm comparisons were slightly less pronounced, but still consistently higher, with plot 202 being the only mulch plot with results similar to the control.

Total average rainfall volume per inch of rain was generally higher in controls vs. the mulch plots located in the same replication for both four- and six-hour simulations. A notable exception in the four-hour storm was control plot 403, which generated about half of the runoff of mulch plot 402 and only about one-third of runoff recorded in mulch plot 401. In the six-hour simulation, runoff volume in the controls were generally multiples of the volume generated in the mulch plots, with the exception of mulch plot 201, which generated about eight times the runoff of the control in that replication (plot 203).

Figure 7 in Appendix D displays average reduction in soil loss for both treatments that received mulch applications as compared to the controls in both rain simulations. In each storm event, Treatment 1 was superior to the erosion control effectiveness of Treatment 2. Only Treatment 1 in the four-hour simulation showed a soil loss savings that approached that of the long-term average predicted reduction estimated by the RUSLE. There was a reduction of 85 percent in Treatment 1 as compared to the control in the four-hour simulation and RUSLE predicted a long-term average reduction of 90.3 percent. However, the 77.4 percent average reduction in soil loss for the same treatment in the six-hour storm event was a considerable improvement over the non-mulched controls.

The data generated in the rainfall simulations in Vineyard 4 should not be compared with the sediment collected over the entire period of natural rainfall from the plots in Vineyard 4 or any of the sites as previously discussed. However, it can be noted that soil savings results for mulch applications were consistently favorable for both the actual field conditions and simulator runs. The simulator provided valuable runoff volume comparisons among plots. That information indicated that for individual storms, mulch may also serve to improve infiltration or retention of rainfall runoff. Further study is needed to determine if these results are consistent under variable site conditions.

Revised Universal Soil Loss Equation Results

The RUSLE was used to compare the existing cropping system (benchmark) and the proposed cropping and management system. In this project, the existing system was defined as a three-year old vineyard with 10 percent ground cover in the vine row, which is non-tilled, and a 30 percent raised canopy. The proposed management system was a three-year old vineyard with 85 percent ground cover in the vine row and a 30 percent raised canopy. The benchmark was used for all vineyards to enhance consistency.

In all four vineyard trials the model predicted a substantial reduction (90 to 90.4 percent) of the average soil loss per acre per year using composted mulch in the vine rows. Estimated average long-term yield per site is presented in Appendix C, Table 1. It also contains a summary table that lists the typical model inputs used in an existing cropping system and a proposed system as defined in this report.

It is important to note that sediment yield should not be confused with soil erosion; the terms are not interchangeable. Sediment yield is the amount of eroded soil that is delivered to a point in the watershed that is remote from the origin of the detached soil particles. Soil erosion is the process that moves soil from one location to another by wind, water, or other natural action. It is a natural process until it is accelerated by human actions. Because the length of the run in this demonstration was significantly shorter than even the smallest of watersheds (the plots were 29 feet), sediment yields were assumed to be equivalent to erosional movement.

Vineyard Soil and Plant Tissue Nutrient Analyses

Each year, soil samples were analyzed for saturation percentage (SP), pH, electrical conductivity (ECe), calcium (Ca), magnesium (Mg), sodium (Na), lime requirement, boron (B), nitrate-nitrogen (NO3-N), phosphorus as phosphate (PO4-P), potassium (K) and zinc (Zn). Treatment means are shown by year for each site in Appendix C, Tables 2–5. In 1999, samples were collected prior to the application of mulch. There were no significant pre-treatment differences in soil fertility macronutrients (NPK) with the exception of sulfuric acid extracted potassium in Vineyard 1. This extraction method was used given the low levels of K found by using the conventional means of atomic absorption (noted by column headings “AA” in Table 2) on a soil water extract. When water extractable K levels are less than 100 ppm, it is common practice for a laboratory to run a sulfuric acid extraction. In 1999, there were no pre-treatment differences in water extractable K levels. There were also no treatment differences the following year in water extractable K levels in Vineyard 1.

In Vineyard 1,Vineyard 2, and Vineyard 4, there were no significant differences in soil fertility among treatments in 2000 (see Appendix C, Tables 2, 3, and 5). Mulch had been placed in the vine rows about eight months prior to the date that samples were collected. In Vineyard 3 (Appendix C, Table 4), phosphate-phosphorous was significantly higher in Treatment 1 in 2000 (p = 0.0095) and potassium was higher in both mulch treatments that year (p = 0.0145). In that vineyard, the application of liquid fertilizer through the drip irrigation system was a standard annual practice. The entire vineyard received a total of 20 and 80 pounds per acre P and K respectively in 1999 and again in 2000**.**

Each year, leaf tissue was analyzed for percent total nitrogen (N), phosphorus (P), potassium (K), sodium (Na), chloride (Cl), calcium (Ca), magnesium (Mg) and for the following micronutrients in parts per million—zinc (Zn), manganese (Mn), boron (B), iron (Fe), and copper (Cu). Treatment means are shown by year for each site in Appendix C, Tables 6–9. In 1999, tissue samples were collected from all sites in August—four months prior to mulch applications. There were no significant pre-treatment differences in nutrients in any site with the exception of Mn in Vineyard 2 and 3 and Cu in Vineyard 3. The differences in vine Mn levels within the two sites did not reoccur the following year when leaf samples were taken after mulch had been applied to the vine rows (Appendix C, Tables 7 and 8).

Vine tissue levels of copper in Vineyard 3 were also not significantly different the following year. In that vineyard, leaves collected in 2000, eight months after mulch was applied, contained slightly more phosphorus in rows designated Treatment 1 than leaves collected from other rows (p = 0.0012). This difference is not significant in the practical sense. That is, the 0.02 percent difference in P would not be noticeable by vine symptoms, nor is it an actionable level (see Appendix C, Table 3).

Vine Yield and Growth Analyses

There were no significant treatment effects (p>0.05) on any component of vine yield in Vineyard 2 or 3 in either 1999 or 2000 (Appendix C, Tables 10 and 11). Average vine yields increased in 2000 from 1999 across all treatments. Yields were up across most North Coast vineyards in the same period. In Vineyard 3, vine yields increased overall treatments due to an increase in cluster number (Appendix C, Table 10); however, this increase occurred similarly across both mulch application treatments and the control. In Vineyard 2, vine yields also increased the second year due to an increase in cluster number as well as an increase in average cluster weights and berries per cluster (Appendix C, Table 11).

There were no significant differences (p>0.05) in fruit maturity among mulch applications in either vineyard (Appendix C, Tables 12 and 13). The maturity indices of Brix, pH, and titratable acidity remained unaffected by treatment in both years.

Vine growth, as indicated by pruning weights, was not significantly affected (p>0.05) by the practice of applying mulch in the vine rows in either site in 1999 and 2000 (Appendix C, Tables 10 and 11).

Market Evaluation

The following topics were discussed at each educational event with potential end-users of the mulch and their concerns with the practice of applying composted mulch in vineyard rows were noted.

How will the material be applied?

Four spreaders had been used at various demonstration events. The Whatcom Northwest Mulch Spreader and Millcreek Row Mulcher were very efficient in mulch applications provided that the mulch was adequately screened to at least 2-inch minus and had a moisture content of 35 to 50 percent. These two spreaders were used for the mulch applications in the project due to local availability. The S & A spreader also performed well; however, local availability was lacking. The Finn Bark Blower had a tendency to clog.

How much material is needed in the vineyard?

An Excel spread sheet was developed to help growers calculate the amount of mulch needed (Appendix C, Table 14). A version of this spreadsheet—termed the "Mulch Calculator"—is available by contacting Will Bakx at willbakx@sonomacompost.com or (707) 664-9113. The grower enters the width of the vine row, vine row spacing, depth of mulch desired, number of acres to be treated, and the cost of the mulch. The program will automatically give information including the amount of mulch needed and the total material cost. Delivery and spreading costs are not included; however, they can be included in the per-cubic-yard material cost.

How long does the mulch last in the vineyard?

Preliminary results indicate that the mulch will remain at least four years. No benefit was observed to date as a result of a second mulch application at the start of the new rainy season.

Are rodents a problem in the mulch?

No increase in activity of rodents was observed during the two years of the project.

Is it possible to get a cost for having the mulch applied in the vineyard by the mulch provider?

Most growers expressed that they have no desire to handle this material. They would apply the mulch to the vineyard, but only if the supplier would provide a service to make the product available on a placed-in-the-vineyard basis.

How does the mulch affect the weeds in the vine row?

More attendees were interested in the weed control potential of the mulch than in erosion control. Growers believed that weed management costs could be reduced if the mulch could reduce the need for herbicide applications. In addition, such benefit would further the efforts of the industry to improve environmentally sound farming practices. A substantial reduction in weeds was observed, but weed control was not quantified. Two of the cooperators have adopted the mulch application as a means for weed control in a few selected blocks.

Conclusions

Erosion Control Assessment

The findings of the two-year project suggest that a reduction of soil movement (soil erosion) of 78 percent to 98 percent was achieved based on field data collected in the second year of the study, which we consider to be more representative of actual field conditions than first year data. This is because of the presence of loose soil created when the plots were installed during 1999. The altered water flows noted in Vineyard 3 increased the soil movement in the control relative to that of the mulched plots in the first rain season, thus resulting in an inflated rate of soil conservation in the mulched plots of that vineyard. With that problem corrected, 2000–2001 data pointed to encouraging consistent results for mulch performance at all vineyards.

It is also interesting to note that despite the additional rainfall at Vineyards 1 and 2 in the winter of 1999-2000, the mulch performed equally as well as in Vineyards 3 and 4, which received less rainfall. Therefore, preliminary results would indicate that the composted mulch is effective in control of soil erosion in locations that have annual rainfalls up to 40 inches.

The observation that runoff from the mulched plots had ceased within a few days after storm events indicates that either a higher rate of infiltration and/or additional moisture retention occurred in the mulched plots. For control plots, it appears that less rainfall is translated to base flow (that is, sub-surface flow), thus minimal infiltration resulted in increased runoff. A higher rate of infiltration in the mulch plots reduced surface runoff that can lead to soil movement. Hence less sediment was generated in the mulch plots. This assumption is further validated by the observation that the water runoff from the control plots was murky and contained sediment, whereas the water runoff from the mulched plots ran clear.

The project to date shows that significant control of soil erosion can be achieved through the implementation of the mulching practices outlined in this project. However, the economic viability of these practices is yet to be determined, and the long-term effect of mulch in the vine row on water and nutrient conservation and weed suppression require further assessment. In addition, the price of the composted mulch, trucking and application costs will strongly impact the adoption of this practice by growers.

Rainfall Simulator Trial

Simulator data demonstrated that composted mulch placed in the vine row reduced both sediment and runoff output. Composted mulch provides a protective cover for the soil surface, reducing raindrop splash action and detachment of soil particles. Reduction of splash action also helps to lessen crusting and compaction of the soil surface. Coupled with the absorptive qualities of the mulch, runoff and transport of soil were also reduced.

Revised Universal Soil Loss Equation (RUSLE)

Long term average soil loss as predicted by the RUSLE will be reduced by an average of 80 to 90 percent or more, provided that the soil cover of mulch is maintained over time. After two years, the 3 inches of mulch applied (Treatment 2) during 1999 still measured 1.4 to 1.7 inches in depth. It is thus anticipated that the effect of the mulch will last for several years.

