**INFLUENCE OF VINEYARD FLOOR MANAGEMENT
PRACTICES ON SOIL AGGREGATE STABILITY,
TOTAL SOIL CARBON AND GRAPEVINE YIELD**

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By
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ABSTRACT

Influence of vineyard floor management practices on soil aggregate stability, total soil carbon and grapevine yield.

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Soil aggregates provide pore spaces of various sizes supplying water, gases and nutrients to plant roots and microorganisms, and facilitate moisture retention and availability. Soil aggregate stability is indicative of soil biological and structural health, and is increased by soil carbon derived from plant roots and the soil microbial biomass. Aggregate stability and soil carbon can be enhanced by increasing organic matter through compost additions or by planting cover crops. Additionally, aggregate stability is enhanced by arbuscular mycorrhizal fungi (AMF) that form a symbiotic association with plant roots, and consolidate soil particles into aggregates through hyphal networks and through the production of glomalin, binding soil particles together. The use of herbicides decreases soil carbon as it removes vegetation and the microorganisms associated with it. Soils having poor aggregate stability slake and disperse into primary soil particles becoming dense and subject to erosion when exposed to heavy rains. The use of herbicides amplifies this risk as it removes vegetation, leaving the soil bare, with nothing to absorb rainfall impact.

The effect of vineyard floor management practices on aggregate stability, soil carbon and grapevine fruit yield was studied at two vineyard sites located within the Estrella district of Paso Robles, CA. In late fall of 2008, treatments were applied to the vine line including an herbicide, an herbicide plus compost, a cover crop, a cover crop plus compost and a cover crop plus a fungal inoculant treatment. The control had no herbicides, compost, cover crop, or fungal inoculant applied to it. The cover crop treatments were applied at 30 lbs/ac consisting of a mixture of 20 % blanco brome (*Bromus hordeaceus*), 20 % Zorro fescue (*Vulpia myuros*), 30 % crimson clover (*Trifolium incarnatum*) and 30 % subterranean clover (*Trifolium subterraneum*). Commercially available compost was applied at a rate of five tons per acre. The fungal inoculant was applied at eight pounds per acre, consisting of the AMF: *Glomus intraradices*, *G. mosseae*, *G. aggregatum* and *G. etunicatum* each at 32 propagules/ cc. Samples were collected in the spring of 2009 and the winter of 2010.

Percent carbon was significantly higher in the areas where compost applications were received ($P=0.014$). Cover crops did not significantly increase the level of carbon in the soil ($P=0.253$). Compost and cover crops significantly increased the amount of > 4.0 mm soil aggregates ($P=0.004$ for compost and $P=0.027$ for cover crops). Herbicide treatments significantly reduced the amount of > 4.0 mm aggregates ($P=0.028$). Fungal inoculants had no effect on > 4.0 mm aggregate stability ($P=0.361$). Compost significantly increased mean fruit weight ($P=0.041$). These results suggest that the addition of compost and cover crops are an effective way of increasing > 4.0 mm aggregates and compost alone is an effective way to increase soil carbon and fruit yield.

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Introduction

Wine consumption has been steadily rising for decades. Records stretching back 80 years show wine consumption has increased from 0.26 gallons per individual per year in 1934 to 2.50 gallons per individual in 2009. Between those years, gallons of wine produced increased from 33 million to 767 million gallons (WI, 2010). Consequently, vineyards have replaced crops of less demand or value and have been established on virgin land or land that has been fallow for years. Inevitably, more pressure to the environment results from greater use of resources. More recently, organic and sustainable wine grape production has captured the interest of the consumer, motivating many farmers to alter their conventional practices to more environmentally friendly techniques. A common cultural practice in vineyard management is to keep the area under the vines (the vine-line) free of weeds, leaving the ground bare. This is achieved by the use of herbicides. As the consumer demands more ecologically friendly practices, the farmer is faced with the question of how to farm using no, or reduced herbicides. The impacts of herbicides on human and environmental health are highly controversial. Preemergent herbicides have been shown to persist in the soil long after their application. During storm events, preemergent herbicides runoff through overland flow into ditches affecting the watershed (Louchart et al., 2001). As regulated groundwater protection areas have been adopted, farmers have relied on repeated applications of the postemergent herbicide, glyphosate, as an alternative. Although postemergent herbicides pose less of a threat to the contamination of water sources, several weeds have developed

glyphosate resistance, becoming more prevalent and more of a pest (Hembree, 2007). Conversely, as herbicide use is reduced, plant biomass and diversity increase. In turn, the duration of root activity during the growing season increases, providing more diverse, higher quality residues that are returned to the soil (Franco-Vizcaino, 1997).

Another impact of herbicides is the degradation of soil structure caused by having bare soil. Raindrop and irrigation splash on bare soil causes soil aggregates to disperse, often forming a soil crust which inhibits water infiltration, resulting in soil erosion and water runoff (Morin and Benyamini, 1977). Additionally, bare soils contain less organic carbon than vegetated soils, decreasing the food supply for microorganisms. The loss of cover resulting from herbicide applications impacts AMF associated with their roots, ultimately decreasing mycorrhizal colonization (Baumgartner et al., 2005). Consequently, the contribution of soil microorganisms to enhanced aggregate stability declines.

Objective/Hypothesis

The objective of this study was to determine if vineyard floor management practices could alter soil aggregate stability and soil carbon, and whether those practices affected grape yield. My hypothesis was that the fungal inoculant plus cover crop treatment would have the greatest positive influence on aggregate stability as it contributes to soil particle binding through increased soil carbon from cover crops and additional binding from fungal hyphae and glomalin. I expected the other treatments' influence on soil aggregate stability via the amount of carbon they contribute to the

soil to be in the following order: cover crop plus compost > cover crop > compost plus herbicide > control > herbicide. I also expected that increased vegetative cover from the cover crops would decrease grape yield as it competes with the vines for water and nutrients.

Literature Review

Why Aggregate Stability Matters

Soil aggregates form when soil particles (sand, silt and clay) bind to each other more strongly than to adjacent particles. Soil aggregate stability is a measure of the persistence of soil aggregates to maintain their structural integrity under a disruptive force. Soil texture and organic matter content largely influence aggregate stability (Le Bissonnais, 1996). Soil aggregation provides pore spaces of various sizes supplying water, gases and nutrients to plant roots and microorganisms (larger pores), and facilitating moisture retention and availability (smaller pores).

Soil aggregates provide an ideal habitat for soil microorganisms, enabling free movement of gases and moisture and by reserving sources of carbon from which they feed. Many benefits arise through harboring microorganisms. One such benefit is the breakdown of organic matter in the soil, recycling nutrients, essential for plant growth. Certain bacteria and cyanobacteria act as biofertilizers, converting plant unavailable nutrients like nitrogen, sulfur, phosphorus, iron and manganese, to plant available forms. Mycorrhizal fungi form symbiotic associations with plant roots, mining for and providing nutrients to the roots of the plant in exchange for plant carbon. Additionally, some microorganisms act as phytostimulators, producing enzymes which are antagonistic to pathogenic fungi and bacteria, as well as producing phytohormones which stimulate plant growth (Chebotar et al., 2009).

Soil aggregate stability is indicative of soil biological and structural health. It is influenced by many variables, most centered on carbon, which may be fostered to enhance the sustainability of a site. When doing so, a symbiotic web is formed, whereby the productivity of one component enhances the productivity of other components. The main components in this web in an agricultural setting include soil microorganisms, primarily bacteria and AMF, and organic matter sources derived from compost additions and through the incorporation of cover crops. Following is an example of how to conceptualize this. A soil has good aggregate stability and water readily infiltrates into the soil during heavy rains, reducing the loss of water and nutrients to erosion. The plant grows well because it has not lost vital nutrients and water has entered the soil, supplying its demand. The more the plant grows the more organic matter it produces for microorganisms to feed on. The more microorganisms in the soil, the more nutrients provided to the plant, and the better the plant grows. Most importantly, as microbial populations increase in the soil, aggregate stability increases. In this thesis, I will describe how management techniques aimed at increasing organic carbon and soil microbial populations are quintessential in improving aggregate stability, along with the numerous benefits to vineyard health and sustainability.

Factors Influencing Soil Aggregate Stability

Several factors influence aggregate stability. The clay minerals calcium, iron, magnesium and aluminum form organic matter-clay bridges, stabilizing aggregates. Conversely, high levels of exchangeable sodium cause soil particles to disperse,

disrupting aggregate stability. Soils containing higher clay tend to have higher aggregate stability than coarser soils. Increasing organic matter promotes biological activity in the soil increasing aggregate stability. This can be achieved through the addition of compost or by planting cover crops. Compost stimulates microbial activity that enhances hydrophobicity and inter-particle cohesion, increasing aggregate stability by decreasing the rate of aggregate wetting (Lynch and Bragg, 1985). Cover crops contribute root-deposited photosynthate, which is an important carbon source for microorganisms (Butler et al., 2003). As microorganisms decompose organic matter, they excrete substances which glue soil particles together. Additionally, AMF form a symbiotic relationship with plant roots and consolidate soil particles into aggregates through hyphal networks and through the production of glomalin, binding soil particles together.

Soil Organic Carbon

The majority of C in most soils is held as soil organic carbon (SOC). SOC is the C occurring in soils comprising plant roots, tissue from plants and animals and the soil microbial biomass. The SOC constituents include sugars, amino acids, lipids, humic substances and glomalin. Several factors influence the amount of SOC. These include vegetation, microorganisms, climate, soil texture and land use practices. Vegetation provides a carbon source through decomposition of fallen plant debris and sloughing off roots and indirectly through housing microorganisms in the rhizosphere, whereby microorganisms secrete organic sugars. Climate influences SOC where warm temperatures with moderate to high amounts of rainfall increase the rate of

decomposition and therefore decrease the turnover time of C in the soil. Soil texture influences SOC as soils higher in clay trap organic matter between clay particles, making them inaccessible to microorganisms, halting microbial decomposition (Milne and Heimsath, 2008).

