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# Transitioning to organic: fertility management in potato production

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**TRANSITIONING TO ORGANIC: FERTILITY MANAGEMENT IN POTATO  
PRODUCTION**

A Thesis

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Master of Science

in

School of Plant, Environmental and Soil Sciences

by

Lacey Theresa Dupré  
B.A., University of Louisiana at Lafayette, 2003  
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## ABSTRACT

An increasing demand for organic crops in the US represents a considerable opportunity for organic, as well as conventional growers interested in exploring the transition to organic production. Renewed interest in organic farming has resulted in a need for research involving organic fertilizers. Limited research has been conducted on organic vegetable production with previous research conducted primarily outside the Deep South US. Field studies were conducted at the Louisiana State University (LSU) AgCenter Burden Center to investigate the effect of three levels of pre-plant organic NPK fertilizer (8-5-5, Nature Safe) combined with a sidedress application of organic NPK fertilizer (13-0-0, Nature Safe), compared to fish emulsion (5-2-2, Agro-K) or no fertilizer control treatments on the growth and yield of “Red LaSoda” potatoes. Plant height, width, leaf area, and above and below ground biomass (dry weights) were determined 3 times (once a month) and marketable yield was evaluated at harvest for the fall 2006 and spring 2007 growing seasons. Plots were harvested 3 months after planting according to USDA guidelines. There were no differences in marketable yield due to fertilizer treatment for the fall growing season, but there were differences for the spring growing season. In the spring study, the recommended rate of nitrogen (100 lbs. N/A) had adequate yields, the double rate (400 lbs. N/A) had lowest yields and the fish emulsion (66 lbs. N/A) had the highest yields. The results of the study suggest that

organic potato production in Louisiana is profitable. If compared, commercial organic fertilizer is more expensive than conventional fertilizer, as are labor costs, but due to price premiums (\$20/50 lb. sack of conventional fresh market potatoes and \$35/50 lb. sack of organic fresh market potatoes, as of 2007), the organic production systems had potentially 2 to 3 times higher gross and net benefits when compared to a conventional production system. In this study, the use of fish emulsion as the sole fertilizer was one of the most costly but profitable production systems, as yields and gross and net benefits were highest. Fish emulsion may have a beneficial association with plant growth regulators.

## CHAPTER 1

### INTRODUCTION

Renewed interest in organic farming has resulted in a need for research in sustainable farming practices (Born, 2004; Bull, 2006; Dimitri and Oberholtzer, 2006; Greene and Dimitri, 2003; Granatstein, 2000; Organic Consumer Trends Report (OCTR), 2007). This interest is in response to environmental and health concerns (Kramer, 2006). Also, there is a perception that organic farming will help alleviate problems associated with food safety, environmental quality and impact, market concentration, and the survival of rural communities.

Sustainable growing practices are and can be implemented by all farmers; methods such as Integrated Pest Management (IPM), biological control, biofumigation, crop rotation, cover cropping, compost, manures, and compost teas (a solution made by soaking compost in water) have been effective. Organic agriculture improves the physical, chemical, and biological characteristics of the soil by addition of organic matter to the soil. Research in these areas is invaluable for both organic and conventional growers, especially since soil science is a relatively new field of study (Carruthers and D'Antonio, 2005; Clark et al., 1998; Dainello, 2000; Helms et al., 2002; Jetter and Paine, 2004; Munoz et al., 2005; Teasdale et al., 2004; Zinati, 2002a, 2002b). Moreover, price premiums, niche markets, reduced chemical inputs, perceived health benefits, and its position as an environmentally friendly alternative growing system presents further attraction for organic production (Dainello, 2000).



Louisiana has an extended growing season along with an abundance of insect, disease and weed species, both beneficial and pest, making it an ideal region for the extensive study of organic farming. One aspect of organic production that is in need of study is fertilizers and their application rates in organic systems.

The objectives of this study were first, to investigate the effect of different rates of organic, USDA National Organic Program (NOP) certified fertilizer, compared to a control with no fertilizer application and a treatment of fish emulsion as the sole source of fertilizer, on plant growth and yield. Secondly, the study intended to answer the question, “Can a farmer make a profit using this fertilizer in an organic program?” To ensure success, predictable, quality products at a competitive price are necessary (Newton, 2004). The literature indicates that the yields between conventional and organic are comparable (Delate et al., 2003; Lang, 2005; Martini et al., 2003); this study aims to look at the problems, issues and economics of transitioning to organic. The crop used in the study was the ‘Red La Soda’ potato. Potato is an important crop in the United States and worldwide. Up to 85% of potato plant biomass is edible as compared to about 50% of cereals. Potato is high in carbohydrates, protein and Vitamin C. These traits make the potato an efficient crop in combating world hunger and malnutrition. Potato consumption has increased in the developing world, and over the last decade world potato production has increased at an annual average rate of 4.5 percent (FAO, 2007). Whether or not potatoes can be grown successfully on a commercial scale using organic methods is unknown. After a thorough review of the literature we found few references to research pertaining to organic potato production (Munoz et al., 2005; van Delden, 2001).

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1. Introduction**

The term ‘organic’ as defined by the USDA is used in labeling an agricultural product produced in compliance of the Organic Foods Production Act of 1990 (USDAa, 2007).

Organic agriculture is an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. These goals are met, where possible, through the use of cultural, biological, and mechanical methods, as opposed to using synthetic materials to fulfill specific functions within the system (USDA National Organic Standards Board (NOSB) definition, 2001).

Furthermore, organic food is produced without bioengineering, ionizing radiation or sewage sludge. A government-approved certifying agent must inspect and pass farms before their products can be labeled organic as according to USDA National Organic Program (NOP) standards (USDAb, 2007).

Defining the term ‘organic’ has not been easy, but the above definitions have been accepted and used by the USDA. An organic seal does not ensure quality, it merely states that the production of the product has met certain standards as set by the USDA National Organic Program (USDAc, 2007).

Farming organically has been practiced for millennia, yet new technologies and mechanization have allowed organic agriculture to again become a viable agriculture system. The USDA implemented the national organic standards in October of 2002, and despite the effort needed to meet these requirements, a million acres of certified organic land were added to the total U.S. pasture and cropland between 1997 and 2001 (Greene and Dimitri, 2003). Consumer demand is also increasing, at a pace of 20 percent or more annually. Organic products can be found in 73 percent of conventional grocery stores and these sales account for about 1-2 percent of total U.S. food sales (Greene and Dimitri, 2003). Increasing energy and fertilizer costs, along with health and environmental concerns over the impact of synthetic chemicals has led to this growing interest in organic production (Hall et al., 2001).

A further example of increased interest in organic production is the unprecedented amount of dialogue the federal Organic Foods Production Act of 1990 (OFPA) legislation elicited when opened for public comment. OFPA regulations are viewed as both beneficial and detrimental to organic production. Listing allowed and prohibited inputs may be the initial step in standardizing organic production. The listings may seem to sanction off-farm input substitution and overuse. Often standards tend to distinguish between an unacceptable and an acceptable product, and a concern exists that such regulations would imply that conventional foods are less safe (Klonsky and Tourte, 1998). Input substitution and overuse without integrating new technology will not likely be economically feasible. Innovation, experimentation and an understanding of soil biology and fertility are key to successful organic farming (Mader et al., 2002). When soil is properly and carefully managed, disease and insect pressure does not often present

a problem, only weed suppression remains a challenge (Fertilization Systems in Organic Farming, 1997; Jetter, 2005; Teasdale et al., 2004). Cultivation and hand weeding are still the most common techniques for weed control, but these are usually only implemented on smaller commercial farms (Klonsky and Tourte, 1998). Long crop rotations using diverse crops can reduce the weed seed bank in an organic system (Teasdale et al., 2004). Sufficient research on the effect of transitioning to organic on weed population has not been done (Zinati, 2002c). One study presented the overall effects of transitioning to organic on weed population. Short-term effects included a decrease in synthetic fertilizers and herbicides in the soil and an increase in species composition and relative abundance of weeds. Medium term effects were changes in chemical, physical and biological soil properties, an increase in populations of beneficial microbes such as bacteria and fungi, and as a result, increased weed seed colonization, further resulting in weed death. Finally, the long-term effects on weed population were weed seed bank depletion (Zinati, 2002c). Cessation of insecticide use results in an increase in phytophagous insect populations that feed on weed seedlings, further reducing weed populations. These effects are a result of the decreased usage of pesticides and synthetic fertilizers and the employment of alternative pest management strategies as outlined by the National Organic Program (USDAa, 2007; Zinati, 2002c). Extended crop rotations most successful at weed seed bank reduction are those that take into account the effectiveness of weed seed bank suppression as a result of the specific crop that initiated the rotation (Teasdale et al., 2004).

## 2.2 History of the Organic Movement

The term 'organic' was coined in 1940. Both J.I. Rodale and Walter Northbourne, influential writers of this time period, are given credit for coming up with the term (Heckman, 2006; Kuepper and Gegner, 2004). The word organic refers to the farming system as a whole and not to the chemistry of carbon-based fertilizers (Heckman, 2006). Britain, Germany, Japan and the U.S. were the major industrial countries that spawned organic movements as an alternative to agricultural practices after World War I. Based on the Haber-Bosch process for fixation of N used in the manufacturing of explosives, synthetic fertilizer production was a prolific industry after the war (Lotter, 2003; Wild, 2003).

Albert Howard is considered the father or pioneer of the organic agriculture movement. He was a British agronomist who worked in India in the early 20<sup>th</sup> century and wrote about key concepts of organic agriculture such as soil management, sustainability, and composting. He popularized the Indore Process, which is the layered composting process most practiced today on organic farms. Howard emphasized the Law of Return, which is the recycling of nutrients and organic waste on farm and from cities to farms. He wrote about these concepts in his 1943 book *An Agricultural Testament*, promoting soil health and fertility. Other European scientists at the time were taking a closer look at mineral nutrition, specifically Carl Sprengel and Justus von Liebig. These men came up with the Law of the Minimum, which is responsible for the 'NPK mentality,' or fertilizing only or primarily with nitrogen, phosphorus and potassium (Heckman, 2006). Howard criticized this mentality as focusing too much on soil

chemistry and not enough on soil biology and physics (Heckman, 2006). Both Liebig and Howard were extreme proponents for their theories. Liebig was absolute in advocating the sole importance of inorganic nutrient uptake by plants, an inaccurate concept that still remains in soil science literature (Enviro Briefs, 2005; Owen and Jones, 2001). This lack of understanding of the soil food web and natural systems, along with the importance of the soil food web, is being explored in today's literature (Brady and Weil, 2002). Organic farmers understand that plants not only absorb inorganic nutrients, but also organic/carbon-based substances, such as herbicides and insecticides in conventional systems and vitamins in healthy soils (Kuepper and Gegner, 2004). Howard didn't help his case by being so uncompromising. He was opposed to the use of any synthetic fertilizers; his extremism may have contributed to the notion that organic farming is farming without the use of fertilizers (Heckman, 2006). This concept was perpetuated when Rachel Carson's book *Silent Spring* came out in 1962. An era of 'neglect' farming ensued after the publication of *Silent Spring* that tainted the concept of organic agriculture. Production was poor and yields were low due to depletion of the soil; fundamental soil management practices were not implemented.

Organic farming has become economically and industrially important over the past few decades. In 1980 the USDA published a study, *Report and Recommendations on Organic Farming*, that reported that organic agriculture was a viable and sound means of growing food on both large and small-scale farms (USDA, 1980). In 1990 Congress passed the Organic Foods Production Act (OFPA). The OFPA required the U.S. Department of Agriculture to establish a set of national standards for organic products

that would assure consumers that these products met consistent guidelines. The OFPA and the USDA National Organic Program (NOP) requires that agricultural products marketed and labeled as organic must pass third party inspection from a USDA certified organic inspector. The final set of rules was published on October 21, 2002 and further excluded the use of sewage sludge, food irradiation, and genetically modified organisms (GMO's). Farmer's who meet these standards and pass inspection can label and market their product as "USDA certified organic" with the official USDA organic seal. This seal indicates that the product was grown and processed in accordance with the USDA standards and does not address food safety or nutrition (Heckman, 2006; Kuepper and Gegner, 2004; USDAa, 2007).

Other influential people credited as key figures in the organic movement are Rudolf Steiner, Edward H. Faulkner, Lady Eve Balfour, and as previously mentioned, Jerome Irving Rodale. Rudolf Steiner is credited with popularizing Biodynamic agriculture, a farming system that parallels organic farming but also recognizes planetary, lunar, and stellar influences and astral forces. Biodynamics emphasizes on-farm inputs and the individuality of the farm as a whole, closed system. Specialized processes for producing foliar sprays and compost are implemented to achieve balance between the physical and non-physical realms and Steiner's philosophy of anthroposophy is employed. The term anthroposophy links the Greek root words *anthropos*, human, and *sophia*, wisdom, that Steiner began using to refer to his philosophy as an alternative to theosophy, or divine wisdom. Biodynamic techniques are practiced worldwide, but the system is most popular in Europe, North America and Australia. Biodynamic farming techniques

came as a response and alternative to degraded soil, crop, and livestock conditions after the use of chemical fertilizers at the turn of the century. In his lectures, Steiner admitted he had not evaluated his ideas according to scientific methodology and encouraged others to do so (Diver, 1999; Steiner, 1958).

Lady Eve Balfour was a British farmer who in 1939 began the Haughley Experiment, the first long-term comparison between organic and conventional farming. In 1943, she published her influential book, *The Living Soil*, writing about the Haughley experiment, and in 1945 co-founded the United Kingdom's Soil Association that promotes sustainable agriculture (Balfour, 1943, 1976).

The year 1943 was a big year for organic agriculture publications, for Edward H. Faulkner also published his classic book, *Plowman's Folly* this year, suggesting alternatives to the moldboard plow, such as harrow disking, which preserves the soil and aids in the soil decomposition process. He said, "The truth is that no one has ever advanced a scientific reason for plowing" (Faulkner, 1943). Faulkner is recognized as a pioneer of the conservation tillage movement.