The field data from the sediment traps, the rain simulator, and the RUSLE modeling are in strong agreement that the anticipated reduction of soil loss in the hillside vineyards studied can be reduced significantly.

Vineyard Soil and Plant Tissue Analyses

At Vineyard 2, both fertilizer and mulch applications may have impacted differences in levels of soil phosphate-phosphorous and potassium. In 2000, higher soil P resulted in a greater uptake of P in leaves. However, higher soil K in 2000 did not result in greater uptake of K in leaf tissue that year. The differences in levels of Mn and Cu in leaf blades in 1999 in this vineyard are not likely related to the presence of mulch, since both mulch treatments were identical that year.

At Vineyard 1, although statistically significant, there was an average of only 8 ppm more sulfuric acid extractable K in soils that received mulch than in those that did not. This difference did not result in an increase in K in leaf tissue in either year.

Overall, the application of mulch to the vine rows did not have a strong impact on either soil or plant nutrient levels over the course of this project.

Vine Yield and Growth Analyses

The application of mulch to the vine rows in Vineyard 2 and Vineyard 3 did not significantly affect any of the parameters that are commonly used to assess grapevine yield and growth. While no treatment effects on several viticultural indices were observed with this practice over a two-year period, long-term responses are not known. In addition, variables such as soil moisture content, vine water potential, and weed control were not measured. These may have been impacted by the presence of mulch in the vine row. The data that were collected and analyzed indicate that there were no negative effects on vines when mulch was applied in the vine row.

Market Evaluation

Members of the grape industry believe that mulch can be used effectively as a tool in erosion control. The continued erosion control observed in the second year confirms erosion control results with the rain simulator and RUSLE. When combined with the effective life expectancy of four years, mulch becomes an appropriate tool for growers with vineyards that are potentially at risk for erosion. The availability of a mulch application service will improve the adoption of the use of mulch in the industry. Increased marketing potential for this product can be achieved when the potential weed control efficacy of the product can be substantiated.

Recommendations

When growers plant a hillside vineyard, they expect some soil loss. Growers should develop a soil management plan that reduces soil loss to the greatest extent possible, and the anomalies of the specific site should be taken into consideration before implementing any soil management practice. The following recommendations provide a tool to assist growers to reduce soil erosion in the vine row where weed management is practiced.

A 3-inch layer of composted mulch produced from yard trimmings may reduce soil loss 80 or 90 percent or more. The remainder of the vineyard floor is typically managed by mowing a vegetative cover such as cover crops or resident plants (weeds)—all of which serve to cover the soil surface.

Mulch applied to the vine row will protect the soil from direct rain impact, reducing the volume of soil that goes in solution when runoff occurs.

Thermophilically treated mulch is recommended because it is created with a process that kills weed seeds and destroys pathogens that may be present in the raw feedstock. The mulch supplier should be able to provide evidence of compliance with the treatment regime necessary to produce thermophilically treated mulch as outlined in this report. The use of untreated mulch is not advised.

In order to facilitate proper spreading, the mulch should be screened to no coarser than 2-inch minus with moisture content of 35 to 55 percent. A finer particle size is acceptable; however, the finer the mulch, the faster it will break down. This will potentially result in a shorter erosion efficacy time. A particle size greater than 2-inch minus reduced the efficiency of the spreaders tested. Mulch with a moisture content of less than 35 percent will create dust problems and may bridge the spreader. Mulch with moisture content greater than 55 percent hampered the efficiency of the spreaders tested in the demonstration project.

The 3 inches of mulch should be effective for at least several years. The lifetime of the mulch is an important factor in determining the economic viability of using mulch applications as an erosion control management practice in hillside vineyards. Further research is needed to assess the efficacy rate of the mulch over time.

Other factors may influence the end user as well in the determination of the economic viability of using mulch in their vineyards. Weed control has been observed to be a significant beneficial side effect of the mulch practice. Future studies need to quantify the effectiveness of the mulch in controlling weeds over its lifespan.

Glossary of Abbreviations, Acronyms, and Terms

B: Boron in saturation extract is expressed as ppm and is required for crop growth, but it may be toxic. Boron is satisfactory if petioles and leaves are above 35 ppm at bloomtime.

Brix: Degree Brix is the measurement of sugar concentration in solution.

Ca: Calcium ions in the soil saturation extract are expressed in milliequivalents per liter and are used to calculate ESP. Satisfactory petiole levels are above 1 percent at bloom.

Cl: Chloride in the soil saturation extract is expressed in milliequivalents per liter. For most crops, chloride is not a factor when the ECe is in a safe range. Bloomtime petiole and leaf chloride is satisfactory at below 0.5 percent. Harvest blade analysis is suggested in areas with high chloride content at bloom.

Cu: Copper petiole levels are satisfactory above 8.0 ppm at bloomtime and leaf values above 4.0 ppm.

ECe: Electrical Conductivity of the saturation extract is an index of salt content expressed as milliohms per centimeter or deciSiemens per meter at 25° C. Salts affect crop growth.

ESP: Exchange Sodium Percentage is the degree to which the soil exchange complex is saturated with sodium. It is used to determine soil permeability and potential phytotoxicity.

Fe: Iron.

GR: Gypsum Requirement is the amount of gypsum, or its equivalent, required to furnish sufficient calcium to correct a sodium-caused permeability problem and/or phytotoxicity. GR is expressed in tons of 100 percent gypsum per acre in 6 inches of soil.

K: Potassium ions in the soil saturation extract are expressed in milliequivalents per liter and are used to calculate ESP. Petiole potassium concentrations are satisfactory above 1.5 percent, deficient below 1.0 percent.

Lignins: Plant substances that form the woody cell wall in combination with cellulose.

Lime: Lime when reported by one to four pluses (+) indicates that the acid-forming amendments (such as sulfur or sulfuric acid) may be used in place of gypsum. The number of pluses indicates the amount of lime present; a minus (-) indicates no lime present.

LR: Lime Requirement.

Mg: Magnesium ions in the soil saturation extract are expressed in milliequivalents per liter and are used to calculate ESP. Petiole levels are satisfactory above 0.3 percent at bloom.

Mn: Manganese maintains petiole and leaf levels above 25 ppm at bloom.

N: Nitrogen status of a vineyard can be established by leaf blade analysis.

Na: Sodium ions in the soil saturation extract are expressed in milliequivalents per liter and are used to calculate ESP. Bloomtime petiole and leaf sodium concentrations are satisfactory below 0.5 percent.

NO3-N: Nitrogen As Nitrate.

Petiole: Stalk of a leaf.

pH: Degree Of Acidity Or Alkalinity of a saturated soil.

Phytotoxicity: Phytotoxicity refers to plant injury caused by exposure to a material that came in direct contact with the plant or was absorbed by its roots.

P: Phosphorus for petiole at bloom is satisfactory between 0.1–0.15 percent.

PO4-P: Phosphorus As Phosphate.

ppm: Parts Per Million.

RUSLE: Revised Universal Soil Loss Equation.

SP: Saturation Percentage is the number of grams of water required to saturate.

TTM: Thermophilically Treated Mulch is composted mulch that has been managed to induce the proliferation of microorganisms by maintaining temperatures of at least 131°F (55° C) for 15 days or more during which time the mulch has been turned at least five times.

Veraison: The period of vine growth that corresponds to the start of fruit ripening as defined when 50 percent of the grapes have changed color or softened.

Zn: Zinc concentrations in petioles and leaves satisfactory above 25 ppm.

Appendix A:
Thermophilically Treated Mulch Manufacturing Information

Thermophilically Treated Mulch Manufacturing Information

Thermophilically treated mulch (TTM) used in the plots is made from self-haul yard trimmings. Self-haul hard debris is material that is delivered to the composting facility by residents and landscapers. No material from curbside collection is used in this product. Sonoma Compost Company found that there were two significant differences between the self-haul and curbside collection feedstock:

1. The self-haul material is virtually free of foreign objects.
2. The self-haul material has a higher ratio of brush to leaves, thus the end product has a high carbon content (wood).

These characteristics make it an ideal feedstock for a coarser mulch product. Even with a coarser particle size, there are virtually no contaminants in the finished product. Cleanliness is an important factor in marketing this material. The relatively high content of woody material extends the lifetime of the product, since the lignins are resistant to decomposition. Further, a mulch high in carbon is fungal dominated and thus much more effective in the development of stable soil aggregates. Soil aggregation tends to cause a crumbly soil structure, higher porosity, and better infiltration rate. Finally, the high carbon content will rob the very surface of the soil of nitrogen. A shortage of surface nitrogen does not affect the grape vine, but it is more difficult for weeds to become established.

The yard debris is ground to roughly 3-inch minus particle size. Water is added to bring the moisture content to about 55 percent. The mulch is placed in a windrow and turned every third day for at least 15 days. The temperature is taken each workday and is maintained at 131° F or higher. Following this period, the TTM is screened to 1.5-inch minus.

For ease of spreading the mulch in a vineyard, the material must have a moisture content of 35 to 55 percent. A lower moisture content creates too much dust and a higher moisture content clogs the mulch spreader during the application in a vineyard.

As a demonstration, an unscreened TTM that was ground finer than 3-inch was applied in 1999 in Napa in the vine rows adjacent to those that contained the plots. The material still contained 2-inch minus particles that make the product hard to spread. Also, sticks in the product caused the mulch to breach in the spreader. Since many compost facilities are not equipped to screen at 2-inch minus, a screened TTM of ½-inch minus was applied in the demonstration sections of the vineyards in Napa for the 2000–2001 season.

Appendix B
Vineyard Site Design (Plot Layout)

Vineyard Site Design (Plot Layout)

Four vineyard sites; 27 contiguous vine rows at each site. Each of the center nine rows contains a sediment trap. The experimental design is the same at each vineyard site.

Plots in 200, 300, and 400 series are one-row replicates. All erosion/mulch behavior characteristics, vine yield components, and soil/tissue data will be collected from these plots.
Plots in 100 and 500 series are three-row replicates. Mulch is applied; however, no data will be collected from these.

All data is reported by 3-digit plot number.

First digit in plot number is the **replication number**. Last digit in plot number is the **treatment number**.

Treatment 1 = A layer of 3 inches of composted material is applied the first year and 1-1/2 inches was re-applied in the second year.
Treatment 2 = A layer of three inches of composted material was applied in the first year only.
Treatment 3 = Untreated control.

Important: Row numbers are read from left to right when facing vineyard from the most commonly used vineyard approach.

TREAT-MENT		3			2			1		1	2	3	3	1	2	2	1	3		3			2			1	
ROW #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
PLOT #		103			102			101		201	202	203	303	301	302	402	401	403		503			502			501	

These rows contain plots with sediment traps. See Appendix E for Plot Schematic.

Appendix C
Project Data Tables

Table 1: RUSLE Factors

Soil Loss Equation = R x K x LS x C x P (tons/acre/year)

R = Rainfall Erosion Index = 10.2 p ^ 2.2 where p = 2 yr. 6 hr. rainfall
K = Soil Erodibility Factor as determined in soil series
LS = Length Slope Factor
C = Cover Factor = 0.62 control; 0.06 treatment
P = Erosion Control Practice Factor = 1

Site	R	K	Slope	LS	Soil Texture	NRCS Soil Classification*	Percent Reduction
Vineyard 1	160	0.28	31%	2.42	Clay loam--loam	Josephine Loam	90.3%
Vineyard 2	140	0.24	25%	1.99	Loam--clay loam	Sobrante Loam	90.4%
Vineyard 3	60	0.37	8%	0.58	Very fine sandy loam	Bressa-Dibble Complex	90.0%
Vineyard 4	80	0.24	7%	0.52	Gravelly loam--loam	Kidd Loam	90.3%

*NRCS = Natural Resources Conservation Service

Table 2: Soil Fertility in 1999 and 2000, Vineyard 1[a]

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
							meq/l							
Trt	SP	SP	pH_s	pH_s	$EC_e \times 10^3$	$EC_e \times 10^3$	Ca	Ca	Mg	Mg	Na	Na	ESP[d]	ESP[d]
1	48	57	7.6	7.5	0.74	0.49	6.6	3.7	1.2	1.1	0.5	0.5	<1.0	<1.0
2	49	53	7.6	7.4	0.68	0.62	6.0	4.9	1.1	1.7	0.5	0.6	<1.0	<1.0
3	50	53	7.6	7.4	0.65	0.74	5.9	5.9	1.0	1.9	0.4	0.8	<1.0	<1.0
P-Value	0.74	0.2924	0.9452	0.9037	0.508	0.2311	0.6453	0.2673	0.527	0.6935	0.25	0.2763		

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
	ppm											
							K					
Trt	B[b]	B[c]	NO_3-N	NO_3-N[d]	PO_4-P	PO_4-P	(AA)	(AA)	H_2SO_4	H_2SO_4[e]	Zn	Zn[f]
1	<0.1	<0.1	3	2	12	5	57	111	85 b		0.2	0.1
2	<0.1	<0.1	3	<1	14	5	61	97	82 b		0.2	0.1
3	<0.1	<0.1	2	2	12	3	46	88	76 a		0.3	0.1
P-Value			0.2844		0.3332	0.5755	0.1665	0.6494	0.0119		0.892	

[a] Soil sample dates: August 25, 1999; September 1, 2000. Lime was not reported in either year.

[b] In 1999, Boron in all replicates reported as <0.1ppm

[c] In 2000, Boron in over half of the replicates reported as <0.1 ppm and the remaining as 0.1 ppm

[d] In both years, all replicates reported <1.0 ESP. In 2000, many replicates reported <1 ppm NO_3-N

[e] Data missing for two replicates, therefore no means presented.

[f] All replicates except one reported as either <0.1 or 0.1 ppm. The remaining replicate reported as 0.2 ppm.

Table 3: Soil Fertility in 1999 and 2000, Vineyard 2[a]

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
							meq/l								T/ac-6 inches	
Trt	SP	SP	pHs	pHs	ECe x 10^3	ECe x 10^3	Ca	Ca	Mg	Mg	Na	Na	ESP[b]	ESP[b]	Lime[c]	Lime[d]
1	42	42	6.2	5.8	0.55	0.98	2.9	5.8	1.8	3.4	0.43 a	0.6	<1.0	<1.0		5533
2	42	45	6.2	5.9	0.65	0.64	3.3	4.0	2.0	2.6	0.5 ab	0.5	<1.0	<1.0		5850
3	41	45	6.3	5.5	0.69	1.61	3.9	9.8	2.1	5.8	0.53 b	0.7	<1.0	<1.0		4633
P-Value	0.7296	0.6018	0.6173	0.2667	0.3628	0.3195	0.2044	0.3382	0.5615	0.3811	0.0494	0.3044				

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
	ppm									
							K			
Trt	B[e]	B[f]	No3-N	No3-N	PO4-P	PO4-P	(AA)	(AA)	Zn	Zn
1	<0.1	<0.1	19	4	21	18	180	180	0.6	1.0
2	<0.1	<0.1	24	3	23	21	177	150	0.7	0.9
3	<0.1	<0.1	23	3	26	14	177	150	0.8	0.7
P-Value			0.3916	0.6732	0.3638	0.2257	0.907	0.2407	0.4201	0.362

[a] Soil sample dates: August 25, 1999; August 21, 2000

[b] All replicates reported as <1.0 Tons/Acre--6 inch

[c] Lime not reported in 1999 because soil pH in all replicates >6.0.

[d] Lime not reported for one replicate in Treatment 2 with soil pH 6.0; therefore, only means presented.

[e] In 1999, Boron in all replicates reported as <0.1 ppm

[f] In 2000, Boron in all replicates except one reported as <0.1 ppm. The remaining replicate reported as 0.1 ppm.

Table 4: Soil Fertility in 1999 and 2000, Vineyard 3 [a]

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
							meq/l					
Trt	SP	SP	pH_s	pH_s	$EC_e \times 10^3$	$EC_e \times 10^3$	Ca	Ca	Mg	Mg	Na	Na
1	37	48	6.0 b	5.8	0.53	0.41	2.3	1.7	1.7	1.0	0.9	0.8
2	36	40	5.8 a	5.7	0.58	0.41	2.4	1.7	1.9	1.1	1.0	0.8
3	37	41	5.8 a	6.0	0.53	0.67	2.3	3.6	1.6	2.0	0.9	1.4
P-Value	0.892	0.4601	0.0421	0.5124	0.9028	0.5844	0.9929	0.5443	0.8784	0.4905	0.5487	0.5023

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
	ppm									
							K			
Trt	B	B	No_3-N	No_3-N	PO_4-P	PO_4-P	(AA)	(AA)	Zn	Zn
1	0.13	0.17	10	4	4	8 b	157	327 b	1.6	2.8
2	0.13	0.13	12	4	4	4 a	122	270 b	1.5	2.8
3	0.13	0.1	13	3	4	4 a	150	200 a	1.5	2.3
P-Value	1.0	0.4444	0.9105	0.5878	0.9529	0.0095	0.4515	0.0145	0.5317	0.3376

[a] Soil analysis dates: August 18, 1999; August 4, 2000.
[b] Lime not reported for one replicate in Treatment 1 with soil pH 6.2; therefore, only means presented.
[c] Lime not reported for one replicate in Treatment 3 with soil pH 6.6; therefore, only means presented.

Table 5: Soil Fertility in 1999 and 2000, Vineyard 4[a]

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
							meq/l						T/ac-6 inches	
Trt	SP	SP	pH_s	pH_s	$EC_e \times 10^3$	$EC_e \times 10^3$	Ca	Ca	Mg	Mg	Na	Na	Lime[b]	Lime[c]
1	41	38	6.2	6.0	0.34	0.39	1.1	1.4	0.6	0.8	1.1	0.8		-
2	40	41	6.2	5.9	0.27	0.46	0.9	1.7	0.6	0.8	0.9	0.8		6700
3	42	40	6.3	5.8	0.36	0.58	1.2	2.3	0.8	1.1	1.0	1.1		7200
P-Value	0.5959	0.1908	0.822	0.6208	0.2123	0.1941	0.3348	0.2807	0.2336	0.4345	0.1736	0.125		

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
							ppm			
							K			
Trt	B[d]	B[d]	NO_3-N	NO_3-N	PO_4-P	PO_4-P	(AA)	(AA)	Zn	Zn
1	<0.1	<0.1	11	13	35	10	260	313	1.4	1.4
2	0.1	0.1	10	13	35	14	260	463	1.6	2.4
3	0.1	0.1	11	20	24	14	260	370	1.9	1.2
P-Value			0.5765	0.2075	0.3144	0.3286	1.0	0.1502	0.7632	0.524

[a] Soil sample dates: August 18, 1999; August 25, 2000.
[b] Lime reported for only one replicate in Treatment 1 with soil pH <6.0.
[c] Lime not reported for two replicates in Treatment 1 each with soil pH >6.0; therefore, only means presented for Treatments 2 and 3.
[d] All boron levels were <0.1.

Table 6: Nutrient Status in Leaf Blades at Veraison, Vineyard 1[a]

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Treatment	% N	% N	%P	%P	%K	%K	ppm Zn	ppm Zn	ppm Mn	ppm Mn	% Na[b]	% Na
1	1.71	1.85	0.27	0.43	0.98	1.04	75	88	707	639	<0.01	0.03
2	1.65	1.94	0.23	0.40	0.96	1.10	57	64	590	769	<0.01	0.02
3	1.76	1.81	0.24	0.43	1.01	1.05	67	98	491	679	<0.01	0.03
P-value	0.2723	0.1664	0.4665	0.9205	0.8009	0.3012	0.3459	0.0760	0.1497	0.7632		0.9273

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Treatment	% Cl[c]	% Cl[c]	ppm B	ppm B	% Ca	% Ca	% Mg	% Mg	ppm Fe	ppm Fe	ppm Cu	ppm Cu
1	<0.1	<0.1	54	112	2.34	1.86	0.54	0.55	947	770	12	113
2	<0.1	<0.1	47	103	2.09	1.78	0.52	0.51	1010	790	18	118
3	<0.1	<0.1	54	97	2.25	1.80	0.51	0.55	1096	649	7	128
P-value			0.0606	0.4007	0.2224	0.7518	0.7474	0.6367	0.1958	0.5498	0.4898	0.7036

[a]Leaf tissue analysis dates: August 25, 1999; August 21, 2000.
[b]One replicate reported as 0.01, all others reported as $\leq$0.01.
[c]All replicates reported as <0.1.

Table 7: Nutrient Status in Leaf Blades at Veraison in 1999 and 2000, Vineyard 2[a]

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Treatment	% N	% N	%P	%P	%K	%K	ppm Zn	ppm Zn	ppm Mn	ppm Mn	% Na[b]	% Na	% Cl[c]	% Cl[c]
1	1.86	2.25	0.16	0.18	1.05	0.92	24	18	60 a	68	<0.01	0.01	<0.1	<0.1
2	1.88	2.28	0.15	0.18	0.98	0.88	24	20	67 ab	65	<0.01	0.02	<0.1	<0.1
3	1.94	2.28	0.15	0.18	1.01	0.94	23	20	73 b	66	<0.01	0.01	<0.1	<0.1
P-value	0.4444	0.314	0.5487	0.4444	0.606	0.5962	0.9431	0.7174	0.0325	0.6707		0.4444		

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Treatment	ppm B	ppm B	% Ca	% Ca	% Mg	% Mg	ppm Fe	ppm Fe	ppm Cu	ppm Cu
1	18	23	2.01	1.93	0.37	0.41	269	474	26	13
2	18	22	1.95	2.04	0.36	0.41	277	571	12	16
3	18	19	1.9	1.93	0.35	0.42	301	702	12	25
P-value	0.8264	0.1538	0.6362	0.0857	0.6468	0.2500	0.5425	0.1520	0.4512	0.6557

[a] Leaf tissue sample dates: August 25, 1999; August 15, 2000.
[b] One replicate reported as .01%, all others reported as <.01%.
[c] All replicates reported as <0.1% in both years.

Table 8: Nutrient Status in Leaf Blades at Veraison in 1999 and 2000, Vineyard 3[a]

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Treatment	% N	% N	%P	%P	%K	%K	ppm Zn	ppm Zn	ppm Mn	ppm Mn	% Na[b]	% Na
1	2.78	2.76	0.19	.23 b	1.46	1.27	22	17	95 ab	129	<0.01	0.01
2	2.89	2.59	0.19	.21 a	1.32	1.23	23	15	103 b	133	<0.01	0.02
3	2.74	2.57	0.18	.2 a	1.26	1.21	22	15	88 a	149	<0.01	0.02
P-value	0.6127	0.2828	0.4878	0.0012	0.4306	0.2872	0.9626	0.0772	0.0371	0.4456		0.64

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Treatment	% Cl[c]	% Cl[c]	ppm B	ppm B	% Ca	% Ca	% Mg	% Mg	ppm Fe	ppm Fe	ppm Cu	ppm Cu
1	<0.1	<0.1	59	67	1.49	1.79	0.3	0.28	237	390	6 a	10
2	<0.1	<0.1	53	59	1.58	1.72	0.29	0.28	245	356	12 b	11
3	<0.1	<0.1	50	58	1.43	1.79	0.28	0.28	233	331	5 a	11
P-value			0.3624	0.2059	0.6466	0.9095	0.4865	0.6944	0.7382	0.3381	0.0005	0.9273

[a]Leaf tissue sample dates: August 25, 1999; August 18, 2000.
[b]All replicates reported as <.01%.
[c]All replicates reported as <0.1% in both years.

Table 9: Nutrient Status in Leaf Blades at Veraison in 1999 and 2000, Vineyard 4[a]

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Treatment	% N	% N	%P	%P	%K	%K	ppm Zn	ppm Zn	ppm Mn	ppm Mn	% Na[b]	% Na
1	3.49	2.97	0.28	0.27	1.71	1.70	59	32	139	78	<0.01	0.02
2	3.55	2.85	0.26	0.27	1.69	1.64	59	32	117	97	<0.01	0.02
3	3.46	2.77	0.28	0.25	1.85	1.63	50	32	108	109	<0.01	0.01
P-value	0.8246	0.6075	0.5855	0.5437	0.4612	0.5661	0.7085	0.9975	0.5223	0.1613		0.6049

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Treatment	% Cl[c]	% Cl[c]	ppm B	ppm B	% Ca	% Ca	% Mg	% Mg	ppm Fe	ppm Fe	ppm Cu	ppm Cu
1	<0.1	<0.1	43	37	1.32	1.26	0.35	0.36	340	255	12	9
2	<0.1	<0.1	43	38	1.31	1.36	0.34	0.39	346	337	8	10
3	<0.1	<0.1	45	38	1.19	1.40	0.32	0.39	322	337	11	14
P-value			0.7888	0.9712	0.555	0.7578	0.6649	0.8093	0.8517	0.0937	0.6959	0.5174

[a]Leaf tissue analysis dates: August 25, 1999; August 18, 2000.
[b]All replicates reported as <.01%.
[c]All replicates reported as <0.1% each year.

Table 10: Yield Components and Growth in 1999 and 2000, Vineyard 3[a]

Treatment	Clusters per Vine		Yield per Vine (lbs)		Tons per Acre[b]		Cluster Weight (lbs)		Berries per Cluster		Berry Weight (g)		Pruning Weight per Vine (lbs)[c]	
1	13.8	22.3	5.0	7.9	2.0	3.1	0.33	0.33	103.4	101.7	1.4	1.5	1.7	1.7
2	13.1	24.1	4.4	7.2	1.7	2.9	0.33	0.28	100.3	86.5	1.5	1.5	1.4	1.6
3	14.4	24.3	5.1	7.4	2.0	2.9	0.32	0.3	97.6	90.6	1.5	1.5	1.4	1.5
P-Value	0.94	0.81	0.93	0.93	0.93	0.93	0.98	0.63	0.96	0.38	0.67	0.98	0.86	0.9

[a] Vines were harvested on October 4, 1999, and September 21, 2000.
[b] Based on 792 vines per acre.
[c] Vines were pruned on December 3, 1999, and January 8, 2001.

Table 11: Yield Components and Growth in 1999 and 2000, Vineyard 2[a]

	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Treatment	Clusters per Vine		Yield per Vine (lbs)		Tons per Acre[b]		Cluster Weight (lbs)		Berries per Cluster		Berry Weight (g)		Pruning Weight per Vine (lbs)[c]	
1	23.7	32.2	7.2	12.0	2.6	4.3	0.29	0.37	77	101	1.7	1.7	1.63	2.03
2	23.6	35.4	7.6	14.0	2.8	5.1	0.30	0.39	82	98	1.7	1.8	1.76	1.83
3	19.5	31.3	5.4	13.3	2.0	4.8	0.26	0.43	67	110	1.8	1.8	1.63	1.98
P-Value	0.5743	0.5959	0.5609	0.4536	0.5609	0.4536	0.6859	0.2011	0.6185	0.1796	0.4724	0.0938	0.7997	0.5663

[a] Vines were harvested on October 10, 1999, and September 17, 2000.
[b] Based on 725 vines per acre.
[c] Vines were pruned on February 9, 2000, and February 8, 2001.

Table 12: Fruit Maturity at Harvest in 1999 and 2000, Vineyard 3[a]

Treatment	Brix 1999	Brix 2000	pH 1999	pH 2000	Titratable Acid (g/L) 1999	Titratable Acid (g/L) 2000
1	23.1	23.1	3.28	3.35	0.97	0.98
2	22.7	23	3.32	3.32	0.97	0.99
3	23.2	22.4	3.25	3.28	0.99	0.98
P-Value	0.49	0.37	0.27	0.31	0.12	0.8

[a] Berry samples occurred on October 3, 1999, and September 20, 2000.

Table 13: Fruit Maturity at Harvest in 1999 and 2000, Vineyard 2[a]

Treatment	Brix 1999	Brix 2000	pH 1999	pH 2000	Titratable Acid (g/L) 1999	Titratable Acid (g/L) 2000
1	25.7	24.9	3.16	3.16	7.94	8.92
2	25.8	24.2	3.18	3.13	7.96	8.97
3	25.6	24.5	3.21	3.14	7.96	9.07
P-Value	0.9166	0.5924	0.3805	0.306	0.9907	0.6489

[a] Berry samples occurred on September 30, 1999, and September 13, 2000.

Table 14: Mulch Calculator

You can download a spreadsheet version of this chart that will help you calculate the amount of mulch to apply in the vine row by contacting Will Bakx at (707) 664-9113.

Fill in the non-shaded columns only. *(See example below.)*

Field Name	Vine Row Swath (Ft.)	Vine Row Spacing (Ft.)	Percent of One Vineyard Acre That Mulch Will Be Applied To	Number of Vineyard Acres That You Want To Put Mulch On	Total Number of "Treated Acres" That Mulch Will Be Applied To	Depth of Mulch To Be Applied (In.)	Cost per Cubic Yard Delivered	Cubic Yards/ Acre	Total Cubic Yards Needed	Mulch Cost/ Acre	Total Mulch Cost for Vineyard
My vineyard	*1.5*	*7*	21.43%	*1*	0.214285714	*3*	*$13.55*	86.428571	86.42857	$1,171.11	$1,171.11

Appendix D
Project Data Figures

Figure 1a: Relative Reduction of Total Sediment Collected as Compared to Control (No Mulch) Values Over 1999–2000 Rain Season (January–May 2000)

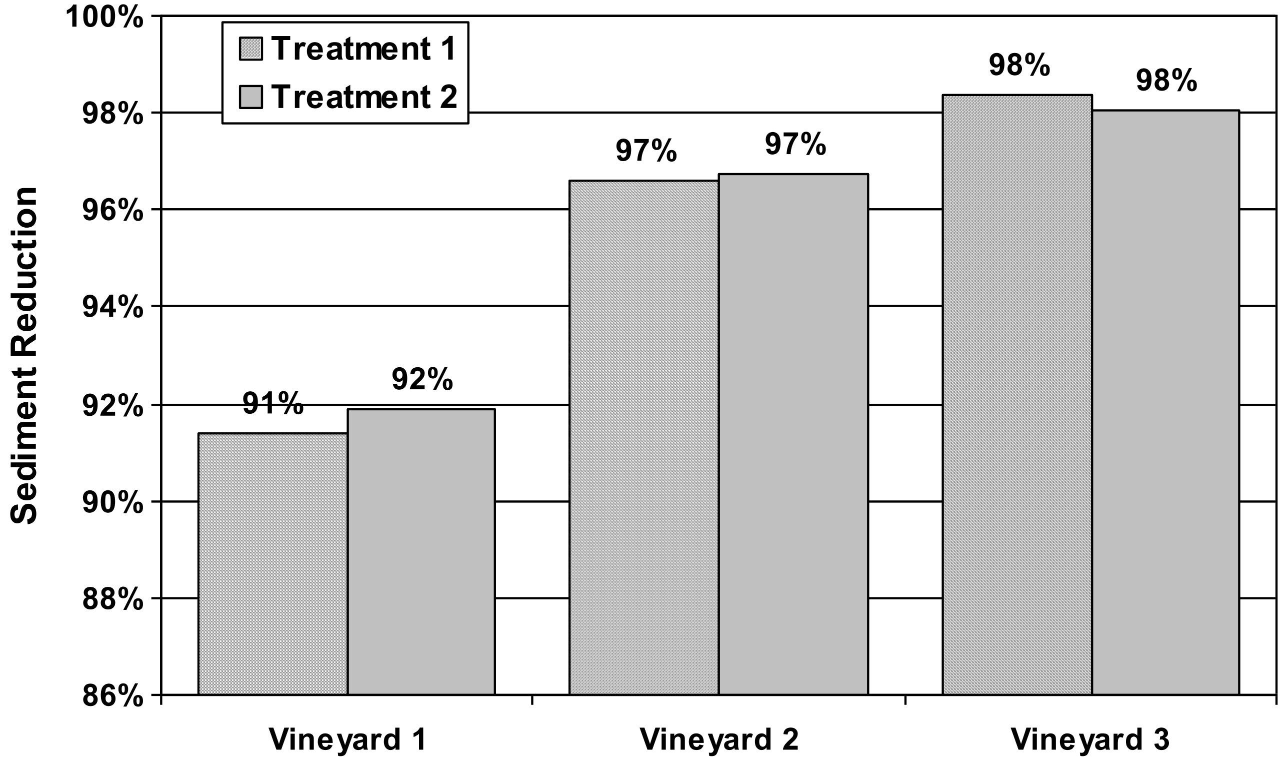


Figure 1b: Reduction of Sediment Collected as Compared to Control (No Mulch) Values

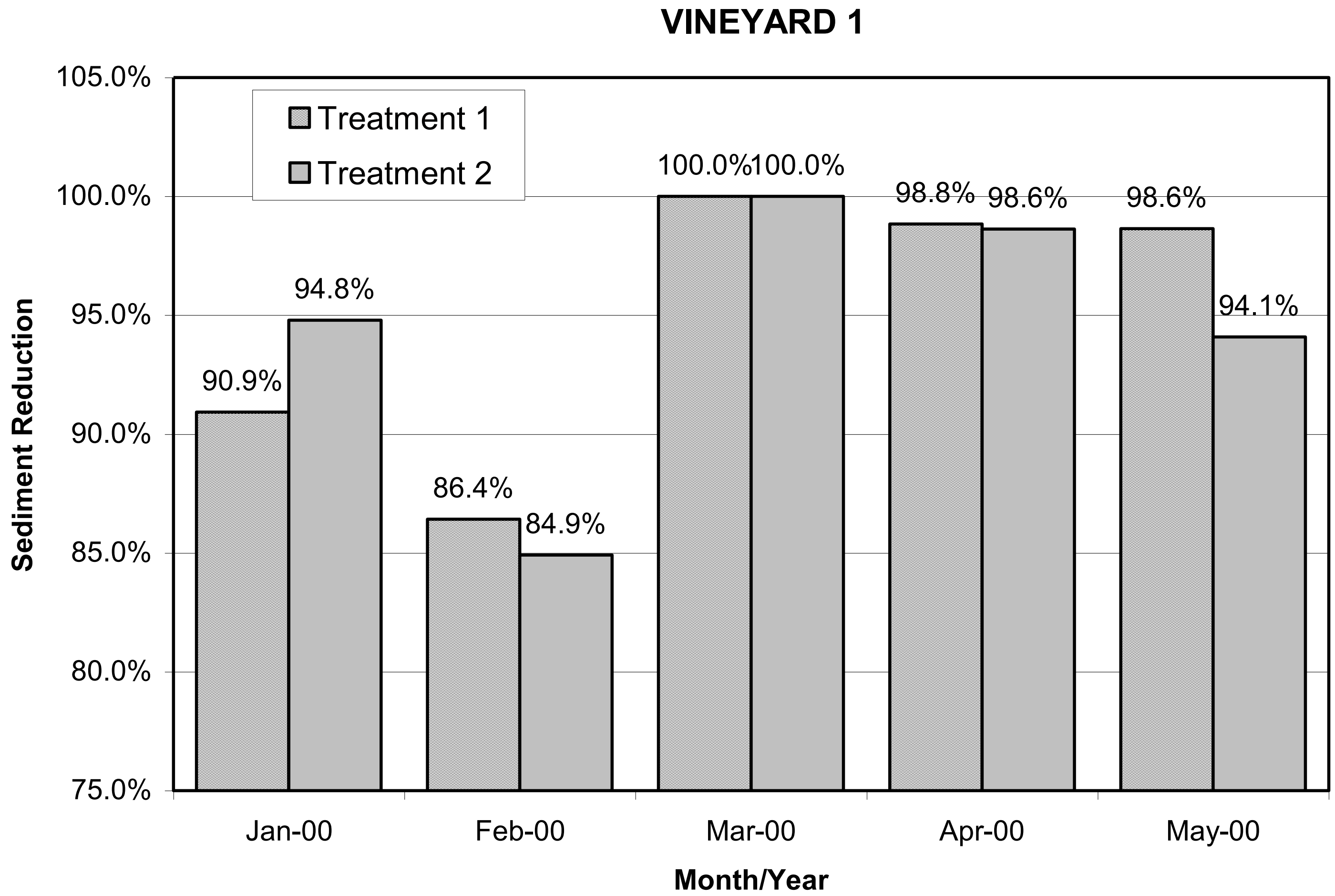


Figure 1c: Reduction of Sediment Collected as Compared to Control (No Mulch) Values

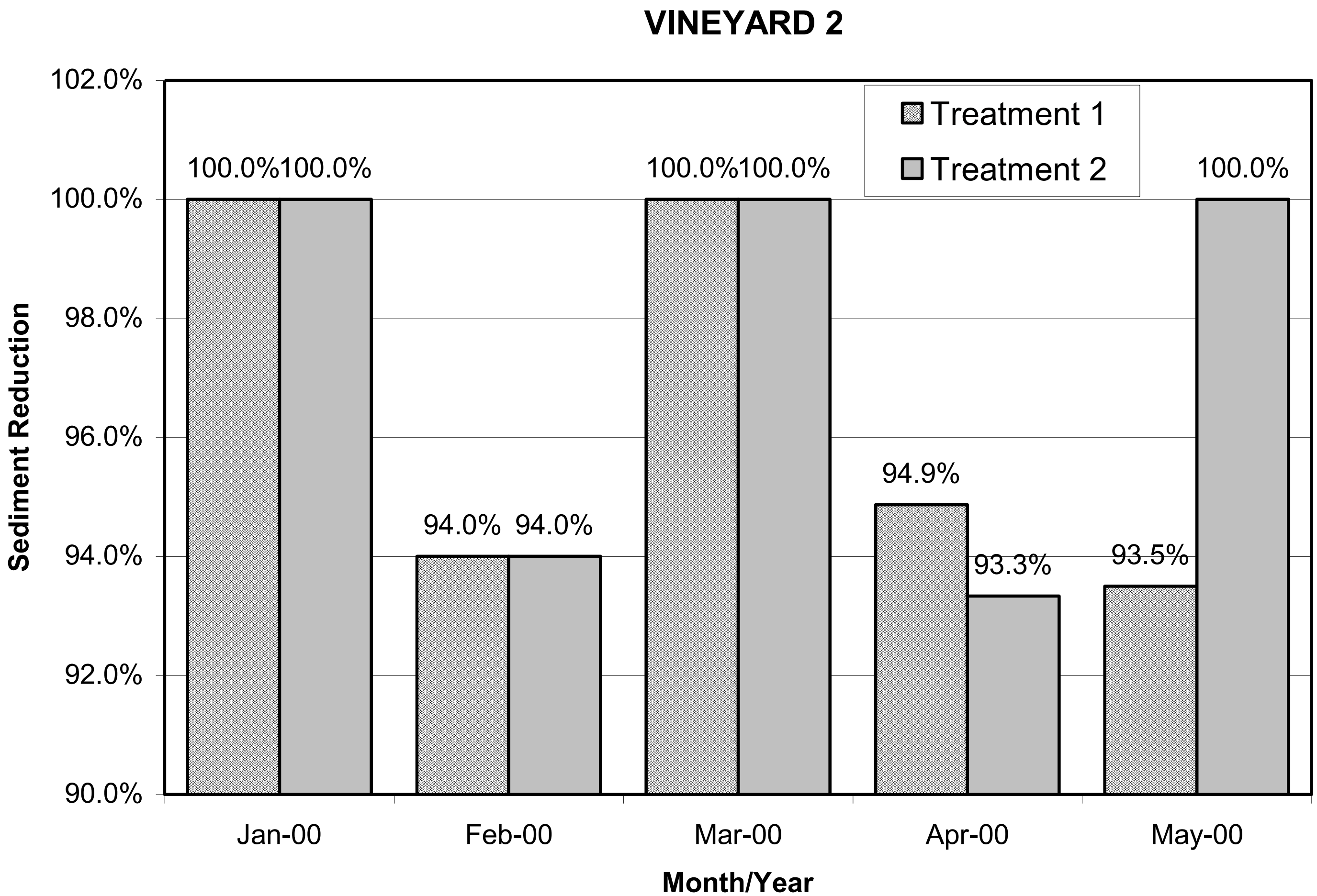


Figure 1d: Reduction of Sediment Collected as Compared to Control (No Mulch) Values

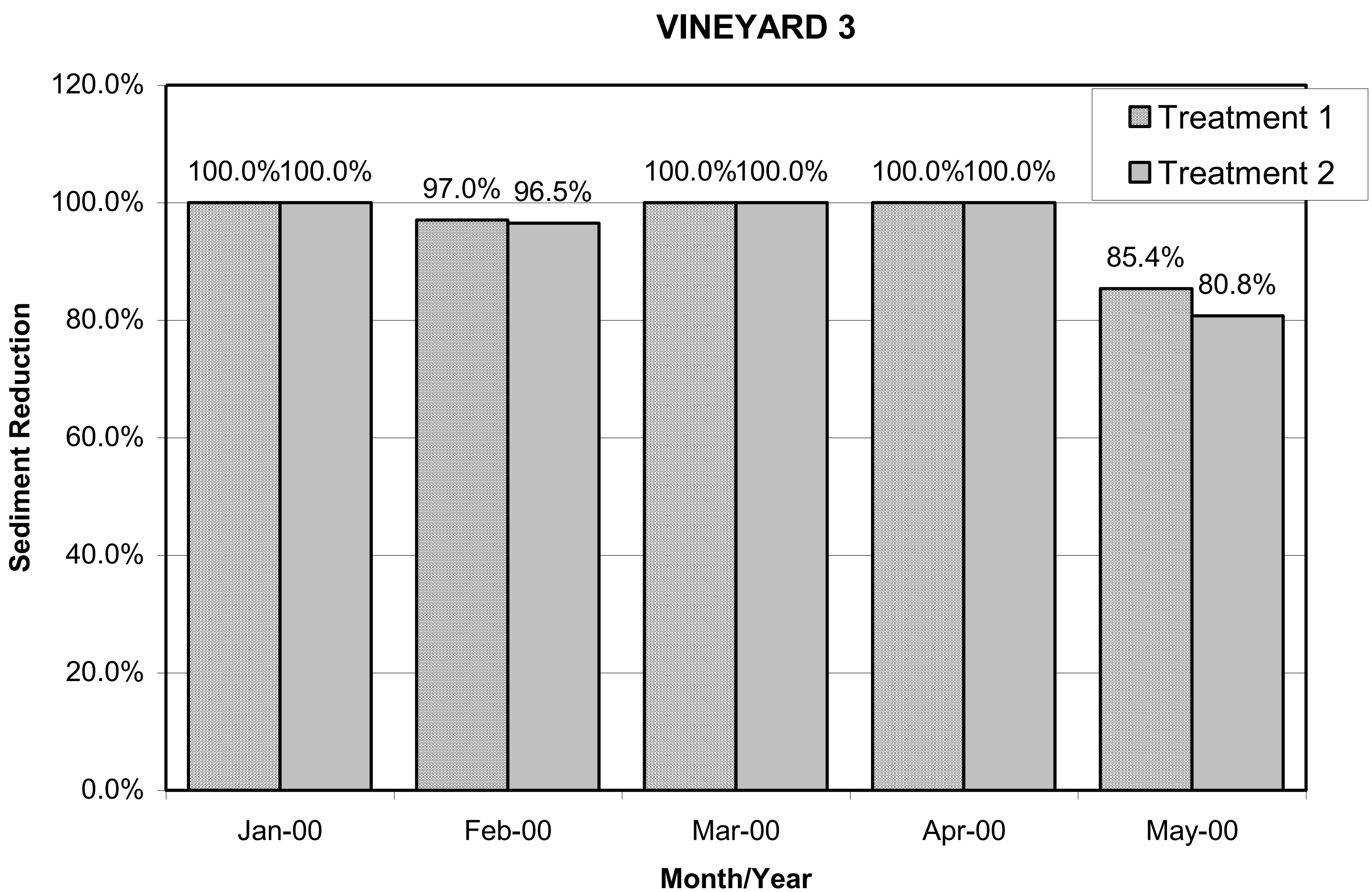


Figure 2a: Relative Reduction of Total Sediment Collected as Compared to Control (No Mulch) Values Over 2000–2001 Rain Season (November 2000–May 2001)

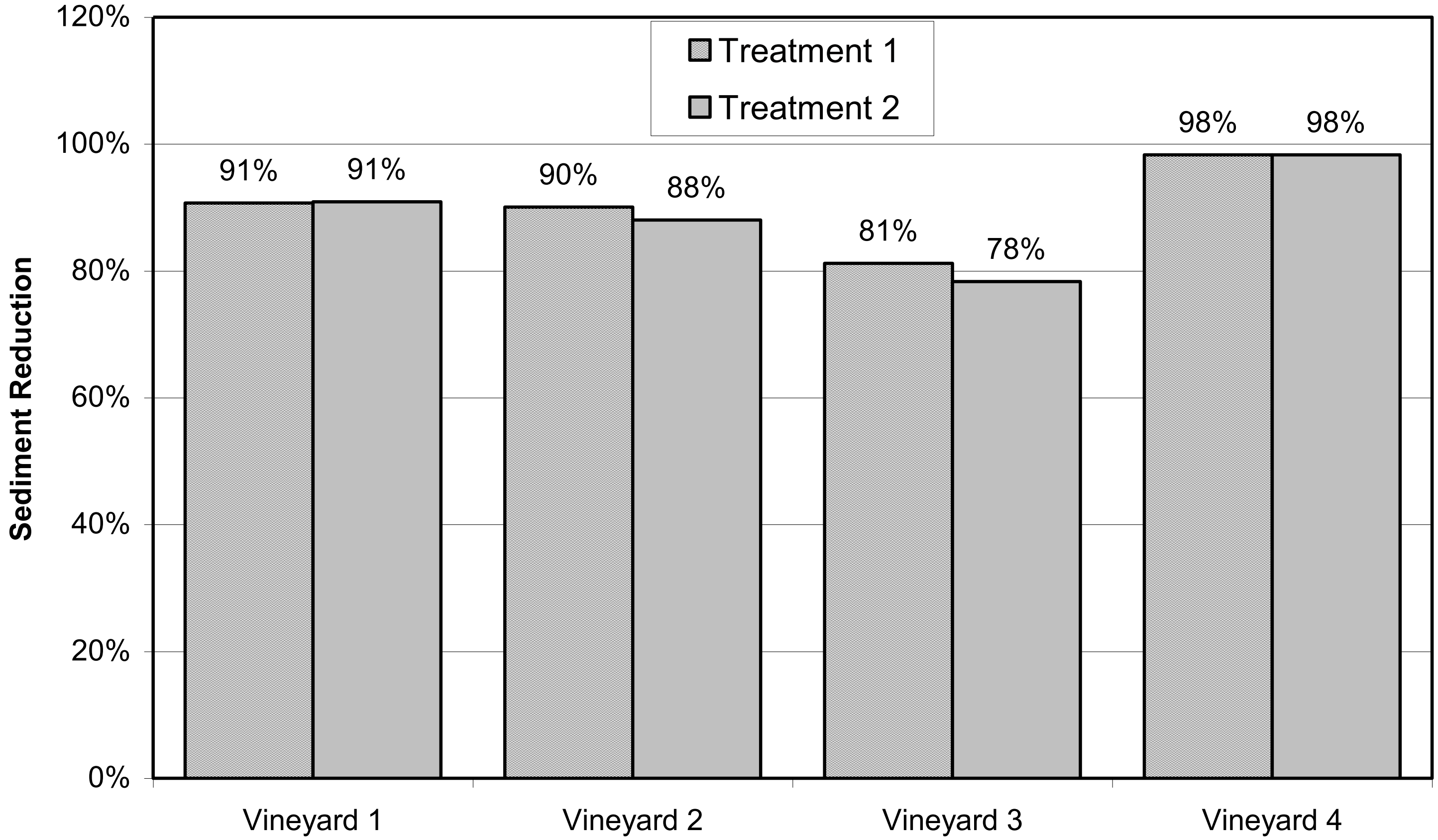
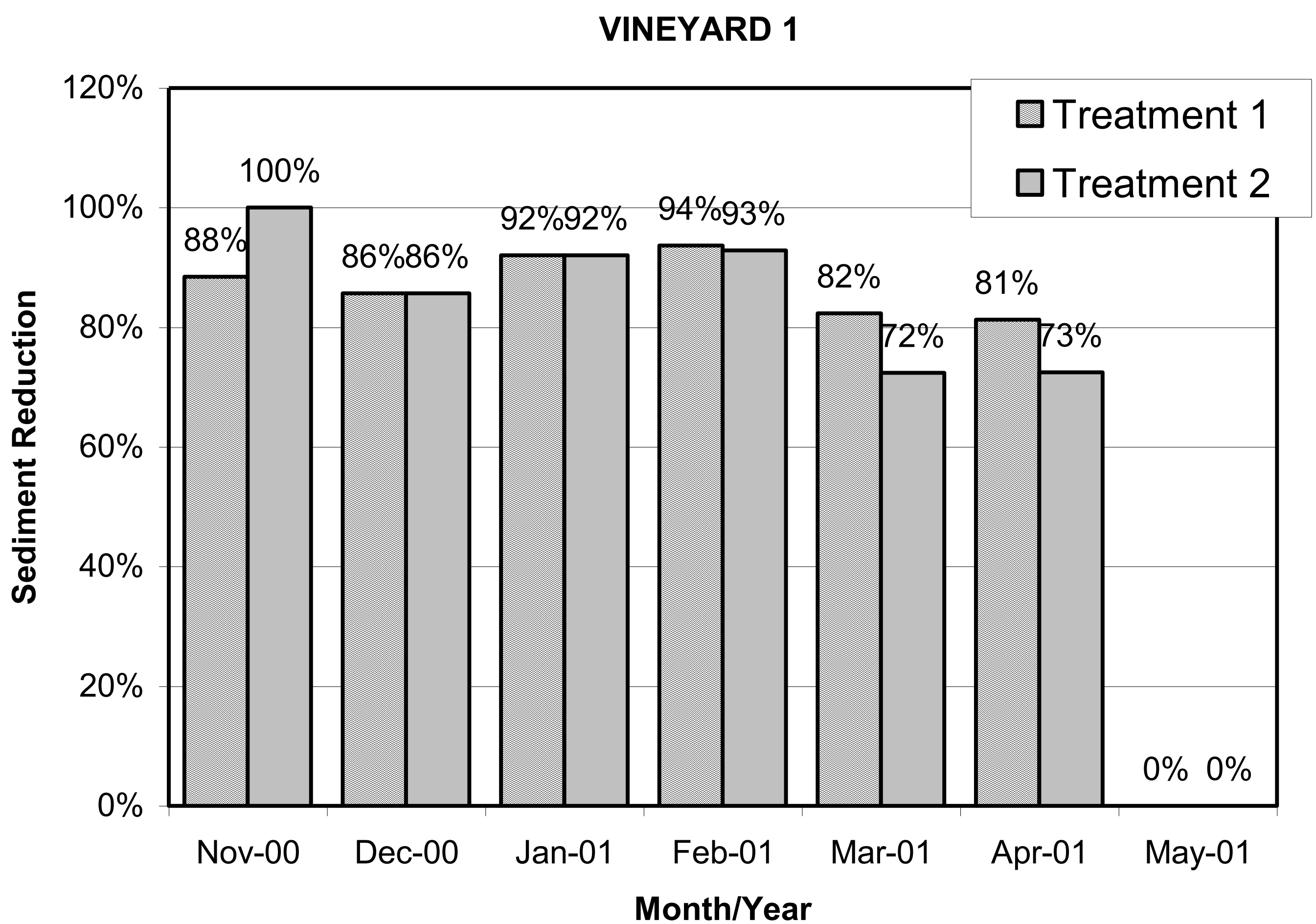


Figure 2b: Reduction of Sediment Collected as Compared to Control (No Mulch) Values



Note: No sediment transport occurred during May 2001.

Figure 2c: Reduction of Sediment Collected as Compared to Control (No Mulch) Values

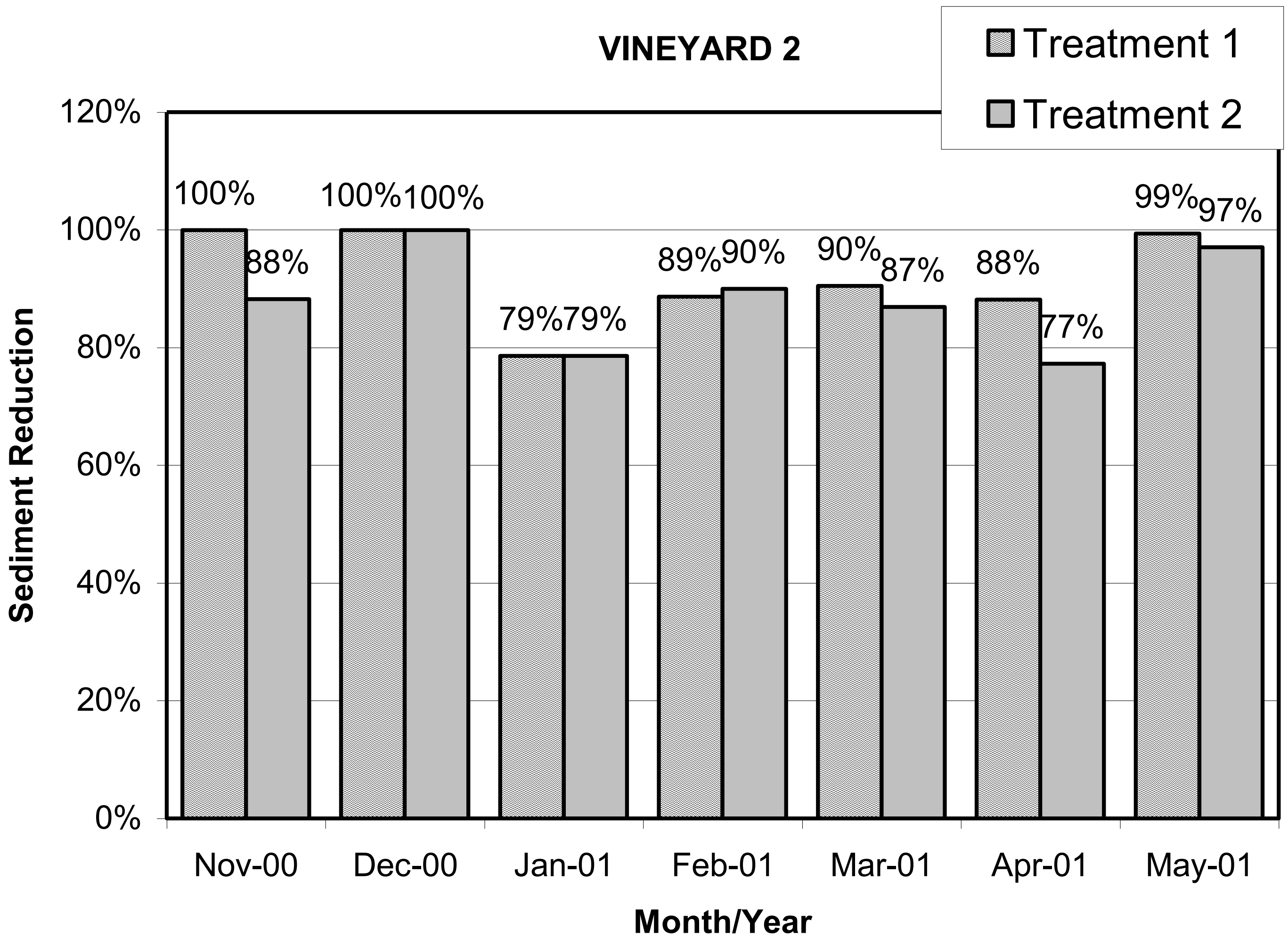


Figure 2d: Reduction of Sediment Collected as Compared to Control (No Mulch) Values

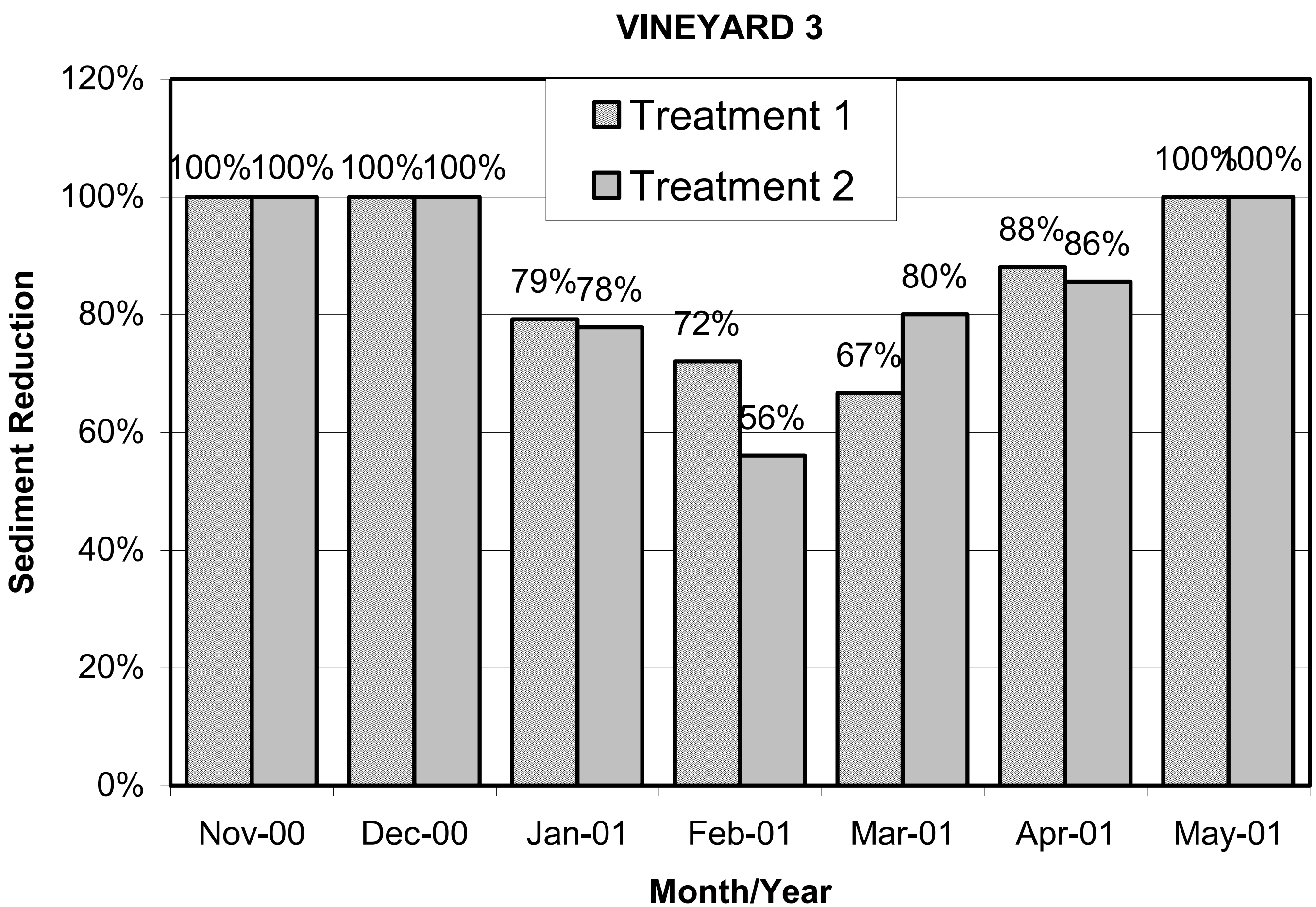
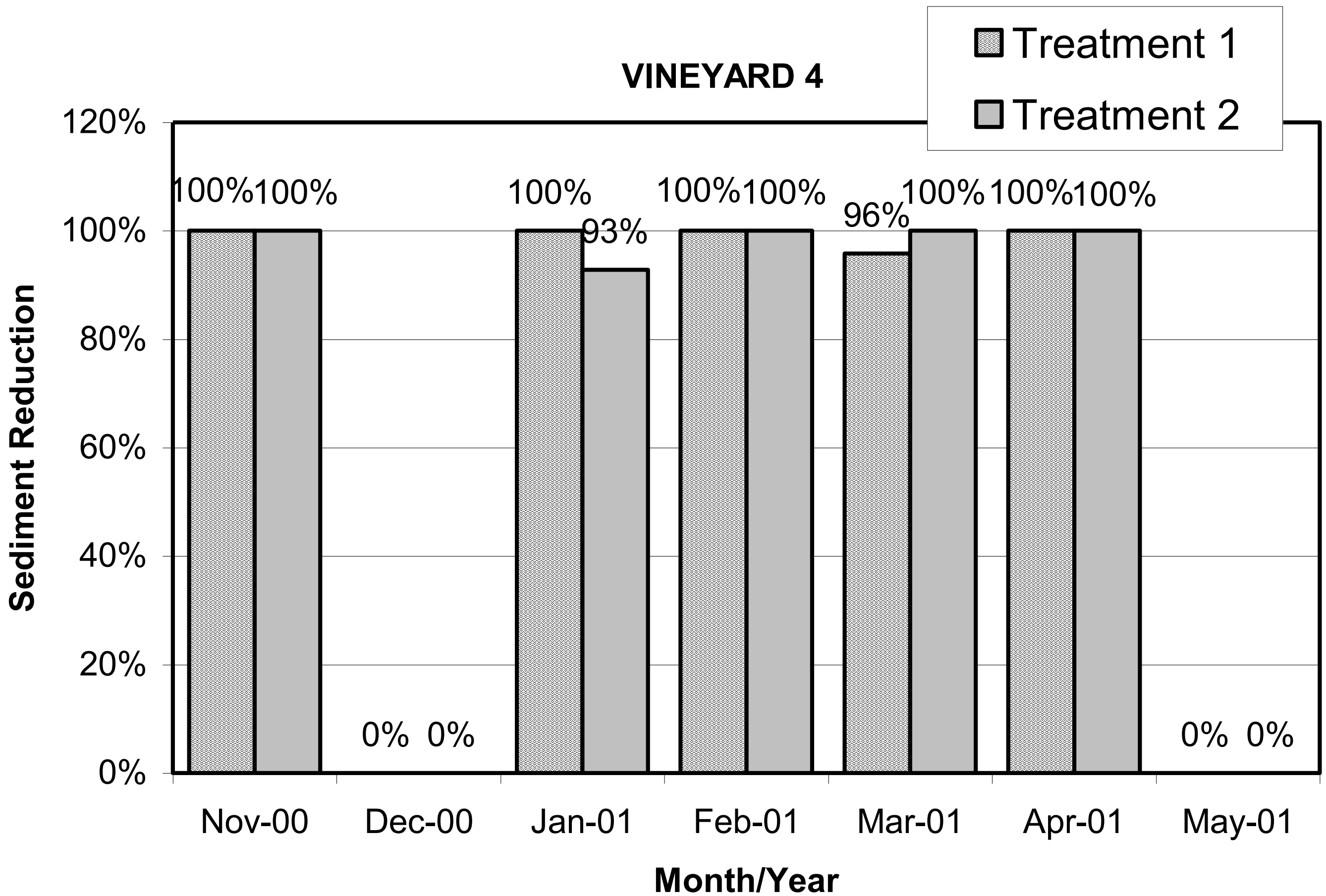


Figure 2e: Reduction of Sediment Collected as Compared to Control (No Mulch) Values



Note: No sediment was transported during the months of December 2000 or May 2001.

Figure 3: Comparison of Reduction In Soil Loss Between Treatments That Contained Mulch as Compared to the Control from 4-Hour and 6-Hour Rainfall Simulations in Vineyard 4

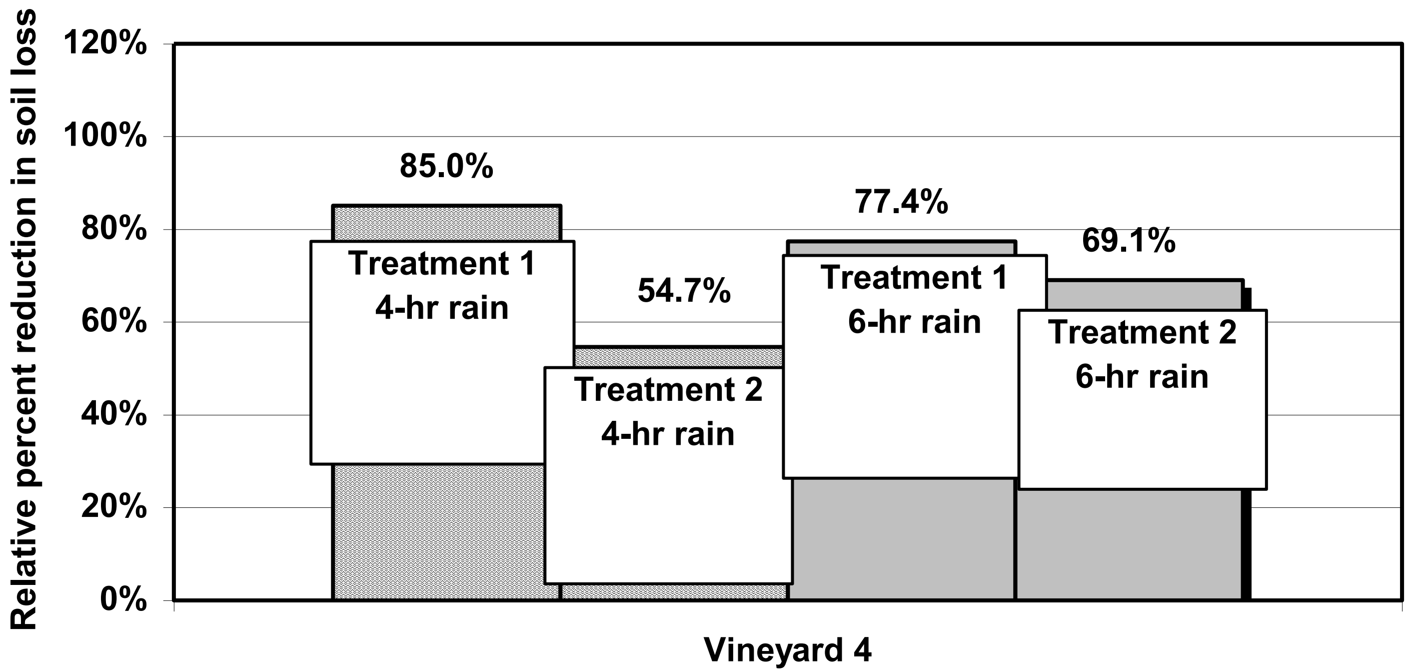


Figure 4: Monthly Rainfall Data Collected in Each Vineyard, 1999–2000

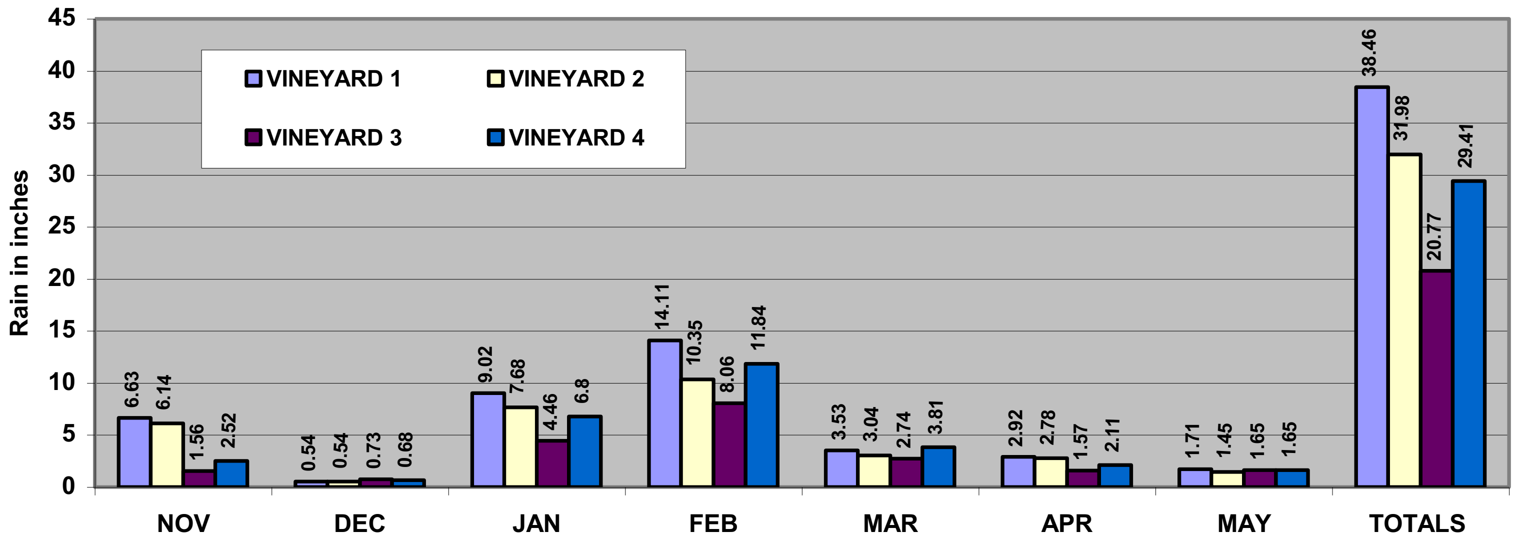


Figure 5: Monthly Rainfall Data Collected in Each Vineyard 2000–2001

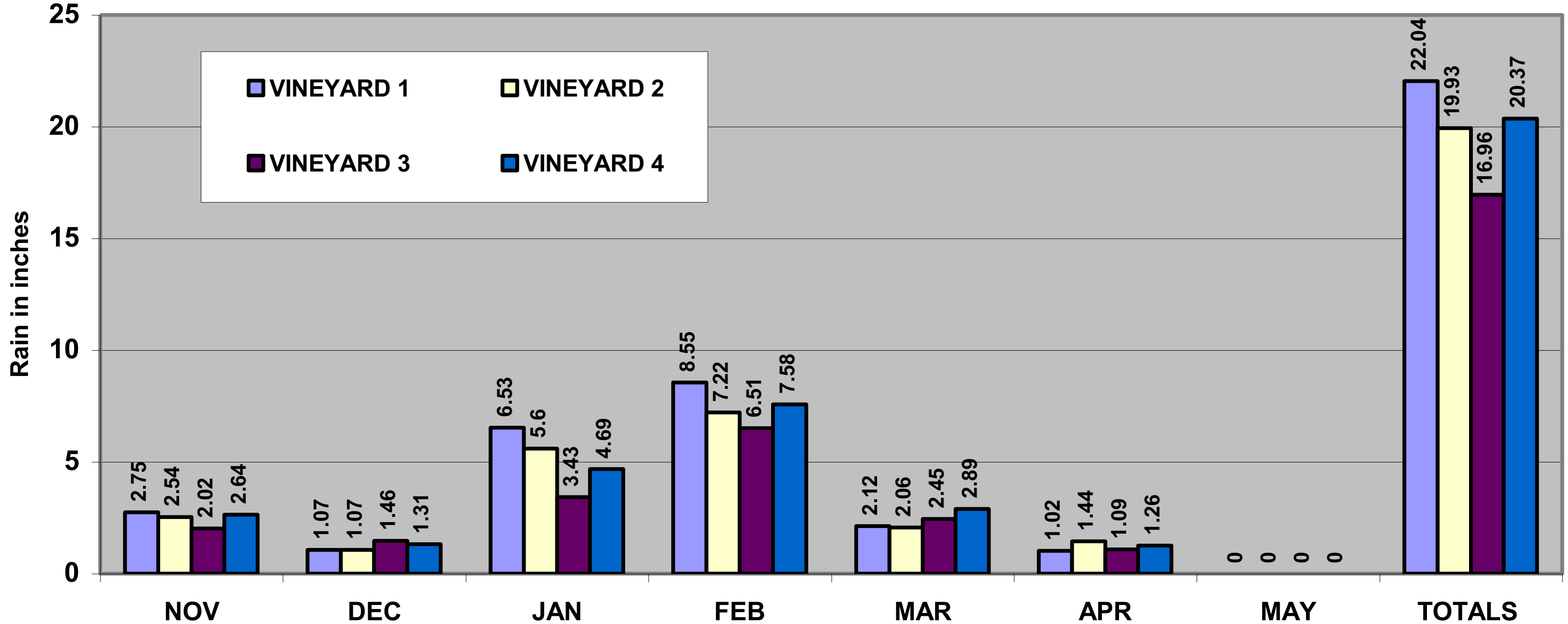
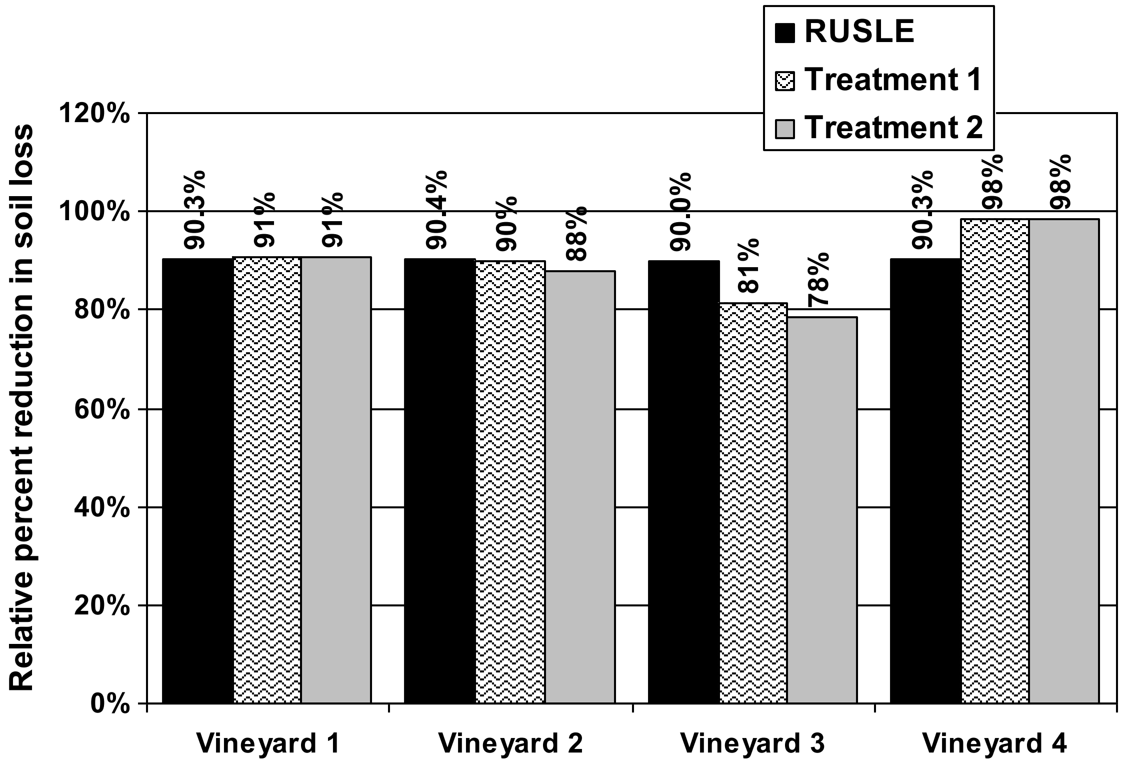
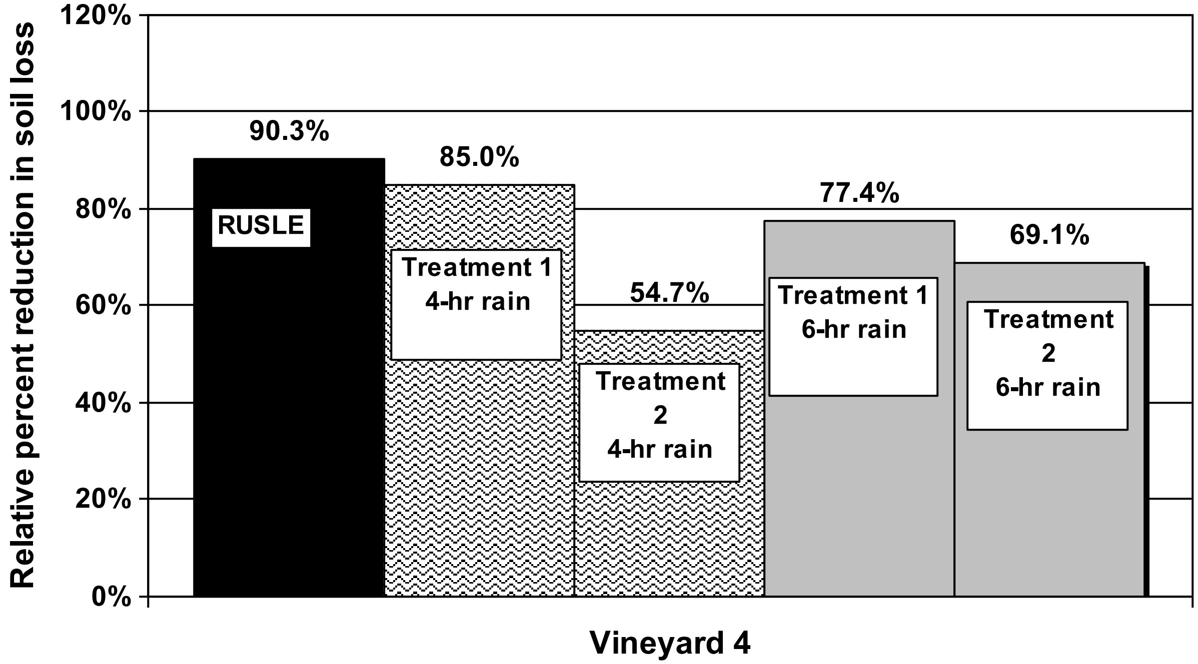


Figure 6: Comparison of Relative Reduction In Soil Loss in 2000–2001



Comparison of relative reduction in soil loss between calculated RUSLE values (tons/acre/year) using cover factor = 0.06 and field results from sediment collected in mulch treatments as compared to control in 2000–2001 (ounces/season).

Figure 7: Comparison of Relative Reduction in Soil Loss After Rainfall Simulations



Comparison of relative reduction in soil loss between calculated RUSLE values (tons/acre/year) using cover factor = 0.06 and experimental results from sediment collected after rainfall simulations (grams/rainfall event).

Appendix E:
Plot Schematic

Plot Schematic