Tillage is a practice used in vineyard floor management. Tillage breaks up soil aggregates, exposing entrapped C to microbial breakdown. This often leads to a significant loss of SOC to CO₂ through microbial respiration. Additionally, untilled soils have greater AMF populations and contain higher amounts of macro-aggregates associated with fungal C byproducts as compared to tilled soils (Simpson et al., 2004). The use of herbicides indirectly decreases SOC as it removes vegetation and all the sources of C that are derived from it.

Additionally, plant type influences percent carbon in soil. In a study looking at aggregate stability and total carbon in response to land use (sun coffee, shade coffee and pasture), pasture soils incorporated significantly more carbon into aggregates than the shade or sun grown coffee (Hoyos and Comerford, 2005). This is likely a result of the fibrous roots of pasture plants increasing plant biomass belowground. Soil carbon is also affected by land management practices. In a study looking at chemical usage and plant biological diversity in relation to soil carbon, it was shown that decreased chemical usage increased biological diversity, resulting in increased total soil carbon (Sanchez et al., 2004).

Arbuscular Mycorrhizal Fungi

Arbuscular mycorrhizal fungi colonize the roots of grapevines, exchanging fungal absorbed mineral nutrients for carbohydrates from the host. AMF increase soil aggregate stability through their hyphae consolidating soil particles together and through the production of glomalin, gluing soil particles together. Grapevine nutrition and growth is often enhanced by these interactions. Many vineyard soils experience declining populations of mycorrhizal fungi due to tillage and herbicide use. This often decreases plant growth. In these instances, the addition of fungal inoculums proves to be highly beneficial. Inoculated grapevines have more highly branched roots compared to non-inoculated grapevines (Schellenbaum et al., 1991), providing them greater access to resources. Additionally, most cover crops host AMF and the growth of cover crops on the vine-line may increase AMF populations (Ingels et al., 2005).

The benefits of AMF to grapevines are well supported, however, not all AMF are equally beneficial and the degree of AMF interactions is plant species specific. In a grapevine rootstock trial using native and non-native AMF, a significant enhancement in growth occurred in inoculated vines of all rootstocks. However, the amount of growth increase in inoculated vines over non-AMF control vines varied with individual rootstocks, ranging from the lowest growth increase of 69 % to the highest growth of 220 %. In addition, the greatest growth increase occurred under vines inoculated with non-native fungi (Linderman and Davis, 2001). Conversely, a study comparing the effects of non-native and native fungi on a leguminous shrub, *Anthyllis cytisoide*, found significantly higher survival rates and twice the growth of

shrubs inoculated with the native fungi compared to the non-native fungi (Requena and Perez-Solis, 2001).

Further, cyclical benefits of incorporating cover crops in conjunction with AMF in vineyards are not well understood. However, Cheng and Baumgartner, 2004 have demonstrated that complex mycorrhizal associations interconnect the cover crop and grapevine roots. Through such a network, nutrients are transported between the same or different plant species. In a greenhouse experiment, AMF-mediated nitrogen transfer from two vineyard cover crops (a grass and a legume) interconnected to grapevines via fungal hyphae was examined. ^{15}N treatments were applied to the cover crops and monitored for ^{15}N transfer to grapevines. They found ^{15}N increased significantly in grapevine shoots under both cover crop treatments demonstrating an interconnection between the two species via AMF.

Compost

Soil aggregate stability is positively correlated with total soil organic carbon (Tisdall and Oades, 1980). The application of compost to the soil increases organic carbon content (Tambone et al., 2007) and thereby increases aggregate stability. In addition, soil organic matter improves porosity, water holding capacity (Oades 1984) and introduces a variety of microorganisms that may assist the cycling of nutrients and serve as a food source for them (CIWMB-EPA, 2001).

The benefits from compost additions on aggregate stability are dependent on location and the presence of microorganisms. In a study conducted by Caravaca et al.,

2002, rhizosphere and non-rhizosphere aggregate stability of two afforested semi-arid plant species treated with a composted residue were examined. For both species, rhizosphere aggregate stability was significantly higher than non-rhizosphere soil. These findings were likely connected to the higher presence of microorganisms in the rhizosphere soil. Annabi et al., 2004 found that after the first compost application, aggregate stability increased as a result of enhanced microbial activity stimulated by the compost.

Cover Crops

The advantages of incorporating cover crops in land management are numerous. Some of the most pronounced advantages include less potential for loss of soil and nutrients to erosion, increased carbon sequestration and greater aggregate stability. When soils are bare, surface crusts may develop from the breakdown and reorganization of aggregates through raindrop or irrigation impact. Surface crusts may result in reduced water infiltration and erosion. Incorporating cover crops in vineyards reduces these effects (Boiffin and Monnier 1986). The roots of cover crops further enhance soil structure through their branching root system consolidating soil particles into aggregates (Rogers et al., 1948) and by releasing organic C. The organic C released by plant roots enhances soil structure by stimulating microbial populations whose excrements glue soil particles together (Jastrow et al., 1998).

Cover crops and plant residues on the soil surface improve water retention by reducing water loss to evaporation (Skroch and Shribbs 1986) and increasing water

infiltration, leaching away salts from the root zone. Cover crops benefit the soil ecosystem in many ways; however, competition with the money crop may pose problems. In a study conducted by Walsh et al., 1996, impact of orchard floor management systems on aggregate stability and volumetric water content was evaluated. Management practices included cultivation, additions of composted manure mulch, straw mulch, geotextile mulch, grass cover crops, and a cover crop mixture of lupin and wild carrot. Aggregate stability was greatest in the cover crops treatments. However, mean volumetric water contents were lowest under cover crop treatments. Mean volumetric water content was greatest under geotextile and straw mulches and correspondingly had increased tree growth. The benefits of having cover crops may potentially be counteracted when grown in dry climates during drought years as the cover crops consume the rainfall that would have been held in the soil profile, leaving insufficient water for the grapevines once the growing season begins. In these instances, competition for water may be significant, whereby additional applications of water of limited supply may be required. Also, competition between cover crops and the vine for nutrients may be an issue where soil fertility is poor.

Carbon Sequestration

Atmospheric carbon has increased by 30 % in the last 150 years, posing a threat to rising global temperatures and the resulting severe weather events (ESA, 2008). Carbon sequestration has great potential for reducing the buildup of greenhouse gasses in the atmosphere. Soils contain approximately 75 % of the terrestrial carbon pool and it is estimated that they can sequester around 20 Pg carbon

in 25 years, which is more than 10 % of the anthropogenic emissions (FAO, 2011).

The vine-line of vineyards is typically sprayed with herbicides leaving the ground bare. This area usually represents 30 % to 50 % of the vineyard depending on row spacing and farmer practices. With thousands of acres of vineyards in production, incorporating cover crops in the vine-line has great potential for sequestering carbon.

Materials and Methods

Site Preparation

Two sites located within the Estrella district of Paso Robles, California, coordinates and elevation, 35°40'20.15"N, 120°40'37.01"W, 764 ft. (Buena Vista Vineyard-refer to Figure 1) and 35°44'15.99"N, 120°40'42.67"W, 720 ft. (Galbraith Vineyard-refer to Figure 1) were studied. Both sites were mapped as the Arbuckle-San Ysidro complex, 2 to 9% slope. These soils' parent material is alluvium derived from mixed rock sources on a stream terrace landform. The drainage class was well drained to moderately well drained and available water capacity was low to moderate (NRCS-WSS). Both sites had soil textures of loam and sandy clay loam.

Vineyards

Buena Vista

Galbraith

Figure 1. Aerial photos of Buena Vista and Galbraith sites.

Vineyards were managed according to J.Lohr Vineyards and Wines Best Management Practices. The Buena Vista vineyard encompassed 1.3 acres of clone 400, Petite Verdot vines on 110R rootstock. The vines had 8 x 7 ft. spacing, an East/West row orientation and were pruned to 16 spurs per vine. Vines were thinned to 2-3 canes per spur and canes were lifted on the north side. The Galbraith vineyard encompassed 2.1 acres of clone 337, cabernet sauvignon on 1103P rootstock. The vines had 8 x 7 ft. spacing, an East/West row orientation and were pruned to 16 spurs per vine. Vines were thinned to 2-3 canes per spur and canes were sprawled and hedged once the canopy invaded the row middles.

On December 13, 2008, the vegetation residing along the vine-line was removed using a Pelenc Sunflower. Five treatments and a control, replicated three times, were established at each site. Each treatment resided in one half of a vineyard row, two treatments per row, making nine contiguous rows per site. A buffer row was placed on either side of the nine rows, managed the same as the experimental rows.

The following treatments were applied to the vine-line of the soil:

- 1.) Herbicide
- 2.) Herbicide plus compost
- 3.) Cover crop
- 4.) Cover crop plus compost
- 5.) Cover crop plus fungal inoculants
- 6.) Control

**Buena Vista
PV (400/110R)**

East

	<u>Rep 1</u>			<u>Rep 2</u>			<u>Rep 3</u>	
Row 1	Row 2	Row 3	Row 4	Row 5	Row 6	Row 7	Row 8	Row 9
Herbicide	Herbicide and Compost	Compost and cover crop	Control	Cover Crop	Inoculant and cover crop	Cover crop	Control	Inoculant and cover crop
Inoculant and cover Crop	Control	Cover crop	Herbicide and Compost	Compost and cover Crop	Herbicide	Compost and cover crop	Herbicide and Compost	Herbicide

West

Figure 2. Schematic diagram of the layout of treatments at Buena Vista Site.

**Galbraith
CS (337/1103P)**

East

	<u>Rep 1</u>			<u>Rep 2</u>			<u>Rep 3</u>	
Row 1	Row 2	Row 3	Row 4	Row 5	Row 6	Row 7	Row 8	Row 9
Herbicide And Compost	Compost and cover crop	Herbicide	Cover crop	Control	Inoculant and cover crop	Herbicide	Herbicide and Compost	Compost and cover crop
Control	Cover crop	Inoculant and cover crop	Compost and cover crop	Herbicide and Compost	Herbicide	Inoculant and cover crop	Control	Cover crop

West

Figure 3. Schematic diagram of the layout of treatments at Galbraith site.

The cover crop mixture purchased from S & S Seed Company consisted of 20% bland brome (*Bromus hordeaceus*), 20% zorro fescue (*Vulpia myuros*), 30% crimson clover (*Trifolium incarnatum*) and 30% subterranean clover (*Trifolium subterraneum*). The cover crops were sown at a rate of 30 lbs per acre on December 16th, 2008, using an Earth Way® EV-N-SPRED 7350 SU Residential Drop Spreader. The seeder width was 20 inches wide and half of the vine-line width was 18 inches wide. To accommodate for this, one end of the seeder was taped off two inches so the correct vine-line width received seeds. The seeder dropped the seeds directly downward. The holes that the seeds were released from could be adjusted to increase or decrease the rate at which the seeds were sown and did not prevent any of the seed types from being applied. To calibrate the seeding rate a tarp was placed on the ground and the seeder was pushed for 10 feet. Afterward the seeds on the tarp were collected and weighed. This was repeated and the seeder openings were adjusted to achieve an application rate of 30 lbs/acre. The following calculation was derived to adjust the seeder to the appropriate application rate.

Grams of seed per 15 ft² = lbs of seed/(10 ft distance covered x 1.5 ft vine-line width) = lbs of seed/15 ft²

15 ft² x 30 lbs of seed/ac x 28.349 g/oz x 16 oz/lb x ac/43,560 ft²

= 4.68 g of seed/15 ft²

Once the seeder was calibrated to the correct rate the seeds were sown by pushing the seeder down one side of the row as close to the vine as possible then continuing this on the other side of the row.

Compost was applied at a rate of five tons per acre on December 18th, 2008, using a conveyor belt spreader pulled by tractor. Following these applications, compost and cover crop treatments were incorporated approximately two centimeters into the soil using a rake.

MycoApply® Micronized Endo (product of Mycorrhizal Applications, Inc.) was applied to the cover crops on March 4, 2009 at a rate of eight lbs per acre using a SP1 Swissmex backpack sprayer with a flat spray nozzle. The cover crops were approximately two to four inches tall when they were sprayed. The fungal inoculant purchased from Myco Apply, consisted of the AMF: *Glomus intraradices*, *G. mosseae*, *G. aggregatum* and *G. etunicatum* each at 32 propagules/ cc. The inoculant was diluted to two tablespoons inoculant per gallon of water. The following calculation was derived to achieve a consistent application rate while using a backpack sprayer.

Two tablespoons inoculants = 25 grams

Square foot area = 91 (vines) x 1.5 ft (half the width of the vine-line) x 7 ft (space between the vines) = **955.5 ft²**

Gallons of inoculant solution per half treatment (while walking sprayed half the vine-line and on the way back sprayed the other half) = $955.5 \text{ ft}^2 \times \text{acre}/43,560 \text{ ft}^2 \times 8 \text{ lbs inoculant/acre} \times 453 \text{ g/lb} \times 2 \text{ tbsp inoculant}/25 \text{ g} \times \text{gal H}_2\text{O}/2 \text{ tbsp inoculant}$

= 3.18 gal inoculant solution/half treatment

The time it took to fill 1 quart of inoculant solution while continually pumping the backpack sprayer to maintain even pressure was calculated.

Table 1. Readings for the amount of time to fill 1 quart of inoculant solution.

Quart replication	Seconds
1	90
2	88
3	91
4	87
5	92
6	89
7	85
8	86
Seconds	708 sec/8 reps = 88.5 sec/quart

Seconds to spray one gallon of inoculant solution = $88.5 \text{ sec/qt inoculant solution} \times 4 \text{ quarts inoculant solution/gal inoculant solution} = 354 \text{ seconds}$

Seconds to spray half of treatment = $354 \text{ sec/gal inoculant mixture} \times 3.18 \text{ gal inoculant solution/half treatment} = 1,125.72 \text{ sec/half treatment}$

Seconds per vine = $1,125.72 \text{ sec/half treatment} \times \text{half treatment}/91 \text{ vines} = 12.37 \text{ sec/vine}$

Two tablespoons of the fungal inoculant were added to one gallon of water in a bucket and vigorously stirred. Afterwards the solution was placed into the backpack sprayer. The inoculant solution was applied to the appropriate sites by walking down one side of the row, spraying only one side of the vine-line (half treatment) and next was continued on the other side of the vine-line. The sprayer was pumped continuously during the application at a rate of 12 seconds per vine using a stopwatch to ensure the pace. After spraying every third row, the time it took to fill one quart of water while continuously pumping the sprayer was calculated, as done initially, to check if the sprayer was working at a consistent rate.

Table 2. Readings to check if the sprayer was working at a consistent rate.

Buena Vista	1	92
Buena Vista	2	90
Buena Vista	3	88
Galbraith	1	87
Galbraith	2	89
Galbraith	3	93
Seconds	539 sec/6 reps = 89.83 sec/quart	

After the inoculant solution was applied, each site was overhead irrigated for 2 hours to ensure the fungi penetrated into the upper inches of the soil and made contact with the cover crop roots.

The herbicide Honcho Ultra was applied in early March and late October of 2009, as was standard for neighboring blocks. It was diluted to eight oz per three gallons mixed with an herbicide enhancer at a rate of 1 quart per 100 gallons of water. The same backpack sprayer used for the fungal inoculant was used for this application.

The herbicide was applied to the appropriate sites by walking down one side of the row, spraying only the side of the vine-line nearest to the applicator and was then continued on the other side of the vine-line.

The control treatments had no herbicide, fungal inoculant, compost or cover crops applied to it.

Sample Collection

Soil Sampling For Organic C

On April 27, 2009 and January 5, 2010, samples were collected at 0 – 4 inch depth every five vines in between emitters using a soil probe. The soil cores were combined into a composite to make one sample per treatment. Collecting samples from under the emitters was avoided because nutrients and salts accumulate there and also, the roots of the vines are denser under emitters; which may have had a consequential effect of the vine roots on the treatments. Before inserting the soil probe into the soil, surface plant debris were gently scraped away. Samples were transferred to a cooler and then stored in a refrigerator until analysis.

Sampling for Soil Aggregate Stability

Pint-sized Dixie cups were filled with water and frozen and then placed in the field at the locations where the aggregate stability samples were to be collected. These ice cubes were placed in the field on May 4, 2009, a day before the sampling was to take place to facilitate the collection of intact soil samples. Prior to this application

the soils were dry and crumbly, diminishing the integrity of the soil upon collection. The second set of samples was collected on January 9, 2010. The soil was moist and did not require the application of ice cubes. Aggregate stability samples were also extracted in between the emitters and on the middle of the vine-line. Collecting samples from under the emitters was avoided, due to the splash from the drip causing aggregates to disassemble and smaller soil particles to move downward leaving coarser soil particles at the surface. Samples were extracted from the middle of the vine-line to avoid any disturbance caused by foot traffic along the outer edges. The drip line and the wall of vines would act as a barrier against foot traffic and equipment. Each sample site was flagged to ensure samples would not be collected again from that particular location to avoid the disturbance caused to the soil from the sampling process.

Three samples per treatment, per replication, were collected and combined into a composite for analysis. Each sample was collected one-third of a treatment row length apart. A garden trowel was used to loosen the soil to a 4 inch depth, working in a circular pattern the size of the circumference of the Dixie cup brim. A narrow shovel was then inserted below the loosened soil and lifted to the surface and discarded. Then the trowel was inserted 4 inches down into the soil, approximately 2 inches from the perimeter of the hole and angled inward, whereby the soil was collected. The outer parts of the soil were gently brushed away to the left and right sides and the remaining soil in the middle was kept as the sample. Each sample was

gently placed into a plastic container and transferred to an ice chest and then stored in a refrigerator until analysis.

Laboratory Measurements

Determination of Soil C Using CNS Combustion Analyzer

On May 7, 2009 and January 28, 2010 soils were mixed by shaking the bag the soil was contained in and then 1,000 g of the soil was placed in a paper boat to air dry. On May 11, 2009 and February 2, 2010, thirty six mortars and pestles, one for each sample, were washed with a sponge and tap water, then rinsed with DI water and placed in an oven for 4 hours to dry. One teaspoon of the air dried soil was placed in a mortar and pestle and ground to a powder to homogenize it. Prior to this, organic debris, roots and rocks > 2 mm were removed through sieving and tweezers. Approximately 1,000 mg of the powder was weighed and placed in a metal crucible to be analyzed by a VarioMax CNS Combustion Analyzer.

Aggregate Stability Moisture Content

On May 21, 2009 and January 18, 2010, samples were air-dried in their collection containers with the lids removed in a hood for 36 hours and then approximately 35 g sub-sample of the soil was weighed. The sub-samples were then oven-dried at 105°C for 24 hours and then weighed to determine percent soil moisture.

Aggregate Stability

Samples were tested for aggregate stability for size classes > 4.0 mm, 2.0 – 4.0 mm, 1.19 – 2.0 mm, 0.5 – 1.19 mm, and 0.25 – 0.5 mm. The wet sieving method was applied (Kemper and Rosenau, 1986 and Nimmo and Perkins, 2002) with the following modifications. The three individual samples collected per treatment per replication were composited before analysis. The entire composited sample was weighed and gently placed on the top of five sieves sitting in a water can at the upward most position of the apparatus. Distilled water was filled approximately 1 mm above the base of the top sieve allowing the sample to pre-wet by DI water wicking up the aggregates. After pre-wetting, DI water was added to the can until the aggregates were submerged in water.

Particle Size Analysis

Soil texture was determined for each treatment of every replication using the Bouyoucus Hydrometer Method (Bouyoucos, 1962). Samples remaining from the organic C analysis were used for this.

Field Measurements

Grape Yield

Before each site was to be harvested, cluster samples were collected randomly in each treatment by collecting all the fruit from the first spur at the first stop, then approximately 5 vines down the row, all the fruit was collected from the second spur

at the second stop and so on. This was done to ensure even sugar distribution as sugar content changes upon spur location. This was repeated until half of a five gallon bucket was collected. After collection, samples were tested for brix.