In the United States, J.I. Rodale was busy promoting Sir Albert Howard's work with his publication *Organic Farming and Gardening* first published in 1942. In 1947 he formed the Soil and Health Foundation, later renamed the Rodale Institute, in order to conduct, educate and encourage the science and practice of organic agriculture worldwide (Kirshenmann, 2004). In Germany, Han Muller founded Bioland, the world's first organic certification label, which is still active (Lotter, 2003). In the 1970's and 1980's, writers Wendell Berry and Wes Jackson published works that argued against



monoculture and industrial agriculture and emphasized the importance of sustainable agriculture (Kirschenmann, 2004). The USDA became interested in organic techniques and Secretary of Agriculture Bob Bergland commissioned a USDA nation-wide study on organic farming led by a team of scientists (USDA, 1980). The product of this study was a paper entitled, “Report and Recommendations on Organic Farming” and gave scientific legitimacy and credence to further research into organic farming techniques. At the 1981 American Society of Agronomy Annual Meeting the first symposium on organic farming was given, and resulted in the ASA Special Publication No. 46, “Organic Farming: Current Technology and Its Role in a Sustainable Agriculture” (Bezdicek et al., 1984; Granatstein et al., 2004). In 1985, the USDA, along with the Rodale Institute, began sponsoring workshops on organic farming. Due in part to the success of these workshops, the United States Congress passed the Food Security Act that year and federal funding was obtained for the Sustainable Agriculture Research and Education (SARE) program, initially called the LISA (Low-Input Sustainable Agriculture) program. The SARE program supports sustainable research and education in agriculture (Madden, 2008).

In 1990, the United States Congress established the Organic Foods Production Act (OFPA) giving greater credibility to the movement by requiring the U.S. Department of Agriculture (USDA) to develop national standards for agricultural products labeled as “organic.” The National Organic Program (NOP) regulations that came about were created to assure consumers that food marketed and labeled as organic meet uniform production standards. The OFPA and the NOP regulations call for third party certifying

agents in order for agricultural products to carry the organic label. They do not address nutrition, food safety, or environmental issues, only marketing (Klonsky, 2000; USDAa, 2007). The recommendations are based on the decisions from the 15-member National Organic Standards Board (NOSB) appointed by the Secretary of Agriculture, who advises the Agricultural Marketing Service (AMS). The NOSB includes four farmers, three consumer or public interest supporters, three environmentalists, two handlers or processors, one retailer, one scientist, and one certifying agent, all fulfilling five year terms (Klonsky 2000; USDAa, 2007).

The regulations allow for most non-synthetic substances to be used in organic production, and prohibit the use of most synthetic substances. The “National List of Allowed Synthetic and Prohibited Non-Synthetic Substances” gives further detail and exceptions. Organic crops are raised and handled without genetic engineering/modification, ionizing radiation, sewage sludge, conventional pesticides, and petroleum-based fertilizers. Organic meat and dairy products must come from animals fed organic feed, given some access to pasture, and raised without antibiotics or growth hormones (USDAa, 2007).

Around the country during these decades, universities were creating centers and programs to study sustainable agriculture. Iowa State University established the first graduate program in the United States in sustainable agriculture in 2000. The 2002 Farm Bill set up the Conservation Security Program, which compensated farmers who implemented sustainable agriculture techniques into their cropping system (USDAa, 2007). Increasingly, organic agriculture has come to include social, moral and ethical

issues leading to further debates, especially in fair-trade and animal ethics matters (Lotter, 2003).

### **2.3. Overview of Organic Crop Production**

During the 1990's certified organic cropland increased twofold. Lowering cost and reliance on inputs and capturing price premiums are some of the reasons for farmers transitioning to organic production. In 1997 farmers committed 1,346,558 acres of cropland to organic production with California, Florida, North Dakota, Montana, Minnesota, Wisconsin, Iowa, and Idaho as the leading producers (Greene, 2001). Almost half of all certified organic vegetables were grown in California that year. Also that year, over 1 percent of tomatoes, oats and dry peas acreage, around 2 percent of lettuce, apple, grape and carrot, and one-third of the mixed vegetable, buckwheat and herb crops were grown organically. Organic fruits, vegetables, and herbs are grown most frequently. Crops commonly grown in the US organically include citrus, onions, nuts, lentils, grain crops such as corn, buckwheat, millet, barley, sorghum, rice, spelt, rye, and oilseeds such as flax and sunflower. (Greene, 2001; Klonsky and Tourte, 1998). Produce, such as the fruits, nuts, and vegetables mentioned above, dominate the organic market in the U.S., whereas agronomic crops such as corn, wheat, hay, and soybeans dominate the conventional sector (Klonsky and Tourte, 1998).

Research involving organic fertilizers in commercial crop production systems and their efficacy is scarce. What work has been done occurs largely outside of the southeastern United States. Soil quality, conservation, nutrient dynamics, cover

cropping, and organic matter and amendment management have been studied in many regions of the country (Bary et al., 2000; Glover et al., 2000). Farmers have been growing vegetables organically for years, but without proper documentation, record keeping, yield comparison, and replication, the data reported is primarily anecdotal and is not very useful (Pimentel et al., 2005). Price premiums remain favorable for organic food due to increasing consumer demand. Even without price premiums however, organic production has been reported to be more than or equally as profitable as conventional agriculture for a variety of crops (Pimentel et al., 2005; Welsh, 1999).

Mineral nutrition and use by potatoes has been extensively studied for conventionally grown potatoes (Asfary et al., 1982; Meyer and Marcum, 1998; Rosen, 1991). Problems associated with potato production include excessive and incorrect timing of nitrogen fertilizer application leading to runoff and groundwater pollution as well as N<sub>2</sub>O emissions (Beckwith et al., 1998; Joern and Vitosh, 1995). Insertion of wild potato plant genes into commercial potato cultivars may be one way of reducing nitrogen fertilizer use and leaching (Munoz et al., 2005). Genetic modification of crops is not allowed according to the USDA NOP guidelines (USDAa, 2007). In a trial conducted in Mississippi, organic potatoes were one crop found to claim high market prices (Evans et al., 2005). Research on organic potato production has found that plant health and prevention of disease is vital to successful organic potato production (Delanoy et al., 2003). According to some researchers, successful organic potato production has been demonstrated when certain tasks are performed. A 4-year rotation implemented to control soil-borne diseases, a legume crop rotated to provide nitrogen, use of certified seed

pieces, adequate soil moisture and nitrogen applied to maintain plant vigor, and planting after danger of frost has passed are key organic practices (Delanoy et al., 2003; Plotkin, 2000). Proper knowledge of a potato crop's nutrient requirements, especially nitrogen is essential (van Delden, 2001). In Idaho, radish, rapeseed meal, and compost are being examined as green manure crops for potatoes (Seyedbagheri, 2000; Seyedbagheri, 2003). Other studies using green manures in potato production include red clover (Porter and Sisson, 1991) and lupin as legume cover crops (Sanderson and MacLeod, 1994), and also barley, wheat and winter rye (Munoz et al., 2005; Shepherd and Lord, 1996; Vos and van der Putten, 2004). Though success of organic potato production has been demonstrated, farmers still express unwillingness to adopt more sustainable techniques, especially when it comes to insect control (Waller et al., 1998).

In terms of overall vegetable yield, several studies have shown that organic production is comparable to conventional and low-input systems (Delate et al., 2003; Gent, 2002; Lang, 2005, Martini et al., 2003). Examples include: carrots, lettuce, tomatoes (Eggert and Kahrman, 1984), cabbage (Warman and Harvard, 1997), and peppers (Roe et al., 1997). When conventional growing did come out ahead in terms of yield, organic and low-input systems had enhanced microbial biomass and activity, water-holding capacity, increased mobile humic acids, water infiltration rates, pools of phosphorous and potassium, and increased soil organic matter (Klonsky, 2000; Temple, 2002). Some studies showed a decrease in organic yields initially during the transitory process (Friedman, 2001). Despite such findings, research is being dedicated to organic production, such as the numerous articles published by ATTRA, or the National

Sustainable Agriculture Information Service, which is managed by the National Center for Appropriate Technology (NCAT) and is funded under a grant from the United States Department of Agriculture's Rural Business-Cooperative Service. Universities are conducting research, such as the sweet cherry system at Ohio State University (Granastein et al., 2004), and a Brassica meal study in Idaho (Johnson-Maynard and Morra, 2002), along with the numerous farm research trials in several states (Dimitri and Greene, 2002). In particular, the Sustainable Agriculture Farming System (SAFS) Project at the Agronomy Farm of the University of California at Davis (Clark et al., 1998) and the USDA Farming Systems Project at Beltsville, MD (Hima, et al., 2005) are examples. Often, the fertilizer application rate may have more of an effect on growth than the type of fertilizer, as was the case with a spinach trial in pots (Barker, 1975). An additional study using spinach grown in a field found that two thirds of the spinach showed higher yields when fertilized with ammonium rather than manure (Peavy and Grieg, 1972). Turkey manure has been reported as a successful alternative to mineral N fertilizer (Waddell et al., 2000). A study using broiler litter compost reported that greenhouse lettuce had sufficient nutrition and yields (Flynn et al., 1995). Another study reported potato leaf N increased in non-fumigated soil and not in fumigated soil when compost was applied, indicating the importance of microbial activity in the soil for the release and uptake of nutrients (Gent et al., 1998).

Along with higher soil organic matter, organic practices increase total soil nitrogen, soil pH, and plant-available nutrients (Alvarez et al., 1988, 1993; Clark et al., 1998; Drinkwater et al., 1995; Garcia et al., 1989; Lockeretz et al., 1981; Reganold,

1988; Reganold et al., 1993). N-uptake and early growth of winter wheat was realized in one study using animal manure compost (Berner et al., 1995). The rates of N, P, K, Ca, and Mg were found to be higher in pepper and potato leaves (Gent et al., 1998; Roe et al., 1997) and lowered nitrate levels and increased K were found in lettuce (Ricci et al., 1995) when compost was used (Gent, 2002). According to several studies, organic systems were more drought and flood hardy, less dependent on external inputs, had longer crop rotations, more crops, and had lower production costs than a conventional crop system (Hepperly, 2005; Mader, et al., 2002; Teasdale, et al., 2004; Welsh, 1999).

Despite these findings, transitioning to organic can be a challenge. Before a farm's produce can be certified organic, it must go through a 3-year transition period (USDAa, 2007) unless the field has remained out of production (fallow) prior to this time. This transitory period is usually marked by reduced yields while soil organic matter builds up, as well as an increase in: beneficial soil microorganisms, nitrogen mineralization, total and inorganic N, organic carbon, soluble phosphorus, exchangeable potassium, pH, arbuscular mycorrhizal fungus colonization, and natural enemies, whereas total insect and weed population decreases (Bending, et al., 2004; Clark et al., 1998; Drinkwater et al., 1995; Zinati, 2002a). Also, the farmer is learning how to grow and manage crops organically during this period. Whether yield increases during and after the transitional period is a result of gradual soil property and quality improvement or increased grower knowledge and experience with organic practices is unknown (Martini et al., 2003). A pre-transitory period is suggested in one study. This hybrid method would allow a grower to use a combination of techniques before the mandatory 3-year

organic period. For example, suppression of weeds by cultural means while continuing the use of synthetic fertilizers until the switch is made to the organic system (Zinati, 2002b). Once the switch has been made, growers have several options in order to build up beneficial soil microorganisms, to decrease pest populations, and to improve soil quality such as cover cropping, composts, manures, peat moss, feather meal, fish emulsion, seaweed and kelp extracts, dolomite, gypsum, and potassium magnesium sulfate. Supplying nitrogen is beneficial and cover cropping is one of the most widely used ways in which this is accomplished, but plant variety selections for disease resistance along with crop rotations are also essential (Zinati, 2002a).

Crop rotation is vital in organic production and assists in lowering production costs. Improvement of soil structure, increased soil nutrient content, and interruption of insect and plant disease cycles are key advantages of crop rotations. Cover cropping is a fundamental aspect of crop rotation (Munoz et al., 2005; Sullivan, 2003; Teasdale et al., 2004). Unlike organic vegetable production, much has been written on cover cropping. Green manures, or cover crops, act as slow-release nitrogen fertilizers and aid in reduced nitrate leaching (Thorup-Kristensen and Nielsen, 1998). Legume cover crops fix nitrogen in the soil and add organic matter. Non-legume cover crops suppress weeds, add biomass, and improve soil tilth. These characteristics aid in reducing nutrient loss through leaching, fertilizer, and pesticide usage (Harrison et al., 2004; Sullivan, 2003). One study examined cover crop mulches in broccoli production and found cover cropping led to faster growth and better yield than conventional fertilization on bare soil (Harrison et al., 2004). Popular cover crops include: annual ryegrass, buckwheat, forage radish,



rapeseed, sorghum-sudangrass hybrid, berseem clover, Austrian winter pea, crimson clover, hairy vetch, red clover, subterranean clover, sweet clover, white clover, Lana v. woollypod vetch (Clark, 2001). Rotating crops can also reduce abundance and seed bank populations of weeds, one of the biggest problems in an organic production system (Teasdale et al., 2004).

Research needs to be conducted on organic agriculture techniques in order to make such a production system feasible. Organic systems are not only more efficient in some cases, but are more environmentally responsible. Many concerns have developed as a result of nitrate leaching into our waterways from conventional production. One study of the Mississippi River Delta documented how increased levels of nitrate may have caused eutrophication and hypoxia in this watercourse (Rabalais et al., 2002). Runoff from nitrogen-fertilized fields has contributed to the Gulf of Mexico ‘dead zone’ as a result of eutrophication and hypoxia (Pimentel et al., 2005). High levels of nitrogen are usually related to excess nitrogen application to crops which is common in conventional potato production (Prunty and Greenland, 1997). Conventional farming has been found to leach more nitrate than organic plots (Drinkwater et al., 1998). Besides nitrate, pesticides in the soil need to be examined. Environmental pollution, efficient use of applied compounds in the soil, and overall effects of pesticides on soil fertility are not well understood (Saltzman and Yaron, 1986). Organic farming is often a sustainable method, using renewable, local inputs when available while building up healthy soil, eventually creating a production system that keeps in check pests and disease.

The organic philosophy also entails notions such as local production, respectful treatment of workers and animals on the farm, and generally avoiding monoculture systems that have made growing huge amounts of food possible in an industrial food system. USDA organic standards do not address these concerns. Thus, the main targets of organic farming are the small to medium size farms where such practices are easier to implement. The other reason organic farming is favored on smaller farms is due to the increased time and labor requirement of organic systems (Klepper, et al., 1977; Lotter, 2003). One study found that small farms are more efficient, productive, and sustainable and have increased biodiversity than large farms (Rosset, 1999). The 1980 USDA Report and Recommendations on Organic Farming found that large-scale organic farms were operating successfully (USDA, 1980).

Though small farms may be the ideal site for implementing an organic production system, sustainable growing practices are and can be implemented by conventional growers, as previously stated. Furthermore, besides being an economic boon, an organic system may aid in risk management. Worker health and safety and diverse market options are advantages on an organic farm (Granatstein, 2002).

Overseas, especially in Europe, transitioning to organic has come about at a more rapid pace. Several European countries offer incentives and direct financial support to farmers transitioning to organic. This is slowly happening in the United States and several states already offer benefits and aid for adopting organic principles. USDA programs have been implemented and are underway that are focused on organic research and promotion (Greene, 2001).

## **2.4. Fertility Management**

### **2.4.1 Crops**

Soil health is imperative to obtain high yielding, quality vegetables. Both the chemical and physical conditions of the soil can be changed to benefit vegetable production. Mineral soils - the sandy, loamy and clayey soils, along with organic soils - the muck or peat soils high in organic matter, are best suited for vegetable production and is where plants obtain their nutrients (Bot and Benites, 2005; Thompson et al., 1957).

The environment also has an effect on successful vegetable production. These environmental factors can be broken down into three groups: climate; temperature, water, wind, radiation, CO<sub>2</sub> concentration, and air pollution, soil; nutrients, soil water, structure, textures, chemical components and air content, and bios; pests, beneficial organisms, and microorganisms. Such features, along with economic aspects such as market influences and input costs, greatly affect crop production (Krug, 1997). The availability and uptake of nutrients from soil is also affected by environmental conditions (Gent, 2002).

The primary nutrients required in plant production are nitrogen (N), phosphorous (P), and potassium (K) and are usually expressed in pounds per acre, for example, 100 lbs. N per acre. Common conventional nitrogen sources are ammonium nitrate and urea. Super phosphate and triple super phosphate contribute phosphorous as well as calcium. Potassium chloride, potassium nitrate, potassium sulfate, potassium-magnesium sulfate and monopotassium phosphate are all sources of potassium. Slow-release or controlled-release fertilizers are often recommended for application of nitrogen or potassium. Some common slow-release fertilizers include polymer-coated potassium or urea, sulfur-coated

urea, or isobutylidene-diurea. Controlled-release fertilizers are more expensive but often, long-term fertilization is needed, or they will aid in reducing fertilizer cost due to leaching or decrease soluble salt damage.

Secondary nutrients, or nutrients required in smaller amounts, are Calcium (Ca), magnesium (Mg), and sulfur (S). Calcium can usually be supplied by the parent soil or applications of lime, super phosphate, or slag. Commonly, only heavily leached farmland that has been in continuous production may be low in calcium. Magnesium can be supplied by the addition of dolomite if lime is needed, and if soil pH does not require liming, magnesium sulfate or potassium-magnesium sulfate can be used to obtain magnesium. The latter two amendments, along with ammonium sulfate, potassium sulfate and super phosphate, can be used to correct sulfur deficiencies. Micronutrient fertilizers are recommended for soils that test low in micronutrients. Copper (Cu), Zinc (Zn), Manganese (Mn) and Boron (B) should be present in the fertilizer and can be supplied as chelates, oxides, or sulfates.

Rate and placement of fertilizer is important for uptake of nutrients, because various elements move differently in the soil. Furthermore, vegetable genotypic variation is affected by the rate and form of fertilizer (Gent, 2002; Hochmuth, et al., 2000). Sulfates, chlorides and nitrates are salts that readily flow with soil water. These salts can leach from the root zone when the soil is flooded or may build up at the soil surface as water evaporates from the soil. Other elements should be placed near the crop's root zone to ensure uptake, such as phosphorous, which does not readily move through the soil. Careful placement is necessary, because soluble salt burn or injury could be a result

of close placement or over-application of fertilizer. While banding, along with foliar spraying, has its benefits with certain nutrients, most fertilizers should be broadcast and incorporated. Often fertilizer is applied in split applications, half at planting and the other half as a sidedress into the growing season in order to help prevent leaching and soluble salt burn (Hochmuth, et al., 2000).

Vegetable fertility requirements depend on several factors, including initial soil fertility or soil parent material, cation exchange capacity, mineralization rate of soil organic matter, soil type, the crop being grown, expected output, and cost of production (Hochmuth, et al., 2000; Taylor and Locascio, 2004). In the past, fertility was managed according to economics (Vos, 1997). Recently, the amount of fertilizer used is judged according to a soil test and the specific requirements of the crop. Sixteen elements are required by plants for optimum growth (C, H, O, P, K, N, S, Ca, Fe, Mg, B, Mn, Cu, Zn, Mo, Cl). Growth, however, is not the only factor to consider; a grower must also consider marketable quality and yield. A soil test can be used to determine if any of these 16 nutrients are lacking in the soil and to supplement the soil. Because nitrogen readily leaches from the soil, prediction of N in the soil is not determined by soil testing.

As previously mentioned, soil type is important and different fertilizer recommendations are used for the various mineral, organic, and calcareous soils. In mineral soils, nitrogen and potassium are mobile and careful management of fertilizer and water is required. Organic soils include the muck and peat soils and do not usually require additional nitrogen fertilizer due to oxidation providing N to the soil. Heavy N feeders such as sweet corn are an exception. The calcareous soils include marine

deposits resulting in soils with a high pH range of 7.5-8.5. Increased fertilizer management is needed because alkaline soils fix nutrients in insoluble forms. To provide the most suitable environment to allow these minerals to be available for uptake by the plant, soil pH for most vegetables should be from 6.0 to 6.5. There are exceptions to this pH range. To avoid potato scab, an acidic soil would be desired, and amended to lower the pH, commonly achieved with elemental sulfur. Or, to avoid aluminum or manganese toxicities, an acidic soil may be limed, usually with calcite ( $\text{CaCO}_3$ ) or dolomite ( $\text{CaCO}_3$   $\text{MgCO}_3$ ) to raise soil pH (Hochmuth, et al., 2000).

#### **2.4.2. Organic Production**

Over fertilization in agriculture has led to surface water and ground water contamination. Nitrogen fertilizer pollution is responsible for eutrophication, hypoxia, and algal blooms in rivers, marshes, ground water, and runoff, and may be a public health risk (Kramer et al., 2006).

Decomposition of soil organic matter, as well as water and wind erosion, is accelerated by ploughing, tillage, and crop burning. Good agricultural practices are performed in most organic production systems, such as minimum tillage, crop rotations, addition of organic materials, and cover cropping to improve overall soil health, fertility, tilth, soil aggregate stability, earthworm number, potential denitrification rates, denitrification efficiency, water holding capacity, soil respiration, nutrient cycling, enzyme activity, and microbial life, biomass, and activity, as well as minimize runoff and erosion (Bot and Benites, 2005; Fertilization Systems in Organic Farming, 1997; Gaskell, et al., 2000; Hochmuth, et al., 2000; Kramer, et. al. 2006; Mader, et al. 2002; Sanchez, et

al., 2003). Increased microbial diversity in the soil leads to efficient production of soil biomass and nutrient utilization (Mader, et al., 2002).

Often organic fertilizers are bulky or are necessary in large quantities. This can make shipping expensive and is one of the reasons organic farming is more viable for small-scale farms and on farm inputs are preferred (Adediran, et al., 2004; Hochmuth, et al., 2000). Reduced reliance on external inputs may be achieved in an organic system due to increased soil fertility and biodiversity (Mader, et al., 2002). As cities are looking for ways to reduce their municipal wastes, agriculture may be an option. Compost from waste facilities can be applied to soils to add nutrients and improve soil, but compost should be mature and the nutrient content known. Immature compost may take nitrogen from the soil in order to complete the composting process, causing nitrogen deficiencies in plants (Hochmuth, et al., 2000). The nutritional condition of the compost may also aid in suppression of soil-borne plant pathogens (Fertilization Systems in Organic Farming, 1997). The decomposition and formation of organic matter releases nutrients into the soil. To adequately determine the amount of nutrients the soil contains, various tests can be used for different nutrients. Calcium, magnesium, and sulfur are usually present in enough quantities in an organic system due to irrigation water, addition of compost, and the use of sulfur fungicide (Gaskell, et al., 2000). The amount of nitrogen a soil contains cannot usually be measured via a test. This is because mineralization of nitrogen is a complex, living process, unlike conventional nitrogen fertilizer, which is determined by

soluble, inorganic nitrogen (Sanchez, et al., 2003). Compost and organic matter contain nutrients that are not readily available for plant uptake, unlike inorganic fertilizers. Thus, soil microorganisms must break down the organic nitrogen into inorganic nitrogen through the biological process of mineralization (Zublena, et al., 1991). The amount of nitrogen a soil contains and needs can be estimated by the amount likely to mineralize over a given period of time, but studies have shown that crop rotations, green manures, cover cropping, compost application and allowable fertilizers can keep soil fertility at optimum levels (Adediran, et al., 2004; El-Tarabily, et al., 2003; Mader, et al., 2002; Sanchez, et al., 2003; Zublena, et al., 1991). Soils under an organic management system can retain nitrogen in the soil longer and uptake of nitrogen is more efficient. In times of drought or flooding, organic soils retained optimum nutrient status allowing crops to survive through harsh conditions (Hepperly, 2005). Studies have shown that an integrated nutrient system is also a viable alternative to conventional growing practices. Inorganic fertilizers combined with compost or other organic amendments provide successful yield rates (Adediran et al., 2004). Increased soil organic matter leads to increased soil quality, and a system that uses organic amendments is promoting the formation of soil biomass (Saleque et al., 2003). The combination of organic matter with mineral fertilizers has shown benefits over mineral nutrient use alone (Berecz, 2005). In addition, integrated systems reduce polluting nitrate losses to the environment and promote more efficient nutrient usage (Kramer et al., 2006). The overuse of mineral fertilizers has been discussed, but growers must also be aware of overuse of organic amendments. Nitrogen leaching may be a problem in organic systems due to the usually



heavy use of animal and green (cover crops) manures. Growers should take care to investigate the nutrient status and requirement of the crops being grown before application of animal or green manures; contamination of waterways could possibly be a result from an organic growing system that uses excessive nitrogen (Beckwith, et al., 1998; Bergstrom, et al., 2004; Havlin, et al., 1999). In addition, contamination of vegetables from uncomposted manure can be a problem if not handled properly (Ingham, et al., 2005). Slurries, broiler litter, biosolids, animal manures, Milorganite (a commercially available refined biosolid manure) and green manures, are common organic fertilizers (Munoz, et al., 2005). Animal manures as well as cover cropping have been shown to be successful organic fertilizers (Gareau, 2004; Munoz, et al., 2005). On-farm inputs via a combined animal and crop production scheme do not have the additional transport and purchase costs and can therefore be substantially more profitable (Gareau, 2004). Additional fertilizers are also commonly used, such as fish emulsion or seaweed extracts. One study reported that yields were comparable in terms of plant growth when fish emulsion was used in place of conventional mineral fertilizers (El-Tarabily, et al., 2003). Enhanced microbial activity was found in the soil with the use of fish emulsion and the use of fish emulsion was found to be economically feasible (El-Tarabily, et al., 2003). Mineralization rates and nutrient content of organic fertilizers should be known for effective management of an organic growing system (Zublena, et al., 1991).

### **2.4.3. Potato**

Fertilizers as well as cultivar selection, time of harvest, and cultural practices determine quality potato production. Commercial potatoes are categorized into grades according to their size and appearance. United States Grade Standards are as follows: U.S. Extra No.1, U.S. No. 1, U.S. Commercial and U.S. No. 2 (Sargent, 1999). For adequate growth, large amounts of nitrogen and potassium are needed (Dean, 1994). Nitrogen is often the limiting nutrient (Rosen, 1991). Though this may be the case, studies have shown that excess nitrogen is commonly applied and nitrogen and water management can be improved and nitrogen kept from being lost to the environment (Munoz et al., 2005; van Delden, 2001). Phosphorous may also be needed in large quantities, and often the potato plant may not use nitrogen in the first four to five weeks of growth (Peet, 2001). Heavy fertilization of potato is common but will only lead to increased yields up to a certain point. In addition, increased yield does not necessarily lead to increased tuber quality (Mondy, 1978).

The amount of fertilizer a potato crop needs depends on a number of factors, especially the fertility level of the field, previous crop, and yield goals (Rosen, 1991). Soil testing of the field is the best way to determine how much N-P-K a potato crop needs. To preserve ground and surface water quality from excessive fertilizer, especially nitrate, yield goals should be established along with fertilizing according to the soil test results. Determining preplant soil conditions, nitrogen concentration, and also monitoring irrigation will aid in achieving optimum growth and yield of potato tubers (Dahnke, et al., 1992; Meyer, et al., 1998; Prunty, et al., 1997). Yield is closely related to

the amount of nutrients taken up by the crop (Rosen, 1991). Both nitrogen and water requirements of potato have been studied and optimal rates to avoid leaching and groundwater pollution along with maximizing profits and increasing yield and quality have been examined (Bradley and Pratt, 1954; Bundy, et al., 1986; Dahnke, et al., 1992; Doll, et al., 1971; Harris, 1978). Nitrogen range for potatoes is 2.5 to 5.9 kg ha<sup>-1</sup> and 3.5 to 10.7 kg ha<sup>-1</sup> for potassium per ton of tuber yields. Commercial cultivars require higher rates of nitrogen (Dean, 1994; Harris, 1992; Rosen, 1991; Rowe, 1969). Adequate water as well as timing of irrigation affects quality, number, and size of potato tubers (Kleinkopf, 1983; Robins and Domingo, 1956). Band application of fertilizer is recommended. This should be done at planting to avoid leaching (Dahnke, et al., 1992), or as the crop needs it (Carolus, 1937). Split applications of fertilizer are also recommended (Meyer et al., 1998). Micronutrient deficiencies are uncommon in potatoes, except for zinc (Zn) and iron (Fe). Rosetting and interveinal chlorosis of the leaves, an “S” shaped leaf midrib and reduced foliage are usually a result of zinc deficiency. Zinc deficiency can be corrected with applications of zinc sulfate or chelates. Iron deficiencies may be a result of free lime in the soil. Plant top, leaf base, and interveinal chlorosis is a result of iron deficiency. Foliar applications of iron are usually effective (Dahnke, et al., 1992). For Louisiana varieties, the recommended soil pH is 5.5-6.0, or if scab is a problem, 4.8-5.2. Application of 50-100 lbs of nitrogen per acre at planting is recommended and 100-150 lbs of phosphorous and potassium per acre at planting (Boudreaux, 2005). A sidedress of 50-100 lbs of nitrogen per acre is recommended between the time the crop marks the row and is 20-25 cm in height. No

sidedress is recommended for early harvest potatoes for the extra nitrogen may delay maturity (Boudreaux, 2005).

## **2.5. Botanical Overview of Potato**

Potatoes (*Solanum tuberosum*) were chosen for this study because they grow well in southeastern Louisiana, are economically important both in the U.S. and worldwide, and they are a world staple crop, able to grow in an array of environments. Potato originated in the Andean mountains of South America and became important worldwide, especially in Europe. A diet consisting mainly of potato satisfies human daily nutritional requirements of protein, calories, iron, and vitamins B and C (Dean, 1994). The potato is in the family Solanaceae, which includes plants such as tomato, eggplant, pepper, tobacco, and petunia. Potato is usually categorized as a dicotyledonous annual, though tubers may persist in the field from one season to the next. The tuber is modified portion of the underground stem, termed a rhizome or stolon. The tips of the stolons produce the tubers, or the edible portions of the plant, and initiation of growth occurs when the plants are approximately 6-8 inches high, or about 5-7 weeks after planting (Sieczka and Thornton, 1993). In terms of nutrition, potatoes provide 6% of the USRDA of protein, 50% of the USRDA of Vitamin C, and 15% of the USRDA of Vitamin B6, and at least 12 essential vitamins and minerals plus they are a great source of dietary fiber (Sieczka and Thornton, 1993). The variety 'Red LaSoda' was chosen for it was developed by the LSU AgCenter and is adapted to Louisiana growing conditions. 'Red LaSoda' potatoes are round to oblong, with medium deep eyes, give a high yield, size up early, are bright red in color, and are suited for the fresh market (Boudreaux, 2005; Hutchinson et al.,

2006; Roberts and Cartwright, 2007). This variety is moderately resistant to Fusarium seed piece decay and its foliage moderately resistant to early blight, and is moderately susceptible to Verticillium wilt, common scab, and blackleg, and is not tolerant of late blight, or scab (Hutchinson et al., 2006; Roberts and Cartwright, 2007). Disease is a major limiting factor in potato production (Secor et al., 1997). Potatoes are a cool season crop; recommended planting time in this region is mid-January, though a fall crop can be planted in mid-August. Further recommendations include use of certified seed pieces for planting, band applied fertilizer to the side and 1-2 inches below the seed piece, 1.5 inches of water every 10 days, maintenance of bed height, proper cultivation, and acidic soils, typically in the range of 5.4-5.8 in order to reduce incidence of scab, a common seed piece disease (Cannon 2003; Nagel, 2003; Roberts and Cartwright, 2007). Common diseases and problems include: bacterial soft rot, ring rot, black leg, black scurf, early blight, late blight, scab, seed piece rot, virus complex, and nematodes. Common insect pests include: Colorado potato beetle, flea beetle, potato tuber worm, wireworms, aphids, leafhoppers, and grubs (Cannon, 2003; Nagel, 2003; Sanders and Creamer, 1996; Sargent, 1999; Secor et al., 1997). Nitrogen must be carefully managed; too much can be detrimental to the crop, but in terms of potassium and phosphorus, potato is a heavy feeder (Peet, 2001; Roberts and Cartwright, 2007). A yield of 9,072 kg (20,000 lbs.) of potatoes per acre can be expected in a good year (Nagel, 2003). Farmers must grow for the type of market where their potatoes will be sold. This is usually to a processing facility, be it chipping, frozen, or dehydrated products, though as mentioned earlier, 'Red LaSoda' is for the fresh market (Sieczka et al., 1993).

## **2.6. Summary of Review**

Interest and consumerism is rising for organic products (Allen and Kovach, 2000; Born, 2004; Bull, 2006; Dimitri et al., 2002; Dimitri et al., 2006; Granatstein, 2000; Organic Consumer Trends Report (OCTR), 2007). Present research in organic agriculture is modest, but increasing (Kristiansen et al., 2006). In general, profits from the organic sector are comparable to those in conventional agriculture (Drinkwater et al., 1998). The cost of allowed organic inputs are a major restraint in the transitioning to organic production (Lotter, 2003). Environmental conservation is one of the main reason consumers choose organic products, more so than price premiums (Allen and Kovach, 2000; Lotter, 2003). This new phenomenon is termed 'green consumerism' and has been growing since the 1980's. Green consumerism is a way for consumers to control the market with their purchasing power, forcing more companies to practice sound management practices or use/carry recycled or organic products (Allen and Kovach, 2000). Increase in consumer demand is not the sole motivation of transitioning to organic, and excessive labeling and standards can slow trade and confuse consumers (OECD, 2003). The reverse is that labeling is widely viewed as information to the public and assures consumers as to how their food was produced (Pimental et al., 2005). Organic products are not for a few, wealthy, health fanatics (Lockie et al., 2006). Our future in agriculture is important to everyone, both farmers and the general populace (Lockeretz, 1983). The industrialization of organics, leveling off of consumer demand, and contamination by genetically modified organisms is hindering the organic movement (Kristiansen et al., 2006). Local marketing and diversity are two key aspects of organic

agriculture. Adoption of a conventional or industrial model of farming would detract from many of the goals of organic farming. Long-distance transport and highly processed and packaged foods are part of this industrial model. Many consumers choose organic to aid in diminishing these aspects of food production (Knudsen et al., 2006). Besides environmental stewardship, consumers are choosing organic products for health reasons, and landscape quality, along with ethical considerations, such as social justice and animal welfare (Browne et al., 2000). Some landscape quality values include biodiversity, efficient and economical use of natural resources, sufficiency, sustainability, clean air and water, ecological coherence, sensory qualities such as smells, sounds, and colors, soil erosion and wild-fire prevention, and fertility and carrying capacity of the soil (Kuiper, 2000; Rossi and Nota, 2000; Stobbelaar and van Mansvelt, 2000). Collaboration between pertinent stakeholders such as environmental groups, conservation organizations, tourism establishments and organic farms is essential (Kuiper, 2000; Stobbelaar et al., 2000; Stobbelaar and van Mansvelt, 2000). Also important is good farm management (OECD, 2003) and agricultural policies that take into account influences of farming on environmental and landscape quality, as well as the socio-economic impacts of farming (Andreoli and Tellarini, 2000). An environmentally sound accounting method needs to be developed which addresses these socio-economic concerns as well as environmental issues (Tellarini and Caporali, 1999). Organic farming demands increased and intensive research (Klepper et al., 1977). Integrated crop management is another alternative methodology to conventional farming, and results show that it can be more profitable than conventional or organic systems (Brumfield et

al., 2000). The moral and ethical facets of consumerism and trade are a public concern. Fair trade has been linked with organic production in some instances. A product that is both organic and fair trade certified can obtain a high price. These two separate notions are not synonymous. Fair trade does not indicate how it was grown, but usually whether or not the grower and workers were given a fair price for labor and the product and if their basic human rights were upheld. Fair trade is an issue dealing with social justice and social conditions and not an ecological condition or method of production. The two concepts are beginning to overlap and both markets are growing. Both are also delineating certain minimum standards (Browne et al., 2000; Raynolds, 2000). Organic agriculture awareness and adoption is happening worldwide. Up to 8% of cropland is managed organically to European Union Regulation standards in some European countries. Japan also has a strong organic movement. Input of energy, fertilizers and pesticides are reduced in organic systems. Soil biological activity, efficient utilization of resources, and microbial, as well as floral and faunal diversity is higher in organic systems. Soil quality is enhanced in an organically managed system and soil health is the basis for successful organic farming and the goal of most farmers. Organic production systems utilizing compost, cover crops and or crop rotation can replace and serve as an alternative to conventional production systems (Alvarez et al., 1988, 1993; Clark et al., 1998; Drinkwater et al., 1995; Garcia et al., 1989; Hepperly, 2005; Klonsky, 2000; Lockeretz et al., 1981; Mader et al, 2002; Mitchell et al., 2000; Reganold, 1988; Reganold et al., 1993; Teasdale et al., 2004; Temple, 2002; Welsh, 1999;).



## 2.7. Literature Cited

Adediran, J. A., L. B. Taiwo, M.O. Akande, R.A. Sobulo, and O.J. Idowu. 2004. Application of organic and inorganic fertilizer for sustainable maize and cowpea yields in Nigeria. *J. Plant Nutr.* 27(7):1163-1181.

Allen, Patricia and Martin Kovach. 2000. The capitalist composition of organic: The potential of markets in fulfilling the promise of organic agriculture. *Agri. and Human Values* 17:221-232.

Alvarez, C.E., C. Garcia, and A.E. Carracedo. 1988. Soil fertility and mineral nutrition of an organic banana plantation in Tenerife. *Biol. Agric. Hortic.* 5:313-323.

Alvarez, C.E., A.E. Carracedo, E. Iglesias, and M.C. Martinez. 1993. Pineapples cultivated by conventional and organic methods in a soil from a banana plantation: A comparative study of soil fertility, plant nutrition, and yields. *Biol. Agric. Hortic.* 9:161-171.

Andreoli, M., and V. Tellarini. 2000. Farm sustainability evaluation: methodology and practice. *Agri. Ecosystems Environ.* 77:43-52.

Asfary, A.F., A. Wild, and P.M. Harris. 1982. Growth, mineral nutrition and water use by potato crops. *J. Agric. Sci.* 100:87-101.

Balfour, E.B. 1943. *The living soil; evidence of the importance to human health of soil vitality, with special reference to post-war planning.* London. Faber and Faber Ltd. 246 p.

Balfour, E.B. 1976. *The Living Soil and the Haughley Experiment.* Universe Books. New York.

Barker, A.V. 1975. Organic vs. inorganic nutrition and horticultural crop quality. *HortScience* 10:50-53.

Bary, A., C.Cogger, and D.M. Sullivan. 2000. *Fertilizing with manure.* PNWO533, Washington State University Cooperative Extension, Pullman, WA. 16 pp.

Beckwith, C.P., J. Cooper, K.A. Smith, and M.A. Shepherd. 1998. Nitrate leaching loss following application of organic manures to sandy soils in arable cropping. I. Effects of application time, manure type, overwinter crop cover and nitrification inhibition. *Soil Use Mgt.* 14:123-130.

Bending, Gary D., Mary K. Turner, Francis Rayns, Marie-Claude Marx, and Martin Wood. 2004. Microbial and biochemical soil quality indicators and their potential for differentiating areas under contrasting agricultural management regimes. *Soil Biol. Chem.* 36:1785-1792.

Berez, Katalin, Tamás Kismányoky, and Katalin Debreczeni. 2005. Effect of organic matter recycling in long-term fertilization trials and model pot experiments. *Commun. Soil Sci. Plant Analysis* 36:191-202.

Bergstrom, Lars, and Holger Kirchmann. 2004. Leaching and crop uptake of nitrogen from nitrogen-15-labeled green manures and ammonium nitrate. *J. Environ. Quality* 33:1786-1792.

Berner, A., D. Scherrer, U. Niggli. 1995. Effect of different organic manures and garden waste compost on the nitrate dynamics in soil, N uptake and yield of winter wheat. *Biol. Agric. Hortic.* 11:289-300.

Bezdicsek, D.F., J.F. Power, D.R. Keeney, and M.J. Wright. 1984. Organic farming: current technology and its role in a sustainable agriculture. Special Publ. 46, Amer. Soc. Agronomy, Madison, WI. p. 192.

Born, Holly. 2004. Organic marketing resources. NCAT ATTRA Publication # IP124. 15 May 2007. <<http://www.attra.org/attra-pub/markres.html>>.

Bot, Alexandra and Jose Benites. 2005. The importance of soil organic matter, key to drought-resistant soil and sustained food and production. Food and Agriculture Organization (FAO) of the United Nations, Rome. FAO Soils Bulletin no 80.

Boudreaux, James E. 2005. Irish Potatoes. Commercial Vegetable Production Recommendations. Louisiana State University Agricultural Center Pub. # 2433.

Bradley, G.A., and A.J. Pratt. 1954. The response of potatoes to irrigation at different levels of available moisture. *Amer. Potato J.* 31:305-310.

Brady, N.C. and R.R. Weil. 2002. *The Nature and Properties of Soils*. Thirteenth Edition. Prentice Hall, Upper Saddle River, NJ.

Browne, A.W., P.J.C. Harris, A.H. Hofny-Collins, N. Pasiecznik, and R.R. Wallace. 2000. Organic production and ethical trade: definition, practice and links. *Food Policy* 25(1):69-89.

Brumfield, Robin G., Arbindra Rimal, and Steve Reiners. 2000. Comparative cost analyses of conventional, integrated crop management, and organic methods. *HortTechnology* 10(4):785-793.

Bull, C. T., C. Greene, J.B. Kotcon, and L. Oberholtzer. 2006. Organic agriculture: Innovations in organic marketing, technology, and research – Introduction to the proceedings. *Crop Mgt.* 14 May 2007. <<http://www.plantmanagementnetwork.org/pub/cm/symposium/organics/intro/>>.

- Bundy, L.G., R.P. Wolkowski, and G.G. Weis. 1986. Nitrogen source evaluation for potato production on irrigated sandy soils. *Amer. Potato J.* 63:385-397.
- Cannon, James M. 2003. Grow Irish Potatoes in the home garden. Louisiana State University Agricultural Center Cooperative Extension Vegetable Garden Hints Pub. # 1903.
- Carolus, R.L. 1937. Chemical estimations of the weekly nutrient level of a potato crop. *Amer. Potato J.* 14:141-153.
- Carruthers, Raymond and Carla D'Antonio. 2005. 9: Benefits and risks of biological control. *Biological Control* 35(3):181-182.
- Clark, Sean M., William R. Horwath, Carol Shennan, and Kate M. Scow. 1998. Changes in soil chemical properties resulting from organic and low-input farming practices. *Agron. J.* 90:662-671.
- Dahnke, W.C., C. Fanning, and A. Cattnach. 1992. Fertilizing potato. North Dakota State University Extension Service Pub. #SF-715.
- Dainello, Frank J. 2000. Organic production, opportunity, requirements, and pitfalls. Horticulture Risk Management Series Publication. Texas A&M Univ., College Station, Texas. 17 May 2007. <<http://aggie-horticulture.tamu.edu/alternatives/riskmanagementseries/organicproduction.html>>
- