Mulch Demonstration Project

Napa County

The Effects of Green Material Mulches on Erosion and Dissolved Organic Nutrient Loss from Recently Disturbed Hillside Vineyard Soils

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California Environmental Protection Agency
Integrated Waste Management Board

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Table of Contents

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Christy Porter-Humpert and Pat Paswater acted as the California Integrated Waste Management Board (CIWMB) staff for the project. Bob Pestoni of Upper Valley Recycling was the Project Manager. Upper Valley (Abelardo "Jose" Ponce and his crew) prepared and applied the composted mulch; test plots were established at Domaine Chandon (Carneros), Hanzell (Sonoma) and Sodaro (Napa). Paul Skinner, Ph.D., and his staff (Craig Rasmussen and Kevin Hultgren) at Terra Spāse, Inc. and Vic Claassen, Ph.D., at the University of California-Davis, performed field monitoring and sample evaluation. Evan and Sean Edgar of Edgar & Associates provided coordination with industry groups and other developers and uses as well as cost and market information. Ernie Hutchings at Upper Valley Recycling was responsible for managing project costs. Melissa Prange and later Marilyn Ryan, professional engineer, provided project support services.

Executive Summary

Erosion Control

The purpose of this project is to compare the effectiveness of clean green mulch to that of the standard erosion control treatment of straw and to evaluate the effects of sediment loss, soil organic matter dynamics, and nutrient leaching. Upper Valley Recycling prepared and applied composted mulch made from the trimmed brush, tree branches, grasses, trimmings, and clippings produced by the northern Napa Valley community for use in erosion control applications.

Test results indicate that the 3-inch minus mulch is more effective than the ground cover and straw applications in reducing the total dissolved solids (TDS), the total suspended solids (TSS) and the sediment being transported off of the test plots. The sediment loads were decreased by 70 to 90 percent with mulch treatments. This suggests the mulch treatments are effective in reducing erosion, especially from newly planted vineyard sites. Unlike straw, which is easily disturbed by operating traffic and needs to be reapplied, the mulch application has not required replacement to maintain its effectiveness for the two rainy seasons of the test.

It was also noted that although runoff sulfate levels increased with rainfall intensity, they decreased with treatment depth and in all events remained less that the maximum contamination level (MCL) for drinking water. Phosphorus levels in the runoff were as much as four times greater in 2000 than in 2001.

Additional Benefits

Vineyard Benefits

It appears that mulched areas retain higher soil moisture content and that the mulch increases the levels of some soil nutrients. In the producing vineyard it was noted that the petiole nitrate levels, cluster weights, and early (May) shoot length increased with mulch depth.

Waste Diversion

The clean green material produced by Upper Valley is suitable for use as composted mulch. Vineyard managers have indicated an interest in obtaining the material for application in new and existing vineyards.

The CIWMB estimates that of the 21 million tons of organic materials collected in the state each year, approximately 15 million tons is deposited in landfills. Approximately six to eight million tons is processed into compost or mulch. This material is also used as alternative daily cover for landfills or as bio-fuel for 26 operating biomass-to-energy (Source: CIWMB, Conversion Technologies for Municipal Residuals, May 3, 2001). The existing statewide industry infrastructure for collected organic materials only processes and uses roughly 1/3 of the estimated supply.

This study observes the environmental benefits of composted mulch in the study areas. In a marketplace of competing erosion control products, composted mulch is an alterative to products such as straw mulch. When expanded to agricultural end-users beyond the Napa Valley area, composted mulch has the promise to deliver even greater diversion from landfill disposal.

Mulch Production, Quality Control, Application, and Costs

Production

The composted mulch is produced from clean green material. The collected clean green material is inspected and non-compostable items (twist-ties, metals, glass, and irrigation lines and other plastics) are removed. The clean green material is then ground, composted, and screened prior to vineyard application.

The composting process and the mechanical screening of the feedstock are used to remove additional undesired characteristics such as invasive plant seeds (zucchini) and pathogens (Salmonella and fecal coliform). Screening the ground mulch appears to dislodge and sort out seeds that may have been carried in the feedstock. Composting in aerated static piles for several days at high temperatures kills the weed seeds and pathogens.

The mulch used for this project was composted for 60 days and held at temperatures averaging 140 degrees for 20 days. This material was tested to assure pathogen kill similar to the requirements specified in the California Code of Regulations (CCR) Title 14, section 17868.2, for compost. A second mulch sample windrowed and composted for 20 days resulted in a reduction of 99.82 percent for fecal coliform and 99.99 percent for Salmonella.

Quality Control

In assessing the quality of a material, one considers the way that the material conforms to a standard or norm. A quality control procedure or process seeks to assure consistent conformance with that standard. For this project the standard is that the material shall be safe—not harmful to the vineyard nor to those applying the material.

To assure the composting process was effective and the material is not harmful, laboratory testing is performed on samples of the mulch to check for the presence of pathogens and heavy metals. CCR Title 14, sections 17868.2 and 3 require these tests for compost products. There are no comparable requirements for mulch.

Vineyard Application

We have determined that the material may be applied either manually or with a modified fertilizer spreader. The modified spreader allowed the material to be applied by a single operator at approximately 30 yards per hour.

Costs

The costs of mulch production are feedstock- and site-specific. We assume a zero cost for the feedstock and itemize the individual production costs. Both project-specific and general industry data are tabulated in Appendix A.

The unit cost to produce and apply the composted mulch product in this study was $10 per cubic yard. The industry average cost for the same service ranged from $15 to $22 per cubic yard, plus delivery costs.

The resources needed to produce the mulch product consist of the feedstock, processing equipment (for example, grinders, screeners, turners, and loaders), and water trucks. In addition, delivery to the end-user requires hauling equipment; final application is achieved through manual and mechanical means. The necessary human labor is an additional cost.

Since the necessary duration of the composting process is related to the “cleanliness” of the feedstock, additional costs may be incurred to clean the feedstock. These costs to adequately process material to control weed seeds and pathogens are site- and process-specific. Use of land, equipment, fuel, and labor are included in the costs.

Recommendations

Managers of hillside vineyards should consider using a 3-inch layer of clean green mulch as a primary erosion control material if it is a cost-effective option in their area. Use of clean green mulch may necessitate the adjustment of other cultural practices in the vineyard, since soil moisture retention and weed suppression are associated benefits.

Upper Valley Disposal and Recycling, Inc. and a number of the project partners intend to continue the evaluation of the long-term benefits derived from this mulch. We request that the CIWMB continue its participation in and support of these efforts.

We also recommend that the CIWMB and our county agencies lend their support as we submit applications proposing the use of the mulch as a viable alternative to the straw mulch now routinely required by county agencies charged with controlling hillside erosion.

Introduction

Project Premise and Objectives

The purpose of this project is to compare the effectiveness of a clean green mulch to that of a standard erosion control treatment of straw. It will also evaluate the effects on sediment loss, soil organic matter dynamics, and nutrient leaching. This information is to be made available to those involved in the writing, approving, and implementing erosion control plans in California vineyards. In addition to the effectiveness of the material when used to control erosion, this project also considered associated benefits and potential economic viability of the product.

In January 1999, Upper Valley Recycling and its project partners joined efforts to study the effects of clean green material mulch on erosion and dissolved nutrient loss from hillside vineyard soils.

Project Description

Vineyards at Domaine Chandon, Hanzell, and Sodaro were selected for use as test sites. The Domaine Chandon vineyard is a producing vineyard. The Hanzell vineyard was planted in 1999 and Sodaro in 2000.

In the late summer and fall of 1999, Upper Valley Recycling processed the clean green material into composted mulch for use in the project. The production of the mulch is described in the project tasks section of this report. The test plots were developed in late 1999. Field data gathering commenced in November 1999. The analysis of this data is included in this report.

In January and February 2001, project workshops were held in Rutherford and Lower Lake to discuss the project interim report, findings, and plans with the interested public. A Web page, www.uvds.com, was developed for the project.

Results and Observances

The results included in this final report represent research carried out over two years. The mulch is effective in providing erosion control for hillside vineyards. There may be additional benefits associated with the use of the material and we expect to pursue them over the next few years.

We have performed a time and temperature study to document the effect of composting on the reduction of pathogens and insects and weed seed kill in the mulch. This program also noted metal concentration and material size. Weekly samples were taken for the duration of the 45-day test. In general it was noted that pathogens were reduced by more than 99 percent during the 20 days of active composting.

A mulch production specification, addressing the reduction of pathogens, insects, weed seed, and foreign material, was developed and is included as Appendix B.

Mulch application guidelines were developed and included as Appendix C.

An analysis of mulch processing costs prepared by Edgar & Associates, Inc. indicates that in April 2001 the industry unit cost ranged from $15 to $22 per cubic yard. Average transportation costs ranged from $0.91 for a haul of less than 11 miles to $5.63 for a haul of 120 miles. These costs are tabulated at Appendix A.

Preliminary data analysis includes the following trends. The specific factors are discussed in detail later in this report.

- Rainfall for the 1999–2000 rainy season was slightly higher than normal, while the 2000–2001 season was shorter with less than normal rainfall.
- On the average, the heavier (or deeper) mulch treatments released greater quantities of phosphorus into the runoff water.
- A marked reduction in total suspended sediment load at all of the sites was noted.
- An analysis of general soil fertility did not show any significant differences between treatments.
- Soil water storage benefits from heavy mulch applications.
- Petiole analysis shows an increase in nitrate concentration with an increase in mulch cover.
- Early season (May) stem lengths increased with depth of mulch.

Project Methodology

Protocol for Data Collection

Soil chemical and physical characteristics were analyzed and a set of soil variability maps produced for each site during the summer of 1999 prior to any treatment applications. These maps helped determine treatment layout and served as a baseline for comparing treatment effects at the end of the project.

Weather stations and soil moisture and soil temperature monitoring equipment was installed at each site during the summer of 1999. Clean green mulch samples were analyzed for weed seed and pathogen status. Time and temperature studies were conducted to produce an optimum disease-free and weed-free material for use in this trial.

Three different treatments consisting of a control (standard erosion control straw material as recommended by the Napa County Resource Conservation District) and two different clean green mulch treatments were used at each site. One mulch treatment was a 3-inch application and the other was a 1-inch application. The treatments were replicated four times at each site.

The treatments were monitored for sediment loss after each major storm event and for soil nutrient concentrations before and after the winter seasons of 1999–2000 and 2000–2001.

Soil samples were collected from each treatment at 0–15 inches and 15–30 inches. The samples were taken to UC Davis where they were analyzed for total organic and inorganic carbon, total organic and inorganic nitrogen, absorbed and readily leachable nitrogen fractions, soil microbial activity, macronutrients, and micronutrients.

Treatments were monitored for their effects on vine growth and nutritional status during the growing season of 2000. Shoot number, shoot length, and pruning or brush weight were measured in each treatment at the one producing vineyard (Domaine Chandon). Petiole and leaf blades were analyzed at mid-season and prior to leaf-fall to determine the differences in vine nutrient status. Cluster numbers and yield per vine were also determined at the Domaine Chandon site.

Soil moisture data was correlated with the precipitation events and compared with treatment effects during the winter rainy season and during the growing season.

Project Tasks and Methods

Mulch Production

Material Source

The clean green material used for the mulch came from the unincorporated areas of the upper Napa Valley and the communities of Calistoga, St. Helena, and Yountville. Upper Valley Recycling Service collected the material at curbside as part of the community yard trimmings recycling program.

Material Processing

Grinding. At Clover Flat Landfill the material was ground so that it would pass through 3-inch screens (3-inch minus). The 3-inch minus material was then transferred to the Upper Valley Recycling facility south of St. Helena.

Composting. The 3-inch minus material was aged and composted for 60 days. During that period the material was maintained at 140°F for 20 days to control pathogens and propagation of seeds that may have been in the raw green material. After the 20-day composting period, the material was sampled and tested for pathogens to assure that the composting period was sufficient. Subsequent testing indicates composting the material for 20 days reduces the pathogen content (Salmonella and fecal coliform) by more than 99 percent.

Final Screening. The composted 3-inch minus product was run through a 3/8-inch screen and materials passing the 3/8-inch screen were set aside. One cubic yard of the finished product (less than 3 inches and greater than 3/8 inches) weighed 550 pounds per cubic yard. The 3/8-inch minus material weighed 950 pounds per cubic yard.

Material Quality

The factors affecting material quality are size and cleanliness.

Product Size. The material is sized to facilitate handling and placement. The grinding and screening processes control product size. For this project the composting process was also considered a factor in the selection of product size. Based on these considerations, the material was sized to be less than 3 inches and greater than 3/8 inches. These parameters were attained through grinding and screening. The product is visually inspected to assure compliance with project standards.

Product Cleanliness. The screening and composting eliminate viable seeds and pathogens from the material. Non-compostable materials are removed from the feedstock. For this project a 35-cubic-yard sample (approximately 20,000 pounds) of the first 200 cubic yards of freshly ground 3-inch minus material was sent across a picking line to evaluate the level of non-green waste contamination of the material. The picking line removed approximately 28 pounds of foreign materials (foam, plastics, twist-ties, etc.) and less than two pounds of miscellaneous metals—less that 0.2 percent of the sample. It was concluded that more closely inspecting the material and removing foreign material before the initial grinding would more effectively reduce this type of contamination.

Quality Control

As noted above, in assessing the quality of a material one considers the way that the material conforms to a standard or norm. A quality control procedure or process seeks to assure consistent conformance with that standard. For this project, and this product, the standard is that the material shall be safe—not harmful to the vineyard nor to those applying the material. Factors that would violate this standard include heavy metals, pathogens, and foreign materials.

Heavy Metals and Pathogens. The mulch is used for vineyard application. Because of this intended use, the mulch was tested to assure that the heavy metals content was within acceptable levels established for compost. Pathogens were reduced to acceptable levels through composting. Pathogen reduction was verified by testing.

Foreign Material. The effectiveness of the removal of foreign material (non-compostable materials such as twist-ties, metals, glass, and irrigation lines and other plastics) is monitored by visual inspection as the material is processed and applied.

Production Costs

The elements of the production cost of the mulch are feedstock costs, removal of non-compostable materials, grinding, composting, and screening. The cost also include processing equipment (for example, grinders, screeners, turners, and loaders), and water trucks. The individual production costs are itemized in Appendix A.

The source of the feedstock for this project is at the point of generation (that is, individual residences). We assume a zero cost for the feedstock and its transportation to the processing site, because the cost to collect and transport the feedstock is highly variable due to geographic and equipment constraints.

The appearance of the product is an increasingly important aspect of mulch production. Consequently, the processor incurs a labor and equipment cost to remove unacceptable materials from the feedstock. As stated above, these materials should be removed before the feedstock is ground. The unit cost of removing the 28 pounds of material cited above was approximately $0.94 per cubic yard of ground feedstock. An additional step to further reduce contamination would be to pass the material across the sorting line a second time at an additional cost of approximately $0.40 per cubic yard.

In addition, delivery to the end-user requires hauling equipment, and final application is achieved through manual and mechanical means. Human labor is required to accomplish each of the tasks above.

Vineyard Application

Application Rates

Nutrients and other additives and supplements are generally applied in tons per acre to assure the proper “chemical balance.” Since the benefit from this mulch application is associated with the mechanical properties of the material, it is applied as a cover of specific depth and measured as cubic yards per acre. Material at all test sites was applied in 1- and 3-inch layers. At Domaine Chandon, the test plots were 90 feet by 16 feet, 42 feet by 16 feet at Hanzell, and 42 feet by 12 feet at Sodaro.

Application Methods

For this test the material was applied using a small loader and manually leveled to attain the pre-determined depth of cover (1-inch and 3-inch). The mulch has been successfully applied manually or using a modified fertilizer spreader. Guidelines that may be used for the application of the mulch are presented in Appendix C.

Field Observations and Test Data

Site Descriptions

Test plots for the Upper Valley Recycling/Terra Spāse, Inc., erosion study are located as follows: Domaine Chandon on Ramal Road in the Carneros Region of Sonoma County, Hanzell Vineyard near the town of Sonoma on Norbaum Road, and Sodaro Vineyard east of the city of Napa on Hagen Road.

The Domaine Chandon site is an existing Pinot Noir vineyard in the Carneros region that has been in production for several years. Current vineyard management includes a no-till system that leaves a cover crop between the vine rows throughout the growing season. The test block lies on a north-facing hillside with an average slope of sixteen percent across the treatment area. The United States Department of Agriculture Natural Resources Conservation Service (NRCS) classifies soil in this area as haire clay loam. The haire series represents heavy clay loam soils formed from sedimentary alluvium, and basic rock. Previous soil work completed by Terra Spāse, Inc., at this site confirms the presence of heavy clay soils in the surface and subsurface soil horizons.

The Hanzell site is a newly established vineyard planted in the fall of 1999. Prior to planting, this site contained a lush oak woodland and Douglas fir ecosystem. After clearing of forest vegetation, this site received a standard pre-plant application of soil amendments including composted grape pomace. The test block lies on an east-facing hillside with an average slope of 28 percent across the treatment area. The NRCS categorizes soils in this area as red hill clay loam. The red hill series represents heavy clay loam soils formed from mixed greenstone and andesitic basalt rock. Initial soil tests at this site indicate the presence of relatively rocky clay loam soils formed from volcanic parent material.

The Sodaro site represents a recent vineyard redevelopment project that was planted in the spring of 2000. This site also received a standard pre-plant application of soil amendments and composted grape pomace during the re-development project. The test block lies on a west-facing hillside with an average slope of 24 percent across the treatment area. The NRCS classifies soils in this area as forward gravelly loam. The forward series represents light loam soils formed from weathered rhyolite. Soil testing completed by Terra Spāse, Inc., indicate extremely acid claylike soils in the surface and subsurface soil horizons formed from rhyolitic volcanic ash.

Materials and Methods

The experimental design consists of three different treatments at the Hanzell and Sodaro sites, and four treatments at the Domaine Chandon site. Treatment one acts as the control with a standard erosion control treatment of straw and cover crop. Treatment two consists of a 1-inch mulch application over the entire surface of the treatment area. Treatment three consists of a mulch application to a depth of 3 inches over the entire treatment area. The mulch treatments were applied on top of the seeded cover crop. Straw applications were not made to the treatments receiving the mulch application.

The Sodaro Vineyard was a newly replanted vineyard at the time that the trial was set up. The composted mulch was laid over soil that had been tilled as preparation for the planting. The composted mulch formed a protective barrier against erosion caused by rainfall impact, and it absorbed some of the precipitation before it could flow off of the vineyard rows.

After the first year, the mulch was tilled into the soil. This action destroyed the protective layer of composted mulch. More loose soil was exposed to the erosive forces of the rain. Since a major percentage of the composted mulch was tilled into the subsurface, the effective depth of composted mulch on the surface was reduced, and therefore the effectiveness of the mulch was reduced.

The process of tilling the soil also breaks up the natural forming soil structure, making erosion easier. This is shown in the sediment loss data table. The data from the second year's rainy season at Sodaro shows little variation between the three treatments (1.102 kg/ac Control, 1.049 kg/ac 1-inch treatment, and 1.176 kg/ac 3-inch treatment). Compare this data with the previous year's data (13.928 kg/ac control, 1.44 kg/ac 1-inch treatment, and 1.759 kg/ac 3-inch treatment) and you can see that the effect of tilling mulch in the soil is a very poor erosion control practice when compared with the control.

The Domaine Chandon treatments differ slightly from Hanzell and Sodaro. The system at Domaine Chandon was designed so that a comparison could be made between till and no-till management systems. As noted above, the current vineyard management design uses no-till agriculture, leaving a cover crop in place throughout the growing season. Treatment one is the control, using the existing cover crop for erosion control. Treatments two and three are the 1- and 3-inch mulch applications respectively. These treatments were tilled between the vine rows prior to the mulch application. Treatment four consists of a 3-inch mulch application placed directly on top of the existing cover crop. Treatment four was not tilled.

Each treatment contains one row of vines with the vine rows on either side receiving the appropriate mulch application. Mulch applications were also applied within the vine row. Above the treatment area, a shallow trench was dug in order to divert water around the treatment area so that water from upslope areas will not enter the treatment zone. Collection bins, located at the end of the vine rows in one replicate of treatments, collect runoff from the test area. Water sample bins consist of 30-gallon plastic drums fed by a 6-inch diameter intake pipe attached to a plastic tarp. The plastic tarp acts to funnel runoff from the treatment areas into the collection bins. Sample bins also have a 6-inch outlet pipe that acts as an overflow device.

Soil Moisture Sensor and Weather Station Installation

Located in each treatment area of the replicate being sampled for water quality are soil moisture sensors attached to an *Adcon* Telemetry remote weather station. The soil moisture sensors are at depths of 6, 12, and 18 inches. Weather parameters measured by the stations include temperature, relative humidity, leaf wetness, and precipitation. Weather data was transferred to a base station in the Terra Spāse, Inc., St. Helena office via radio telemetry.

Soil moisture sensors at the Sodaro site were removed in the spring of 2000 as a result of the tillage practices involved in vine planting. These sensors were reinstalled in the fall of 2000.

Water Sample Collection and Analysis

Water samples were collected after each major storm from November through the end of February. Half-liter samples were collected in new 250-milliliter Nalgene Polyethylene bottles and sent to A&L Western Agricultural Laboratories located in Modesto, for chemical analysis. All water samples were analyzed for the following: calcium, magnesium, sodium, potassium, ammonium, boron, phosphorous, bi-carbonate, chloride, nitrate, sulfate, carbonate, pH, electrical conductivity, sodium absorption ratio, total dissolved solids, and total suspended solids. Samples for chemical analysis were not collected for the month of March, but the amount of runoff was measured and water was removed from the sample bins.

Sample bins were emptied and sealed for the season in early April. Sediment collected during the rainy season was removed from the bins and weighed to provide a measurement of sediment movement from the treatments. A water sample from the 3-inch treatment at each site was also sent to UC Davis to determine concentrations of any organic constituents leaching from the mulch treatment.

Soil Sample Collection and Analysis

Soil samples were collected after the rainy season at each site. A composite sample from the surface (0–15 inches) and subsurface (15–30 inches) horizons was collected from each treatment. These samples were sent to A&L Western Agricultural labs for measurement of soil fertility and to UC Davis for nitrogen analysis. The analyses run at UC Davis included total nitrogen and carbon and mineralizable nitrogen, as well as extractable ammonium-nitrogen and nitrate-nitrogen.

Mulch Sample Collection and Analysis

A composite mulch sample was collected from each site and sent to the Soil and Plant Lab, Santa Clara, for nutrient analysis, and to UC Davis for nitrogen analysis. These samples were collected prior to the rainy season.

Vine Nutrition Monitoring

Data vines in each treatment and replicate at Domaine Chandon were sampled for petiole and blade analysis after bloom of the 2000 season. These results provide a measurement of the general fertility of the vines.

Findings

Production Costs

The physical production costs per cubic yard (based on statewide average rates) are:

Cleaning feedstock: $2.03

Grind feedstock: $5.40

Composting Costs (4 weeks): $1.80

Screening: $1.35

An itemization of the individual production costs is found in Appendix A. The unit costs of this study are distinctive, based on the relatively small scale of production. The statewide production cost ranges are derived from project partners Cold Canyon Landfill and California Wood Recycling in California's central coast and southern regions (San Luis Obispo and Ventura counties, respectively). These operations together produce approximately 300,000 cubic yards of mulch per year. In contrast, Upper Valley Recycling processes approximately 30,000 cubic yards of clean green material per year. Consequently, the identified unit cost for the smaller-scale operations of this study is higher than the statewide production cost ranges.

Cleaning Feedstock

Cleaning of the feedstock includes the removal of foreign non-compostable materials such as twist-ties, metals, glass, and irrigation lines and other plastics. For this test the material was visually inspected and manually sorted by company employees. Electro-mechanical equipment is also available to perform these functions.

The feedstock from the upper Napa Valley used in this study is extremely clean compared to green materials collected curbside from other urban environments. Although there is no source of statewide information compiled on level of non-compostable material, urban regions typically generate non-compostable materials in excess of 5 percent and in some cases as high as 20 percent.

The industry average unit cost of $2.03 per cubic yard for removal of non-compostable materials represents the action of putting project feedstock across a sorting line with laborers removing these materials. A second sorting of the feedstock to improve quality would cost approximately $0.56 per cubic yard. The sorting line, or "pick line," method of removal of non-compostable material requires a capital investment of $75,000 to $250,000 for equipment purchase in addition to the labor cost to operate.

Grinding of feedstock

The unit cost of $5.40 per cubic yard for grinding the feedstock includes the equipment used to handle the material within the processing facility. The processing rate of the grinding equipment is affected by the moisture content of the feedstock. Dry and woody material is processed more rapidly than wet and oversize material.

Composting

The unit cost of $0.45 per cubic yard per week is the industry average. Composting methods such as windrow composting require substantially higher turning and watering costs, as reflected in this statewide unit cost provided. The less labor-intensive aerated pile method used at the project composting facility costs approximately $0.17 per week. This method requires limited turning of the pile during the composting process.

Screening

The unit cost of $1.35 per cubic yard for screening the mulch is industry average. In addition to sizing the mulch, this mechanical process provides the additional opportunity to remove foreign materials that may have remained through the previous steps.

Hauling Costs

The industry average unit costs of $2 per ton for an 11-mile radius and $13 for a 120-mile radius are within the expected range for bulk freight transport. Not analyzed in this unit price is the combination transport and application systems (for example, Rexius system) considered below.

Application Costs

The unit cost of $3.30 per cubic yard to apply the project mulch in the study period reflects the level of effort required to work in the hillside vineyard subject plots. A combination of factors affects the application of mulch at the vineyard site. The unique nature of vineyard geometry is not easily captured in a simple formula. The steepness of the terrain, vehicle access, vineyard spacing, and age of the vines are important considerations in the selection of the method to apply mulch. Because the test plots were small and involved partial rows, mulch application for the project was performed mostly by hand.

Alternative mulch application methods include mechanical systems such as blowers. The costs are retailed at approximately $11 to $15 per cubic yard. The density and particle size of the material applied are variables affecting the actual cost to apply. (Source: Rexius Systems.)

Application

Upper Valley Recycling’s modified 5-cubic-yard spreader applies the material at approximately two minutes per cubic yard (one minute and 45 seconds per cubic yard, applied. Note: the material as applied is less dense than the material in the hopper).

Rainfall

Rainfall data for each site was collected using *Adcon* Telemetry weather stations. This data compares well with rainfall totals from the California Department of Water Resources rain gauge located at the Napa City Fire Department.

California Department of Water Resources (Napa)

> Average: 23.4 inches
>
> 5/1/00 to 4/30/01: 19.8 inches

Project Sites (Average)

> 5/1/00 to 4/30/01: 22.5 inches

The heaviest rainfalls occurred during February 2000 and February 2001. Rainfall data is shown in Table 1 of Appendix D, page 30.

Chemical and Sediment Load Analysis

Samples of the runoff water were collected throughout the rainy season for chemical and sediment load analysis. It should be noted that at no time did the runoff chemical concentrations exceed allowable drinking water standards. Data detailing runoff water or sediment analysis is tabulated in Tables 2–5 of Appendix D, pages 30 through 36.

Phosphorus

The phosphorus concentration in runoff water varied from the different treatments. It appears that at all of the test sites, the heavier mulch treatments released greater quantities of phosphorus into the runoff water. The exceptions to this trend are the 3-inch plus cover treatment at Domaine Chandon. At Sodaro, where the mulch was plowed into the soil prior to the second season, the trend is reversed with the phosphorus content of the control being the greatest and the 1-inch treatment being greater than the 3-inch treatment. There is a general trend of decreasing phosphorus release as the rainy season progresses and from one season to the next, but the release rates may fluctuate with rainfall intensity and totals. Phosphorus levels during peak rainfall in February 2000 are about four times greater than the peak rainfall in February 2001 at Sodaro and Hanzell for all treatments. Phosphorus levels during peak rainfall in February 2000 are about 1.25 times greater than peak rainfall during February 2001 at Domaine Chandon across all of the treatments.

In the early part of the rainy season, there was a spike in phosphorus seen in all treatments. Further into the season, the values become steadier and only fluctuate slightly.

Sulfate

Sulfate release increased with rainfall intensity at Domaine Chandon and Hanzell, while sulfate levels were relatively equal across the three treatments at Sodaro. Sulfate concentrations vary inversely with depth of mulch application at Hanzell. Sulfate concentrations at Domaine Chandon are higher in both the 3-inch tilled application—and the 3-inch application that retained the cover crop—than in the other two treatments. All of the sulfate levels at all of the vineyards were under the maximum contaminate level (MCL) for drinking water.

Sediment Load

Sediment load analysis of project data found in Tables 2–4 of Appendix D, pages 31 through 34, indicates a marked reduction in total suspended sediment load in the 1- and 3-inch treatments at all of the sites. The data presented in Appendix D is a subset of all data collected. The chart below shows calculated values for sediment loss for each treatment at the three sites. Values for calculated sediment loss (kg/acre) are relative amounts of soil loss, calculated from the total suspended solids measured in the collected water samples multiplied by the volume of water removed from each sample bin. These are not absolute values for soil loss. The results show an increase in erosion control for the 1999–2000 rainy season in the 1- and 3-inch treatments at Hanzell and Sodaro as well as in the 1- and 3-inch and the 3-inch plus cover treatments at Domaine Chandon. The total suspended sediment load generally appears to decrease with time. There was a spike in sediment load in the later half of February 2001. This may be due to the large amount of high intensity rainfall received during this time period. Sediment collected in each bin was measured and weighed in order to better quantify the amount of sediment moving off of the treatments. Based on this evaluation it was noted that sediment moved off the test plots as shown in the following site summary:

Site Summary

	Domaine & Chandon	Hanzell	Sodaro
Slope	16%	28%	24%
Sediment Load in kilograms per acre (Kg/A)			
1-inch application	10.4	17.3	1.5*
3-inch application	9.8	8	2.0*
3-inch application with cover crop	3.4	N/A	N/A
Straw application	10.8	41.3	13.9*

*Numbers only include suspended solids, since total solids data was unavailable.

Samples of the supporting data are provided in Table 2 of Appendix D, page 31.

The total dissolved solids (TDS) and total suspended solids (TSS) for the runoff from most mulch applications averaged less than the amounts originating from the straw treatments. The treatment summary includes a tabulation of these values.

Treatment Summary

	TDS (Kg/A)	TSS (Kg/A)
1-inch application	14.8	1.6
3-inch application	21.5	75
Straw application	18	2.3

Samples of the supporting data are provided in Table 3 of Appendix D, pages 32 and 33.

Other Advantages

Soil Fertility. An analysis of the general soil fertility did not show any significant differences between the treatments, especially at Hanzell and Sodaro where the sites were heavily amended with composts and fertilizers prior to planting. The upper 15 inches of the tilled 3-inch treatment at Domaine Chandon showed slightly greater quantities of total soil potassium as well as micronutrients such as zinc and boron. Changes in soil fertility may become more apparent over the long term as the soils tend towards equilibrium.

Heavy mulch applications provide several possible advantages, including the enhancement of long-term soil fertility and soil water storage as well as controlling nitrogen loss to leaching or runoff. The mulch analysis (Table 4 in Appendix D, page 34) reveals a relatively low level of nutrients as well as a very high carbon:nitrogen (C:N) ratio. According to these results, the applied mulch will not add a significant amount of nitrogen and other nutrients to the soil in the short term, but it will provide valuable long-term soil fertility.

The high C:N ratio of the mulch makes it difficult for soil microorganisms to break down the organic matter into constituents readily available for plant uptake. Microorganisms may actually pull nitrogen out of the soil and soil solution in the short term to assist in the decomposition of the highly carbonaceous material. This short-term nitrogen depletion may ameliorate nitrogen loss to runoff/leaching through microbe utilization of the readily available, leachable nitrogen for the decomposition of the mulch materials. Any negative effects of the short-term nitrogen depletion may easily be overcome by the addition of nitrogen fertilizers. One benefit of this nitrogen uptake is that any nitrogen absorbed by the soil microbes will become a source of slow-release nitrogen as decomposition continues.

Soil Moisture. Soil water storage also benefits from the heavy mulch applications. Soil moisture data for Hanzell and Domaine Chandon show a significant decrease in soil dry-down for the mulch treatments. Soil moisture content increases with the heavier mulch applications. Figures 1a through 4c in Appendix E illustrate these phenomena for the Hanzell site. Please note that Figures 1 and 2 share the same soil moisture and rainfall data from Hanzell vineyard for 2000. A similar relationship exists between Figures 3 and 4 displaying the data for 2001.

The soil moisture sensors show the plant use of available soil moisture in the upper 18 inches of the soil, as well as how precipitation moves through the upper 18 inches of the soil profile (Figures 1a through 4c).

General trends at Domaine Chandon and Hanzell show the sensors under the 3-inch treatments respond more slowly to evaporation than do the control treatments. At Hanzell, soil moisture measured in kilopascals (kPa) of pressure varies greatly between the treatments in the spring of 2000. The 3-inch treatment (Figure 1b) values may be up to 10 times smaller than the control (Figure 1c). The smaller the kPa value, the more water is available for plant use. In the spring of 2001, we see this trend reverse, where the soil in the 3-inch treatment (Figure 3b) is dryer than the soil in the control plot (Figure 3c). This is due to the plant uptake of water at bud break. More water is available in the 3-inch treatment, so the plant uses it for shoot growth. Photographs and shoot length measurements of Hanzell show this effect, where the vines in the 3-inch treatment are more vigorous and longer than in the control row. The 1-inch treatment vines fall in between the control and 3-inch vines (Figure 5).

During the first rain of the season, the sensors at Domaine Chandon control plot show water moving though the soil profile sooner than the rows with the mulch treatment. During the first few precipitation events, the mulch is absorbing the water. Once the mulch is saturated, then the water will start moving through the soil profile.

This storage effect of the mulch has a positive effect on vine growth during the spring. More water is available in the mulch treatments for the vines to use, so the vines show more vigorous growth when compared to the control row. This effect is clearly seen at Hanzell.

It is difficult to see trends at Sodaro because the mulch treatments were tilled into the ground. This practice exposes bare soil to evaporation and erosion from raindrop impact. Both the 1-inch and 3-inch treatments behaved similar to the control plot.

The graphs in Appendix E (Figures 1a through 4c) show differences in soil moisture status under the different mulch treatments at the Hanzell Vineyard. The soil moisture sensors show the response of the soil to climatic conditions at each treatment. In these graphs, the higher the kPa value, the less moisture is in the soil. The control graph (Figure 3c) shows a large response to a precipitation event that occurred on April 20, 2001 (after the soil had a chance to dry). This large drop shows the water moving down through the soil, past the 6-inch sensor, relatively rapidly.

The response for the same precipitation event from the 1-inch (Figure 3a) and 3-inch treatments (Figure 3b) is much less dramatic. This more controlled response is due to the mulch. There is also a difference between the 1-inch and 3-inch application. The 3-inch treatment shows the soil drying very slowly, while the 1-inch treatment dries faster. The heavier mulch application retards evaporation from the surface soil.

The apparent drying out of the soil under the 3-inch application (Figure 3b) occurs faster than the 1-inch application (Figure 3a) and control rows (Figure 3c) correlates with the bud break stage of the vines growth cycle that started about March 21, 2001. This stage in the growth of a vine requires large amounts of water. Since irrigation has not started, the vines must draw their water from the available water in the soil. The more vigorous the vine growth, the more water is needed to support the growth. This is evident in the soil moisture readings as well as in the photos.

Shoot lengths were measured on May 22 at Domaine Chandon and Hanzell vineyards. The results are shown on Figure 5 and correlate with the photos and soil moisture measurements for the date (not included in Figures 1a through 4c). Soil moisture charts for the week indicate that the vines to support the more vigorous growth drew down the surplus available moisture in the 1- and 3-inch mulch applications.

Soil Nitrogen. The soil nitrogen analysis (Table 5 in Appendix D, pages 35 and 36) provides several insights into differences between the sites as well as variations within each site. The initial soil nitrogen data does not necessarily reflect the addition of mulch to the surface of these soils. Rather, it provides a picture of the formation and past management of these soils.

The soil properties that were measured include total carbon/nitrogen, extractable ammonium, and nitrate nitrogen as well as mineralizable nitrogen. Different ratios of these components were also calculated to assist in the interpretation of these results. Total nitrogen and carbon were determined using a Carlo-Erba machine, which utilizes high temperature combustion. These results measure the total organic nitrogen and carbon present in the soil. Extractable nitrogen, measured using a potassium chloride extraction procedure, provides a measure of the readily available or leachable fractions of nitrogen. Mineralizable nitrogen was measured using an anaerobic respiration procedure and represents the amount of nitrogen that will be released through microbial decomposition. This can be used as an indicator of the general microbial activity of the soil.

The ratios of mineralizable nitrogen to total nitrogen and mineralizable nitrogen to total extractable nitrogen are indicators of soil fertility. The mineralizable nitrogen to total nitrogen ratio represents the portion of total nitrogen that can be converted into forms readily available for plant uptake. In general, soils fall within a range of 1 to 2 percent mineralizable nitrogen to total nitrogen. The mineralizable nitrogen to extractable nitrogen ratio represents the relative storage to availability of soil nitrogen. A high ratio indicates a large pool of slow release nitrogen as compared to readily available nitrogen. A low ratio indicates readily available nitrogen with very little slow release, mineralizable nitrogen. Fertile soils supporting a diverse ecosystem generally contain a high mineralizable nitrogen to extractable nitrogen ratio. Barren sites with very low organic matter tend to have very low ratios, less than one.

The Sodaro results suggest a relatively low fertility site. Total nitrogen and carbon levels as well as extractable nitrogen levels are high, while mineralizable nitrogen levels are low. The high level of extractable nitrogen indicates a large pool of readily available nitrogen with very little nitrogen available via slow release mineralization. The subsurface soils have very low mineralizable nitrogen levels while maintaining relatively high extractable nitrogen. This suggests nitrogen leaching from surface horizons into the subsurface.

There are several possible explanations for the low nitrogen status of these soils. Prior to vineyard development, the native vegetation at the Sodaro site produced highly acidic soils that may have reduced the generation of biomass, thereby reducing the addition of organic material to the soil. The pre-existing vineyard may also have mined any available subsurface nitrogen through root and plant growth.

Nitrogen analyses for Hanzell soils suggest a fertile site rich in mineralizable nitrogen as compared to total nitrogen. All Hanzell treatments show a greater proportion of mineralizable and extractable nitrogen in the surface horizons.

The Hanzell test site represents a newly developed vineyard that contained a lush oak woodland and Douglas fir ecosystem prior to development. The pre-existing ecosystem contributed large amounts of organic matter to the soil through above- and below-ground biomass production. The site also received large quantities of composted grape pomace during vineyard development, enhancing the mineralizable and extractable nitrogen values, particularly in the surface horizons. The Hanzell soils contain greater quantities of slow release organic nitrogen than either Sodaro or Domaine Chandon.

Soils at Domaine Chandon fall in between Hanzell and Sodaro in regards to nitrogen status. All of the treatments at Domaine Chandon follow the pattern of greater quantities of mineralizable and extractable nitrogen in the surface layers, except for the 3-inch and cover treatment, which contains more mineralizable nitrogen in the subsurface.

The Domaine Chandon site represents a mature vineyard farmed using no-till agriculture. No-till management practices allow surface soils to maintain nitrogen content through the constant addition and decomposition of organic material via the cover crop. These soils represent more of a steady state than the other newly developed vineyards.

Tissue samples were collected post-bloom at the Domaine Chandon test site. Petiole and blade samples were collected from each treatment in each replicate. Petiole analysis shows an increase in nitrate concentration with an increase in mulch cover. The 3-inch treatment combined with the cover crop gave the highest values.

One possible explanation for these phenomena is the enhanced soil moisture retention afforded by the thicker mulch layers. The soil moisture data shows a significant difference in the soil moisture content of the soils under the 3-inch treatments as compared to those of the control and 1-inch treatment. The increased soil moisture in the heavier mulch treatments may more readily facilitate nitrification, making nitrate more available for uptake. Nitrification is the microbial process of converting ammonium-nitrogen to nitrate-nitrogen.

Plant Vigor. As noted above, more soil moisture is maintained with mulch treatment. The plant uses this additional available water for shoot growth. Photos and shoot measurements of Hanzell show this effect, where the vines in the 3-inch treatment are more vigorous and longer than in the control row (Figure 5). The 1-inch treatment vines fall in between the control and 3-inch vines. Similarly, petiole samples from Domaine Chandon show an increase in nitrate concentration with an increase in mulch cover. (Nitrate content of petioles with the 3-inch mulch treatment was twice that of the control sample.) Finally, the treated vines at Domaine Chandon and Hanzell had a delayed senescence or leaf drop compared to the control, or no mulch vines.

All of these factors are reflected in the vine growth, yield, and fruit composition. On July 31, 2000, cluster weight, berry weight, and Brix (a measure of sugar content) were measured at Domaine Chandon. Results show that berry weight was greater in all three of the mulch treatments compared to the control (18 percent). Cluster weights were greater in the 1-inch and 3-inch with cover treatments. Brix was also slightly higher in these treatments.

On August 17, 2000, the shoots per vine, cluster weight, berry weight, and Brix were measured. The shoots per vine and berry weight were slightly greater in all three mulch treatments compared to the control. Clusters per vine and cluster weight were greater than the control treatment in two of the three mulch treatments. Brix levels decreased with the increased levels of mulch treatment and would also indicate greater yields in mulch treatments because increased yields tend to delay ripening.

The Domaine Chandon vines were sampled again in August 2001. The results of this sampling are similar to the results noted the preceding August and are shown on Figure 6.

Weed Control. In September 2000 project staff evaluated three sample plots located at Rutherford Grove Winery for weed control effectiveness. The plots were each approximately 100 feet square. The results are as follows:

Treatment	Plants per 100 sq. ft.
No mulch	90
1-inch application	17
3-inch application	5

These results were consistent with visual inspection of the various test plots. It was observed that mulch-treated vine rows displayed fewer weeds. In areas planted with existing cover crop, apparent vegetation was limited to those varieties that would germinate under cover. It is expected that weed seeds requiring soil contact for germination are “disenfranchised” by mulch treatment.

A separate test of mulch indicated that the mulch did not carry viable seeds.

Conclusions

Mulch prepared from clean green material is effective in the control of erosion from hillside vineyards. During the course of this study it was noted that the total dissolved solids and total suspended solids for the runoff from most mulch applications average less than the amounts originating from the straw treatments.

Composting does improve the quality of the mulch. It significantly reduces the feedstock pathogen count and weed seeds in the mulch.

In addition, the mulch layer inhibits the growth of competing weeds, and it conserves soil moisture resulting in reduced water requirements, healthier vines, and better fruit.

A single application of mulch is effective for at least two years, the duration of this study.

Based on the response to our workshops this last winter, we believe that there is a market for the material and that the market may out-strip reasonably available supplies. From the community's view, the mulch successfully diverts material from the landfill. From the growers' view, the product brings options and multiple benefits: successful erosion control, increased soil moisture retention, and improved vineyard health along with a potential for improved long-term soil fertility.

Feedstock cleanliness is important to the processor and the vineyard manager. Education and enforcement of collection policies at the source will improve the aesthetic qualities of the mulch.

One of the downsides of using mulch is the cost of transportation. The product in its current form is lightweight and bulky. Market forces may lead to the investigation of bagging or compacting the mulch for ease of shipment at reasonable costs.

Further research and development in the area of additional benefits to the vineyard from the application of the clean green mulch will further support its use.

Recommendations

Managers of hillside vineyards should consider using a 3-inch layer of clean green mulch as a primary erosion control material if it is a cost-effective option in their area. Use of clean green mulch may necessitate the adjustment of other culture practices in the vineyard since soil moisture retention and weed suppression are associated benefits.

Upper Valley Recycling and a number of the project partners intend to continue the evaluation of the long-term benefits derived from this mulch. The effects of the mulch treatments on phosphorus levels in runoff need to be further considered. Levels of phosphorus in runoff water were quite variable with regard to site, rainfall event, and treatment. Phosphorus in runoff can be transported in either soluble or particulate form. The mechanisms of transport and the transformations of phosphorus in these two forms are complex and dynamic. Although levels of phosphorus were generally increased in the runoff from the mulch treatment, it is not clear whether the relative increases are significant with respect to any negative impacts on water quality in receiving bodies during high flow conditions at this time of year. We request that the CIWMB continue its support of these efforts.

We also recommend that the CIWMB and our county agencies lend their support as we submit applications proposing the use of the mulch as a viable alternative to the straw mulch now routinely required by county agencies charged with controlling hillside erosion.

Appendix A:
Cost Data

Upper Valley Recycling Company Composted Mulch Costs Summary (2nd Quarter 2001 dollars)

Operating Days	5	days/wk		
Feedstock	50	ton/day or	152	yd^3/day
Finished Mulch Product	25	ton/day or	76	yd^3/day
Weight of Feedstock	660	lbs/cu.yd.		

	Site Specific Costs		Industry Ranges				
			Low		High		
Item	Unit Cost	Unit Cost	Unit Cost	Unit Cost	Unit Cost	Unit Cost	Average
	($/ton)	($/cu.yd.)	($/ton)	($/cu.yd.)	($/ton)	($/cu.yd.)	($/cu.yd.)
Feedstock Cleaning	2.83	0.94	4.00	1.80	5.00	2.25	2.03
Grinding	12.86	4.24	11.00	4.95	13.00	5.85	5.40
Composting	0.50	0.17	0.50	0.23	1.50	0.68	0.45
Screening	3.63	1.20	2.00	0.90	4.00	1.80	1.35
Application Costs	10.00	3.30	15.00	6.75	25.00	11.25	9.00
Totals	29.82	9.84	32.50	14.63	48.50	21.83	18.23
Hauling Costs							
up to 11 mi radius			1.50	0.68	2.50	1.13	0.91
120 mi radius			10.00	4.50	15.00	6.75	5.63

Appendix B:
Specification for
Clean Green Mulch Production

Specification for Clean Green Mulch

"Clean green" means plant material that is processed by a permitted solid waste facility in order to reduce contamination to the greatest extent possible as set forth in CCR Title 14, section 17868.4. Tree and landscape trimmings that have never been combined with waste materials are also considered "clean green." This specification describes the production of clean green mulch developed by Upper Valley Recycling for use in this project.

1. Visually inspect incoming clean green material or trimmed brush and tree branches for foreign non-compostable materials such as twist-ties, metals, glass, and irrigation lines and other plastics. If the feedstock is free of such foreign materials, it should be set aside for grinding without additional processing. If the incoming material appears to contain more than 1 percent, by volume, of foreign material, it should be set aside for cleaning before grinding.
2. Grind clean green material using a 3-inch screen for the grinder.
3. Prepare ground clean green material for composting process by establishing static piles or windrows. Woody feedstock may require the addition of nitrogen-rich materials such as grasses, trimmings, and clippings to support the composting process of the mulch.
4. Compost clean green material for at least 20 days at 140° Fahrenheit.
5. Test composted mulch for pathogen content.
6. Screen composted mulch to remove particles less than 3/8-inch in size. Reserve fines for another use.
7. Mulch is now ready for vineyard application.

Notes

Maximum particle size, feedstock composition may affect composting time and application rates.

Ambient conditions at the processing site (for example, weather) or pathogen contamination of feedstock may affect composting duration.

Appendix C: Application Guidelines for Clean Green Mulch

Application Guidelines for Clean Green Mulch

These guidelines describe the application of clean green mulch developed by Upper Valley Recycling for use in this project.

1. Purchase clean green composted mulch.
2. Select distribution equipment sized to accommodate the mulch characteristics including maximum particle size, moisture, and weight.
3. Select distribution equipment suitable to the vineyard parameters such as row spacing.
4. Establish a distribution pattern that matches mulch flow with equipment travel time to allow for even, consistent application of product. Note that the best pattern may include multiple passes of a single area to get uniform distribution. Also note that the optimal scatter pattern may include more than one vine row.
5. Locate mulch stockpiles to most efficiently support the application process.
6. Monitor application depth to assure consistent coverage.

For this project the most effective application was a 3-inch screened mulch applied at 3-inch depths. Both manual and mechanical broadcasting methods were used to apply mulch at the test plots. The mechanical broadcasting was done using a modified fertilizer spreader.

Appendix D:
Project Data Tables

Table 1: Rainfall

Table 2: Sediment Loss

Table 3: Runoff Water Summary Data: total dissolved solids, total suspended solids, runoff water phosphate concentrate

Table 4: Mulch (3-inch Sample): Nutrient Content

Table 5: Estimation of Nitrogen Content of Field Soils by Surface and Subsurface Horizons

Table 1: Rainfall

Sample Period	Domaine Chandon	Hanzell	Sodaro	Average	Napa County Fire Department Actual	Napa County Fire Department Average
Annual: October thru April						23.03
Dec-99						
Jan-00						
Total (3Q)	7.69	5.48	5.91	6.36		
Feb-00					9.88	
Mar-00					2.92	
Apr-00					1.69	
Total (4Q)	13.76	20.82	14.78	16.45	14.49	
May-00					1.54	0.61
Jun-00					0.12	0.02
Jul-00					-	Trace
Total (5Q)	1.99	2.64	1.88	2.17	1.66	0.63
Aug-00					-	Trace
Sep-00					0.08	0.20
Oct-00					2.29	1.20
Total (6Q)	2.51	3.29	2.61	2.80	2.37	1.40
Nov-00					1.37	2.30
Dec-00					1.22	4.90
Jan-01					4.34	4.90
Total (7Q)	6.76	10.41	6.84	8.00	6.93	12.10
Feb-01					7.26	4.30
Mar-01					1.08	3.30
Apr-01					0.46	1.70
Total (8Q)	8.54	11.17	8.91	9.54	8.80	9.30
Summary May 2000 thru April 2001	19.80	27.51	20.24	22.52	19.76	23.43

Table 2: Sediment Loss (Kg/A)

	Domaine Chandon				Hanzell			Sodaro		
Treatment	**Control**	**1"**	**3"**	**3"+Cover**	**Control**	**1"**	**3"**	**Control**	**1"**	**3"**
Sample Date										
11/9/1999	0.084	0.077	0.035	0.000						
11/19/1999	0.063	0.045	0.031	0.010	3.565	1.459	0.566			
12/3/1999	0.004	0.004	0.006	0.007	0.064	0.151	0.119			
12/15/1999	0.061	0.019	0.007	0.000	0.053	0.090	0.040			
1/11/2000					0.236	0.447	0.138			
1/12/2000	0.000	0.000	0.000	0.000				0.581	0.103	0.000
1/18/2000	0.004	0.004	0.000	0.000	0.111	0.111	0.135	3.485	0.097	0.247
1/25/2000	0.015	0.015	0.004	0.004	0.008	0.008	0.016	2.974	0.313	0.395
2/1/2000	0.026	0.030	0.007	0.015	0.016	0.088	0.095	1.727	0.121	0.178
2/11/2000	0.007	0.026	0.007	0.004	0.004	0.032	0.056	0.506	0.022	0.049
2/14/2000					0.032	0.048	0.024	1.405	0.453	0.277
2/15/2000	0.074	0.089	0.004	0.026						
2/23/2000	0.122	0.078	0.059	0.118	0.004	0.040	0.008	2.024	0.287	0.514
2/28/2000	0.030	0.033	0.041	0.004	0.008	0.239	0.088	1.226	0.044	0.099
10/26/2000					1.340	1.440	1.040	No Runoff Collected in Collection Barrels		
10/30/2000	0.080	0.080	ND	0.060	0.610	0.640	2.720			
1/9/2001	0.007	0.007	0.011	0.011	0.016	0.016	0.024	0.022	0.066	0.148
1/22/2001	0.015	0.030	0.033	0.011	0.016	0.016	0.008	0.326	0.397	0.623
1/29/2001	0.070	0.107	0.100	0.052	0.008	0.016	0.016	0.281	0.375	0.306
2/14/2001	0.167	0.011	0.100	0.019	0.024	0.024	0.000	0.202	0.210	0.099
2/22/2001	0.044	0.026	0.033	0.004	0.000	0.000	0.016	0.270	0.000	0.000
3/7/2001	0.118	0.004	0.000	0.022	0.008	0.008	0.008	0.000	0.000	0.000

Note: All sample values were calculated from total suspended solids and volume of water removed from sample bins.
Does not account for runoff lost to overflow from sample bins.

Table 3: Runoff Water Summary Data

	Total Dissolved Solids (ppm) Average				Total Suspended Solids (ppm) Average				Runoff Water Phosphate Concentration Average			
	Control	1"	3"	3" + Cover	Control	1"	3"	3" + Cover	Control	1"	3"	3" + Cover
Domaine Chandon												
Nov-99	39	33	34	17	21	18	10	3	0.14	0.17	0.25	0.01
Dec-99	49	47	40	38	3	6	2	1	0.16	0.15	0.21	0.17
Jan-00	36	20	12	13	4	3	2	1	0.29	0.13	0.19	0.07
Feb-00	105	145	162	99	14	14	6	9	0.16	0.18	0.27	0.20
Mar-00	ND	ND	ND	ND					ND	ND	ND	ND
Apr-00	ND	ND	ND	ND					ND	ND	ND	ND
Oct-00					22	22	ND	16				
Nov-00					ND	ND	ND	ND				
Dec-00					ND	ND	ND	ND				
Jan-01					6	10	11	6				
Feb-01					57	10	36	6				
Mar-01					32	N/A	N/A	6				
Apr-01					ND	ND	ND	ND				
Hanzell												
Nov-99	355	452	611		504	220	80		1.23	1.25	1.43	
Dec-99	388	280	380		9	18	13		1.28	0.72	1.27	
Jan-00	425	373	494		31	35	16		0.24	0.61	1.69	
Feb-00	543	283	436		2	11	7		0.07	0.03	0.05	
Mar-00	ND	ND	ND						ND	ND	ND	
Apr-00	ND	ND	ND						ND	ND	ND	
Oct-00					151	137	236					
Nov-00					ND	ND	ND					
Dec-00					ND	ND	ND					
Jan-01					4	4	4					
Feb-01					3	3	2					
Mar-01					1	1	1					
Apr-01					ND	ND	ND					

Table 3: Runoff Water Summary Data (continued from previous page)

	Total Dissolved Solids (ppm) Average				Total Suspended Solids (ppm) Average				Runoff Water Phosphate Concentration Average			
	Control	**1"**	**3"**	**3" + Cover**	**Control**	**1"**	**3"**	**3" + Cover**	**Control**	**1"**	**3"**	**3" + Cover**
Sodaro												
Nov-99	ND	ND	ND		ND	ND	ND		ND	ND	ND	
Dec-99	ND	ND	ND		ND	ND	ND		ND	ND	ND	
Jan-00	70	94	33		259	22	33		0.74	0.70	2.09	
Feb-00	78	77	111		123	17	23		0.32	0.69	1.37	
Mar-00	ND	ND	ND						ND	ND	ND	
Apr-00	ND	ND	ND						ND	ND	ND	
Oct-00					ND	ND	ND					
Nov-00					ND	ND	ND					
Dec-00					ND	ND	ND					
Jan-01					31	42	78					
Feb-01					75	68	63					
Mar-01					24	N/A	N/A					
Apr-01					ND	ND	ND					
Total	2088	1804	2313	167	1376	661	623	48				
As a Percent of Control	100%	86%	111%	8%	100%	48%	45%	3%				

Table 4: Mulch (3-Inch Sample): Nutrient Content

(May 2000 - July 2000)

Nutrient		Total Nutrient Levels		Nutrient Mass (Lbs/Cy of Mulch)		Nutrient Mass (Lbs/Ton Mulch) at 52% Moisture		Percent Available of Total
		Portion (%)	Concentration (ppm)	Total	Available	Total	Available	(%)
Nitrogen	N	0.48		1.87	0.01	7.32	0.02	0.29
Phosphorous	P	0.05		0.21	0.07	0.82	0.27	33.20
Potassium	K	0.44		1.72	1.38	6.71	5.40	80.42
Calcium	Ca	0.86		3.35	0.82	13.12	3.20	24.38
Magnesium	Mg	0.16		0.63	0.30	2.47	1.18	47.89
Sulfur	S	0.08		0.31	0.13	1.22	0.49	40.53
Copper	Cu		44.0	0.0169	0.0013	0.0669	0.0063	9.09
Zinc	Zn		48.0	0.0188	0.0100	0.0731	0.0394	54.20
Managanese	Mn		116.0	0.4500	0.0400	0.1769	0.1556	87.90
Iron	Fe		3,594.0	1.4000	0.0450	5.4844	0.1769	3.23
Boron	B		35.0	0.0138	0.0004	0.0538	0.0015	2.83
Sodium	Na	0.04						
Organic Matter				276.00		1,080.00		

Carbon/Nitrogen Ratio: 81.9

Analyses run by Soil and Plant Lab, Santa Clara, Calif.

Analysis sample passed through a 1/2-inch screen. On a percentage by weight basis, about one-half of the 3-inch sample did not pass the 1/2-inch screen.

Table 5: Estimation of Nitrogen Content of Field Soils by Surface and Subsurface Horizons

(May 2000 - July 2000)

Vineyard	Treatment	Sample Horizon	extNH4	extNO3	minN	totN	totC	minN/totN	minNH4/extN	Total C:N
		(inch)						(%)	(ratio)	(ratio)
			kgN/ha	kgN/ha	kgN/ha	kgN/ha	kgC/ha			
Values represent one 15-inch (37 cm) horizon										
Domain Chandon										
	Control	0-15	18.8	26.5	105.9	6074	66511	1.70	2.30	11.00
	Control	15-30	10.5	12.3	37.6	4756	51569	0.80	1.60	10.80
	1-inch	0-15	9.5	17.6	67.4	5696	66389	1.20	2.50	11.70
	1-inch	15-30	9.8	19.9	45.5	5606	63116	0.80	1.50	11.30
	3-inch	0-15	8.6	17.9	104.3	6440	73209	1.60	3.90	11.40
	3-inch	15-30	12.0	14.5	38.8	4813	49695	0.80	1.50	10.30
	3-inch +	0-15	9.9	24.2	81.7	5245	59935	1.60	2.40	11.40
	3-inch +	15-30	11.1	23.4	153.8	6034	69715	2.50	4.50	11.60
Hanzell										
	Control	0-15	5.4	8.8	107.2	3757	63844	2.9	7.5	17.0
	Control	15-30	3.0	5.1	35.1	1918	25785	1.8	4.4	13.4
	1-inch	0-15	5.5	11.4	92.0	3621	69197	2.5	5.4	19.1
	1-inch	15-30	41.0	17.0	44.7	2716	35565	1.6	2.1	13.1
	3-inch	0-15	4.7	25.5	81.8	3276	56715	2.5	2.7	17.3
	3-inch	15-30	4.3	10.3	57.1	2497	37828	2.3	3.9	15.1
Sodaro										
	Control	0-15	18.9	40.8	51.2	8935	96507	0.6	0.9	10.8
	Control	15-30	24.9	32.0	23.1	6055	65134	0.4	0.4	10.8
	1-inch	0-15	13.8	46.3	66.9	10431	118780	0.6	1.1	11.4
	1-inch	15-30	11.5	37.1	23.1	6247	64107	0.4	0.5	10.3
	3-inch	0-15	15.5	70.1	60.3	9901	107907	0.6	0.7	10.9
	3-inch	15-30	23.7	58.4	15.9	7406	77166	0.2	0.2	10.4

Table 5: Estimation of Nitrogen Content of Field Soils by Surface and Subsurface Horizons (continued from previous page)

(May 2000 - July 2000)

Vineyard	Treatment	Sample Horizon	extNH4	extNO3	minN	totN	totC	minN/totN	minNH4/extN	Total C:N
		(inch)						(%)	(ratio)	(ratio)
			kgN/ha	kgN/ha	kgN/ha	kgN/ha	kgC/ha			
Sum of both values for whole rooting profile to 30-inch (74 cm) depth.										
Domain Chandon										
	Control	0-30	29.3	38.8	143.5	10830	118081	1.3	2.1	10.9
	1-inch	0-30	19.3	37.5	113.0	11301	129505	1.0	2.0	11.5
	3-inch	0-30	20.5	32.5	143.1	11253	122904	1.3	2.7	10.9
	3-inch +	0-30	21.0	47.6	235.4	11279	129650	2.1	3.4	11.5
		0-30								
Hanzell		0-30								
	Control	0-30	8.4	13.9	142.4	5675	89629	2.5	6.4	15.8
	1-inch	0-30	9.6	28.4	136.7	6337	104762	2.2	3.6	16.5
	3-inch	0-30	9.1	35.8	138.9	5774	94542	2.4	3.1	16.4
		0-30								
Sodaro		0-30								
	Control	0-30	43.8	72.8	74.3	14990	161641	0.5	0.6	10.8
	1-inch	0-30	25.3	83.4	90.0	16678	182887	0.5	0.8	11.0
	3-inch	0-30	39.2	128.5	76.2	17307	185073	0.4	0.5	10.7

Appendix E:
Project Data Figures

Figure 1a: Soil Moisture and Rainfall, Hanzell—2000, 1-inch Mulch

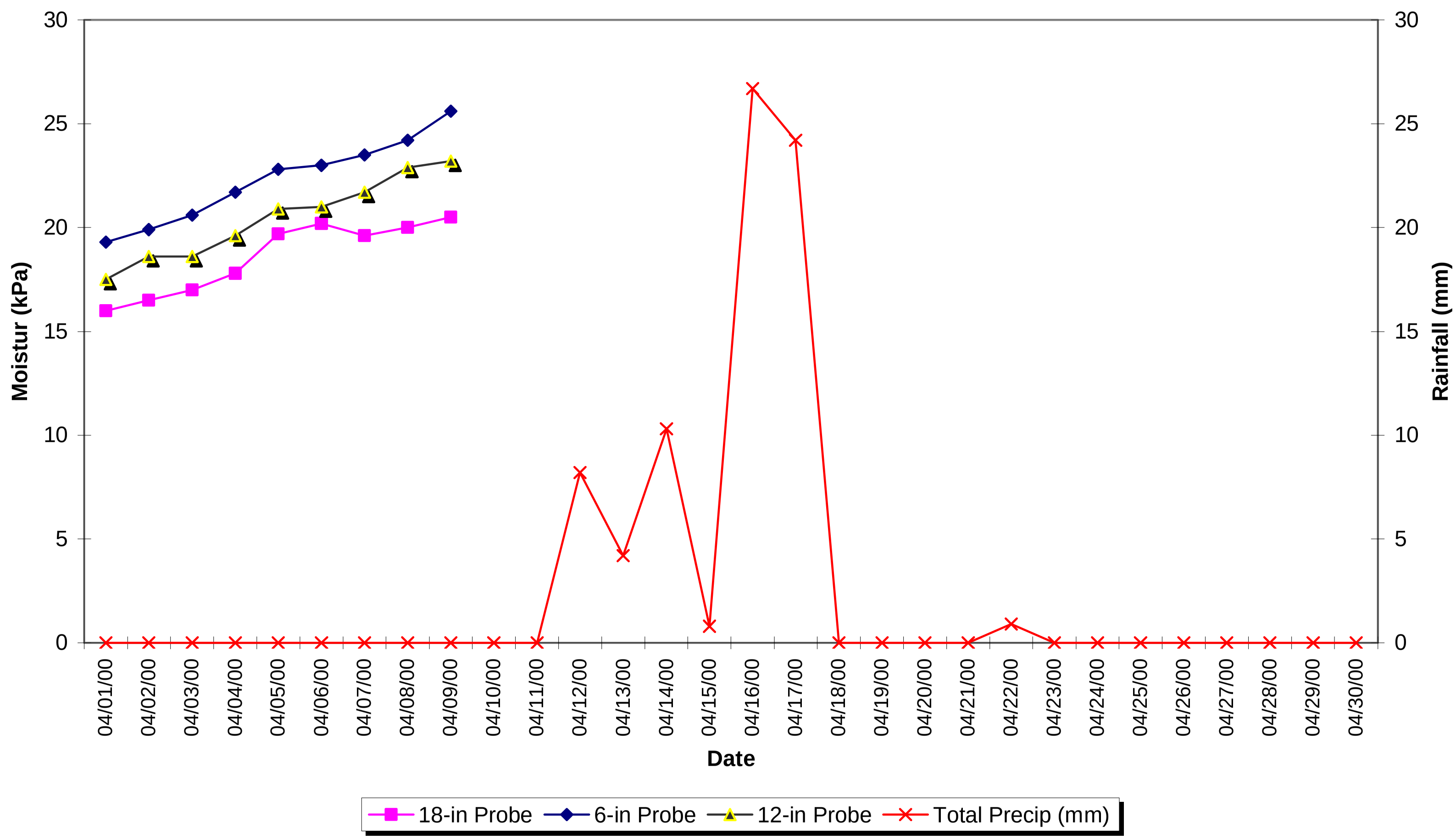


Figure 1b: Soil Moisture and Rainfall, Hanzell—2000, 3-inch Mulch

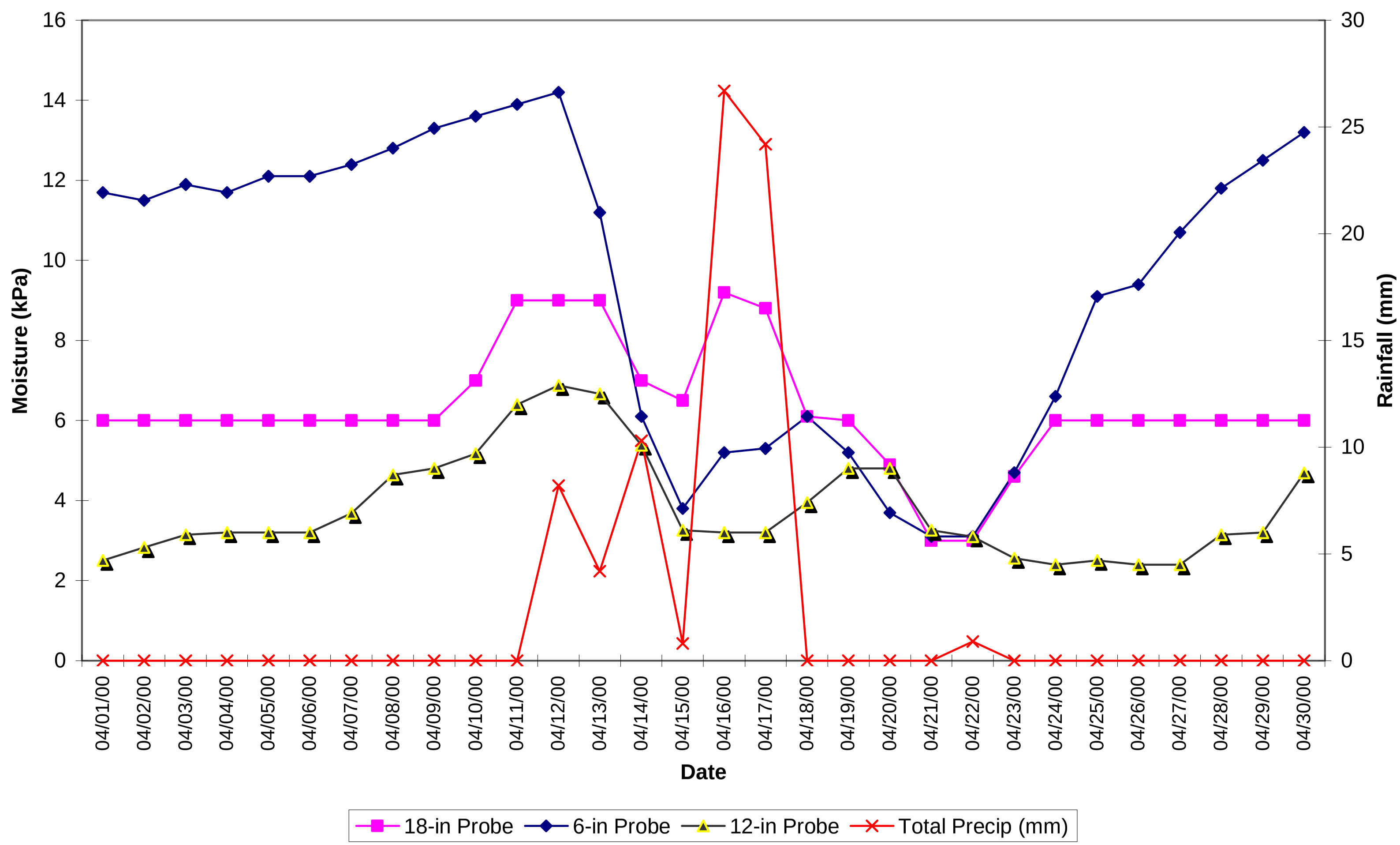


Figure 1c: Soil Moisture and Rainfall, Hanzell—2000, Control

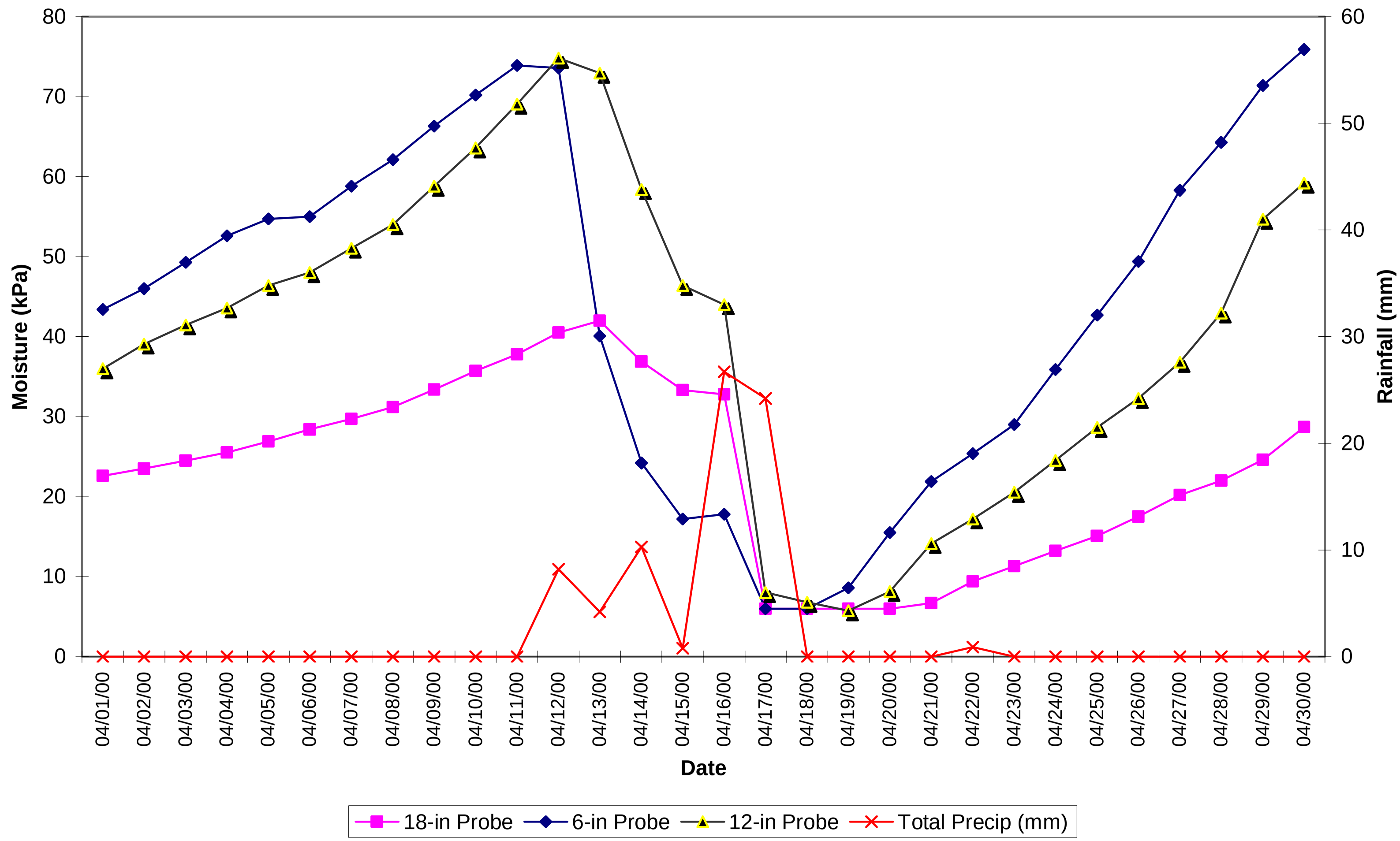


Figure 2a: Soil Moisture and Rainfall, Hanzell—2000, 6-inch Probes

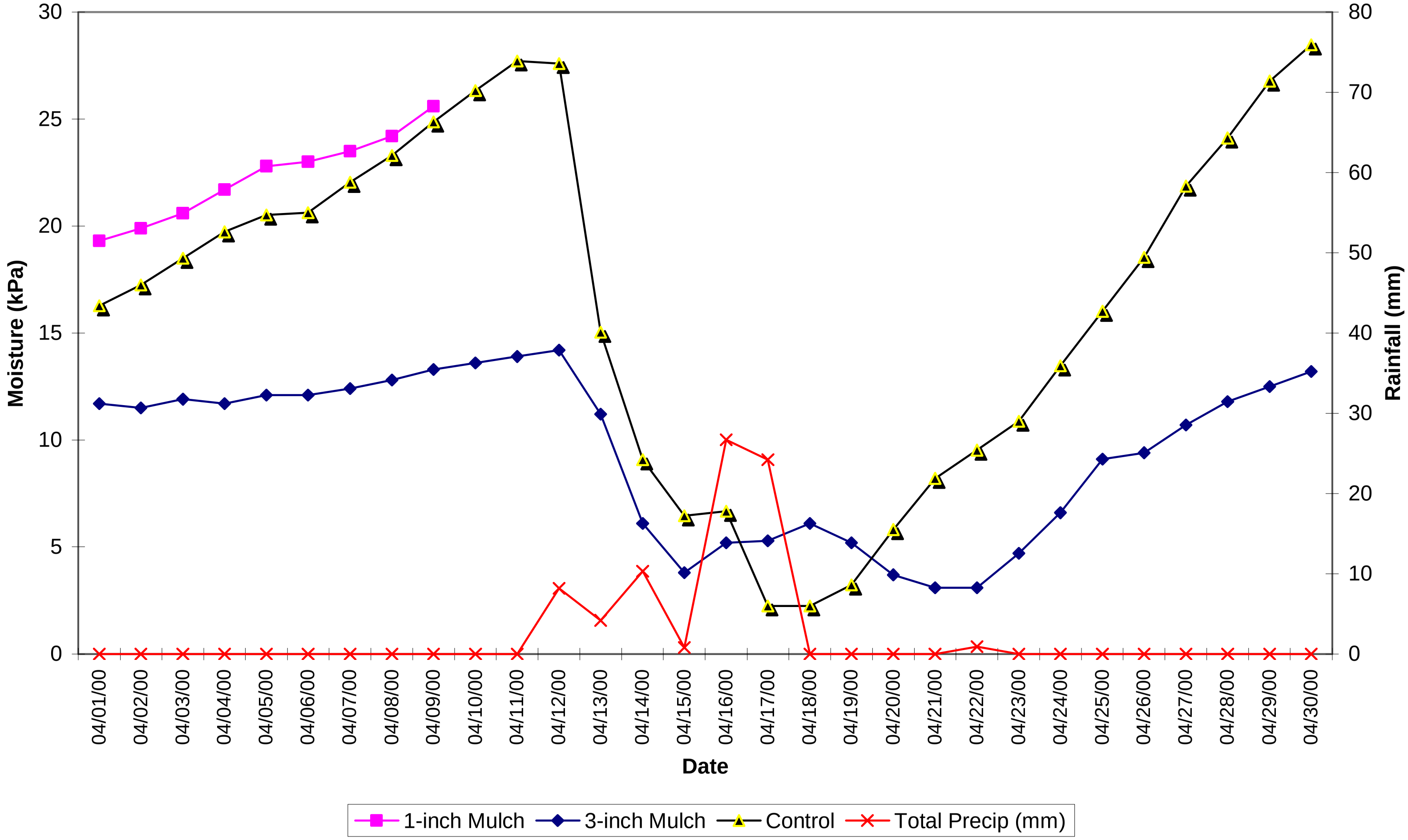


Figure 2b: Soil Moisture and Rainfall, Hanzell—2000, 12-inch Probes

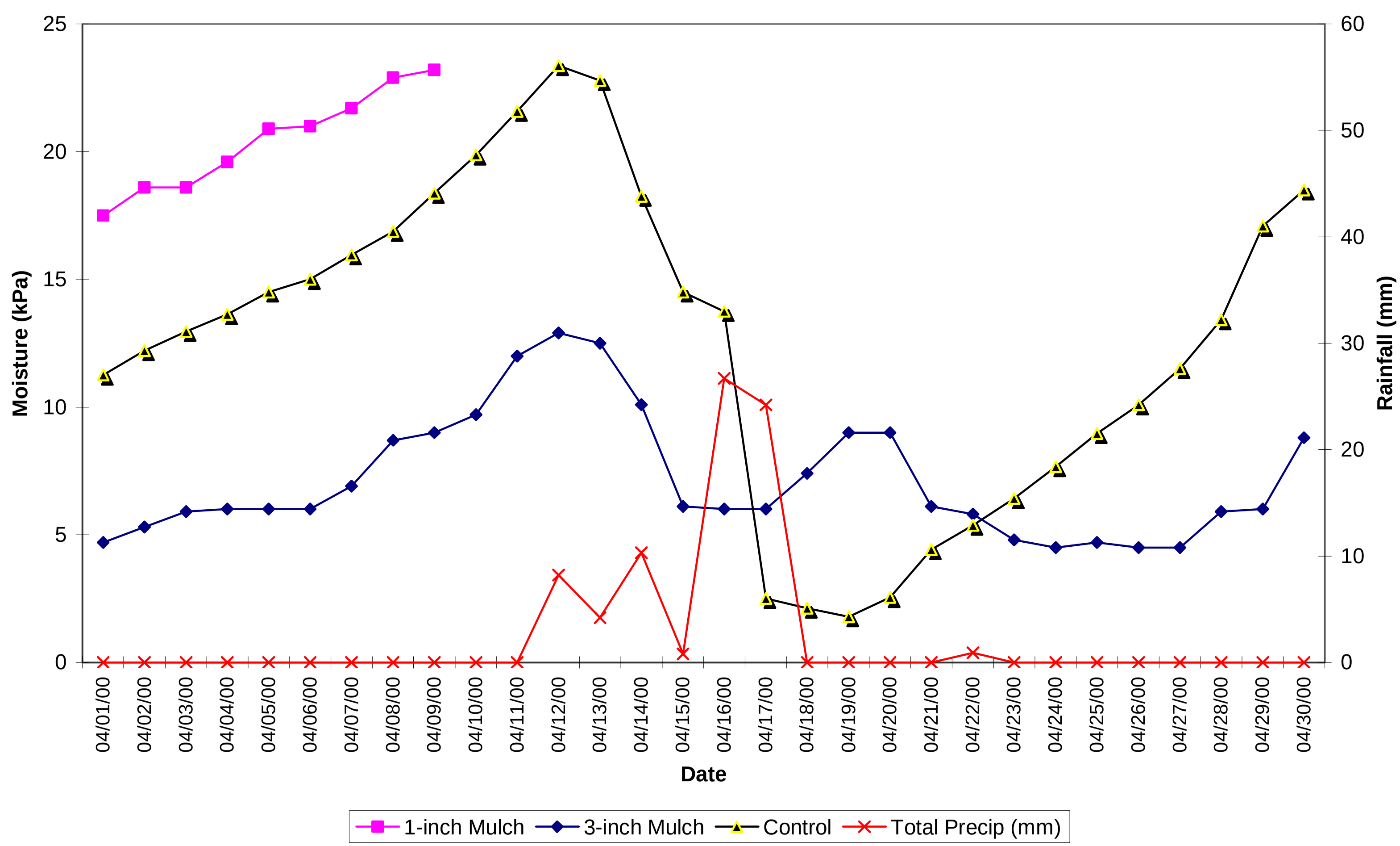


Figure 2c: Soil Moisture and Rainfall, Hanzell—2000, 18-inch Probes

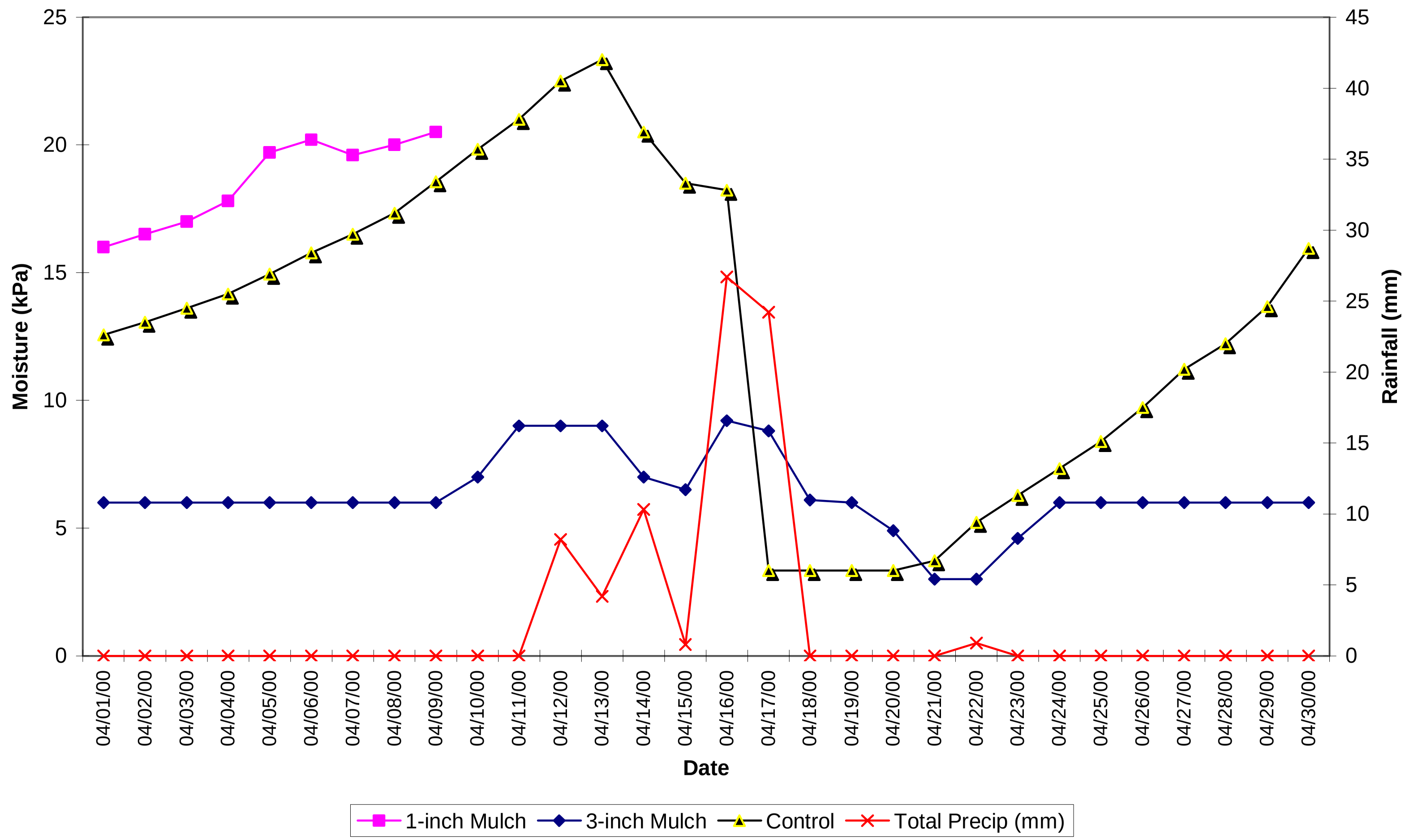


Figure 3a: Soil Moisture and Rainfall, Hanzell—2001, 1-inch Mulch

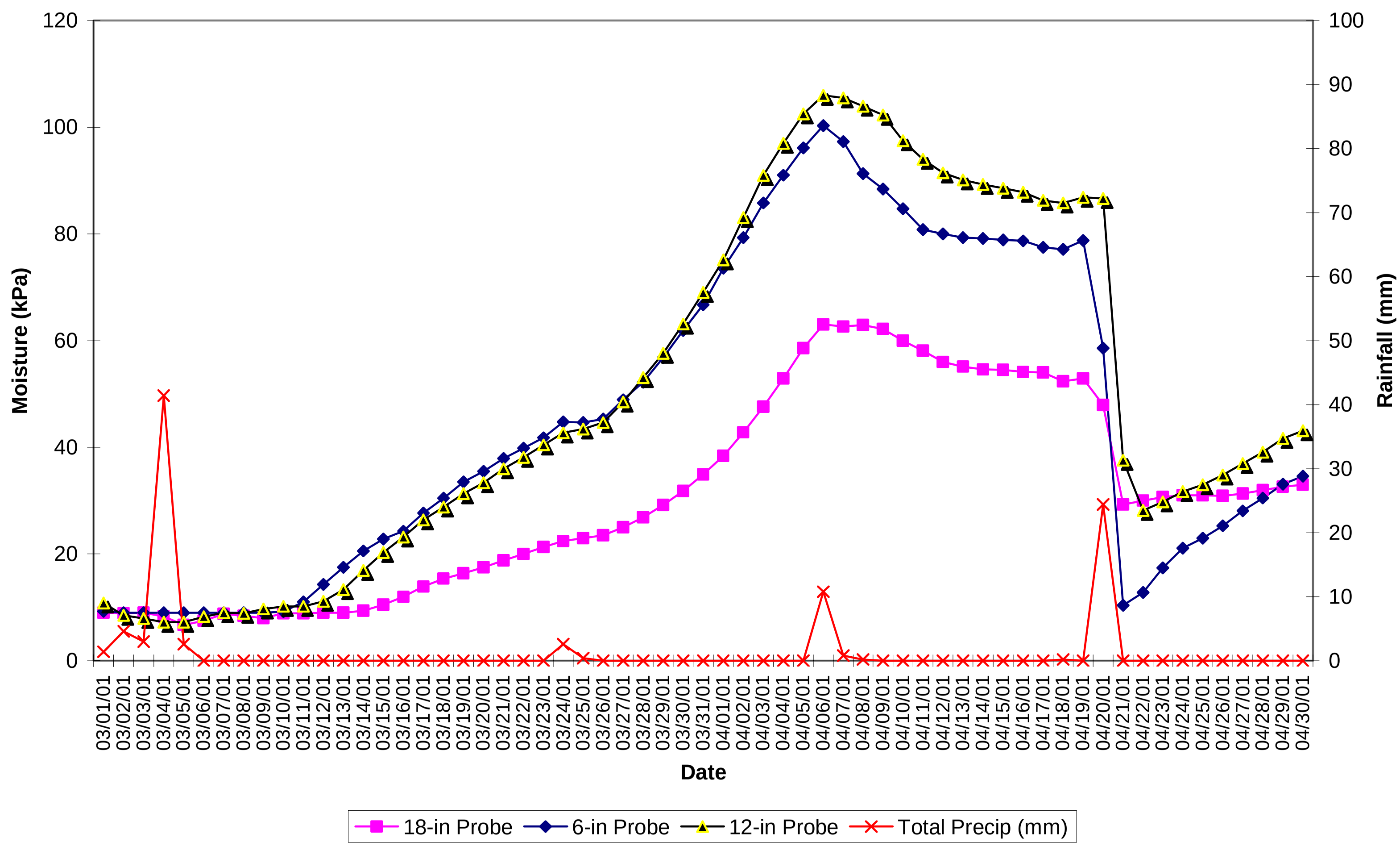


Figure 3b: Soil Moisture and Rainfall, Hanzell—2001, 3-inch Mulch

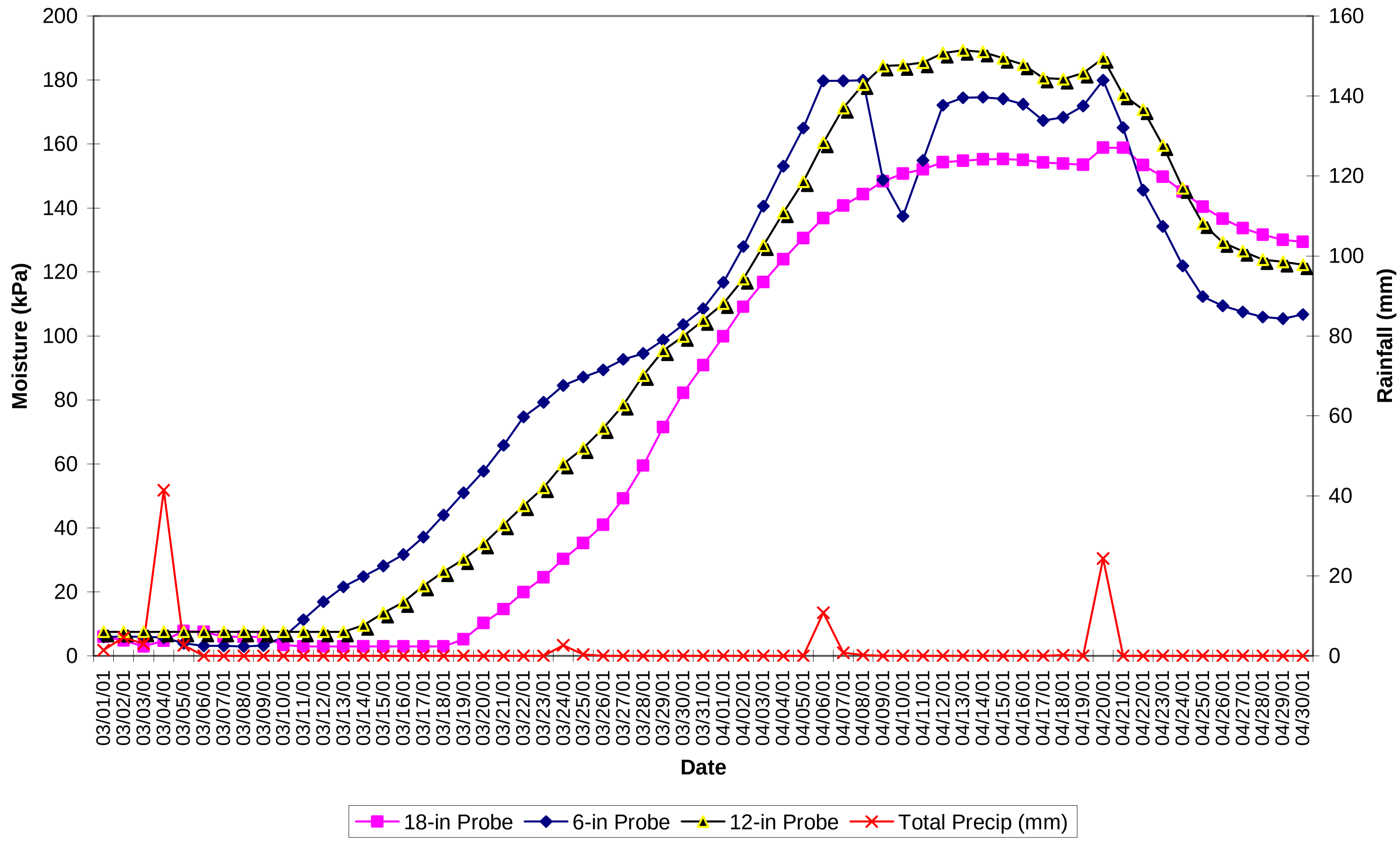


Figure 3c: Soil Moisture and Rainfall, Hanzell—2001, Control

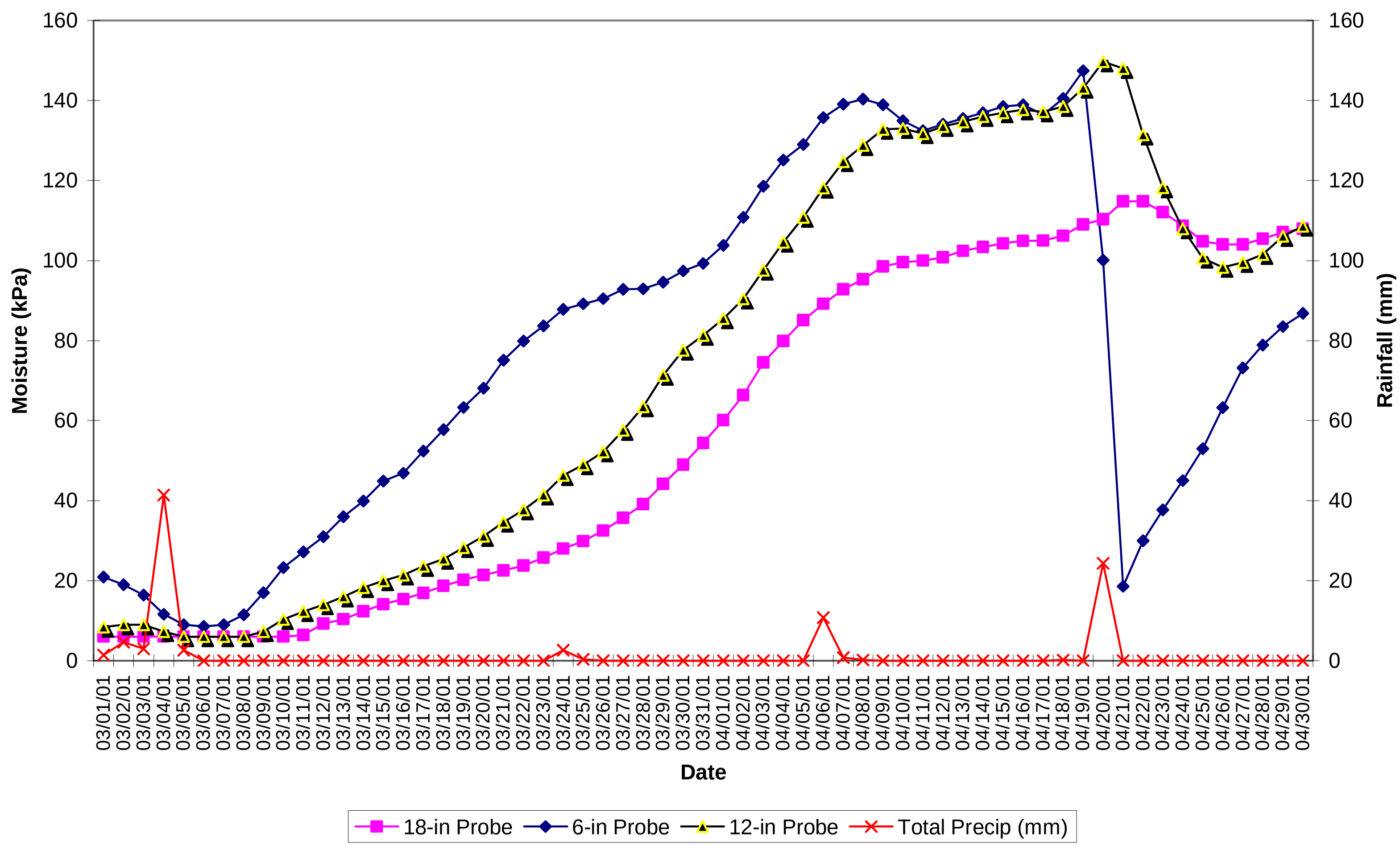


Figure 4a: Soil Moisture and Rainfall, Hanzell—2001, 6-inch Probes

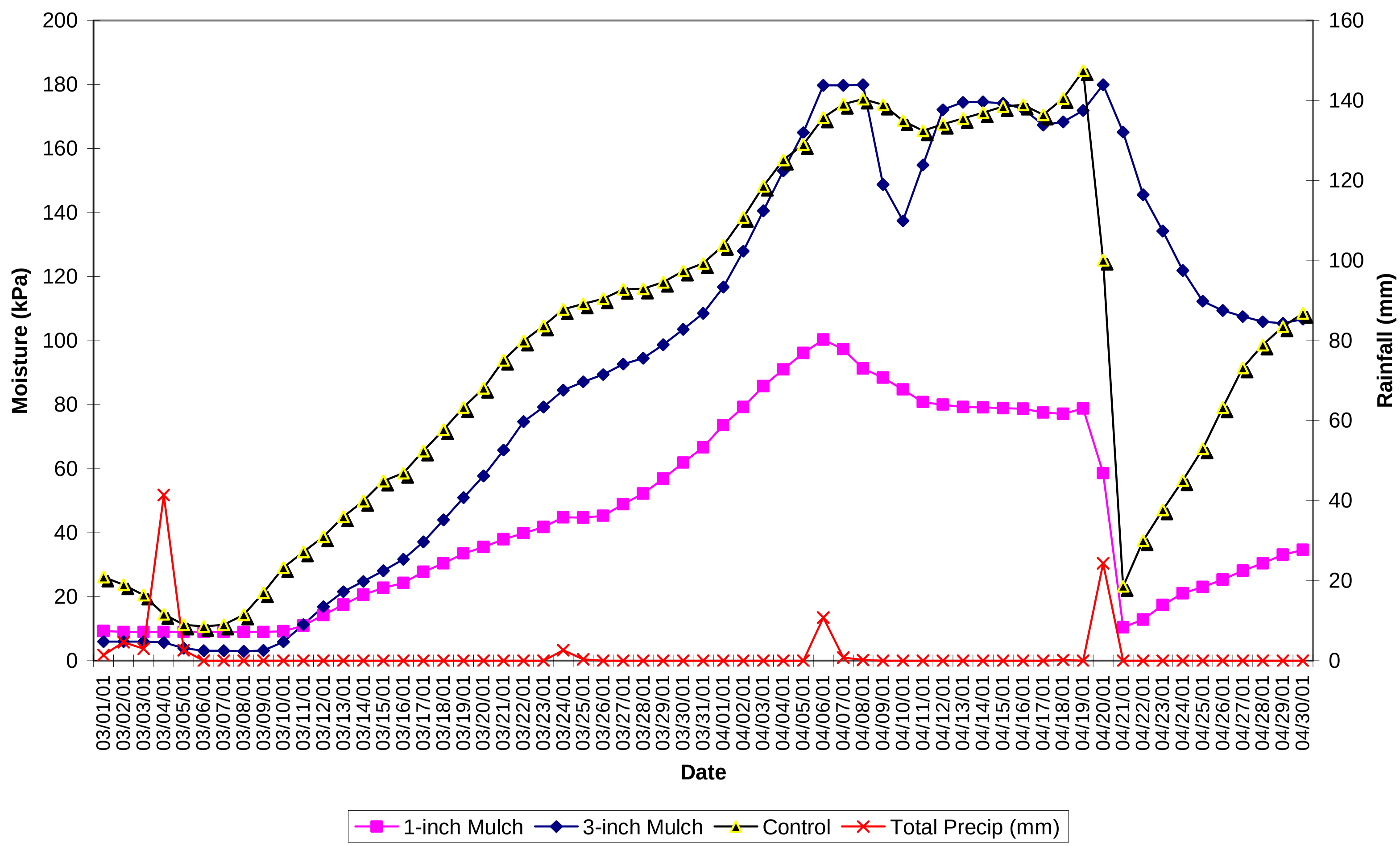


Figure 4b: Soil Moisture and Rainfall, Hanzell—2001, 12-inch Probes

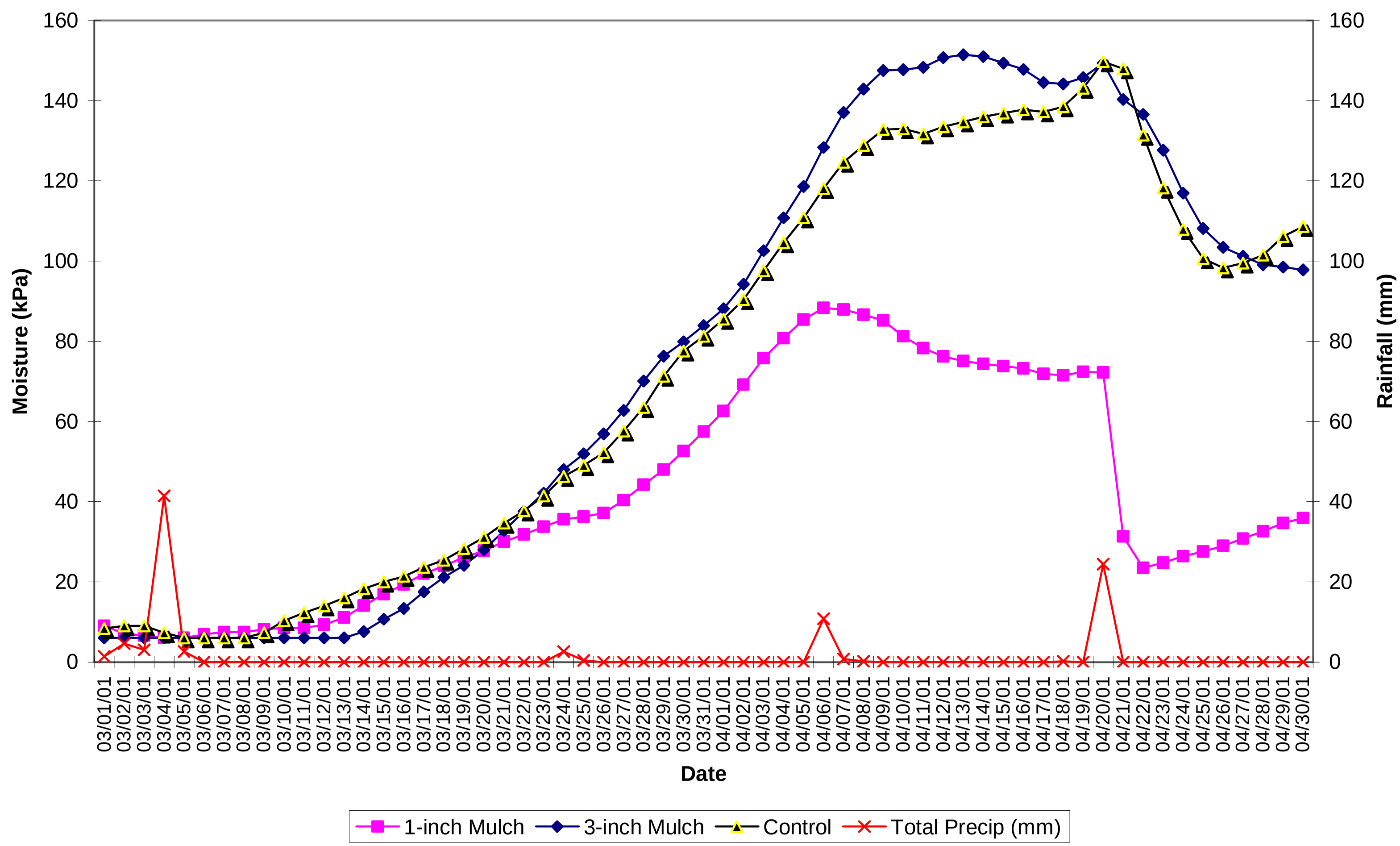


Figure 4c: Soil Moisture and Rainfall, Hanzell—2001, 18-inch Probes

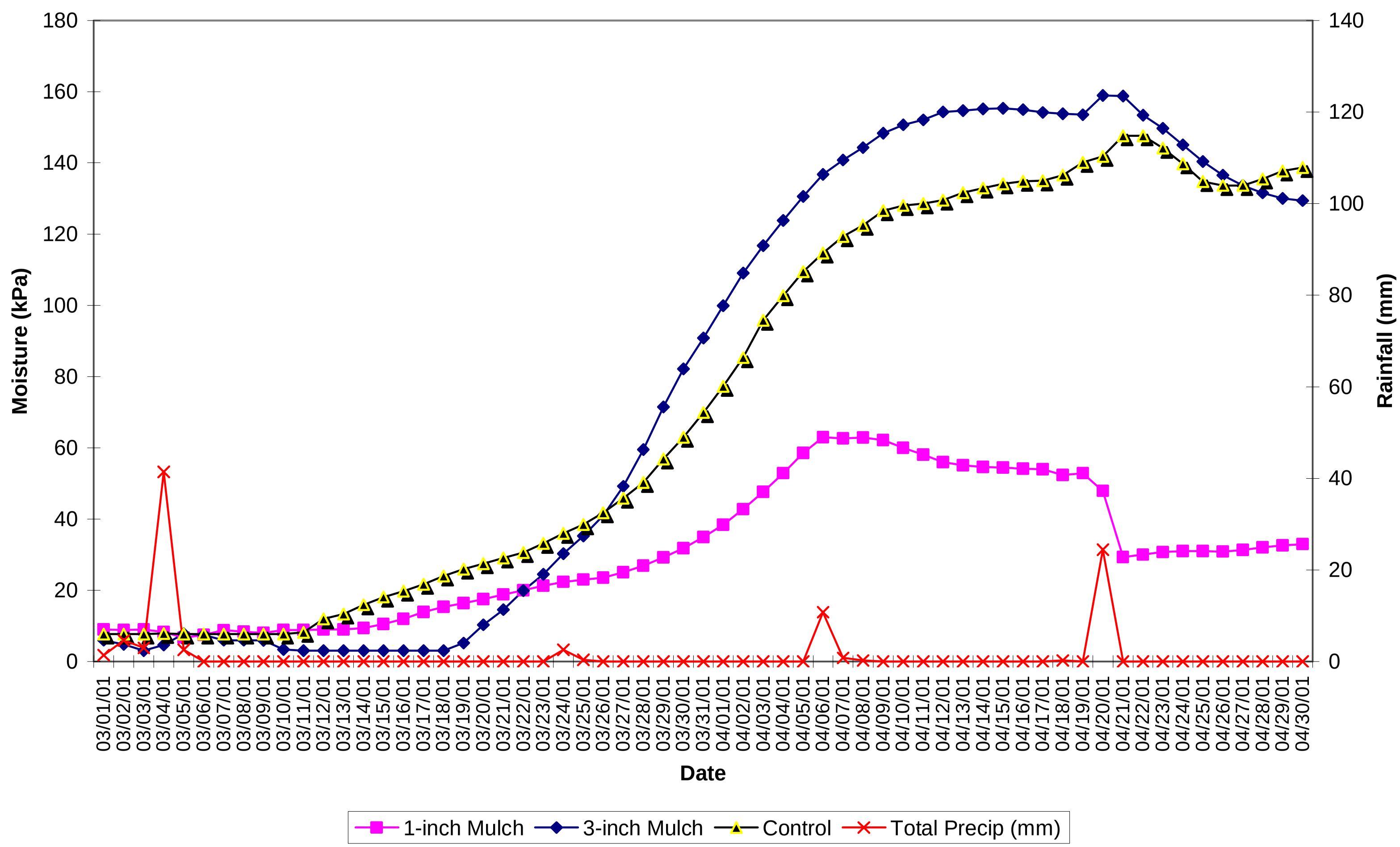
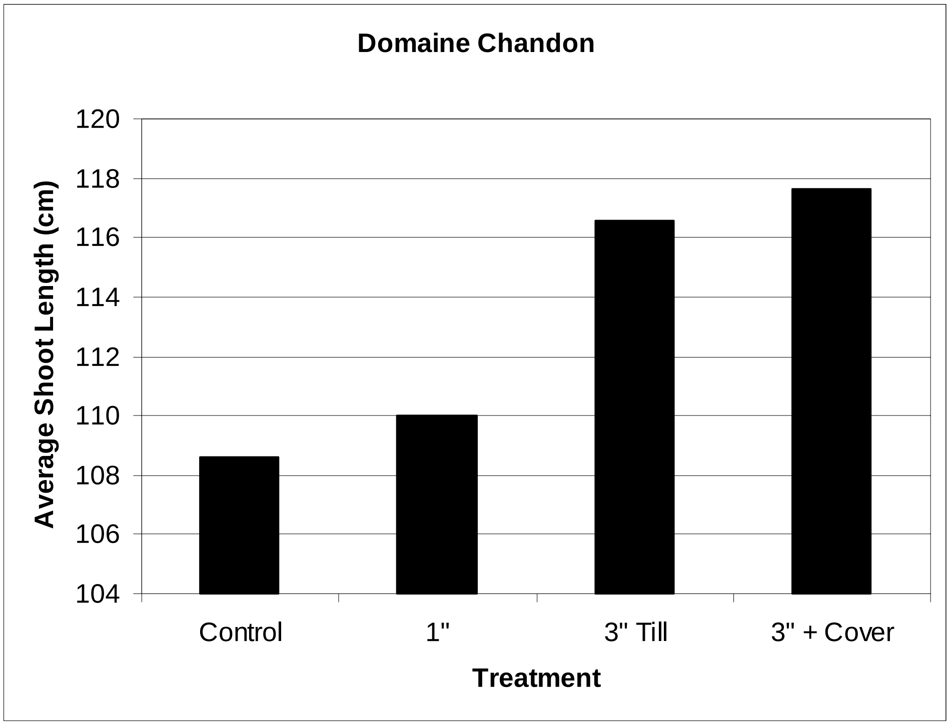


Figure 5: Shoot Lengths, Domaine Chandon and Hanzell



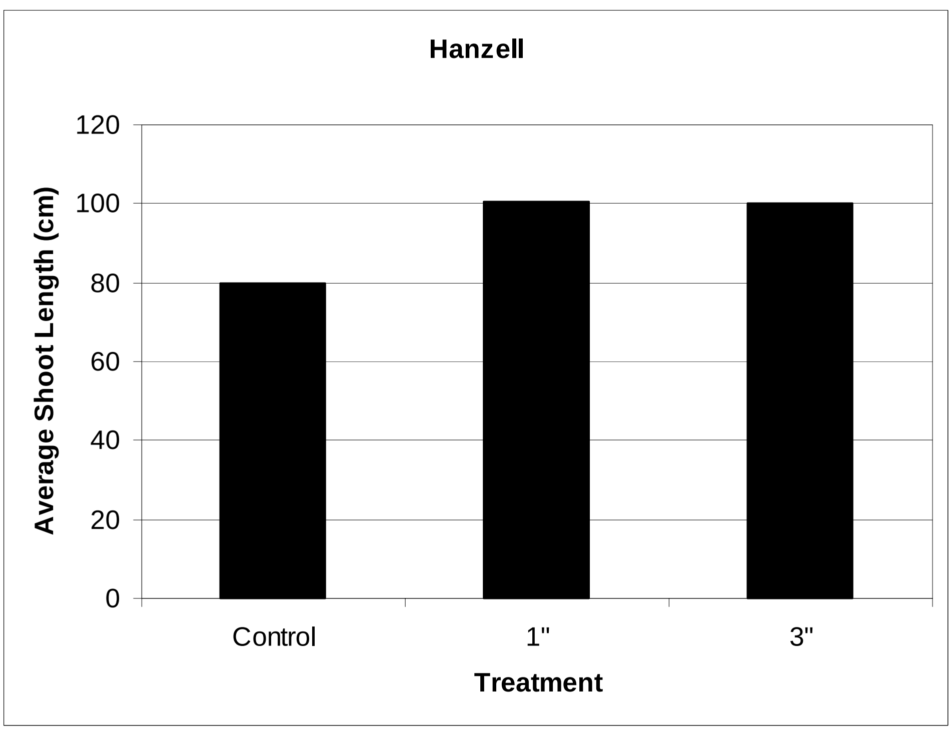


Figure 6: Vine Data, Domaine Chandon—8/6/01