Three contiguous vines per replication, located in the middles of the treatment's rows, were established to determine fruit yield per vine. At peak berry weight of 24 brix as determined by field sugar samples, all the clusters from the established vines were harvested and weighed.

Additional Vineyard Management

Fertilization

Throughout the growing season, calcium ammonium nitrate solution (CAN-17) and potassium thiosulphate fertilizer (KTS) were applied through fertigation at varying rates at both sites following manufacturer's recommendation (Tables 3 and 4).

Table 3. Fertilizers used through the duration of experiment.

Block	Date Applied	Product	Gal/acre
Buena Vista	5/6/2009	CAN-17	10
	7/15/2009	KTS	6
	Post-harvest	KTS	10
Galbraith	5/8/2009	CAN-17	10
	7/13/2009	KTS	5
	11/7/2009	KTS	10

Table 4. Nutrient compositions of fertilizers used through the duration of experiment.

<u>Can-17—Calcium Ammonium Nitrate Solution</u>	
Total Nitrogen.....	17.0%
5.4 % Ammoniacal Nitrogen	
11.6 % Nitrate Nitrogen	
Calcium derived from Ammonium Nitrate and Calcium Nitrate.....	8.8 %
<u>KTS—Potassium Thiosulfate Fertilizer</u>	
Soluble Potash (K ₂ O).....	25 %
Total Sulfur.....	17 %
17.0 % Combined Sulfur	
0 % Free Sulfur	

Mowing/herbicide application

In June of 2009, vegetation on the vine-line was mowed to approximately 1 inch height from the ground using a weed eater. The vegetation re-grew as irrigation began, necessitating the use of herbicides to avoid competition between the cover crop and the vines during canopy growth and fruit production. The same herbicide and procedure was used as was for the herbicide treatments.

Statistical Analysis

The statistical method used for data analyses for this project was Minitab 16, analysis of covariance (a general linear model). All tests were performed at a 0.05 confidence level. Pairwise comparisons were used instead of comparisons with a control.

Results

Data from Buena Vista and Galbraith blocks were combined in the following analyses. Block position and row position within each block were factored in to indicate within-site variability. Data from the first collection in the Spring of 2009 was insignificant and will not be presented.

Treatment Comparisons

The mean percentage of stable aggregates >4.0 mm in diameter were significantly different among treatments using a basic statistical model encompassing treatment as the only component ($P=0.000$; appendix C, analysis H). The compost plus cover crop treatment had greater percentages of >4.0 mm stable aggregates compared to the herbicide plus compost and herbicide treatments ($P=0.0001$ for compost plus cover crop versus herbicide plus compost and $P=0.0000$ for compost plus cover crop versus herbicide treatment; appendix C, analysis H).

Figure 4. Mean percentage of >4.0 mm stable aggregates per sample mass of each treatment.

Mean percent carbon was not significantly different between treatments when using a basic statistical model encompassing treatment as the only component ($P=0.404$; appendix C, analysis I).

Figure 5. Mean percent carbon for each treatment.

As different treatments shared some of the same components, for example cover crop and cover crop + compost, analyses of the different treatments were separated, as follows; to narrow in which components of the treatments were significant.

Model Components

Block	15-4 (Buena Vista), 17-2 (Galbraith)
Block position (Block)	Middle, North, South
Row position (Block)	East, West
Cover crop, no cover crop	
Fungal inoculant, no fungal inoculant	
Herbicide, no herbicide	
Compost, no compost	

Soil Carbon

Using the complete model, encompassing all model components, percent carbon was significantly higher in the areas where compost applications were received compared to non-compost treatments ($P=0.014$; appendix C, analysis A). Cover crops did not significantly increase the level of carbon in the soil ($P=0.253$, appendix C, analysis A). Percent carbon was variable within row positions of the blocks; the east side versus the west side of the row ($P=0.003$; appendix C, analysis A).

Figure 6. Mean percent soil carbon for compost treatments.

Aggregate Stability

Aggregate stability was not variable between treatments in relation to percentages of sand, silt and clay as soil texture was consistently similar between and within blocks (Appendix B).

>4.0 mm Stable Aggregates

Compost and cover crop treatments significantly increased the percentage of >4.0 mm stable aggregates compared to non-compost and non-cover crop treatments ($P=0.004$ for compost and $P=0.027$ for cover crop; appendix C, analysis B).

Figure 7. Percentage of >4.0 mm stable aggregates per sample mass for cover crop, no cover crop and compost, no compost treatments.

Herbicide treatments significantly reduced the percentage of >4.0 mm stable aggregates compared to non-herbicide treatments ($P=0.028$; appendix C, analysis B). Fungal inoculants had no effect on > 4.0 mm stable aggregates ($P=0.361$; appendix C, analysis B).

Figure 8. Mean percentage of >4.0 mm stable aggregates for herbicide and non-herbicide treatments.

Percent C ($P=0.007$; appendix C, analysis J) gave similar results for > 4.0 mm aggregates when substituted for compost and cover crops as model components, suggesting % C as a method of measuring > 4.0 mm aggregates.

2.0 mm – 4.0 mm Stable Aggregates

There was a significantly reduced percentage of 2.0-4.0 mm stable aggregates under cover crop treatments compared to non-cover crop treatments ($P=0.038$; appendix C, analysis C). Row position within the blocks, the east side versus the west side of the row, had variable percentages of stable aggregates in this size class ($P=0.012$; appendix C, analysis C).

Figure 9. Percentage of 2.0-4.0 mm stable aggregates for cover crop and non-cover crop treatments.

There was a significantly higher percentage of 2.0 – 4.0 mm stable aggregates under herbicide treatments compared to non-herbicide treatments when replacing cover crop and compost with % C in the model ($P=0.000$; appendix C, analysis K). Percent C was statistically significant ($P=0.000$, appendix C, analysis K), similarly representing the effect of having a cover crop on aggregate stability between 2.0-4.0 mm stable aggregates. Row position within the block, the east side versus the west side of the row, had variable percentages of 2.0-4.0 mm stable aggregates ($P=0.000$; appendix C, analysis K).

Figure 10. Mean percentage of 2.0-4.0 mm stable aggregates for herbicide and non-herbicide treatments.

< 2.0 mm Aggregates

The remaining aggregate size classes, 1.19 – 2.0 mm, 0.5 – 1.19 mm, and 0.25 – 0.5 mm had identical trends and statistically significant factors for all aggregate stability analyses except for one factor in the 0.5 – 1.19 mm aggregate size class. Stable aggregates in the 0.5 – 1.19 mm size class was not variable depending upon row position within the block, the east side versus the west side of the row ($P=0.145$; appendix C, analysis E), but was variable for the two other particle size classes ($P=0.005$ for 1.19-2.0 mm; appendix C, analysis D and $P=0.014$ for 0.25-0.5 mm; appendix D, analysis F).

11-a

11-b

11-c

Lines represent the averages of herbicide and non-herbicide treatments.

Figures 11-a, 11-b and 11-c. Mean percentages of <2.0 mm stable aggregates for herbicide and non-herbicide treatments.

All aggregate size classes < 2.0 mm had significantly higher percentage of stable aggregates under herbicide treatments compared to non-herbicide treatments (P=0.001 for 1.19 – 2.0 mm; appendix C, analysis D, P=0.000 for 0.5 – 1.19 mm; appendix C, analysis E and P=0.011 for 0.25 – 0.5 mm; appendix C, analysis F). Identical patterns were found when % C was substituted for compost and cover crop in the statistical model.

Fruit Weight

Figure 12. Mean fruit weight for compost and non-compost treatments.

Fruit weights were highly variable wherein block, Buena Vista versus Galbraith ($P=0.000$), block position, the north versus the middle versus the south side of the block ($P=0.021$) and row position, the east side versus the west side of the row ($P=0.000$) were significantly different. Compost significantly increased mean fruit weight compared to non-compost treatments ($P=0.041$). Neither cover crop treatments ($P=0.182$) nor herbicide treatments ($P=0.807$) significantly influenced fruit weight (Appendix C, analysis G).

Discussion

Percent Carbon

Cover crops increased > 4.0 mm soil aggregate stability, but did not significantly increase percent carbon in the soil. This is contrary to what one would expect given that increasing plant biomass should increase soil carbon. Total carbon was studied in three corn-soybean-wheat rotation treatments (Hao and Kravchenko, 2007). They found that total carbon was significantly higher, regardless of a whole range of soil textures or chemical inputs, in treatments having greater plant cover. One explanation for why the cover crops did not contribute to increasing amounts of soil carbon is the cover crop roots were readily degraded whereby much of the carbon that was contributed to the soil was lost as CO₂ through microbial respiration. In contrast, compost did increase percent carbon as well as > 4.0 mm aggregate stability. This is likely due to the more recalcitrant form of carbon found in compost, which would degrade more slowly. The slower decomposition rate of the compost could explain why it was shown to significantly increase percent carbon as it was still present in the soil at the time of sampling. Increases in soil carbon have been shown to be proportional to the amount of compost applied (Tambone et al., 2007).

Another possibility for why the cover crops did not increase soil carbon is the carbon measured was total carbon, which may take longer to build up and detect in soil given the short duration of this study. Measuring dilute acid-extractable polysaccharides, which is a measurement of labile soil carbon originating from soil

micro-organisms and cover crop exudates, may have better detected the less structurally complex forms of carbon produced by the cover crops. Increases in aggregate stability have been reported under short-term cover crops (Liu et al., 2005). The increased aggregate stability was highly correlated with increases in dilute acid-extractable polysaccharides produced by the cover crops. These data suggest that in the present study, carbon may have been contributed to the soil by the cover crops, but was not detected when measuring total carbon. The increase in aggregate stability may have been attributed to increases in dilute acid-extractable polysaccharides.

The lack of contribution of soil carbon from the cover crops could also have been due to the fact that winter annual cover crops were used. Consequently, there was insufficient time during this experiment for the effects of the cover crops and their contribution of carbon to be detected. The cover crops were planted in the winter of 2008 during a drought year where growth was slow, resulting in low plant biomass. Samples were collected the following spring leaving little time for C sequestration to occur. Had the samples been collected in the spring of 2010, the amount of carbon in the soil may have been altered. The additional time for plant growth during warmer weather and the accompanying microorganisms stimulated by the increased biomass and temperatures, likely would have increased soil carbon levels. Sequestered carbon has been found to be dependent on the age and growth characteristics of plants (Tolbert et al., 1998). Additionally, permanent cover crop treatments in a semi-arid vineyard increased soil organic C, particulate organic carbon, water stable carbon and water aggregate stability (Peregrina et al., 2010). Also, the above ground cover crop

biomass was not incorporated into the soil, breaking down slowly compared to below ground biomass where soil microorganisms are more active. Again, as more time is allowed, the above ground biomass would eventually become sequestered into the soil, thereby increasing soil carbon.

Aggregate Stability

Aggregate stability was not significantly affected by % sand, % silt and % clay. This finding was likely due to the homogeneity of the soils. All soils were situated close along the boundary between loam and sandy clay loam on the soil textural triangle. Counter to my hypothesis, the fungal inoculant treatments did not increase aggregate stability which is contrary to the majority of studies looking at the effect of AMF on aggregate stability. Higher mycorrhizal infections have corresponded to increased aggregate stability (Celik et al., 2004). A possible explanation for the lack of correlation between AMF and aggregate stability could have been due to poor root colonization. It is not fair to assume that the fungal inoculations were successful at increasing AMF populations since mycorrhizal populations were not measured.

One soil characteristic known to hinder the effectiveness and colonization of AMF on roots is high use of fertilizer inputs and high fertility soils (Karagiannidis and Nikolaou, 1999). Soil tests taken prior to experimental set-up indicated high fertility at both sites and of particular concern, high phosphorus fertility. Additionally, the sites were fertilized twice with potassium thiosulfate and once with calcium

ammonium nitrate adding to the sites already high fertility. High concentrations of phosphorous may effect root colonization by inhibiting mycorrhizal formation (Lambert and Baker, 1979). Also, phosphorus additions may decrease AMF colonization on roots as their relationship is no longer symbiotic due to the plant's lack of need for assistance from the fungi to supply its phosphorus demand and the fungi continuing to extract C from the plant (Hayman, 1982).

> 4.0 mm Aggregates

There were significantly higher amounts of > 4.0 mm aggregates in the cover crop and compost treatments which were likely a result of the additional organic matter added to the soil under these treatments. Similar findings have been reported (Celik et al., 2004). They found that management practices that increased organic matter sources under wheat, pepper and maize crops resulted in decreased bulk density and increased soil aggregation compared to management practices relying on inorganic fertilizers. Significant increases in water stable aggregates were found under two legume and four grass cover crop treatments compared to bare soils (Obi, 1999). After one application of compost, aggregate stability has been found to increase (Annabi et al., 2004). The increase in aggregate stability was related to increases in microbial activity stimulated by the compost. In the present study, it is not known whether the increase in > 4.0 mm aggregate stability under compost treatments was attributed to increased microbial activity since microbial populations were not measured.

The herbicide treatments had significantly fewer > 4.0 mm aggregates. This was likely due to the decreased contribution of organic matter to aggregate stability as the herbicides hindered vegetative growth. Additionally, herbicides may have decreased microbial populations associated with the once present vegetation, lowering aggregate binding exudates produced by soil microorganisms. The effects of herbicide treatments on soil microbial biodiversity in two vineyards with different temperatures and rainfall have been examined (Whitelaw-Weckert et al., 2004). All sites had significantly lower *Pseudomonas* spp., cellulolytic bacteria and fungi under herbicide treatments. The cooler climate with higher rainfall showed the greatest decreases when using herbicides with the pseudomonad population reduced by 97 %, the cellulolytic bacteria by 61 % and the fungal populations reduced by 39 %.

Percent C showed a similar a similar trend for > 4.0 mm aggregates when substituted for compost and cover crop in the model, suggesting % C as a method for predicting the amount of large aggregates in soil. This concept, however, is not supported by the finding that cover crops did not increase percent carbon but did increase > 4.0 mm aggregate stability. This suggests another interaction may be involved in association with cover crop roots and enhanced aggregate stability. Researchers have demonstrated that by increasing grasses on a site, aggregates become entangled in the roots, increasing aggregate stability (Oades, 1984). These data may explain why > 4.0 mm aggregate stability increased under cover crop treatments, but did not increase soil carbon.

2.0 mm – 4.0 mm Aggregates

There were significantly fewer aggregates between 2.0 – 4.0 mm with a cover crop present compared to non-cover crop treatments. This may have been a result of aggregates less than 4.0 mm in diameter already being present in the soil prior to experimental set-up. With the absence of cover crops, the smaller aggregates present at the initiation of the experiment did not form into larger aggregates, due to the absence of the cover crops and their influence on enhancing aggregation through root entanglement. Consequently, there would be greater amounts of smaller sized aggregates without the presence of cover crops. When using % C to predict 2.0 – 4.0 mm aggregate stability, herbicide treatments significantly increased aggregates of this size class. This is in agreement with the absence of cover crops increasing aggregate stability in 2.0 – 4.0 mm aggregates, because herbicides essentially remove vegetation.

< 2.0 mm Aggregates

The remaining aggregate size classes, 1.19 – 2.0 mm, 0.5 – 1.19 mm, and 0.25 – 0.5 mm had identical trends and statistically significant factors for all aggregate stability analyses except for one factor. In the 0.5 – 1.19 aggregate size class, row position of the blocks was not statistically significant, but was for 1.19 – 2.0 mm and 0.25 – 0.5 mm.

All aggregate size classes < 2.0 mm had significantly higher aggregate stability under herbicide treatments. This finding again may be viewed from the perspective that prior to experimental implementation, an amount of smaller aggregates was

already present in the soil. Due to an absence of vegetative cover, which stimulates microorganisms and enhances aggregation, the smaller aggregates did not form into larger aggregates and therefore were statistically detected as having greater amounts under herbicide treatments. Additionally, identical patterns were found when percent C was used to predict aggregate stability. With the absence of compost, soil C was not enriched and, therefore, enhanced aggregation was not promoted. Without the presence of the aggregating factors, compost and cover crops, the aggregates remained as they were prior to this study.

Fruit Weight

Fruit weight was highly variable, whereby block, block position and row position were significantly different from each other. It is not known the exact cause of why there was such yield variability in relation to location, but it may have been a result of uneven irrigation distribution. Often emitters become corroded; reducing the amount of water and nutrients through fertigation a plant receives. This has the potential to hinder vegetative growth and fruit yield. Soil texture plays a role in how well the soil holds onto water and nutrients and could be a factor in vine vigor and fruit productivity. Although soil texture was very similar throughout both blocks, samples only represented the 0 – 4 inch depth. Samples taken from greater depths may have revealed differences in soil texture, which may have affected yields.

There are numerous factors which affect grape yield. Certain practices may be implemented to encourage greater yields; however other factors may limit any gains. Floor management practices have been shown to influence yield. Wheaton et al., 2008 compared the depth of soft soil influenced by ryegrass and straw mulch, to grapevine performance. Ryegrass outperformed the straw mulch treatment having greater macropores, softer soil to a greater depth and greater grapevine root concentration compared to straw mulch. Also the greater soft soil depth in the ryegrass led to greater yields and vegetative growth. Increasing vegetative cover may also negatively impact grapevine performance. Past studies have demonstrated that increased infiltrated water due to continuous cover cropping was counteracted by increases in water use by 46 % versus bare soil (Gulick et al., 1994). In a floor management experiment, decreased soil moisture under cover crops reduced the weights of summer trimmings and winter prunings by up to 80 %, but did not affect grape yield compared to bare soil (Caspari et al., 1997). This lack of effect on grape yield in relation to increased floor cover is unexpected; however the present study shared similar findings. This may have been a result of using winter annual cover crops that were no longer growing during the time of fruit development. Compost was the only treatment shown to significantly increase fruit yield. This could have been caused by drier conditions, whereby water was a limiting factor and compost enhanced water holding capacity, maximizing the benefits of what little water entered the soil. Additionally, compost may have contributed to greater vine health by contributing more nutrients to the soil, which may have promoted higher yields.

Conclusions

Vineyard floor management practices have the potential to influence soil and vine parameters. In this study, the greatest benefits came from compost applications, whereby > 4.0 mm soil aggregate stability, percent soil carbon and fruit yield significantly increased. Cover crops also increased > 4.0 mm soil aggregate stability, but did not enhance any other elements. Improving soil aggregate stability is a big step forward in ameliorating degraded soils and farming sustainably. Often, increases in aggregate stability are correlated with increases in soil carbon. Increasing soil carbon holds great potential in decreasing greenhouse gases, which are likely influencing global warming. Although this was demonstrated through compost applications, it was not supported by the cover crop treatments, whereby aggregate stability was improved, but soil carbon did not increase. The exact reason for this finding is not known, but given more time, soil carbon would likely increase as cover crops are a direct source of carbon. Further analysis may reveal increases in labile soil carbon through the incorporation of cover crops, which may not have been detected by the CNS combustion analyzer used in this experiment.

The fungal inoculant treatments had no effect on soil aggregate stability or soil carbon. This is counter to the hypothesis that the fungal inoculant plus cover crop treatment would have the greatest positive influence on soil aggregate stability and soil carbon. Although this finding is unexpected, no clear conclusions may be drawn as AMF populations were not measured and the fungal inoculants may have not successfully infected the cover crop roots.

Fruit yield was only affected by compost additions. Unlike most crops, increased grape yield is not always desirable. High canopy vigor and fruit yield are sometimes attributed to reduced wine quality depending upon fruit ripeness and the site's topography, aspect, soil type, and climate. Conversely, high quality wines may not be the goal of the farmer where increased yield is the primary objective. Consumer demand often drives the different styles of farming. Currently there is an oversupply of grapes and consumers are developing a more sophisticated palate, demanding higher quality wine. During this study, fruit yields were very low in all treatments and were likely a result of cyclical drought conditions. As a result, increased fruit yield was beneficial as too low of a yield is not economical and fruit quality may suffer when crops are too sparse. Counter to the hypothesis, cover crops did not decrease fruit yield. Also herbicides did not affect yield. One would expect the cover crop to compete with the vine for nutrients and water, especially during a drought year. Likely yield would decrease as nutrition decreases. Conversely, herbicides would indirectly help to preserve the nutrients and water taken up by a cover crop, potentially increasing yields. This was not the case in the present study. Perhaps time would reveal more yield differences given the short duration of this study. Additionally, the fungal inoculant treatment did not affect yield. It is well supported that AMF are capable of substantially increasing grape yields. Again, it may have been that the fungal inoculant did not successfully infect the roots. Additionally, AMF readily form associations with grapevine roots and may have been

present prior to experimental set-up. If this were the case, treatment would not be a reliable way to judge the effects of AMF on grape yield.

There are many complexities with sustainable farming. Some include site variability, climate, time, resources and measuring affects on soil parameters like aggregate stability and soil carbon. Practioners may fail if attempting to be too idealistic in their approach to farming sustainably. Often the biggest complications come down to economics and time. Unfortunately, economic sustainably does not always work in conjunction with biological sustainability. A cost-benefit analysis was beyond the scope of this experiment. Further studies should include the economics behind these practices, as the farmer may listen more intently when discussing dollars and cents over discussing the nuts and bolts jargon of sustainability.

LITERATURE CITED

Annabi, M., S. Houot, M. Poitrenaud, J.N. Rampon, H. Gaillard, and Y. Le Bissonnais. 2004. Effect of organic amendments on soil aggregate stability. Sustainable Organic Waste Management for Environmental Protection and Food Safety. Ramiran 2004. 1:51-54.

Baumgartner, K., R.F. Smith, and L. Bettiga. 2005. Weed control and cover crop management affect mycorrhizal colonization of grapevine roots and arbuscular mycorrhizal fungi spore populations in a California vineyard. Mycorrhiza 15:111-119.

Boiffin, J. and G. Monnier. 1986. Infiltration rate as affected by soil surface crusting caused by rainfall. Pages 210-217 in Callebaut F., G. Gabriels, and M. de Boodt. Assessment of soil surface sealing and crusting. Ghent, Belgium: Flanders Research Centre for Soil Erosion and Soil Conservation.

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soils. Agronomy Journal 54:464-465.

Butler, J.L., M.A. Williams, P.J Bottomley, and D.D. Myrold. 2003. Microbial community dynamics associated with rhizosphere carbon flow. Applied and Environmental Microbiology 69(11):6793-6800.

California Integrated Waste Management Board—EPA. 2001. Compost microbiology and the soil food web. Available at:

<http://www.calrecycle.ca.gov/publications/default.asp?pubid=857>

Caravaca, F., T. Hernandez, C. Garcia, and A. Roldan. 2002. Improvement of rhizosphere aggregate stability of afforested semiarid plant species subjected to mycorrhizal inoculation and compost addition. Geoderma 108:133-144.

Caspari, H.W., S. Neal, and A. Naylor. 1997. Management in vineyards to enhance deficit irrigation in a humid climate. ISHS Acta Horticulturae 449: II International Symposium on Irrigation of Horticultural Crops.

Celik, I., I. Ortas, and S. Kilic. 2004. Effects of compost, mycorrhiza, manure and fertilizer on some physical properties of a Chromoxerert soil. Soil and Tillage Research 78(1):59-67.

Chebotar, V.K., N.M. Makarova, A.I. Shaposhnikov, and L.V. Kravchenko. 2009. Antifungal and phytostimulating characteristics of *Bacillus subtilis* Ch-13 rhizospheric strain, producer of biopreparations. Applied Biochemistry and Microbiology 45(4):419-423.

Cheng, X., and K. Baumgartner. 2004. Arbuscular mycorrhizal fungi in mediated nitrogen transfer from vineyard cover crops to grapevines. Biology Fertility Soils 40:406-412.

Ecological Society of America. 2008. Soil carbon sequestration fact sheet. Available at:

http://www.eoearth.org/article/Soil_carbon_sequestration_fact_sheet

Food and Agriculture Organization of the United Nations. 2011. Natural resources and environment: soil carbon sequestration. Available at:

<http://www.fao.org/nr/land/sustainable-land-management/soil-carbon-sequestration/en/>

Franco-Vizcaino, E.. 1997. Comparative soil quality in maize rotations with high or low residue diversity. Biology Fertility Soils 24:32-38.

Gulick, S.H., D.W. Grimes, D.S. Munk, and D.A. Goldhamer. 1994. Cover-crop-enhanced water infiltration of a slowly permeable fine sandy loam. Soil Science Society of America Journal 58(5):1539-1546.

Hao, X., and A.N. Kravchenko. 2007. Management practices effects on surface total carbon: Differences along a textural gradient. *Agronomy Journal* 99:18-26.

Hayman, D.S.. 1982. *Endomycorrhizae*. Pages 401-442 in *Interactions Between Nonpathogenic Soil Microorganisms and Plants*. Eds. Elsevier, Amsterdam.

Hembree, K.. Farm Advisor, UCCE, Fresno County. 2007. Control of Glyphosate-Resistant Marehail in Orchards and Vineyards. Available at:
http://www.cwss.org/proceedingsfiles/2007/113_2007.pdf

Hoyos, N., and N.B. Comerford. 2005. Land use and landscape effects on aggregate stability and total carbon of Andisols from the Colombian Andes. *Geoderma* 129(3-4):268-278.

Ingels, C.A., K.A. Scow, D.A. Whisson, and R.E. Drenovsky. 2005. Effects of cover crops on grapevines, yield, juice composition, soil microbial ecology, and gopher activity. *American Journal of Enology and Viticulture* 56(1):19-29.

Jastrow, J.D., R.M. Miller, and J. Lussenhop. 1998. Contributions of interacting biological mechanisms to soil aggregate stabilization in restored prairie. *Soil Biology and Biochemistry* 30:905-916.

Karagiannidis, N., and N. Nikolaou. 1999. Arbuscular mycorrhizal root infection as an important factor of grapevine nutrition status: Multivariate analysis application for evaluation and characterization of the leaf and soil parameters. *Agrochimica* 43:151-165.

Kemper, W.D., and R.C. Rosenau. 1986. Aggregate stability and size distribution, P. 425-442. In Arnold Klute (editor), *Methods of Soil Analysis, Part I. Physical and Mineralogical Methods*. Agronomy Monograph 9, American Society of Agronomy-Soil Science Society of America, Madison WI.

Lambert, D.H., D.E. Baker. 1979. The role of mycorrhizae in the interactions of phosphorus with zinc, copper and other elements. *Soil Science Society of America Journal* 976-980.

Le Bissonnais, Y.. 1996. Aggregate stability and assessment of soil crustability and erodibility: I. Theory and methodology. *European Journal of Soil Science* 47:425-437.

Linderman, R.G., and A. Davis. 2001. Comparative response of selected grapevine rootstocks and cultivars to inoculation with different mycorrhizal fungi. *American Journal of Enology and Viticulture* 51(1):8-11.

Liu, A., B.L. Ma, and A.A. Bomke. 2005. Effects of cover crops on soil aggregate stability, total organic carbon, and polysaccharides. *Soil Science Society of America Journal* 69:2041-2048.

Louchart, X., M. Voltz, P. Andrieux, and R. Moussa. 2001. Herbicide transport to surface waters at field and watershed scales in a Mediterranean vineyard area. *Journal of Environmental Quality* 30(3):982-991.

Lynch, J.M., and E. Bragg. 1985. Microorganisms and soil aggregate stability. *Advances in Soil Science* 2:133-171.

Milne, E. and A. Heimsath. 2008. Soil organic carbon. in: *Encyclopedia of Earth*. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment).

Morin, J., and Y. Benyamini. 1977. Rainfall infiltration into bare soils. *Water Resources Research* 13(5):813-817.

Natural Resource Conservation Service Web Soil Survey. Available at:
websoilsurvey.nrcs.usda.gov/app

Nimmo, J.R., and K.S. Perkins. 2002. Aggregate stability and size distribution, p. 317-328. In Jacob H. Dane and G. Clarke Topp (editors), Methods of Soil Analysis. Part 4. Physical Methods. Soil Science Society of America Book Series No. 5, Soil Science Society of America, Madison, WI.

Oades, J.M.. 1984. Soil organic matter and structural stability: mechanisms and implications for management. Plant and Soil 76:319-337.

Obi, M.E., 1999. The physical and chemical responses of a degraded sandy clay loam soil to cover crops in southern Nigeria. Plant and Soil 211(2):165-172.

Peregrina, F., C. Larrieta, S. Ibanez, and E. Garcia-Escudero. 2010. Labile organic matter, aggregates, and stratification ratios in a semiarid vineyard with cover crops. Soil Science Society of America Journal 74(6):2120-2130.

Requena, N., and E. Perez-Solis. 2001. Management of indigenous plant-microbe symbiosis aids restoration of desertified ecosystems. Applied and Environmental Microbiology 67(2):495-498.

Rogers, W.S., T.H. Raptopoul, and D.W.P Greenham. 1948. Cover crops for fruit plantations. IV. Long-term leys and permanent swards. Journal of Horticultural Science 24:228-270.

Sanchez, J.E., R.R. Harwood, T.C. Wilson, K. Kizilka, J. Smeenk, E. Parker, E.A. Paul, B.D. Knezek, and G.P. Robertson. 2004. Integrated agricultural systems: managing soil carbon and nitrogen for productivity and environmental quality. Agronomy Journal 96:769-775.

Schellenbaum, L., G. Berta, F. Ravolanirina, B. Tisserant, S. Gianinazzi, and A. Fitter. 1991. Influence of endomycorrhizal infection on root morphology in a micropropagated woody plant species (*Vitis vinifera* L.). Annals of Botany 68:135-141.

Simpson, R.T., S.D. Frey, J. Six, and R.K. Thiet. 2004. Preferential accumulation of microbial carbon in aggregate structures of no-tillage soils. *Soil Science Society of America Journal* 68:1249-1255.

Skroch, W.A., and J.M. Shribbs. 1986. Orchard floor management: an overview. *HortScience* 21:390-394.

Tambone, F., P. Genevini, and F. Adani. 2007. The effects of short-term compost application on soil chemical properties and on nutritional status of maize plant. *Compost Science & Utilization* 15(3):176-183.

Tisdall, J.M., and J.M. Oades. 1980. The effect of crop rotation on aggregation in a red-brown earth. *Australian Journal of Soil Resources* 18:423-434.

Tolbert, V.R., F.C. Thornton, J.D. Joslin, B.R. Bock, W.E. Bandaranayake, D.D. Tyler, D. Pettry, T.H. Green, R. Malik, A.E. Houston, S. Schoenholtz, M. Shires, L. Bingham, and J. Dewey. 1998. Soil and water quality aspects of herbaceous and woody energy crop production: Lessons from research-scale comparisons with agricultural crops. *Proceedings, BioEnergy'98: Expanding BioEnergy Partnerships*, Madison, WI, pp. 1272-1281.

Walsh, B.D., S. Salmins, D.J. Buszard, and A.F. MacKezie. 1996. Impact of soil management systems on organic dwarf apple orchards and soil aggregate stability, bulk density, temperature and water content. *Canadian Journal of Soil Science* 76:203-209.

Wheaton, A.D., B.M. McKenzie, and J.M. Tisdall. 2008. Management to increase the depth of soft soil improves soil conditions and grapevine performance in an irrigated vineyard. *Soil and Tillage Research* 98(1):68-80.

Whitelaw-Weckert, M., R. Hutton, E. Rouse, and R. Lamont. 2004. The effect of herbicides and permanent swards on microbial population in the vineyard. *In* *Supersoil 2004: Program and Abstracts for the 3rd Australian New Zealand Soils Conference*, University of Sydney, Australia, 5-9 December 2004.

Wine Institute. 2010. Wine consumption in the U.S. Available at:
<http://www.wineinstitute.org/resources/statistics/article86>

Appendix A: Summarized Research Data

Summarized Research Data											
Calculation	Treatment	>4.0 mm	2.0-4.0 mm	1.19-2.0 mm	0.5-1.19 mm	0.25-0.5 mm	Carbon %	Fruit wt. (kg/vine)	Sand %	Silt %	Clay %
Average	Control	16.2	2.8	2.2	3.5	7.2	0.6	5.0	47.2	30.0	22.7
STDEV		6.7	0.4	0.4	0.9	3.2	0.0	2.4	2.5	1.9	2.4
Average	Herbicide	8.0	3.3	3.1	5.7	9.0	0.6	5.3	47.7	29.7	22.6
STDEV		6.9	0.5	0.8	1.1	1.7	0.2	1.0	1.6	2.0	2.2
Average	Herbicide + compost	13.9	4.3	3.3	5.7	9.0	0.6	6.2	47.4	29.7	22.9
STDEV		7.2	0.7	0.8	0.8	3.0	0.1	1.5	2.0	1.9	2.3
Average	Cover crop	26.4	2.4	2.0	3.5	6.7	0.6	4.6	47.4	29.4	23.2
STDEV		14.9	1.2	0.5	1.3	3.1	0.1	2.3	3.0	2.2	2.5
Average	Compost + cover crop	47.1	2.2	1.8	2.9	4.7	0.7	5.3	48.3	29.5	22.2
STDEV		11.2	0.7	0.4	1.0	1.9	0.1	1.9	2.1	1.9	2.1
Average	Fungal inoculant + cover crop	31.5	2.8	2.0	3.8	6.7	0.6	4.5	47.6	29.2	23.2
STDEV		10.2	1.2	0.4	0.7	2.9	0.1	2.0	2.9	2.2	2.2

Appendix B: Soil Textures at 0-4” Depth

Soil Textures (0-4 inch depth)								
Block	Rep.	Block Position	Row Position	Treatment	% Sand	% Silt	% Clay	
15-4	R1	North	West	Control	45.4	33.6	21	Loam
15-4	R2	Middle	East	Control	48.4	30.6	21	Loam
15-4	R3	South	East	Control	50.4	28.6	21	Loam
15-4	R1	North	East	Herbicide	49.4	30.6	20	Loam
15-4	R2	Middle	West	Herbicide	46.4	32.6	21	Loam
15-4	R3	South	West	Herbicide	48.4	30.6	21	Loam
15-4	R1	North	East	Herb. + compost	50.4	29.6	20	Loam
15-4	R2	Middle	West	Herb. + compost	46.4	32.6	21	Loam
15-4	R3	South	West	Herb. + compost	47.4	30.6	22	Loam
15-4	R1	North	West	Cover crop	44.4	33.6	22	Loam
15-4	R2	Middle	East	Cover crop	49.4	29.6	21	Loam
15-4	R3	South	East	Cover crop	51.4	27.6	21	Sandy clay loam
15-4	R1	North	East	Compost + CC	51.9	28.1	20	Loam
15-4	R2	Middle	West	Compost + CC	47.4	32.6	20	Loam
15-4	R3	South	West	Compost + CC	48.4	30.6	21	Loam
15-4	R1	North	West	FI + CC	44.4	33.6	22	Loam
15-4	R2	Middle	East	FI + CC	50.4	28.6	21	Loam
15-4	R3	South	East	FI + CC	50.4	27.6	22	Loam
17-2	R1	North	West	Control	44.4	29.8	25.8	Loam
17-2	R2	Middle	East	Control	49.4	28.8	21.8	Loam
17-2	R3	South	West	Control	45.4	28.8	25.8	Loam
17-2	R1	North	East	Herbicide	47.4	28.8	23.8	Loam
17-2	R2	Middle	West	Herbicide	45.4	28.8	25.8	Loam
17-2	R3	South	East	Herbicide	49.4	26.8	23.8	Sandy clay loam
17-2	R1	North	East	Herb. + compost	47.4	28.8	23.8	Loam
17-2	R2	Middle	West	Herb. + compost	44.4	29.8	25.8	Loam
17-2	R3	South	East	Herb. + compost	48.4	26.8	24.8	Sandy clay loam
17-2	R1	North	West	Cover crop	45.4	28.8	25.8	Loam
17-2	R2	Middle	East	Cover crop	49.4	27.8	22.8	Sandy clay loam
17-2	R3	South	West	Cover crop	44.4	28.8	26.8	Loam
17-2	R1	North	East	Compost + CC	48.4	27.8	23.8	Sandy clay loam
17-2	R2	Middle	West	Compost + CC	45.4	29.8	24.8	Loam
17-2	R3	South	East	Compost + CC	48.4	27.8	23.8	Sandy clay loam
17-2	R1	North	West	FI + CC	46.4	28.8	24.8	Loam
17-2	R2	Middle	East	FI + CC	49.4	27.8	22.8	Sandy clay loam
17-2	R3	South	West	FI + CC	44.4	28.8	26.8	Loam

Appendix C: Statistical Data Analyses

General Linear Model for Analyses A-G:

Factor	Type	Levels	Values
Block	random	2	15-4, 17-2
Block position(Block)	random	6	Middle, North, South, Middle, North, South
Row position(Block)	random	4	East, West, East, West
cc	fixed	2	cover crop, no cover crop
fi	fixed	2	fi, no fi
h	fixed	2	herb, no herb
comp	fixed	2	comp, no comp

Analysis A

Analysis of Variance for Percent C, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	0.055775	0.055775	0.055775	1.16	0.379 x
Block position(Block)	4	0.041246	0.041246	0.010311	1.87	0.149
Row position(Block)	2	0.058161	0.082283	0.041141	7.48	0.003
cc	1	0.006595	0.007568	0.007568	1.38	0.253
fi	1	0.005563	0.001045	0.001045	0.19	0.667
h	1	0.007842	0.002417	0.002417	0.44	0.514
comp	1	0.037821	0.038549	0.038549	7.01	0.014
cc*comp	1	0.008706	0.008706	0.008706	1.58	0.221
Error	23	0.126506	0.126506	0.005500		
Total	35	0.348215				

x Not an exact F-test.

S = 0.0741638 R-Sq = 63.67% R-Sq(adj) = 44.72%

Unusual Observations for W10 % C

Obs	W10 % C	Fit	SE Fit	Residual	St Resid
4	0.853000	0.669556	0.046249	0.183444	3.16 R
13	0.652000	0.772056	0.046249	-0.120056	-2.07 R

R denotes an observation with a large standardized residual.

Analysis B

Analysis of Variance for Percent >4.0mm Stable Aggregates, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	0.06879	0.06879	0.06879	3.36	0.338 x
Block position(Block)	4	0.02356	0.02356	0.00589	0.41	0.801
Row position(Block)	2	0.03628	0.05642	0.02821	1.95	0.164
cc	1	0.70955	0.08060	0.08060	5.58	0.027
fi	1	0.00407	0.01515	0.01515	1.05	0.316
h	1	0.05627	0.07901	0.07901	5.47	0.028
comp	1	0.14203	0.14392	0.14392	9.97	0.004
cc*comp	1	0.01589	0.01589	0.01589	1.10	0.305

S = 0.120144 R-Sq = 76.09% R-Sq(adj) = 63.61%

Analysis C

Analysis of Variance for Percent 2.0-4.0mm Stable Aggregates, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	0.0041229	0.0041229	0.0041229	1.77	0.352 x
Block position(Block)	4	0.0004949	0.0004949	0.0001237	0.26	0.898

Row position(Block)	2	0.0035498	0.0050964	0.0025482	5.42	0.012
fi	1	0.0004626	0.0004249	0.0004249	0.90	0.352
h	1	0.0142938	0.0014514	0.0014514	3.09	0.092
cc	1	0.0008839	0.0022879	0.0022879	4.87	0.038
comp	1	0.0009972	0.0009571	0.0009571	2.04	0.167
cc*comp	1	0.0009671	0.0009671	0.0009671	2.06	0.165

S = 0.0216776 R-Sq = 70.45% R-Sq(adj) = 55.04%

Analysis D

Analysis of Variance for Percent 1.19–2.0mm Stable Aggregates, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	0.0013248	0.0013248	0.0013248	0.86	0.453 x
Block position(Block)	4	0.0008692	0.0008692	0.0002173	1.00	0.428
Row position(Block)	2	0.0012767	0.0029237	0.0014618	6.72	0.005
fi	1	0.0014291	0.0000028	0.0000028	0.01	0.910
h	1	0.0119464	0.0032696	0.0032696	15.04	0.001
cc	1	0.0003032	0.0003370	0.0003370	1.55	0.226
cc*comp	1	0.0000230	0.0000222	0.0000222	0.10	0.752
comp	1	0.0000197	0.0000197	0.0000197	0.09	0.766
Error	23	0.0050008	0.0050008	0.0002174		
Total	35	0.0221930				

S = 0.0147454 R-Sq = 77.47% R-Sq(adj) = 65.71%

Analysis E

Analysis of Variance for Percent 0.5–1.19mm Stable Aggregates, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	0.0034373	0.0034373	0.0034373	2.22	0.224 x
Block position(Block)	4	0.0042669	0.0042669	0.0010667	2.58	0.064
Row position(Block)	2	0.0001997	0.0017370	0.0008685	2.10	0.145
fi	1	0.0004520	0.0002853	0.0002853	0.69	0.415
h	1	0.0275188	0.0091876	0.0091876	22.22	0.000
cc	1	0.0002132	0.0002245	0.0002245	0.54	0.469
cc*comp	1	0.0003164	0.0003256	0.0003256	0.79	0.384
comp	1	0.0001624	0.0001624	0.0001624	0.39	0.537

S = 0.0203354 R-Sq = 79.36% R-Sq(adj) = 68.59%

Analysis F

Analysis of Variance for Percent 0.25–0.5mm Stable Aggregates, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	0.0592727	0.0592727	0.0592727	17.02	0.051 x
Block position(Block)	4	0.0030635	0.0030635	0.0007659	1.24	0.321
Row position(Block)	2	0.0060938	0.0063641	0.0031820	5.16	0.014
fi	1	0.0006352	0.0000063	0.0000063	0.01	0.920
h	1	0.0247780	0.0046948	0.0046948	7.61	0.011
cc	1	0.0031582	0.0022729	0.0022729	3.68	0.067
cc*comp	1	0.0018133	0.0019011	0.0019011	3.08	0.092
comp	1	0.0025356	0.0025356	0.0025356	4.11	0.054
Error	23	0.0141864	0.0141864	0.0006168		
Total	35	0.1155367				

S = 0.0248355 R-Sq = 87.72% R-Sq(adj) = 81.32%

Analysis G

Analysis of Variance for Fruit Weight per Vine, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	48.2446	48.2446	48.2446	86.78	0.000
Block position(Block)	4	7.9684	7.9684	1.9921	3.58	0.021
Row position(Block)	2	44.2848	40.5987	20.2994	36.51	0.000
cc	1	3.2726	1.0514	1.0514	1.89	0.182
fi	1	0.3844	0.0533	0.0533	0.10	0.760
h	1	1.1751	0.0339	0.0339	0.06	0.807
comp	1	2.6396	2.5964	2.5964	4.67	0.041
cc*comp	1	0.4070	0.4070	0.4070	0.73	0.401
Error	23	12.7864	12.7864	0.5559		
Total	35	121.1630				

S = 0.745607 R-Sq = 89.45% R-Sq(adj) = 83.94%

General Linear Model for Analyses H and I:

Factor	Type	Levels	Values
Treatment	fixed	6	Compost + CC, Control, Cover crop, FI + CC, Herb. + compost, Herbicide
Block	random	2	15-4, 17-2
Block position(Block)	random	6	Middle, North, South, Middle, North, South
Row position(Block)	random	4	East, West, East, West

Analysis H

Analysis of Variance for Percent >4.0 mm Stable Aggregates Versus Treatment, Block, Block Position (Block), Row Position (Block), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Treatment	5	6061.91	6140.24	1228.05	13.34	0.000
Block	1	303.53	303.53	303.53	2.03	0.383 x
Block position(Block)	4	177.26	177.26	44.32	0.48	0.749
Row position(Block)	2	382.78	382.78	191.39	2.08	0.148
Error	23	2116.62	2116.62	92.03		
Total	35	9042.11				

x Not an exact F-test.

S = 9.59308 R-Sq = 76.59% R-Sq(adj) = 64.38%

Tukey Simultaneous Tests

Response Variable Percent >4.0 mm Stable Aggregates
All Pairwise Comparisons among Levels of Treatment
Treatment = Compost + CC subtracted from:

Treatment	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Control	-28.90	5.653	-5.113	0.0005
Cover crop	-18.79	5.653	-3.324	0.0310
FI + CC	-13.63	5.653	-2.411	0.1938
Herb. + compost	-33.13	5.539	-5.981	0.0001
Herbicide	-39.03	5.539	-7.047	0.0000

Treatment = Control subtracted from:

Treatment	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Cover crop	10.12	5.539	1.826	0.4695
FI + CC	15.28	5.539	2.758	0.1014
Herb. + compost	-4.22	5.653	-0.747	0.9736
Herbicide	-10.12	5.653	-1.791	0.4903

Treatment = Cover crop subtracted from:

Treatment	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
FI + CC	5.16	5.539	0.932	0.9340
Herb. + compost	-14.34	5.653	-2.536	0.1547
Herbicide	-20.24	5.653	-3.581	0.0174

Treatment = FI + CC subtracted from:

Treatment	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Herb. + compost	-19.50	5.653	-3.450	0.0234
Herbicide	-25.40	5.653	-4.494	0.0020

Treatment = Herb. + compost subtracted from:

Treatment	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Herbicide	-5.902	5.539	-1.066	0.8899

Analysis I

Analysis of Variance for Percent Carbon Versus Treatment, Block, Block Position (Block), Row Position (Block), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Treatment	5	3.7807	4.3187	0.8637	1.07	0.404
Block	1	0.4407	0.4407	0.4407	0.43	0.598 x
Block position(Block)	4	3.7834	3.7834	0.9459	1.17	0.350
Row position(Block)	2	1.7824	1.7824	0.8912	1.10	0.349
Error	23	18.6029	18.6029	0.8088		
Total	35	28.3901				

x Not an exact F-test.

S = 0.899345 R-Sq = 34.47% R-Sq(adj) = 0.29%

Unusual Observations for W10 % C

Obs	W10 % C	Fit	SE Fit	Residual	St Resid
1	6.00000	2.63922	0.56084	3.36078	4.78 R

R denotes an observation with a large standardized residual.

Tukey Simultaneous Tests

Response Variable W10 % C

All Pairwise Comparisons among Levels of Treatment

Treatment = Compost + CC subtracted from:

Treatment	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Control	0.9185	0.5299	1.7333	0.5251
Cover crop	0.0305	0.5299	0.0576	1.0000
FI + CC	0.0492	0.5299	0.0928	1.0000
Herb. + compost	-0.0600	0.5192	-0.1156	1.0000
Herbicide	-0.1025	0.5192	-0.1974	1.0000

Treatment = Control subtracted from:

Treatment	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Cover crop	-0.888	0.5192	-1.710	0.5391
FI + CC	-0.869	0.5192	-1.674	0.5611
Herb. + compost	-0.979	0.5299	-1.846	0.4578
Herbicide	-1.021	0.5299	-1.927	0.4122

Treatment = Cover crop subtracted from:

Treatment	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
FI + CC	0.0187	0.5192	0.0360	1.0000
Herb. + compost	-0.0905	0.5299	-0.1708	1.0000
Herbicide	-0.1330	0.5299	-0.2510	0.9998

Treatment = FI + CC subtracted from:

Treatment	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Herb. + compost	-0.1092	0.5299	-0.2060	0.9999
Herbicide	-0.1517	0.5299	-0.2862	0.9997

Treatment = Herb. + compost subtracted from:

Treatment	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Herbicide	-0.04250	0.5192	-0.08185	1.000

General Linear Model for Analyses J and K:

Factor	Type	Levels	Values
Block	random	2	15-4, 17-2
Block position(Block)	random	6	Middle, North, South, Middle, North, South
Row position(Block)	random	4	East, West, East, West
fi	fixed	2	fi, no fi
h	fixed	2	herb, no herb
Percent Carbon			

Analysis J

Analysis of Variance for Percent >4mm Stable Aggregates, Substituting Percent Carbon for Compost and Cover Crops, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	0.06879	0.18245	0.18245	1.54	0.336 x
Block position(Block)	4	0.02356	0.08572	0.02143	1.08	0.389
Row position(Block)	2	0.03628	0.25679	0.12840	6.45	0.006
fi	1	0.09722	0.01492	0.01492	0.75	0.395
h	1	0.49385	0.48681	0.48681	24.46	0.000
Percent C	1	0.17113	0.17113	0.17113	8.60	0.007
Error	25	0.49761	0.49761	0.01990		
Total	35	1.38843				

S = 0.141082 R-Sq = 64.16% R-Sq(adj) = 49.82%

R-sq 76.09;64.16

Analysis K

Analysis of Variance for Percent 2.0–4.0mm Stable Aggregates, Substituting Percent Carbon for Compost and Cover Crops, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	1	0.0041229	0.0007318	0.0007318	0.20	0.703 x
Block position(Block)	4	0.0004949	0.0008468	0.0002117	0.54	0.708
Row position(Block)	2	0.0035498	0.0085025	0.0042512	10.85	0.000
fi	1	0.0004626	0.0000979	0.0000979	0.25	0.622
h	1	0.0142938	0.0141138	0.0141138	36.01	0.000
W10 % C	1	0.0038586	0.0038586	0.0038586	9.85	0.004
Error	25	0.0097977	0.0097977	0.0003919		
Total	35	0.0365803				

S = 0.0197967 R-Sq = 73.22% R-Sq(adj) = 62.50%

R-sq 70.45;73.22