Analysis of Potential Vermicompost Market in California

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ABSTRACT

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Vermicompost transforms agricultural waste into a high quality soil amendment, though market acceptance remains in its infancy. This study examines how growers’ willingness to pay for vermicompost is affected by grower’s crop, region, income per acre, knowledge level of vermicompost and compost, previous use of compost, and the willingness to pay for compost. The survey results pulled together 223 responses from California growers. It was discovered growers’ had less knowledge of vermicompost than compost but were willing to pay more for vermicompost. There was statistical difference amongst the responses. It was shown the market value per ton of vermicompost lies between $20 and $30; and feasibility of a potential vermicompost facility depends on transportation costs of the finished product. A vermicompost company should focus on North Coast grape growers.

Keywords: Willingness to Pay, Vermicompost, Compost, Knowledge, Correlation, North Coast, Grapes, Income, Soil Amendment
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I. INTRODUCTION

Roughly 10,000 years ago, agriculture emerged as a viable practice for the human race. Throughout most of this period, agriculture worked within a natural flow. Agricultural communities learned how to manipulate key aspects of nature to produce enough crops to support themselves. This holistic approach allowed for the production of a safe and nutritious crop, while mitigating damage to the natural ecosystem. In the last 100 years, a shift from this organic growing practice has transpired. The emergence of synthetic fertilizers and pesticides brought about greater yields and gave growers a cheap fix to many crop nuisances. This new technology also came with unforeseen consequences leading to devastating impacts on the natural ecosystem (Tilman, et al., 2002).

In many cropping systems, nitrogen is the most limiting factor in crop production (Balthensperger, etc., 2008). On July 2, 1909, two German Scientists Fritz Haber and Carl Bosch were able to synthesize ammonia (Paull, 2009). This synthesized chemical was originally used in ammunition and bombs to fuel the German war machine. Following the war, the large ammonia stockpiles created by the Haber-Bosch process were converted into the world’s first synthetic fertilizer (Paull, 2009). With growers able to apply fixed nitrogen to the soil, yields almost immediately increased, even in the most inferior soils. This fertilizer application improved profitability for growers while decreasing labor costs. The Haber-Bosch process was further utilized to derive more synthetic fertilizers and gave growers the ability to meet all the nutrient demands of their crops. These fertilizers were not the only chemicals being synthesized during the 20th century.

The birth of synthetic pesticides began in 1939 when the Swiss chemist Paul Mueller created the synthetic organic compound dichlorodiphenyltrichloroethane, also commonly...
referred to as DDT (Muir, 1998). This compound showed immense potential to control and eliminate pests. Following World War II, an increase in the number of synthetic pesticides hit the market. These new synthetic compounds gave growers the ability to produce higher quality foods, while increasing the quantity (Delaplane, 1996). Besides the beneficial impact these new chemicals were having on crops, they were also able to stop, or slow down, the spread of disease. This was proven in Africa during the middle part of the 20th century when DDT brought Malaria infections under control (Muir, 1998).

These new synthetic chemicals provided growers with the capacity to meet the nutritional demands of their crops and protect them from an array of pests. This allowed American farms to become the breadbasket of the world, but these chemicals also created an intense agricultural practice that began showing devastating effects on the surrounding ecosystem. The balance agriculturalists once experienced with nature was now gone. These newly developed synthetic fertilizers were killing beneficial microorganisms in the soil causing the soil to become sterile (Vitousek, et al., 1997). With sterile soils, growers were applying more and more fertilizer to achieve the same yields they had previously experienced. Over fertilized soils become deficient in nutrients such as calcium and potassium, reducing the positive benefits of synthetic fertilizers (Vitousek, et al., 1997). Besides deteriorating the soil, synthetic fertilizers, especially nitrogen based, have the ability to leach and pollute groundwater and other bodies of water (Sinha, et al., 2010). Not being mindful of the harsh qualities of these fertilizers has led to many unintended negative consequences.

The promise of synthetic pesticides like DDT was also short lived when it was discovered that many of these chemicals were able to harm predatory bird species through biomagnification (Muir, 1998). Not only are predatory bird species affected, but many pests have become
resistant leading to the development of more potent pesticides. The concern over these negative consequences led President Nixon to create the Environmental Protection Agency.

The Environment Protection Agency was given the authority to determine which synthetic chemicals would be allowed for use in agricultural production. California, being the top producer of agricultural products in the country, has a vested interest in the consequences of these chemicals. California has become the most progressive state when it comes to implementing tough regulatory measures on agriculture. Many of these regulatory actions have occurred to protect against environmental degradation. These new policies have targeted the chemical agriculture industry by limiting the number of applications and by narrowing the chemicals that can be used in California. The tighter regulations coupled with the environmental concerns over chemical usage will create a market for alternative fertilizers and pesticides.

A new fertilizer could potentially allow growers to return to working within the ecosystem, while still providing the necessary nutrients to grow a productive crop. Vermicompost is believed to be one fertilizer that will return farming once again to a sustainable practice. Vermicompost is the utilization of earthworms to convert organic waste into a fertilizer. The cost of agricultural production is expected to be lower with the utilization of vermicompost because of a variety of associated benefits. Vermicompost reduces the number of chemical fertilizer applications because it slowly releases a constant stream of nutrients to the plant (Sinha, et al., 2010). It creates healthier plants, lessening the pest pressure and decreasing the need for pesticide applications. Vermicompost helps save water through the addition of organic matter, which has water-holding capabilities (Sinha, et al., 2009). Besides the characteristics mentioned it also provides dairies and feedlots with a way to dispose of manure in an eco-friendly manner. Vermicompost will allow beneficial microorganisms to flourish and re-
establish life in the soil (Sinha, et al., 2010). It is believed that this fertilizer will create a sustainable and environmentally friendly practice that will allow agriculture to prosper into the future.

California grows over 400 commodities and is the fifth largest agricultural economy in the world. Coupled with high regulatory restrictions, California has a high potential to accept and establish vermicompost as a new fertilizer option (CDFA, 2016). Vermicompost is potentially a way to ease environmental concerns over agricultural practices such as dairies, while meeting nutritional requirements for crops, especially for farmers operating in highly regulated areas like those close to residential zones, watersheds, and potential runoff sites.

Vermicompost has been in California since 1936 when Thomas Barrett first established Earthmaster Farms in El Monte, California (Sherman and Bogdanov, 2011). Later in 1967, entrepreneur Ronald Gaddie started North American Bait Farms in Ontario, California. Within 10 years, he was making over one million dollars per year and had sold 1,000,000 copies of the book he coauthored, *Earthworms for Ecology and Profit*. His business practices led to an investigation from the Securities and Exchange Commission for possible pyramid scheme, this led to the closure of his business, and a bitter taste in the mouths of many growers.

Other vermicomposting operations have begun in California over the years. Vermicomposting Biosolids, a subsidiary local government in Fallbrook, California, created a vermicomposting program to treat biosolids produced by municipal sewage treatment plants. They used a two phase process, first precomposting for 30 days to comply with EPA standards to reduce pathogens and then transferring to vermicompost beds. The sanitary district sold its compost for $20 m-3 ($15 yd-3) and its vermicompost for $46 m-3 ($35 yd-3) (Harris et al.,
1990). The vermicompost facility was forced to close with the increased residential development, as it became a suburb of San Diego.

San Diego continued this process under the new name Canyon Recycling. They purchased 5,000 pounds of earthworms from Vermicomposting Biosolids. This landfill diversion site received tipping fees for removal of municipal yard trimmings, manure from the San Diego Zoo, San Diego Wild Animal Park, and Del Mar Race Track. They were treating between 13.6 and 18.1 tons of green waste every day with the worms. They began sales of vermicompost in the form of Vermigro, a blend of earthworm castings with compost that was made for nurseries, landscapers, organic farmers, and the general public. The product was sold in bags of one cubic foot for $7. The subsidiary struggled to keep up with demand and was put up for sale in 1997. Because of the early debt of the investment, local officials were left nervous and wanting a quicker return.

Pacific Southwest Farms in Ontario, California started its operation in 1994. At its climax it was taking in 90.7 tons of municipal solid waste per day. It charged a tipping fee and used roughly 120,000 gallons of water per day. Roughly 90 tons of earthworms processed material in 360 windrows. Each windrow was eight feet in width and 100 feet in length and consumed 3.63 tons of waste per week. Their end product was sold to agricultural consumers in the Central Valley. In 1996, San Bernardino Local Enforcement Agency shut down Pacific Southwest Farms stating it did not have a waste facilities permit as a transfer/processing station. Pacific Southwest Farms appealed this decision in 1997 and won because earthworm bed activity is excluded from composting regulations. Two victories were won by Pacific Southwest Farms; vermicompost received an agricultural exclusion from California’s composting regulations because Food and Agriculture Code cites vermicompost and its by-products as agriculture. The
second victory was that precomposting of feedstock for vermicomposting does not fall under California Integrated Waste Management Board’s (CIWMB’s) compost regulations. Even with the litigation wins, Pacific Southwest Farms closed down due to the loss of feedstock from waste sites and tipping fees while the legal process was going on.

There are at least two examples of successful vermicomposting facilities operating in California. Sonoma Worm Farm is currently selling vermicompost to several high-end vineyards. The vineyards were losing 20% of their new plantings, but after vermicompost the loss was reduced to 1%. The other operation is The Worm Farm in Durham, California; they sell three species of earthworms, vermicompost, worm bins, coir bricks, worm chow, books, hats, and 55 types of soil amendments. They also offer educational seminars. About 95% of the earthworms they sell are to households and 90% of these sales happen online. Each of these different operations has found niche markets to participate in; some have been very successful, while others were forced to shut down. Discovery of a focus grower population for vermicompost is expected to increase the viability of vermicompost companies.

Problem Statement

What is the market for vermicompost soil amendments in California compared to traditional fertilizers?

Hypothesis

Hypothesis 1

\[ H_0 = \text{Growers who are willing to pay will purchase vermicompost at the same price as compost.} \]

\[ H_a = \text{Growers who are willing to pay will purchase vermicompost at a higher price than compost.} \]
Hypothesis 2

\( H_0 = \) Growers’ knowledge of compost and vermicompost are independent of one another.

\( H_a = \) Growers’ knowledge of compost and vermicompost are not independent of one another.

Hypothesis 3

\( H_0 = \) North Coast Grape Growers who are willing to pay will purchase vermicompost at the same price as all other crop growers.

\( H_a = \) North Coast Grape Growers who are willing to pay will purchase vermicompost at a different price than all other crop growers.

Objectives

1. Discover growers’ knowledge of vermicompost and compost.

2. Find potential grower population for vermicompost companies.

3. Examine the potential return for a vermicompost facility with the information gathered in this study.
II. REVIEW OF LITERATURE

In California, the market for vermicompost is in its infancy. To generate a comprehensive market survey, this literature review explores several topics including growers’ willingness to pay for inputs, strategies used to produce soil amendments, advantages of vermicompost that distinguish it in the market place, and a potential raw material source for vermicompost in California. This literature review also explores regulations that affect vermicompost production and distribution, the economics of producing vermicompost, and an examination of established and potential markets. To produce a reliable survey, several academic survey methods are reviewed. The examination of the literature aims to identify accurate market drivers, production strategies and provides the basis for developing a market survey.

Growers’ Willingness to Pay for Inputs

Growers must make decisions on what inputs to use when producing a crop. Often an input’s return on investment is a key driver in a growers’ willingness to pay. Growers contemplate the profit to be made when choosing a new input. Theoretically, it was discovered the maximum amount a growers is willing to pay for a new input is equal to the cost of the old input plus the difference between the new profit level and the previous profit level (Zapata, el al., 2014). Growers’ willingness to pay can be affected by numerous variables.

Municipalities in Ghana examined compost as a solution to dispose of waste and produce a fertilizer for growers. The contingent valuation survey was identified as a viable method to understand growers’ willingness to pay (Danso, et al., 2006). Sixty percent of growers in Ghana were willing to pay for compost and 10% were not willing to pay any amount. Thirty percent stated a negative amount and expected the government to subsidize this input (Danso, et
al., 2002 and 2006). All growers stated that compost would improve soil structure and help with restoration of their soils but stressed that they were not willing to make a long term investment because of insecurity of land tenure. Growers’ willingness to pay was affected by the variables level of education, current inputs, age, location, experience with compost and total annual income. It was also shown that farming practices and location affect growers’ willingness to pay for compost. As growers’ understand the benefits and risks of compost their willingness to pay increases. However, the production cost of compost is still too high and the lack of demand for compost makes it unattractive to produce compost on a large-scale. A better market for compost might be for commercial landscaping.

Soil Amendments - Composting Strategies

The concern of waste disposal is becoming a large dilemma for many industries, especially agriculture. The production of livestock creates large amounts of organic waste in the form of manure while pushing farmers to use chemical fertilizers to produce enough feed for their animals. This results in contamination of both surface and groundwater and leaves producers with an organic waste disposal predicament (DeLuca and DeLuca, 1997). There are currently solutions to these challenges that livestock producers are facing. The two best-known processes for the biological stabilization of solid organic wastes are composting and vermicomposting (Dominguez and Edwards, 2011a). Both processes reclaim organic wastes to be used as organic matter for soil amendments and as a source of nutrients (Gonzalez, et al., 2010).

The two biological waste reduction processes each have their strengths and weaknesses. It is necessary to explore each to grasp why combining the two is most preferred by private companies. In the composting process, microorganisms and heat transform the waste, compared
to vermicompost, in which the waste is transformed by microorganisms and earthworms (Fornes, et al., 2012). The better understood process is composting, and it is necessary to know how vermicompost fits around composting and the market dynamics between the two processes.

Composting requires less water and goes through a thermophilic stage at higher temperatures, ensuring sanitation of pathogens (Fornes, et al., 2012). A draw-back of composting is the long duration, the amount of turning to keep the pile in the thermophilic phase, the loss of nutrients because of the high temperatures, and the product not being of a homogeneous nature (Ndegwa and Thompson, 2001a). In large scale composting facilities, material must be moved as quickly as possible through the facility to remain cost effective (Papadimitrio and Balis, 1996). This requires a large expense in capital because heavy machinery is necessary to keep the compost in an aerobic condition to produce a more stable end product.

The composting process has two distinct phases; first is the active composting phase, followed by the curing phase. During the active phase, intense decomposition takes place (Dominguez and Edwards, 2011b). The United States Department of Agriculture (2013) explains that during the active phase, an increase in temperatures activates different microbes. These microbes in the active phase have been categorized into three distinctive stages, psychrophilic stage, mesophilic stage, and thermophilic stage. Microbes are segregated by where the microbes meet their peak growth rates and efficiencies (Strentiford and De Bertoldi, 2010).

The temperature of the pile plays an essential role in the outcome of the composting process, as temperatures must reach 131 degrees Fahrenheit to eradicate plant pathogens and weed seeds (Border, 2002). It is usually referred to as the conversion process because during this
phase more complex materials, such as cellulose, will be decayed (USDA, 2013). This phase will last 10-60 days depending on the environment, and turning the pile can regulate temperature and rate of decomposition (Border, 2002). The microbes decay material by moving soluble components through their body walls or by releasing enzymes into the environment that break down the material (USDA, 2013). The pile will reach its maximum temperature and microbial activity as the microbes deplete the degradable material and oxygen. The temperatures will become too high for many microbes to operate. Not all the microbes will die as the temperatures increase, some will shut down while others will enter their reproductive stage. At this point, with the decreased activity level of the microbes, the pile begins to cool, thus entering the next stage (Border, 2002).

High quality and low quality compost are separated by the curing phase being performed correctly. This stage can last from one to six months, with the temperature decreasing over that time. The length of the curing will depend on the complexity of the materials in the pile. The process will be complete when ambient temperature remains constant even after the pile is aerated. At this point the compost should be very dark and have an earthy smell, with none of the original material being recognizable. If the process is not complete, the under developed compost may inhibit plant growth because of the unsuitable C: N ratio, non-nitrate forms of nitrogen, organic acids, and other chemicals not stabilized during the curing stage (USDA, 2013).

There are five factors that affect the efficiency of composting: nutrient balance, moisture content, oxygen supply, temperature, and pH. For composting to be done as efficient as possible, the nutrient ratio of materials being added to the pile needs to have a carbon to nitrogen ratio between 20:1 and 30:1, with an optimal ratio at 25:1 (Border, 2002). The compost pile should be
measured for proper moisture levels after 60 percent of the raw material has been mixed. At this time the pile should contain 50 to 70 percent moisture, and it should feel like a damp sponge that is not leaking water. If moisture levels become too high oxygen penetration into the pile will stop, increasing the risk of inducing odor-causing anaerobic decomposition (Border, 2002). The oxygen supply permits biological processes to occur so it is critical to keep the pile-aerated (Stanley and Turner, 2010). The remaining two factors, temperature and pH, are self-regulating. The pile’s temperature and pH depend on the microbial activity.

Under Federal law, states are responsible for regulating composting facilities (Brinton, 2000). In 1993, the United States Federal Government passed a section of the Clean Water Act, the Standards of the Use or Disposal of Sewage Sludge (40 CFR Part 503, 1993), which states that certain pathogen reduction must occur to be compliant. Similarly, the commercial requirements set forth by the National Organic Standards Board (2006) necessitates that waste materials used in composting must reach certain temperatures to ensure the elimination of harmful pathogens and parasites. All management practices must be documented from feedstock materials, temperature, elevation, maintenance, and decreases in weight, volume, and carbon to nitrogen ratio, and increase in nutrient stability. As it has been shown, the government agencies in the United States dictate the standards required for the sale of compost. When compost is used as feedstock for vermicompost, there is an increase in the positive attributes found in the soil amendment and a decrease in regulations.

**Soil Amendments – Vermicomposting Strategies**

The improved characteristics of vermicompost begin with worms being included in the process. Vermicompost is the managed process of worms digesting organic matter to transform the material into a beneficial soil amendment (National Organic Standards Board, 2006). This
organic matter can be generated from animals manure, green waste, or urban solid waste. Much of this waste can create odor problems or pollute surface and groundwater (Edwards, 2011). Vermicompost has the potential to accelerate aerobic decomposition of organic waste, in turn reducing odors and pollution.

Vermicompost processes organic waste through earthworms and microorganisms to bio-oxidize and stabilize organic matter (Arancon, et al., 2007). The earthworms aerate, condition, and fragment the waste, allowing for an increase in microbial activity. There are two phases in vermicomposting. The first is the active phase, in which the earthworms modify the physical properties and composition through the ingestion of the waste. The second is the maturing phase when the earthworms move towards the surface, allowing the microbes to continue the process of converting an organic waste into a soil amendment.

The most important biological feature of earthworms concerning vermicompost is how the organic material changes as the worm processes it (Arancon, et al., 2007). The material is swallowed and passes through the gizzard that grinds the material into smaller fragmented particles (Edwards and Fletcher, 1988). The grinded material is mixed with enzyme-filled fluids by strong muscles lining the earthworm’s digestive tract (Sherman, 2003). The digestive fluids of the worm separate sugars, amino acids, fungi, protozoa, nematodes, bacteria, and other microorganisms from the waste. The worms’ nourishment comes from these molecules and microorganism that are separated out of the waste as it moved through the worms’ digestive track (Edwards and Bohlen, 1996). The earthworms feed on the microorganism and simpler molecules by absorbing them through their intestinal membranes (Sherman, 2003). These nutrients are consumed for energy and cell production. The rest of material swallowed is released in the form of castings.
In phase two, the earthworms move towards the fresher layers of waste, allowing for microorganisms to take over decomposition and maturation of the waste (Sherman, 2003). Vermicompost has better structure, microbial content, and available nutrient content than compost (Dominguez and Edwards, 2011). This microbial diversity and activity is created because vermicompost doesn’t reach high temperatures like those generated during the thermophilic stage of compost that suppress microbial communities (Arancon, et al., 2007). The microbes convert the material into plant nutrients that are more soluble and available than the original material particularly nitrogen, potassium, phosphorus, and calcium (Edwards and Bohlen, 1996).

The State of California considers vermicomposting an excluded activity from California’s solid waste regulation (CalRecycle, 2012). California food and agriculture regulations affirm that worms are considered livestock, but feed material is under regulation by solid waste regulations. If the smell of a vermicompost facility becomes a nuisance, the community’s environmental health department will have jurisdiction. This is beneficial to owners and operators of vermicomposting because they are not subject to State inspections and retain power over management practices (Wang, et al., 2007). This is also a disadvantage because the State of California does not recognize vermicomposting as a solid waste disposal process on its own. To be considered a solid waste disposal process it will have to comply with the processes ability to complete the pathogen reduction requirement.

The National Organic Program (NOP) through the United States Department of Agriculture’s Agricultural Marketing Service implemented on July 22, 2011, gives the most complete marketing standard for vermicompost. The standard by the NOP states that the feedstock must be approved by NOP and the process must meet the following requirements:
aerobic conditions to be maintained by regular additions of layers of organic matter, turning, or employing forced air pipes such that moisture is maintained at 70-90%; and the duration of vermicomposting is sufficient to produce a finished product that does not contribute to contamination of crops, soil, or water by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances (NOP, 2011).

Each of the bedding or systems for vermicompost has their advantages and disadvantages. The outdoor windrow is a simple bed dug in the ground (Edwards, 2011). It costs very little capital to establish and is easily managed. The worms have the ability to crawl out of the bed and into the soil adjacent if the bed becomes too warm (Sherman, 2003). Its simple design has many drawbacks; it takes large amounts of land and is labor intensive. The long outdoor processing period, 6-18 months to process 18 inches, allows for many of the nutrients to either wash away or volatize (Edwards, 2011). Besides losing many nutrients, the vermicompost is impossible to harvest without extracting earthworms in the process. Many processors using this system use mechanical harvesters to separate the worms from their castings (Sherman, 2003).

Another popular bedding choice is the indoor container system, which needs very little space as the containers can be stacked on top of one another. This option is beneficial to composters who are working in areas with high property values and can’t afford much land (Edwards, 2011). The cost of capital limits the benefits for this system. The majority of the expense is incurred with cost of the heavy equipment to move the containers. It’s also difficult to regulate moisture because the containers must be moved, creating labor-intensive tasks and costs. The harvesting is another challenge as the worms must be run through a screen to separate
them from the vermicompost (Sherman, 2003). This in turn means each time a new container is started, worms have to be introduced, once again incurring another expense (Edward, 2011).

The angled wedge systems offer more benefits than the previous two but still have their own set of challenges. It works by creating a 90-degree angle with a concrete floor and a removable wall; then laying the material at a 45-degree angle (Edwards, 2011). The pile is covered with a plastic tarp to keep in moisture. About one inch of waste material is added daily and water must be frequently sprayed on the pile to keep it moist. This is a low capital set up, with many benefits over windrows such as less labor, faster processing time, and less leaching and volatilization because the material is not placed in the ground. This process requires less space and it is easier to separate the worms because the portion of the pile to be harvested can be targeted and scooped off the concrete floor (Sherman, 2003). This system still has its drawbacks; compared to more advanced systems, the processing time is slow and the need for labor and machinery to frequently apply waste and moisture to the pile is high.

The continuous flow reactors are the most technologically advanced systems and process the largest amount of waste in the shortest amount of time. The system is a box raised above ground with four legs supporting it where waste can be applied on top daily. The bottom is composed of a mesh screen; a scraper is run across the bottom to harvest the vermicompost (Sherman, 2003). The worms continually make their way from the old material to the new material. The capital to establish a system like this is more expensive than any other process but the return of quick waste processing and no separation of the worms from the vermicompost has great benefits (Edwards, 2011). Not having to separate allows for the process to continue constantly without disturbing the worms. The continuous flow reactors are the most reliable composting system in the industry because they allow the operators to run the process efficiently
and quickly. To produce the highest quality and most efficient soil amendment, many use multi-treatment processes.

**Multi-Treatment Strategies**

Overall, vermicompost is claimed to have greater market acceptance than compost because it has a better appearance, higher nutrient content, and more microbial activity (Tognetti, et al., 2005). A drawback of vermicomposting is that it cannot ensure pathogen removal because it does not remain in the thermophilic temperature range for a long enough period of time. Depending on the feedstock, a short 3-day thermophilic composting will have to occur before vermicompost is compliant with EPA’s process to further reduce pathogens (Ndegwa and Thompson, 2001b).

To solve the pathogen problem, vermicomposting has been integrated with composting. The composting sanitizes the waste and eliminates toxic compounds while the vermicompost reduces particle size and increases nutrient availability (Domínguez and Edwards, 2011). Mixing of the two processes also reduces the expense and duration of the treatment process (Ndegwa and Thompson, 2001a). An integrated approach also creates higher quality vermicompost in the form of pH, acceptable pathogen reduction, homogeneity, and higher nutrients. It was demonstrated that composting followed by vermicomposting is the most effective strategy to stabilize cow manure with less impact on the environment, while achieving pathogen elimination standards (Domínguez and Edwards, 2011b). Optimal effectiveness when using the multi-treatment process occurs when worms are quickly added to the material after the initial heat is reduced. This strategy shortens the time for stabilization and curing of the compost (Logsdon, 1994).
There are many advantages to composting prior to vermicomposting such as eliminating pathogens from animal waste. However, if composted too long there can be negative effects on nutrients and the worms during vermicomposting (Mupondi, et al., 2010). A study was conducted to discover the optimum length of time to compost before vermicomposting; to eliminate pathogens and to identify what effects composting would have on the worms and the vermicompost (Munpondi, et al., 2010). A mixture of dairy manure and paper were used as the organic waste because of the large amount of manure produced on dairies and the large amount of paper waste created by developing countries; these two wastes are easily accessible around the world.

The diseases tested for were fecal coliforms, Escherichia coli 0157:H7, Cryptosporidium and Giardia oocysts. These diseases were chosen because they are commonly found in animal waste and cause a majority of the food borne illnesses. Four trials were set up where the composting period ranged from one to four weeks, followed by eight weeks of vermicomposting.

The results from the trial showed that after 1 week of composting, 94% of fecal coliforms were eliminated and after 3 weeks, no fecal coliforms were detectable. E. coli and the Cryptosporidium and Giardia oocysts followed a similar trend. Worms were weighed at the beginning of each trial and each week as the trial progressed. The worm mass was largest following the first week of composting and declined in the following weeks. The total carbon decreased the longer the composting process progressed. Results after the vermicomposting process indicated that one-week compost had the highest total nitrogen levels. The best C:N ratio was observed after 4 weeks of composting, followed by 3 weeks, 2 weeks, no composting, and 1 week. Vermicompost that was composted first for one week had both pathogen reduction
and the highest nitrogen level, making it the ideal composting length. The concern over pathogens has led to thermophilic composting before vermicomposting.

A study tested the nutrient difference between vermicompost and compost (Frederickson, et al., 2007). For sanitation, the one hundred and seventy five tons of paper based household waste were thermophilically composted for 14 days. During this process, 9% of the organic matter and 5% of the nitrogen was lost. Following the 14 days, the material was separated either into vermicompost beds or composting windrows. The study was repeated in five different beds for each of the two set-ups. The compost in each of the beds was allowed to mature for 84 days and then pulled out for quality testing.

It was found that the vermicompost had a higher mass of fine particles than the compost. Vermicompost mass consisted of 65.3% fine particles compared to compost’s mass consisting of 36.9% fine particles. This implies that vermicompost has superior fragmentation of the original feedstock. The mature vermicompost and compost had similar macro nutrient levels of nitrogen, phosphorus, and potassium, with a C:N ratio of 20:1. The level of electrical conductivity and water-soluble potassium were not significantly different. However, once the two were run through screens, the compost had more water-soluble potassium and had 42% more electrical conductivity. The more water-soluble potassium correlates directly to increased yield of the crop and quality of the plant, but too much can become a ground water pollutant (Cassman, et al., 1990). The high soil electrical conductivity is concerning because the EC levels correlate to salt levels in the soil. The higher the EC levels, the higher the salt levels, which can negatively affect crop yields, plant nutrient availability, and the activity of microorganisms. The windrow compost also had 20% more total nitrogen, 24% more total phosphorus, and 48% more total
potassium. The final C:N ratio of compost was 14:1 and the vermicompost ratio was 17:1. The overall results seem to favor the compost over the vermicompost.

The ideal C to N ratio is 25 to 1 (Ndewga and Thompson, 2001b). At this ratio, the composted material achieves its highest degree of stability. It was also found that the material at this ratio had the most nitrogen, the greatest reduction of soluble nitrogen and the only treatment that had a reduction in soluble phosphorus, which can result in becoming potential pollutants. The ratio of 25:1 also produced a product with the highest fertilizer value with a pH closest to neutral, resulting in a material that would be most ideal for commercial use.

Following the conclusion of Ndewga and Thompson’s (2001a) lab work, the composts were then placed into a 28-day plant growth trial. A fertilizer was added to the compost, vermicompost, and peat media, which contained a nutrient ratio of (15:10:16). There were three different crops used: tomatoes, marigolds, and radishes and each trial had ten replicates. Reviewing the data, the highest fresh mass per plant, dry mass per plant, and mean number of plants per tray tend to favor vermicompost, but the statistics did not show a significant difference. Ndewga and Thompson (2001a) concluded the vermicompost was better at transforming a larger amount of the waste into fine particle compost but lacked the nutrients found in the windrow compost. The control, compost, and vermicompost all performed equally in the plant growth trials. The best results were shown when a multi-treatment process was used; composted for one week, which reduced many harmful food borne diseases by 95% and then followed by vermicompost. It was determined that the best length for composting was nine days, followed by 75 days of vermicompost. Composted material consisted of grass clippings, shredded paper, and a variety of vegetables (Nair, et al., 2005). The time interval for each
individual process stated above illustrates the best pathogen reduction and the best C:N ratio, 15:1 to 20:1 in replicated trials.

The benefits of pre-composting before vermicomposting have been demonstrated by scientific studies. Many of the studies pre-compost and then vermicompost, but some studies have examined the benefit of doing the process in reverse. Three experiments were set up; one test was vermicomposting then composting, another was composting then vermicomposting, and the last was just vermicomposting (Ndewga and Thompson, 2001a).

The waste material used in this study was bio solids blended with paper waste to create a C:N ratio of 25:1 which from their previous work was determined to be the optimal C:N ratio to maximize efficiency. The processing order experiment was a completely randomized and replicated study. The experiment was held in an ambient temperature as close as possible to 77-degrees Fahrenheit and the moisture was maintained at 80%. Each process was performed for 28 days before switching to the other process; thus resulting in a total trial time of 56 days. The last experiment, vermicomposting alone lasted for 56 days.

Ndewga and Thompson’s (2001a) experiments demonstrated that when considering waste treatment, using combined systems was more efficient than a vermicomposting system alone. Total solids were reduced by nearly 45% in combined systems which was 10% better than vermicompost alone. Vermicompost followed by composting had the greatest reduction of volatile solids at 15%, 2% better than composting followed by vermicomposting and 5% better than vermicomposting. It was observed there was no significant difference in the reduction of soluble nitrogen; all three trials resulted in about a 70% decrease. Vermicompost followed by compost did have a significant difference in soluble phosphorus at 33% decrease and was 50% more efficient than the other trials. The other two trials tied at 16% decrease in phosphorus.
However, the only trial to meet the EPA requirements for pathogen reduction was compost followed by vermicompost and both of the other two systems would require further testing before they would be approved for sale. The composting followed by the vermicomposting was the best system, it met EPA requirements and was the most homogenous, had less soluble nitrogen and phosphorus. The composting phase could have been done in a shorter amount of time than was conducted in the trial, making it more efficient.

**Advantages of Vermicompost**

Vermicompost accelerates the biological degradation of organic waste by earthworms and microorganisms (Arancon, et al., 2011). The transformation happens as the earthworms consume the waste and fragment it into finer particles. This process increases the rate of microbiological decomposition while altering the physical and chemical properties of the organic material. This leads to quickened humification, during which unstable organic matter becomes fully oxidized and stabilized.

As sustainability practices become of increasing concern, sometimes the best place to look for a sustainable practice is in nature itself. Vermicompost meets growers’ demands through natural processes. The interactions of earthworms in the form of castings and microorganisms on organic wastes produce a soil amendment that provides a balanced nutritional release to plants (Edwards and Fletcher, 1988). Organic amendments like vermicompost have long been shown to provide a more balanced and better-timed source of nutrition for plant growth (Sinha, et al., 2010).

Plants are great beneficiaries of vermicompost. The organic matter found in vermicompost provides plants with a balanced source of nutrients that effect the composition and physiology of the plant (Arancon, et al., 2003). Vermicompost has the ability to provide some
essential nutrient elements that are not found in inorganic fertilizers. When vermicompost has been applied to fields or substituted in as a soil media, it has been shown to increase crop growth significantly (Sinha, et al., 2010).

An experiment that utilized vermicompost derived from animal manure spread on a chardonnay grape variety boosted the yield by 35% (Arancon and Edwards, 2011). One application of vermicompost had positive effects for 5 years on grape growth and yields (Webster and Buckerfield, 2011). A variety of peer-reviewed experiments were investigated and it was shown that increases of yields and growth were achieved with vermicompost in a number of crops that included bananas, rice, tomatoes, potatoes, sunflowers, sugarcane, mulberries, China asters, peppers, and strawberries (Arancon and Edwards, 2011).

Vermicompost has had great success with specialty crops. When field crop growers use vermicompost, it is common for vermicompost to be in combination with chemical fertilizers. A study found evidence of the effects of vermicompost with chemical fertilizers on growth and marketable fruits in field-grown tomatoes, peppers, and strawberries (Arancon, et al., 2002). The experiment compared chemical fertilizers to vermicompost supplemented with chemical fertilizers to equalize the initial nitrogen levels. The marketable tomato yields increased when the vermicompost mixture was used. In the pepper trial the vermicompost treatment showed significant improvement in the weight of the shoot, leaf mass, and total marketable fruit compared to chemical fertilizer only treatment. The strawberry trial showed a significant increase in leaf mass, number of strawberry stolons, number of flowers, shoot weights, and total marketable fruit, when the vermicompost treatment was used. These results were suggested to have occurred because of the large increase in microbial biomass and the vermicompost acting as a plant-growth regulator of nutrient supply.
Besides providing timely applications of nutrients to crops, vermicompost has other desired characteristics. The combination of high microbial activity and slow release of nutrients have led vermicompost to indirectly enhance the plant’s ability to suppress insect attacks (Arancon, et al., 2006). The form of nitrogen in vermicompost is the mechanism that inhibits attacks by arthropod pests on the foliage and fruits of the crops. Within vermicompost, phenolics are found and this naturally occurring compound has insecticide like characteristics. Vermicompost decreased infestations by aphids on pepper plants significantly (Arancon, et al., 2003). In other studies, vermicompost suppressed population of plant parasitic nematodes (Arancon et al. 2002). Other major pests were shown to be suppressed including jassids, aphids, cabbage white caterpillars and spider mites (Rao, et al., 2001; Rao, 2002; Arancon, et al., 2005).

The benefits to soil by vermicompost are numerous. The application of vermicompost on soil has the ability to maintain organic matter in the soil, reclaim degraded soils, and supply plant nutrients (Arancon, et al., 2006). A common environmental practice is to use vermicompost for soil restoration. Vermicompost also stimulates soil microbial growth and activity while increasing the vegetative cover.

Economics of Vermicompost

A vermicompost operation is most concerned with the economic value of the vermicompost produced. It was originally viewed that vermicompost was not commonly used by large commercial growers because of the high cost compared to synthetic fertilizers (Sherman, 2003). Nonetheless, organic growers and home gardeners are increasingly using vermicompost. In more recent trends, vermicompost is viewed to have potentially as high of an economic value as soil conditioners or media for plant growth (Dominguez and Edwards,
The economic value of vermicompost from Worm Power, a large composter on the East Coast, is $400 per cubic yard (Herlihy, 2014).

Vermiculture has six current market outlets: the sale of earthworms, sale of earthworm castings, sale of vermicompost teas, resource recovery services, development and marketing of vermicompost bins, and vermicompost systems (Jensen, et al., 2011). There are two unique markets with vermicompost: the volume and the dollar market. The volume market is users like the agricultural industry, which take large quantities but is unwilling to pay much for it. The volume market is more tolerant of variances in quality. The dollar market is for users in the landscape industry where it is being used for flowerbeds or turf. These customers are willing to pay the high-end price. The dollar market is focused on the appearance, odor, and performance of the vermicompost (Tyler, 1995). The profitability will increase with higher quality and more consistent vermicompost.

The most profitable market is the sale of vermicompost to landscapers and home gardeners (Jensen, et al., 2011). The sale of bagged vermicompost is marketed to nurseries, farmers markets, gardeners, and homeowners. In bulk, vermicompost retails between $75 and $300 per ton and bagged product value can increase between five to ten times that of bulk. It has been determined that a ton is usually between 2-3 cubic yards. The capital investment needed to start an annual 40,000 pound vermicomposting system is estimated to be between $30,000 and $100,000.

A study conducted by Jensen, et al. (2011), established the economics of a large-scale operation, including the cost of a continuous-flow batch reactor facility and processing cost. The study showed financial data that would be expected by an indoor continuous-flow batch reactor facility and showed vermicompost of 100 tons of organic waste per day. This information will
vary by location, but on average 35 continuous-flow vermicomposting reactors, at a cost of $50,000 each, would total $1,750,000.

Jensen, et al. (2011), alternatively found that a mobile gantry, or an automated system that lays the hot compost on the beds, would cost approximately $12,000. The concrete base of the facility would cost $162,000 and a facility with insulated greenhouse type material would cost $80,000. The chopping, grinding, and mixing machine is estimated at $20,000 with another front-loading machine cost of $15,000. The liquid waste separator to produce the raw material would be $35,000 and the earthworm waste separator would be $5,000. The moving belts that transport the vermicompost to the processing facility are estimated to be $30,000 and the storage bays for the final product would be $10,000. It would be $40,000 if the operation decided to purchase its own truck. Thus, all totaled the initial investment to start a large-scale vermicompost facility would be approximately $2,159,000. Operating costs also need to be factored into the long-term cost.

The total operating cost per year is estimated to be $220,000 and this includes the cost of labor, transport, energy, repair and maintenance. The labor cost to have four workers to run a facility with 35 continuous-flow reactors is estimated at $140,000. The repair and maintenance is estimated to be $20,000 for a large 35 continuous-flow reactor facility. The energy cost is $10,000 and transportation cost to bring the product to market is roughly $50,000. However, in California the transportation cost are estimated to be much higher. It costs $4.48 per ton of dry manure to be moved 21-25 miles (Hughes and Dusault, 2005). The transportation cost could potentially limit the feasibility of an operation.

The study indicates income will come from two areas: the fee to municipalities for waste disposal or tip fees and the sale of the vermicompost. It was estimated that the average waste fee
is $30 a ton, and this scale set up can take in 100 tons of organic waste a day, which estimates to be roughly $1,050,000 a year. Using an estimated price of $35 per ton, the annual income from the sale of vermicompost is estimated to be $1,225,000. One ton of vermicompost usually sells between $50 and $500 and more specifically, vermicompost using cow manure averages roughly $100 per ton. As seen in Table 1, the total expected income is therefore $2,275,000 and with a potential annual profit of $2,055,000 (Jensen, et al., 2011). This is an approximation and this scenario is based on an established market for vermicompost.

Table 1: Capital Cost for Indoor Continuous-Flow Reactor

<table>
<thead>
<tr>
<th>Equipment Investment</th>
<th>$</th>
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<tbody>
<tr>
<td>35 continuous-flow vermicomposting reactors at $50,000 each</td>
<td>1,750,000</td>
</tr>
<tr>
<td>Mobile gantry (multiple reactor)</td>
<td>12,000</td>
</tr>
<tr>
<td>Concrete base</td>
<td>162,000</td>
</tr>
<tr>
<td>Insulated polyethylene greenhouse building</td>
<td>80,000</td>
</tr>
<tr>
<td>Chopping/grinding/mixing machine</td>
<td>20,000</td>
</tr>
<tr>
<td>Front loader machine</td>
<td>15,000</td>
</tr>
<tr>
<td>Liquid waste separator to produce solids</td>
<td>35,000</td>
</tr>
<tr>
<td>Earthworm waste separator</td>
<td>5,000</td>
</tr>
<tr>
<td>Moving belts</td>
<td>10,000</td>
</tr>
<tr>
<td>Storage bays</td>
<td>10,000</td>
</tr>
<tr>
<td>Truck</td>
<td>40,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$2,159,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual Returns</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste disposal fee ($30/ton)</td>
<td>1,050,000</td>
</tr>
<tr>
<td>Sales of vermicompost ($35/ton with loss of 10% during processing)</td>
<td>1,225,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$2,275,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual Operating Costs</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor costs (four workers)</td>
<td>140,000</td>
</tr>
<tr>
<td>Transport costs</td>
<td>50,000</td>
</tr>
<tr>
<td>Energy costs</td>
<td>10,000</td>
</tr>
<tr>
<td>Repair and maintenance</td>
<td>20,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$220,000</td>
</tr>
<tr>
<td>**Potential Annual Profit (without initial investment)</td>
<td>$2,055,000</td>
</tr>
</tbody>
</table>

Jensen, et al., 2011

**Income Strategies**

In North America, most large vermicomposting facilities use thermophilic composting to reduce the pathogens, followed by vermicomposting (Sherman and Bogdanov, 2011). These facilities’ feedstocks come from organic waste material from landfills. Tipping fees can generate
around 80% of the total revenue brought in by these facilities. Other revenue is generated through the selling of vermicompost and worms to be used as bait or other activities. These facilities use different composting methods based on region.

Facilities on the West Coast of the United States located in temperate climate tend to be outdoor windrow systems. This is the region where the largest amount of vermicomposting occurs. The East Coast and South consist of facilities that have a covering to protect from the weather. Areas with very cold winters or extreme fluctuations in weather use indoor systems to produce a consistent product all year around.

In North America, composting facilities are owned by private entities, municipalities, or partnerships between the two (Sherman and Bogdanov, 2011). It is far less common to find vermicomposting facilities owned by municipality because municipalities focus on disposal and stabilization of waste. Composting facilities owned by municipalities do not usually have the ability to choose their waste stream. Alternatively, vermicomposting facilities are usually privately owned by entrepreneurs trying to maximize their revenue. These entrepreneurs are promoting the value of the earthworms and the by-products. Driven by product quality, vermicomposting facilities are looking to acquire organic waste material that can be standardized and replicated. The standardization of waste stream is valuable in creating a consistent and marketable product.

*Estimating Vermicompost Market Potential*

Establishing a vermicompost market requires knowing the potential return. A survey employing willingness to pay methods can be used to examine potential market behavior. This type of survey gathers market information without actually having the product or service in the market. Under willingness to pay lies a sub-group called stated preference methods (Bateman, et
Stated preference methods establish consumers’ preferences in hypothetical scenarios or alternative attributes that have not been offered in the market place (Louviere, et al., 2000). There are a number of stated preference methods, each possessing their own strengths and weaknesses.

**Stated Preference Method**

The stated preference method is used in hypothetical situations where services or products are not currently in the market place. There are two underlying categories that form stated preference, contingent valuation method and choice modeling techniques. The academic community has shown more preference to contingent valuation methods when developing and analyzing current and potential markets (Competition Commission, 2010). Contingent valuation methods focus on the willingness to pay for, or willingness to accept, the good or service as a whole (Hanemann, 1984). Compare this to choice modeling techniques, which focus on individual attributes and how the willingness to pay values change for different attributes of a good. In the survey or questioning phase, the questions posed by contingent valuation methods ask direct questions about the respondent’s willingness to pay for a good or service, but may cause cognitive problems because of the difficult decisions put upon the respondent. Respondents only provide one response per question. The choice modeling technique differs in that it doesn’t directly ask monetary valuations but asks respondents to choose between options. It is easier for the respondents to understand these types of questions. The cognitive issues are lessened because respondents also have the ability to provide multiple answers to questions (Bateman, et al., 2002).
Contingent Valuation Methods

The creation of contingent valuation methods in the 1960s provided a way for researchers to study the overall monetary value of goods or services in a hypothetical market (Bruce, 2006). The contingent valuation methods approach the good or service in its entirety and determine value based on respondents willingness to pay or willingness to accept. To generate this overall monetary value of the goods or service, a large sample size is required to generate accurate data. A common criticism is the high cost of large sample size requirements for small amounts of information (Kjaer, 2005). The first contingent valuation method developed was an open-ended questions method and progressed into dichotomous choice methods in the 1980’s (Hanemann, 1984). Contingent valuation methods are comprised of five approaches: open-ended, iterative bidding, payment card, dichotomous choice, and double-bounded dichotomous choice. Each of these contingent valuation methods comes with advantages and disadvantages.

The original contingent valuation method, the open-ended method, questions respondents about their maximum willingness to pay. Straightforward questioning, without anchoring bias, means respondents won’t be provided with hints about the change in value of the good or service (Pearce and Ozdemiroglu, 2002). It provides the maximum willingness to pay for each individual respondent and the data is easy to analyze with straightforward statistical techniques. The open-ended method does have some shortcomings, usually in the form of large non-response rates, protest responses or unreliable responses. It has also been determined that respondents can find it challenging to give a maximum willingness to pay for a good or service they haven’t thought about valuing (Competition Committee, 2010). Most decisions respondents face in actual markets are based on whether to buy or not to buy, instead of deciding the maximum they are willing to pay for a good or service. This method has been surpassed by more evolved valuation methods.
Iterative bidding method discovers how much respondents would pay for an improved attribute. If the respondent accepts the additional cost for the improved attribute, the questionnaire will continue to increase the cost until the respondent no longer accepts the cost (Pearce and Ozdemiroglu, 2002). This method, through continued questioning, compels respondents to consider their preferences carefully. The catch is the risk of anchoring bias; the respondents could be influenced by the initial starting cost. This method may lead to a large number of responders saying yes to an unrealistic cost and creating outliers. The desired audience for this type of questioning method is limited because accepting cost or bidding games are not suitable for mail surveys; a telephone survey would be preferred.

The payment card method presents the respondents with a range of payment options and asks them to choose the maximum they are willing to pay for a product or an added service. This method provides context to the bids without creating a biased starting point (Competition Committee, 2010). The number of outliers is reduced compared to other contingent valuation methods because each respondent can relate the initial cost to their own situation. This benefit of giving the respondents the ability to relate the cost to their own personal situation also creates a drawback because a respondent’s personal situation may cause bias towards the questionnaire (Pearce and Ozdemiroglu, 2002). The payment card method has challenges being implemented over telephone questionnaires because of the large list of possible choices presented to the respondent. It is best performed through mailed surveys.

The evolution of contingent valuation methods progressed to the dichotomous choice methods. There are two types of dichotomous choice, the single bound and the double bound. The single bound dichotomous choice method questions respondents randomly on the cost they are willing to pay to improve a service or good (Competition Committee, 2010). Respondents
are given a cost for the service or good and they must decide whether to accept or reject. Cognitive problems are lessened because respondents only have to accept or reject; this impersonates how respondents make decisions in actual markets. The respondents are more likely to tell the truth, from a strategic standpoint, the bid will be accepted if their willingness to pay is higher or equal to the price solicited (Pearce and Ozdemiroglu, 2002). This method minimizes non-responsiveness and evades outliers. The National Oceanic and Atmospheric Panel endorses the use of the single-bounded dichotomous choice method (Arrow et al., 1993). A potential drawback is that respondents may be encouraged through this style of questioning to say yes to a bid that they would not accept in actual markets (Pearce and Ozdemiroglu, 2002). This can dictate a natural starting bias. When comparing single-bounded dichotomous choice to open-ended questions, observed study data verifies that single-bounded dichotomous choice has a significantly higher willingness to pay than open-ended questions. This could correspond to the fact that the simple design and removal of cognitive problems makes it easier for respondents to agree to a price. The dichotomous choice surveys require larger samples to depict respondents’ true willingness to pay. Besides requiring larger samples, these surveys provide respondents with less background information, which can cause respondents to create assumptions.

The final progression of contingent valuation method has been to double-bounded dichotomous choice. It shares many similarities to its predecessor. It asks the respondents for a bid if they are willing to accept and how much of an additional cost they would accept above the bid (Pearce and Ozdemiroglu, 2002). This method is more efficient because more information is gathered about willingness to pay from each of the respondents’ choices. It has been found that
respondents have an additional problem of truth telling and the ensuing questions may increase yes saying biases and lead to anchoring problems.

Each of these contingent valuation methods come with strengths and flaws. The two most preferred methods are payment card or a form of the dichotomous choice (Bateman, et al., 2002). These methods are superior to open-ended questions and biddings games in the ability to gather more accurate data on respondents’ real life choices (Pearce and Ozdemiroglu, 2002). Dichotomous choice offers respondents with the ability to give valuations of a good or service and can be driven by incentives. Payments cards have the upper hand on gathering more information, at a less expensive cost, and less cognitive burden when compared to dichotomous choice.

Choice Modeling Techniques

The choice modeling techniques describe goods or services by their specific attributes or characteristics. The valuation comes from how respondents assess the different attributes placed in front of them. This differs from contingent valuation methods, which assesses goods or services as a whole instead of by specific attributes (Competition Committee, 2010). There are four categories that comprise choice modeling techniques, each using different theoretical assumptions, analysis methods, and the overall design of the survey (Adamowicz and Boxall, 2001). The four categories are discrete choice or stated choice experiments, contingent ranking, contingent rating, and pair comparisons.

In discrete choice experiments, respondents decide between alternatives and their trade-offs. The selection of attributes could be asked multiple times to a respondent and attributes change from one respondent to another. In this questioning style, respondents will be given the ability to choose the status quo alternative, thus creating a realistic option (Competition
Committee, 2010). Throughout the questionnaire, discrete choice experiments will switch between willingness to pay and willingness to accept questions, honing in to the true monetary value associated with the attribute of the good or service. Data will only be collected on the chosen alternative. This technique is viewed as having weakly ordered data and mimicking the economic theory of rational and probabilistic choice (Bateman, et al., 2002).

The data provided by contingent rankings are strongly ordered because respondents rank all the alternatives listed. The respondent will be presented with a list and will rank the options from most preferred to the least. Contingent rankings are shown to the respondent as a sequential choice process; the alternative that finishes last in the rankings is dropped and the process continues until one choice remains (Competition Committee, 2010). The respondents are given the choice to remain with the status quo. This approach can become a hindrance as it may cause cognitive issues in the form of not being able to decipher between alternatives that the respondent views as equal or doesn’t have enough knowledge to rank (Louviere et al., 2000). The depth of information provided by contingent rankings is unmatched by the other choice modeling techniques.

When employing contingent ratings, respondents are asked to give a rating to each alternative. The respondents are shown an alternative, which they rate 1-10, 10 being the most preferred and 1 being the least preferred (Competition Committee, 2010). This technique causes cognitive challenges for the respondent because the respondent must place a value on each alternative even when they have little to no knowledge of the alternative (Louviere et al., 2000). Like the other choice modeling techniques, a status quo option is provided. No direct comparison is made between alternates, which may lead to alternatives coming back with equal
rankings. If alternatives come back with similar ratings it may be impossible to interpret which alternative respondents prefer.

The pairwise comparison technique presents the respondent with two alternatives. The respondent selects between the alternatives and specifies their overall view of the alternative (Competition Committee, 2010). The respondent indicates on a scale from highly preferring one of the alternatives to not being able to choose between the alternatives. It is commonly stated that this technique is a mixture of discrete choice experiment and a rating exercise. The limiting factor is that only preference information is provided but no economic value. This renders the technique useless when trying to derive the economic value of a good or service.

The preferred choice modeling technique by both the academic community and in practical application has been discrete choice experiment. The majority of literature has embraced discrete choice experiments because they closely mimics respondents’ real life decision-making when choosing between alternatives (Hensher, et al, 2005). Even though discrete choice experiments can’t provide respondents’ exact valuation of willingness to pay, it does provide an indirect estimate. It has become the recommended approach by Her Majesty’s Treasury in the United Kingdom (Cave, et al, 1993). Choice modeling techniques provide the ability to evaluate respondents’ preferred choices among alternatives that most naturally mirror real life.

**Summary**

The markets for organic waste have been established, along with the regulations that dictate what steps must be taken to convert organic waste into a soil amendment. It was discovered the best process would be to compost then vermicompost to meet government regulations of pathogen reduction and create a high quality product. The continuous-flow reactor
is the most efficient system in producing a consistent product all year long and lowering operating costs. The market for vermicompost is broken into two markets, the dollar and volume markets. The dollar market requires small package sizes at a high profit margin and high quality requirements. On the opposite side there is the volume market, large quantities with lower profit margin but less concern over quality. A vermicompost facility in California would need to determine the grower population to focus on. Survey techniques like contingent valuation methods will determine the grower population to focus on based on growers’ willingness to pay for vermicompost.
III. METHODOLOGY

Procedures for Data Collection

A willingness to pay survey was utilized to determine the scope of the soil amendment market in California (see Appendix A). The survey gathered data on multiple topics including demographics of growers, growers’ knowledge of compost and vermicompost, and growers’ willingness to pay for compost and vermicompost. The study utilized academic and verified information gathering techniques, such as stated preference methods, which establish consumers’ preferences in hypothetical scenarios (Louviere, et al., 2000). This study provided an understanding of vermicompost potential in the agricultural regions of California where vermicompost has yet to be established or is minimally used. Utilizing stated preference methods allows for analysis of the monetary values for goods or services in hypothetical markets.

To accurately collect data from respondents and determine potential valuations of a good or service, the survey instrument needs to be sound. The conductor of the survey should consider these principles to receive the most accurate answers: the depth at which the respondent understands the alternatives they are choosing between, the extent the respondent is motivated to switch alternatives by change in price or good, and the effect the survey instrument has in persuading the respondent to a change in price, creating over-estimation of the price elasticity (Kjaer, 2005). All questions should be set up that do not create a pre-determined response. No ambiguity should be in the questions and everything needs to be clearly stated (Hanley, et al, 1998). It is imperative to avoid language that creates judgments based on values but instead focuses the survey with verbiage that puts the respondent in a common choice situation environment. The alternatives presented to the respondents need to be seen as viable choices.
It has been established that providing additional background to the respondent before the questionnaire can be helpful. Such information may include current market prices of possible alternatives or an explanation of an alternative’s attributes. When examining multiple alternatives the survey needs an experimental design that permits different pricing scenarios to be presented independently of one another.

Besides asking clear and relevant questions, a survey has to be developed in a way that limits error and provides the best conditions to perform an accurate survey. To limit bias in the survey and get an accurate result, it is necessary to limit sampling error (Competition Committee, 2010). Sampling error is limited when respondents are selected randomly. Another issue that surveys can experience is non-response error, where the lack of response affects the outcome of the survey. This error is avoided by maximizing response rates using tactics like a short, well-designed questionnaire, assuring protection of confidentiality and data protection, and mentioning the reputable name of the survey sponsor. If it is impossible to create a short and simple survey, use incentives to motivate respondents. The length of the questionnaire should be no longer than 10 minutes in length. The sample size required depends upon on the cost and precision that is desired. For contingent valuation methods, it is recommended that the total sample size be 400 surveys with at least 75 responses (Adamowicz, et al, 1998). This sample size and response rate gives an accurate assessment of valuation for the alternatives. Following these guidelines will create a survey that provides accurate information for the conductors while providing an overall good experience for the respondents.

To produce accurate and cost-effective responses, surveymonkey.com was employed. This website is reputable and is used by many public organizations, businesses, and universities to collect data. An email was sent by surveymonkey.com to a list of California growers. The
distribution list was provided by Syngenta, a global Swiss agribusiness that produces agrochemicals and seeds. The 3,360 grower emails provided the study a diverse and accurate representation of California growers. If the grower chose to open the email, he was instructed to click the hyperlink, which led him to the surveymonkey.com website. Before the grower began the survey he read a short excerpt about the purpose of the survey. This helped to establish the validity of the survey in the minds of growers and laid the framework for the survey.

Following the short excerpt, the survey transitioned to the questions. Questions one through four uncovered growers’ demographics. The survey asked grower’s gross annual income, in what growing region their ranch or farm is located, what is their largest crop in terms of income, and acres used for production. This information helped to identify what growers responded to the survey and provide demographic information. Evaluation of growers’ largest crop assisted in focusing a potential vermicompost company’s marketing efforts, specifically the growing region and crop.

The growers were asked to answer open-ended questions about their current fertilizer use on their most lucrative crop. This section of questioning explored the current market for fertilizers and nutrient requirements. Survey questions five through seven inquired about growers’ yearly fertilizer use in terms of pounds per acre of nitrogen, phosphorous, and potassium, notated as N-P-K respectively. Additionally, the grower was asked what his average yearly fertilizer expense was per acre for his most profitable crop and what he believes the optimum N-P-K ratio is for the crop. These survey questions investigate growers’ fertilizer requirements and the amount growers are currently paying for fertilizers.

The survey transitioned to gather data on each grower’s knowledge of compost. The grower was initially given a definition of compost and key attributes. This preliminary
information provided each grower with baseline knowledge and alleviated possible ambiguity.
The eighth question inquired if the grower has ever used compost before on any of his crops.
Question nine investigated each grower’s knowledge of compost. The question established the
growers’ knowledge based on three rankings; never heard of it, heard of it but have limited
knowledge, and know the attributes well. This ranking system was chosen because growers
could easily group themselves into one of the three rankings. Questions ten and eleven explored
what growers perceive as market value for compost. Response data gathered from these two
questions was compared to response data gathered from two similar questions about
vermicompost later in the survey. The grower is asked in question ten to state the amount he
would be willing to pay per ton of standard dairy manure compost. The compost the grower was
evaluating has an N-P-K ratio of 1.5-0.7-1.5, which is a very common fertilizer ratio for this type
of soil amendment. To make sure that question eleven could not influence question ten
responses these questions were separated; question ten on page 4 of the survey and question
eleven on page 5 of the survey. If the grower entered zero or no answer for question ten, the
following page of the survey asked what amount of compensation per ton would be required to
accept the standard composted dairy manure. It was understood that some growers may never
accept compost no matter the level of compensation, if this was the case the grower was asked to
put an X. This section of questions examined growers’ perceived economic value of compost.
These answers, coupled with the demographics collected at the beginning of the survey, provided
insight to growers’ knowledge of compost and the potential lucrative regions for compost type
soil amendments.

The next section of the survey focused on understanding the potential vermicompost
market by mirroring the questions of the compost section, but for vermicompost. The grower
was provided with a definition of vermicompost and its attributes. Question 12, discovered growers’ knowledge of vermicompost. The responses from this question were directly compared to the responses received on growers’ knowledge of compost. The grower was asked in question 13 what is the maximum amount they would be willing to pay per ton of standard dairy manure that has been vermicomposted with an N-P-K ratio of 1.5-0.7-1.5. This question allowed the study to compare vermicompost to compost at the same fertilizer ratio, to determine if growers find more value in vermicompost, compared to compost. Question 14 mimics question 11, where it is displayed on a separate page so as to not influence the ‘willingness to pay’ answer. If the grower responded with zero, the grower was asked how much he would need to be compensated per ton to accept standard dairy manure that has been vermicomposted. If the grower would never accept this vermicompost, the response is marked with an X. The responses in this section gleaned knowledge growers have of vermicompost, their willingness to pay and accept vermicompost, and compared vermicompost to compost in potential markets.

**Procedures for Data Analysis**

To analyze the responses gathered from the survey, Microsoft Excel was used to generate a regression analysis, statistical tests, generation of graphs and Pearson’s Correlation Coefficient. The data from the survey questions are comprised of nominal, ordinal, and ratio data. For all statistical tests performed in this study an alpha of 0.05 was chosen as the cutoff for significance. An alpha of 0.05 is preferred; it provides 95% confidence of the statistical test being true and 5% chance of the statistical test being untrue (SurveySystem, 2016). Pearson’s Correlation Coefficient, Chi-square test of independence, two-sample t-tests, and a multiple regression analysis were performed to determine the demographics of the California market, the knowledge of the growers, and growers’ willingness to pay between distinct markets.
The study utilized Pearson’s Correlation Coefficient to discover the correlation between growers’ knowledge of vermicompost and compost, and growers’ willingness to pay for compost and vermicompost. The coefficient provides a value between -1 and 1. It states whether or not there is linear dependence between the two variables being evaluated. The two variables are plotted against one another; analyzed where the lines are similar or random to one another. If the data plots are random the correlation will be near zero. The closer the data plots are to 1 the higher the positive correlation, and the closer the plots are to -1 the higher the negative correlation.

A Chi-square test of independence was utilized to determine if there is a statistically significant relationship between two categorical variables. The regularity of each category for one categorical variable is compared across the categories of the second categorical variable (Bradley, et al., 1979). This statistical test was used to evaluate hypothesis one. An example of a Chi-square test is the evaluation of voting habits by gender.

A paired two sample or two-sample t-test is utilized to determine if two population means are equal (Snedecor and Cochran, 1989). It compares the average difference between the two and determines if there is really a statistical significance. This statistical test will be used to evaluate hypothesis two and three. An example of a two-sample t-test is the evaluation of whether there is a significant difference in the average delivery time of flower shop A vs. flower shop B.

A multiple regression analysis was employed to determine which grower population could support a vermicompost company. A multiple regression is used to study the relationship between several independent variables or predictor variables and a dependent variable (Statsoft, 2016). The grower populations were evaluated by willingness to pay for vermicompost.
determined by the variables growers’ knowledge of vermicompost and compost, grower’s willingness to pay for compost, if the grower has used compost, agricultural region, and crop.

When the regression line is discovered, the independent variables are run through the equation to determine the relationship of the independent variables to the dependent variable. To understand if any of the predictor variables regression coefficients were inflated compared to when the predictor variables are not linearly related a variance inflation factor was utilized.

The best fit line of a multiple regression analysis is a fitted line in a multi-dimensional space; defined by the equation \( Y = A + B_1X_1 + B_2X_2 + \ldots + B_nX_n + e \). The \( Y \) variable, the dependent variable, is the variable that is being predicted by the relationship between the independent variables. The \( A \) coefficient represents the estimate of the regression intercept, where the line intercepts the \( Y \)-axis. The \( B \) coefficients are the slope of the \( X \) coefficient. In other words, \( B_1 \) is the slope of \( X_1 \), \( B_2 \) is the slope of \( X_2 \), and so on, for the number of independent variables that exist. The \( B \) variables in the equation determine whether the relationship is positive or negative among the independent variables to the dependent variable. The \( X \) variable is the independent variable, i.e., the variable used to predict the \( Y \) variable or dependent variable. The \( e \) variable is regression residual, or error of the regression model. The regression for this study will be: \( Y \) (Growers’ Willingness to Pay for Vermicompost) = \( A + (B_1 \times \text{Region}) + (B_2 \times \text{Crop}) + (B_3 \times \text{Income per Acre}) + (B_4 \times \text{Used Compost}) + (B_5 \times \text{Compost Knowledge}) + (B_6 \times \text{Vermicompost Knowledge}) + (B_7 \times \text{Growers’ Willingness to Pay for Compost}) + e \).

The real world is rarely perfectly predictable and there is usually a large variation of observed points around the fitted regression line (statsoft.com, 2016). To understand the variability a p-value is given to each variable to determine if the variable is statistically significant. Also, the residual value accounts for this variation and is the deviation of a particular
point from the regression line. The R-square provided by the multiple regression analysis provides a statistic to evaluate the regression line’s fit. The R-square is discovered from the formula 1 minus the ratio of residual variability. The overall variability of the residual values from the regression line determines the fit of the regression equation. The smaller the variability, the better the predictions of the regression equation. The R-square will fall between 0.0-1.0, the closer R-square is to 1.0, the better the equation accounts for almost all of the variability amongst the variables. The regression analysis provides a correlation coefficient, r, to express the degree to which two or more independent variables are related to the dependent variable. The closer the correlation coefficient is to 1, the stronger the relationship and closer to 0, the weaker the relationship. The confidence interval for this study is 95%. The confidence interval is a range of values so defined that there is a specified probability that the value of a parameter lies within it (Statsoft, 2016).

Assumptions

Growers in California truthfully responded to the survey questions. Growers were able to comprehend the meaning of each question and understand the attributes of the different soil amendments.

The response data was assumed to follow a continuous or ordinal scale, the data was presumed to be collected from a randomly selected portion of the total population, and the plotted data would have a bell-shaped distribution curve. It was assumed the data had a large enough sample size to create a bell-shaped curve and provide significant values. An assumption was made that the data has a homogeneous variance, and the standard deviations of the samples are approximately equal. It was assumed the response data follows each assumptions of the statistical tests performed in the study.
Limitations

1) The study could be limited by the bias of the growers. It’s possible that growers who have no knowledge of vermicompost or don’t see value in vermicompost won’t spend their time to respond to the survey.

2) The study could be limited by growers that are willing to share email addresses with Syngenta. It’s possible that grower that would find the most value in vermicompost is not the same grower that finds value from Syngenta’s business.
IV. DEVELOPMENT OF THE STUDY

Survey Results

California is in search of a sustainable fertilizer. Vermicompost provides Californians with the ability to dispose of agricultural waste and turn it into a sustainable fertilizer for the diverse crops grown in the state. It also provides vermicompost companies with a potential new market. For vermicompost companies to be successful, growers need to understand the value of vermicompost. Positioning vermicompost as an environmentally sustainable practice would be a useful tactic. To understand the potential market, a survey collected responses on grower demographics, knowledge of soil amendments, and the perceived value of both compost and vermicompost. Correlations and statistical tests provided a depth of analysis on these responses.

On September 1, 2015, an email was sent to 3,360 growers requesting participation in the survey and were given two months to respond, during which they received three reminders to complete the survey. The growers were asked to identify their agricultural region, crop, acres, income level, knowledge of soil amendments, and willingness to pay for compost and vermicompost. Respondents selected one of six agricultural regions their farm or ranch is located. The six regions are the North Coast, Central Coast, South Coast, Central Valley, Inland Empire, and Foothill and Mountains. North Coast region includes the coastal counties stretching from the Oregon Border to Marin County. Central Coast region is the coastal counties from Contra Costa to San Luis Obispo. The South Coast region is the coastal counties from Santa Barbara to San Diego. The Inland Empire region is the non-coastal counties from Imperial to Mono. The Central Valley region is the counties in the valley from Kern to Tehama. The Foothill and Mountain region is all non-coastal and non-valley counties from Siskiyou to
Mariposa. Growers from all regions identified with seven crops: grapes, tree nuts, miscellaneous vegetable crops, citrus, corn silage, stone fruit, and rice.

The survey had a seven percent response rate capturing responses from 223 California growers. However, only 82 growers answered all survey questions. The survey was sent to growers during a traditionally slow time of year. The responses demonstrated some limitations of the survey. Growers were challenged by questions five through seven. Many struggled with what N-P-K ratio they use on annual basis, what they spend annually on fertilizer, and the optimum N-P-K ratio for their crop. This can be attributed to the fact the ratio could fluctuate based on outside recommendations, new fertilizer options, or a change in soil nutrient levels. Demographic groups were collapsed to better represent grower populations. The counties were grouped into six agricultural regions designated by the University of California, Agriculture and Natural Resources. The income and acreage levels were collapsed to seven. There were few growers who were willing to accept; low responses forced these questions to be removed from the analysis.

Out of the 82 growers, 37 were located in the North Coast Region and account for 45% of all responses. Grapes are the most commonly grown crop in this region. The high response rate from the North Coast skews the analysis towards grapes. Grapes were selected 76% of the time as the largest economic crop for growers. California Agricultural Statistics Review shows grapes only represent 10.4% of the crop acres in California (CDFA, 2016). It is unclear why growers of grapes had this high of a response rate. Growers who identified with tree nuts were number two, comprising around 10% of the responses. California has a large number of tree nut growers and it is surprising more growers didn’t respond to the survey. Tree nuts have unique growing practices compared to other crops; it’s possible tree nut growers don’t find enough value in
compost and vermicompost to complete the survey. The full breakdown of crops by region can be seen in Figure 1.

Figure 1: Number of Growers per Crop by Region

The response data illustrated a large discrepancy in the acreage between regions. Acreage is important in terms of the quantity a vermicompost company will need to provide to a region. As would be expected, growers in the Central Valley region have more acreage than growers in other regions. As seen in Table 2, the average acreage for the Central Valley was 1,012 acres with a standard deviation of 1,524. The wide variation comes from the large difference of acreage sizes in the region; 35% of Central Valley growers stated as having at least 1,000 acres, while 43% stated as having less than 220 acres. Acreage was closely correlated to yearly income level, with 35% of growers in this region having an income of one million dollars or more. The farm sizes in this region are roughly 600 acres larger than the survey average. The other regions had significantly smaller acreage, with South Coast growers averaging 548 acres, Central Coast 254 acres, North Coast 155 acres, Inland Empire 100 acres, and Foothill and Mountain 4 acres. The overall average among all regions was 435 acres per farm.
The North Coast is opposite of the Central Valley, with 70% of growers farming less than 220 acres and only one grower indicating an operation larger than 1,000 acres. Survey responses indicated that 62% of growers had an income less than $500,000. On the North Coast more growers are below $500,000 than the Central Valley but the rate of return per acre is actually higher on the North Coast than the Central Valley. This is because of the higher value of the coastal grape market. Even within a crop, growers have different levels of income based on their market position. A grower must manage his market position and the inputs used in producing the crop.

The value of each grower’s crop affects which inputs, such as pest control, irrigation, and fertility, the grower is willing to use and the amount he is willing to pay for each. Compost and vermicompost are two of many soil amendment options that growers must consider for possible return on investment when choosing whether or not to use them. Certain crops had few responses and might not accurately represent the value growers are willing to pay for soil amendment fertility. In the survey, grape growers were willing to pay the highest average amount per ton at $59. This is significant because grapes had the largest response giving an indication of market opportunity. This grower population is one to focus upon.

Grape growing respondents were willing to pay on average $23 per ton more for vermicompost than compost. When delving into the data, only 25% of grape growers would

<table>
<thead>
<tr>
<th>Region</th>
<th>Central Coast</th>
<th>Central Valley</th>
<th>Foothill and Mountain</th>
<th>Inland Empire</th>
<th>North Coast</th>
<th>South Coast</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>254</td>
<td>1,012</td>
<td>4</td>
<td>100</td>
<td>155</td>
<td>548</td>
<td>435</td>
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<tr>
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<td>1,524</td>
<td>5</td>
<td>75</td>
<td>281</td>
<td>819</td>
<td>952</td>
</tr>
</tbody>
</table>
actually pay more than $59 per ton and 73% of these growers are located on the North Coast. Of these growers willing to pay $59 per ton, all grow less than 220 acres, and half are making more than $500,000. This shows how position in the grape market can affect the amount growers are willing to spend on inputs. North Coast grape growers’ crop is valued at a higher price and have a higher income per acre than other grape growers; in turn these growers are willing to spend more on inputs. A few grape growers are willing to pay $59 per ton of vermicompost. If the price per ton of vermicompost was $20, 76% of all growers would pay this amount. Removing a few growers willing to pay more adjusts the value down and better represents the market.

Many crop segments value vermicompost and compost similarly. As seen in Figure 2, crops like citrus, rice, stone fruit, and tree nuts value soil amendments below the overall average. Tree nut growers’ value vermicompost almost 35% below the overall average, with 50% of growers willing to pay $34 per ton. The averages across all crops are being pulled up by a few growers, but the market value for vermicompost is $20. If the market value of vermicompost was closer to $20, 83% of tree nut growers would be willing to pay this price. Growers often make their input choices, such as fertility plans, based on the market value of their crops, so the market value can be influenced by where the crop is grown and, in turn, can affect fertilizer choices.
Both crop and region influence a grower’s willingness to pay for vermicompost. Growing practices can remain the same or change by region, even though the same crop is being produced. In regions where grape growers are the majority, there is a positive effect on the amount growers are willing to pay for vermicompost. This relationship is demonstrated by the North Coast. On average, growers of all regions will pay $62 per ton for vermicompost, compared to $44 per ton for compost. Only 17% of respondents would pay $62 per ton, with all growers in this demographic being grape growers and 70% specifically North Coast grape growers. This differs from the majority, as 76% of all growers would be willing to pay the lower cost of $20 per ton of vermicompost.

On average, growers are willing to pay $44 per ton of compost, but only 30% of respondents will pay this amount. There is crop and regional diversity amongst growers willing to pay at least $44; this was not seen with vermicompost. A wider demographic of growers
understand compost than vermicompost. If compost was offered at $20 per ton, 78% of growers willing to pay would be part of the market.

When comparing the data for vermicompost and compost, differences begin to arise. Growers willing to pay the overall average per ton for vermicompost are generally grape growers found on the North Coast. However, when looking at compost data, growers willing to pay the average price are diverse in both crop and region. As seen in Table 3, there are wide variances in the averages growers are willing to pay for vermicompost. This isn’t the same pattern for compost, where the variances are almost cut in half. It appears the grower population has a better understanding of the value provided by compost. Since many growers don’t indicate having the same knowledge level for vermicompost, the value they are willing to pay may be less than the actual value it provides growers.

<table>
<thead>
<tr>
<th>Region</th>
<th>Central Coast</th>
<th>Central Valley</th>
<th>Foothill and Mountain</th>
<th>Inland Empire</th>
<th>North Coast</th>
<th>South Coast</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vermicompost Average</td>
<td>119</td>
<td>26</td>
<td>46</td>
<td>20</td>
<td>65</td>
<td>30</td>
<td>62</td>
</tr>
<tr>
<td>Vermicompost Std Dev</td>
<td>161</td>
<td>89</td>
<td>20</td>
<td>0</td>
<td>116</td>
<td>15</td>
<td>103</td>
</tr>
<tr>
<td>Compost Average</td>
<td>29</td>
<td>24</td>
<td>54</td>
<td>9</td>
<td>48</td>
<td>31</td>
<td>44</td>
</tr>
<tr>
<td>Compost Std Dev</td>
<td>19</td>
<td>74</td>
<td>25</td>
<td>0</td>
<td>41</td>
<td>13</td>
<td>48</td>
</tr>
</tbody>
</table>

Respondents’ level of knowledge can indicate their willingness to pay for compost and vermicompost. Survey responses show 72% of growers know the attributes of compost well, 28% had at least heard of compost but had limited knowledge of its attributes, and there were no growers who had never heard of it. As seen in Figure 3, 75% of growers from the agricultural regions of Central Coast, North Coast, South Coast, Foothill and Mountain, and Inland Empire indicated they know the attributes well. The only agricultural region that was different was the Central Valley with 43% knowing the attributes well and 57% having heard of compost but having limited knowledge of its attributes. Central Valley knowledge level being lower than the
other regions is associated with the lower value they put on compost. It’s surprising that more growers in the Central Valley do not know the attributes well because the region possesses a large number of potential raw materials that can be transformed into compost. The diversity of the crops grown in the Central Valley could explain the knowledge gap, as it possibly creates an unfocused marketing message from compost companies. This correlation between the lower knowledge level and a lower value was demonstrated by the Central Valley growers.

The survey responses show that growers from all regions have a general understanding of compost and some of its attributes. When comparing growers’ understanding of compost to vermicompost, a gap appears in knowledge levels. Overall, 30% of growers had never heard of vermicompost, 44% had heard of vermicompost but had limited knowledge of its attributes, and 26% know the attributes well. Overall, 70% of growers have some knowledge of vermicompost, which is 30% lower than overall knowledge levels of compost. This knowledge difference is closely associated with a variance in value amongst growers in certain regions.

On the North Coast 22% of growers had never heard of vermicompost; 43% of growers in this region have limited knowledge and 35% know the attributes well. Although the majority
of North Coast growers have some understanding of vermicompost, they may need more
education on the value for adoption of the product. A tactic that potential vermicompost
companies might want to consider is positioning vermicompost around the environmentally
sustainable messaging many North Coast grape growers are currently utilizing.

Of the North Coast growers who rated themselves as knowing the attributes of
vermicompost well, 28% would be willing to pay the average of $62 per ton. However, North
Coast grape growers with a high level of knowledge were willing to pay a $40 premium for
vermicompost over compost. All but one of these growers had previously used compost on their
operation. Interestingly, 50% of growers with limited knowledge of vermicompost would be
willing to pay the $62 average.

On average, growers with limited knowledge valued both vermicompost and compost at
$55 per ton. These growers do not have enough knowledge of vermicompost to value
vermicompost more than compost. As expected, growers that had no knowledge of
vermicompost would not pay the overall average of $62 per ton and the majority answered they
would pay zero for vermicompost. With certain grower populations it appears as knowledge
increases the value difference between vermicompost and compost increases.

As seen in Figure 4, only 6% of growers in the Central Valley know the attributes well
and 50% have never heard of it, which raises concern over the market viability of this region.
Vermicompost companies will need to provide outreach and education for there to be demand
from growers. It’s a promising region in terms of manure being easily accessible as a raw
material and the sheer crop acreage. This low level of knowledge aligns with the region’s low
dollars per ton average compared to the other regions’ dollars per ton average. With the many
tree nut growers found in this region, the survey results demonstrate that tree nut growers’ value
vermicompost significantly lower than grape growers. However, it is interesting that growers in this region who have never heard of vermicompost value it $4 per ton higher than compost. It is possible that their responses can be explained just because as a new product, vermicompost is perceived as being worth more. Growers who have at least limited knowledge of vermicompost value it at $3 per ton less than compost. It is possible these growers had a bad experience with vermicompost or overestimated their knowledge level. A vermicompost company must be willing to spend resources educating growers and have the patience for adoption to occur.

Because of that, many companies might want to focus on a different region.

**Correlations: Knowledge and Willingness to Pay amongst Growers**

Compost and vermicompost are competing inputs and share a relationship. The survey responses showed a difference between growers’ knowledge of vermicompost and compost. A Pearson Correlation Coefficient was employed to represent the relationship. The r = 0.45, which describes a positive relationship between the two variables, but not a strong relationship.

Growers that have knowledge of compost have some level of vermicompost knowledge. The correlation is weakened by 30% of growers having no knowledge of vermicompost but all
growers having some level of compost knowledge. Growers’ also have a high level of compost knowledge and a limited level of vermicompost knowledge. The relationship will strengthen as growers’ vermicompost knowledge increases. Thus, the knowledge of these two soil amendments are not independent of each other. This correlation suggests that the amount growers are willing to pay for vermicompost in certain areas will increase as growers gain more knowledge of vermicompost. The knowledge of both these two soil amendments have room to strengthen.

When comparing the relationship between growers’ willingness to pay for vermicompost and compost, the correlation equals 0.76, a strong positive relationship between the two. Some growers will pay zero for compost but will pay greater than zero for vermicompost. The growers that stated this ranked themselves as having limited or no knowledge of vermicompost. The growers in this grouping are assuming a new product is better than the current standard and are willing to pay more.

There are three outliers, all are North Coast grape growers located in Napa County, and these three growers had the largest income per acre of all growers. Each ranked themselves as knowing the attributes of vermicompost and compost well. Two of the three growers had previously used compost. Vermicompost was valued on average $290 per ton higher than compost by these growers. These growers have either experienced the difference of vermicompost to compost or are placing more intrinsic value on vermicompost. Delving further into the regional analysis, it was discovered that two regions in California had a stronger positive correlation than California as a whole. North Coast and Central Valley have a strong positive correlation of r=0.83, and r=0.98. These two regions value vermicompost and compost closely. The survey data shows a difference between the average means, but these two products are
valued at similar prices to each other in the different regions. Removal of the outliers strengthens the relationship and provides a clearer view of the market value.

The relationship between willingness to pay for vermicompost and compost strengthens to 0.91 with removal of the three North Coast outliers. This is an extremely strong correlation. In Figure 5, the equation for the correlation is represented, if a grower pays zero for compost the market value is $9.84 per ton of vermicompost. With every additional dollar a grower is willing to spend on a ton of compost, the grower is willing to spend $0.87 per ton of vermicompost. This equation demonstrates growers who won’t pay for compost will for vermicompost; but it also shows growers that are willing to pay for compost are willing to pay less for vermicompost. Growers who won’t pay for compost assume vermicompost must be better and are willing to pay for it. This equation also illustrates growers need more outreach and education around vermicompost to increase its value compared to compost. The equation explains 74% of the variation of the “Y” variable explained by the “X” variable. There is a cluster of data points from $20 to $30 per ton. It appears the market value for vermicompost lies around $20 per ton.
Paired Two Sample T-Test: Compost vs Vermicompost

To determine if there is a monetary value difference between vermicompost and compost, a paired two-sample t-test was utilized (see Appendix B). A total of 55 growers responded with the price per ton they were willing to pay for vermicompost and compost. Growers that responded would be willing to pay on average $61 per ton of vermicompost and on average $42 per ton of compost. The paired two-sample for mean t-test showed a statistical difference. The one-tail p-value is below 0.05, thus rejecting the null hypothesis. The one-tail p-value statistic was used because the upper-tailed alternative hypothesis is assumed to be greater than zero. Growers who are willing to pay will purchase vermicompost at a higher price than compost.

Chi-square Test for Independence

A Chi-square test for independence was performed to determine if there was a significant statistical difference between respondents’ knowledge of compost and vermicompost (see
Appendix B). There were 138 growers who ranked their knowledge level of compost and 131 growers who ranked their knowledge level of vermicompost. The chi-square test for independence has a chi statistic of 70.6 and a critical value of 5.99. The chi statistic is greater than the critical value, therefore the null hypothesis is rejected. The knowledge that growers have of compost and vermicompost is not independent. Thus, there is a relationship between growers’ knowledge of compost and vermicompost. Growers have more knowledge of compost than vermicompost.

Two-Sample T-Test: North Coast Grape Grower Value

A two-sample t-test was utilized to determine if North Coast grape growers find a significant monetary difference of vermicompost, compared to crops of all other regions (see Appendix B). A total of 30 North Coast grape growers stated the value they see in a ton of vermicompost and 38 growers answered for crops of all other regions. North Coast grape growers that responded would be willing to pay $69.70 per ton of vermicompost and growers of crops from all other regions were willing to pay $51.13. While there is a difference between the two means, the two-sample t-test assuming unequal variances showed no statistical difference. The two-tail p-value was above 0.05, thus failing to reject the null hypothesis. A few growers in this region have a high level of vermicompost knowledge and are willing to pay more for vermicompost than the average. These growers are making the average appear higher, but it is not statistically different from the average for other crops of all other regions.

Grower Population: Multiple Regression Equation

The survey data has provided detailed insight about how crops, regions, and knowledge levels affect the amount growers are willing to pay for vermicompost. To evaluate the relationship between these variables and the effect it has on the amount growers are willing to
pay, a multiple regression analysis was performed (see Appendix E). The multiple regression analysis calculates the relationship between a dependent variable and several independent, or predictor variables. (Statsoft, 2016). The dependent variable is growers’ willingness to pay for vermicompost and the independent variables are growers’ income per acre, crop, region, if the grower has used compost, growers’ compost knowledge, growers’ vermicompost knowledge, and growers’ willingness to pay for compost.

Excel was used to calculate the regression and provided insight into each variable’s effect on growers’ willingness to pay for vermicompost. There were 56 growers who responded with data for all the independent variables and were willing to pay for vermicompost. Two growers were removed from this analysis for being extreme outliers. Dummy variables were created for some of the independent variables: grower has used compost, crop, region, growers’ compost knowledge, and growers’ vermicompost knowledge. The variable “grower has used compost” was transformed into a value of one for ‘yes, the grower has used compost’ and zero for ‘the grower has not’. “Crop” variable was changed to one for grape grower and zero for all other crops. The variable “Region” was altered to one for North Coast Region and zero for all other regions. The variable for growers’ “Compost Knowledge” was one for knowing attributes well and zero for limited knowledge of attributes. Growers’ “Vermicompost Knowledge” was transformed to one for growers having some level of knowledge and zero for never have heard of vermicompost.

This data provided a multiple R of 0.87, which indicates a strong positive correlation between the dependent and independent variables. The adjusted R square is 73%, which represents the percentage of the variation of the dependent variable explained by the independent variables taking into consideration the number of explanatory variables. With these factors
being high, the regression equation explains a large number of the data population. Very low levels of multicollinearity were found between the variables. The regression equation can be found in Figure 8.

The regression equation states that the “Intercept” is 13.02. If no other variables were in the equation, a grower would pay $13.02 per ton of vermicompost. The p-value makes the “Intercept” a significant variable. “Region” was found to have a $0.50 increase in the overall equation if the grower was on the North Coast. This suggests that growers are willing to pay more on the North Coast for vermicompost than all other regions. However, this variable was not found to be significant. If the “Crop” variable was grapes, growers would pay an additional $3.29 per ton, but this variable was also not significant. “Income per Acre” had a negative coefficient. This variable suggests as growers become more successful they are willing to pay less for vermicompost. This variable is not significant in the equation. If a grower has “Used Compost”, the grower is willing to pay $6.61 less per ton of vermicompost, but this variable is not significant. The data shows growers are willing to pay more for compost than vermicompost if a grower had not previously used compost. This suggests growers do not know the true value of a soil amendment until they have firsthand experience. If a grower knows the attributes of compost well, a grower is willing to pay an additional $4.85 per ton of vermicompost, which is not a significant variable. If a grower has some level of knowledge of vermicompost, a grower will pay $2.74 less per ton, this is not a significant variable. This coefficient provides insight that growers overestimate their knowledge and may not understand the value of vermicompost. The variable “Willingness to Pay for Compost” is a significant variable and every dollar a grower is willing to spend per ton of compost, they are willing to spend $0.87 per ton of
vermicompost. Growers willing to pay for compost is variable to focus on when evaluating potential grower populations.

*Table 4: Regression Characteristics*

<table>
<thead>
<tr>
<th>Regression Statistics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple R</td>
<td>0.87</td>
</tr>
<tr>
<td>Adjusted R Square</td>
<td>0.73</td>
</tr>
<tr>
<td>Observations</td>
<td>56.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regression Equation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Willingness to pay for Vermicompost ((y)) = 13.02 + (0.5<em>Region) + (3.29 * Crop) + (-0.0004</em>Income per Acre) + (-6.61<em>Used Compost) + (4.85</em>Compost Knowledge) + (-2.74<em>Vermicompost Knowledge) + (0.87</em>Willingness to pay for Compost)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Coefficients</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>13.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Region</td>
<td>0.50</td>
<td>0.92</td>
</tr>
<tr>
<td>Crop</td>
<td>3.29</td>
<td>0.54</td>
</tr>
<tr>
<td>Income/Acre</td>
<td>-0.0004</td>
<td>0.21</td>
</tr>
<tr>
<td>Used Compost</td>
<td>-6.61</td>
<td>0.27</td>
</tr>
<tr>
<td>Compost Knowledge</td>
<td>4.85</td>
<td>0.38</td>
</tr>
<tr>
<td>Vermicompost Knowledge</td>
<td>-2.74</td>
<td>0.57</td>
</tr>
<tr>
<td>Willingness to pay Compost</td>
<td>0.87</td>
<td>0.00</td>
</tr>
</tbody>
</table>

To utilize the multiple regression, characteristics of an average grower that represents 20% of the population was selected. The grower is located on the North Coast, grows grapes, has an income of at least $5,000 per acre, has used compost, has a high knowledge level of compost, has some knowledge of vermicompost and is willing to pay at least $20 per ton of compost. This grower population would pay $27.71 per ton of vermicompost, which falls in between $20 and $30 as the survey data illustrated. A vermicompost company can focus on this potential grower population and extract $27.71 per ton.
**Hypothetical Vermicomposting Facility**

The regression analysis identified a grower population that values vermicompost at $27.21 per ton. To understand if a vermicompost facility is feasible in California, a hypothetical market analysis has been performed. The hypothetical analysis is based on Jensen’s 2011 study assumptions. The Jensen study believed it would cost $2.15 million to create a vermicompost facility that had a concrete platform, vermicompost reactors, multiple storage bays, a vehicle to transport and machines to process the vermicompost. Also, includes an estimation of California transportation cost provided by the Hughes and Dusault 2005 study. With the Central Valley being a source for raw materials this study added in the average cost of acreage in the Central Valley, the cost of interest for a loan and possible regulatory costs.

A facility in Tulare with these hypothetical expenses and annual sales of 35,000 tons of vermicompost a year has a break-even point of $20.73 per ton. This hypothetical scenario only accounts for the delivery of vermicompost within a 25 mile radius. The cost will increase if deliveries occur outside this radius. Survey results, indicate the grower population was willing to pay $27.21 per ton of vermicompost. If the vermicompost facility was able to capture this market value the facility would have a yearly income of $226,728 before interest and taxes. After the initial capital investment is paid off the yearly income before interest and taxes would increase to $625,550. It would take 13 years to breakeven on the initial investment. After 20 years the return on investment would be 20%, if another large capital expense is not required. If growers knowledge increased quickly and growers saw an increase in value of vermicompost this could speed up the return on investment. Of all growers in the study willing to pay for vermicompost, 54% stated they would pay at least $27.21 per ton of vermicompost. The feasibility of a vermicompost facility is in question; it is a long-term investment with restrictions on how far the finished product can move. It appears a vermicompost facility would only have
success in areas where the grower base is within 25 miles and near a suitable raw material source.

**Figure 6: Hypothetical Vermicompost Scenario**

<table>
<thead>
<tr>
<th>Approximate Capital Costs for Indoor Continuous-Flow Reactor Facility Vermicomposting 100 Tons of Organic Waste per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial Investment</strong></td>
</tr>
<tr>
<td>35 continuous-flow vermicomposting reactors at $50,000 each</td>
</tr>
<tr>
<td>Mobile gantry (multiple reactor)</td>
</tr>
<tr>
<td>Concrete base</td>
</tr>
<tr>
<td>Insulated polythene greenhouse building</td>
</tr>
<tr>
<td>Chopping/grinding/mixing machine</td>
</tr>
<tr>
<td>Front loader machine</td>
</tr>
<tr>
<td>Liquid waste separator to produce solids</td>
</tr>
<tr>
<td>Earthworm waste separator</td>
</tr>
<tr>
<td>Moving belts</td>
</tr>
<tr>
<td>Storage bays</td>
</tr>
<tr>
<td>Truck</td>
</tr>
<tr>
<td>Five agricultural acres in Tulare (no water rights)</td>
</tr>
<tr>
<td>Loan Interest (5%)</td>
</tr>
<tr>
<td>Miscellaneous regulation expenses</td>
</tr>
<tr>
<td><strong>Initial Investment Costs</strong></td>
</tr>
</tbody>
</table>

| **Annual Operating Costs**                                  |       |
| Labor costs (four workers)                                   | 140,000 |
| Transport costs                                              | 156,800 |
| Energy costs                                                 | 10,000  |
| Repair and maintenance                                       | 20,000  |
| Pay off initial investment over 7 years (5% interest rate)   | 398,822 |
| **Annual Costs**                                             | $ 725,622 |

| **Annual Returns**                                          |       |
| Annual Vermicompost QTY (10% loss during processing)         | 35,000  |
| Sales of vermicompost (Break-even $/ton)                      | 20.73   |
| Selected Grower Population Willingness to Pay                | 27.21   |
| First 7 years Revenue                                        | 952,350 |
| Profit First 7 years EBIT                                    | 226,728 |
| Profit after Initial Investment is Paid off EBIT             | $ 625,550 |
V. SUMMARY

Fertilizers are a critical aspect of growing an economically viable crop. There is a wide variety of fertilizer options, from chemical compounds to soil amendments. Some of these fertility options present environmental concerns. Growers are utilizing soil amendments to produce environmentally friendly crops. Compost is an established soil amendment, but new products, like vermicompost, are entering this market. Many growers know the attributes well and are willing to pay for compost. However, the market for vermicompost is still in its infancy. As a vermicompost company enters the market, focusing on a likely grower population will help them succeed.

Through grower email addresses provided by Syngenta, 223 growers participated in a survey to determine what current market conditions exist for vermicompost. The survey discovered growers’ knowledge of vermicompost, the amount growers are willing to pay, the influence crops have on the amount growers are willing to pay, and the feasibility of establishing a vermicomposting facility. Each grower was asked a range of questions: demographics of their growing operations, use of compost, knowledge of both vermicompost and compost, and their willingness to pay for vermicompost and compost. Grower’s responses were analyzed utilizing multiple methods: chi-squared of independence, two-sample t-test, Pearson’s Correlation Coefficients, and a multiple regression analysis, to determine the grower population to focus resources and market potential for vermicompost.

Growers, on average, have a higher knowledge level of compost than vermicompost. All growers stated they had some compost knowledge, while vermicompost knowledge appeared to be regional and crop dependent. For growers to understand the attributes and recognize the value a potential vermicompost company will need to educate their grower population. Growers were
willing to pay a higher price per ton of vermicompost than compost. However, there was more variability around the price growers would pay for vermicompost; conceivably the variability comes from the different knowledge levels among growers. If there is an increase in knowledge levels, the market value will become more defined. A positive correlation was observed between growers’ willingness to pay for vermicompost and compost. An even stronger correlation was found in North Coast and Central Valley regions. This strong correlation helped identify that the compost and vermicompost market are closely linked and, as of now, many growers don’t understand the added benefit of vermicompost. Survey results indicate grapes should be a focus crop for a potential vermicompost company to concentrate on. Grape growers had a high knowledge level of vermicompost and were willing to pay a higher than average price per ton. A vermicompost company may want to partner with wineries who are trying to produce grapes in a sustainable way, as it could be a tactic that drives vermicompost adoption.

There was a statistical difference that growers would be willing to pay a higher amount for vermicompost than compost, even though their vermicompost knowledge is lower than compost knowledge. It was determined that growers’ knowledge of vermicompost and compost are linked. Growers have more knowledge of compost than vermicompost. Even though, growers have less knowledge of a new product they appear to value a new product higher than the current product in the market place. It was shown however there was no statically significant difference that North Coast grape growers are willing to pay a higher price for vermicompost than growers of crops from other regions.

The multiple regression analysis demonstrated that growers’ willingness to pay for vermicompost was affected by certain variables: growers’ income per acre, willingness to pay for compost, region, crop, if the grower has previously used compost, and the growers’ knowledge
level of compost and vermicompost. The most significant variable in the regression was the price growers were willing to pay for compost. Every dollar a grower was willing to spend on compost, the grower was willing to spend $0.87 on vermicompost. A potential grower population was a North Coast grape grower who had used compost, made at least $5,000 per acre, had knowledge of compost and vermicompost, and was willing to pay at least $20 per ton of compost. It was found that this grower was willing to spend $27.21 per ton of vermicompost. The potential price point and target market allowed for examination of the feasibility of a vermicompost facility.

Utilizing the North Coast grape grower target market, a hypothetical scenario was run to understand the feasibility of establishing a vermicompost facility. Utilizing assumptions from Jensen, et al., (2011), Hughes and Dusault (2005), and additional assumptions made by this study, it was concluded that 80% of growers willing to pay for vermicompost would pay the California facility break-even point of $20.73 per ton of vermicompost. At $27.21 per ton of vermicompost, 54% of growers would be willing to pay this amount. It would take 13 years to break-even on the investment and 20 years to have a return on investment of 20%. A vermicompost company would only be viable if it was a long term investment and deliveries were within 25 miles of the facility.

Conclusions

For hypothesis one, the study rejects the null hypothesis: growers who are willing to pay will purchase vermicompost at the same price as compost. The survey response data shows that growers are willing to pay a premium for vermicompost, and the paired two-sample t-test proves there is a statistical difference. The average for vermicompost is $61.69 per ton compared to $42.20 per ton of compost. Growers see more value in vermicompost than compost. There is
more variance around the amount growers are willing to pay for vermicompost. As growers become more educated about vermicompost that variance around the value per ton will shrink.

For hypothesis two, the study rejects the null hypothesis: growers’ knowledge of compost and vermicompost are not independent. There is a relationship between growers’ knowledge of vermicompost and compost. Growers have a higher knowledge of compost than vermicompost. A potential vermicompost company must educate growers about the attributes of vermicompost to differentiate from compost and drive a higher price per ton.

For hypothesis three, the study fails to rejects the null hypothesis: North Coast grape growers who are willing to pay, will purchase vermicompost at the same price as all other crop growers. When examining the amount a grower is willing to spend for vermicompost on a crop, grapes ranked the highest at $59 per ton, which is $7 above the average. Coupled with regional data, it might seem that North Coast grape growers would pay more than all other crop growers, but the variance causes there to be no statistical difference. North Coast grape growers are a lucrative market based on growers’ willingness to pay and higher levels of knowledge.

Overall, it will be challenging to make a vermicompost facility in California feasible. If a vermicompost company chooses to operate in California, the focus should be North Coast grape growers, as these growers have the best opportunity to maintain a sustainable business. Knowledge levels for vermicompost are not as high as compost and it will be beneficial for a vermicompost company to continue to educate growers about the attributes of vermicompost to increase the value compared to compost. Focusing on a sustainability message with North Coast grape growers could increase the adoption rate and enhance the value of vermicompost in the target market. If regulations or input requirements change California may find vermicompost to
be an effective way to manage agricultural waste and provide a sustainable soil amendment for crops.

**Recommendations**

A focus for future research is to look into each region’s crop mix and how the crop mix affects the overall market potential. Some regions may be eliminated because the crops grown in that region can’t use, or are economically limited from using, a premium soil amendment. For a potential vermicompost company to get a more complete view of the cost of setting up a facility in a given market, an examination needs to be completed as to where to source the raw materials and the cost for transportation of the raw materials and the completed product. The vermicomposting regulations need to be examined to find how they differ between counties and air resource boards.

A vermicompost company can take the results from this study and understand the potential value of each region and crop. The results could have been strengthened by a larger sample size in some of the regions and crops. Some regions and crops had more responses than others. Syngenta provided an email list that most likely has growers that use conventional agricultural practices, which is the majority of the growers in California. Perhaps an organic company’s grower email list would bring a different segment of growers that might value vermicompost differently. More data could provide a clearer view of the potential vermicompost market in California.
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doi:10.1016/S0960-8524(00)00104-8


doi: https://doi.org/10.1007/978-94-009-1569-5_96


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Appendix A: Grower Survey

Dear Grower:

This survey is being conducted to understand your willingness to use and willingness to pay for compost and vermicompost. This study is being conducted by Jason Thomas in conjunction with the Department of Agricultural Business at the California Polytechnic State University. Participation in this survey is voluntary and you are under no obligation to answer any of the questions. All responses to this survey will be kept confidential and only summarized in aggregated form. Your cooperation and time in this matter is greatly appreciated. If you have any questions or concerns regarding this survey, please feel free contacting Dr. Sean Hurley by email (shurley@calpoly.edu) or phone: (805) 756-5050. Thank you for taking your valuable time participating in this research project.

1. In 2014, what was your annual gross income for your farm/ranch?

☐ Less than $1,000
☐ $1,000 to $2,499
☐ $2,500 to $4,999
☐ $5,000 to $9,999
☐ $10,000 to $19,999
☐ $20,000 to $34,999
☐ $25,000 to $39,999
☐ $40,000 to $49,999
☐ $50,000 to $69,999
☐ $100,000 to $249,000
☐ $250,000 to $499,999
☐ $500,000 to $999,999
☐ $1,000,000 to $2,500,000
☐ $2,500,000 to $5,000,000
☐ $5,000,000 or more

2. What county is your farm located in? (If in multiple counties check where majority of the farm is located)


3. What was your largest crop in 2014 in terms of income?

○ Almonds
○ Walnuts
○ Pistachios
○ Grapes (wine/table/raisins)
○ Tomatoes
○ Alfalfa
○ Silage Corn
○ Citrus
○ Stone Fruit
○ Potatoes
○ Other (please specify)

4. In 2014, how many acres did you use for production of your crops?

○ 1 to 9 acres
○ 10 to 49 acres
○ 50 to 69 acres
○ 70 to 99 acres
○ 100 to 139 acres
○ 140 to 179 acres
○ 180 to 219 acres
○ 220 to 259 acres
○ 260 to 499 acres
○ 500 to 999 acres
○ 1,000 to 1,999 acres
○ 2,000 to 4,999 acres
○ 5,000 acres or more
5. How many pounds per acre of N-P-K are you applying to your top crop on a yearly basis? Numerical response only.

6. What is your average yearly spend per acre on fertilizer for your top crop? Numerical response only.

7. What is the optimum N-P-K ratio for your top crop? Respond in N-P-K form.

What is compost?
Compost is decayed organic material used as a plant fertilizer. The process of composting turns organic waste (e.g. dairy manure) into a fertilizer that can build soils by the addition of organic matter and improve soil quality. Soils can be improved for water holding capacity, drainage, structure, and even the ability for plant roots to penetrate through the soil. Compost can be coupled with chemical fertilizers to meet specific needs of crops and respond to environmental conditions.

8. Have you used compost before on any of your crops?
   - Yes
   - No

9. Before this survey, how would you describe your knowledge of compost?
   - Never heard of it
   - Heard of compost but had limited knowledge
   - Know the attributes well

10. What is the maximum amount you would be willing to pay per ton for standard composted dairy manure that had a N-P-K ratio of 1.5-0.7-1.5? Numerical response only.

11. If your answer was zero in the previous question, how much would you need to be compensated per ton to accept standard composted dairy manure that had an N-P-K ratio of 1.5-0.7-1.5? If you would never accept this product, put an X.
What is vermicompost?
Vermicomposting is a technology that utilizes earthworms to transform organic waste (e.g. dairy manure) into a nutritious soil amendment and pathogen free fertilizer. The application of vermicompost on soil has the ability to maintain and improve the organic matter in the soil, reclaim degraded soils, and supply plant nutrients. Soils can be improved for water holding capacity, drainage, structure, and even the ability for plant roots to penetrate through the soil. Vermicompost can be coupled with chemical fertilizers to meet specific needs of crops and respond to environmental conditions.

12. Before this survey, how would you describe your knowledge of vermicompost?

- Never heard of it
- Heard of it but had limited knowledge about it
- Know the attributes well

13. What is the maximum amount you would be willing to pay per ton for standard dairy manure that has been vermicomposted and had an N-P-K ratio of 1.5-0.7-1.5? Numerical response only?

14. If your answer was zero in the previous question, how much would you need to be compensated per ton to accept standard dairy manure that had been put through a vermicomposting process and had an N-P-K ratio of 1.5-0.7-1.5? If you would never accept this product, put an X?
## Appendix B: Statistical Tests

### Table B1: Two-Sample T-Test: Vermicompost & Compost Value

<table>
<thead>
<tr>
<th>t-Test: Paired Two Sample for Means</th>
<th>Willingness to Pay for Vermicompost</th>
<th>Willingness to Pay for Compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>61.69</td>
<td>42.20</td>
</tr>
<tr>
<td>Variance</td>
<td>10307.81</td>
<td>2247.76</td>
</tr>
<tr>
<td>Observations</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>Hypothesized Mean Difference</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>df</td>
<td>54.00</td>
<td></td>
</tr>
<tr>
<td>t Stat</td>
<td>1.95</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>1.67</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) two-tail</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>2.00</td>
<td></td>
</tr>
</tbody>
</table>

Fail to reject null hypothesis, two-tail p-value is greater than .05

### Table B2: Chi-square test of Independence: Knowledge

<table>
<thead>
<tr>
<th></th>
<th>Know Attributes Well</th>
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α = 0.05
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Fail to reject null hypothesis, two-tail p-value is greater than .05
### Appendix C: Grower Population Multiple Regression

#### Table C1: Correlations Test

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Region</th>
<th>Crop</th>
<th>Income/Acre</th>
<th>Used Compost</th>
<th>Compost Knowledge</th>
<th>Vermicompost Knowledge</th>
<th>Willingness to pay Compost</th>
<th>Willingness to pay Vermicompost</th>
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#### Table C2: Descriptive Statistics

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<th>Compost Knowledge</th>
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<td>56.00</td>
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#### Table C3: Regression Statistics and Equation

### Regression Statistics

- **Multiple R**: 0.872379788
- **R Square**: 0.761046495
- **Adjusted R Square**: 0.726199108
- **Standard Error**: 13.86391492
- **Observations**: 56

**ANOVA**

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<th>MS</th>
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**Regression Equation**

\[
\text{willingness to pay for vermicompost (y) = 13.02 + (0.5*Region) + (3.29 * Crop) + (-0.0004*Income per Acre) + (-6.61*Used Compost) + (4.85*Compost Knowledge) + (-2.74*Vermicompost Knowledge) + (0.87*Willingness to pay Compost)}
\]

### Summary Output

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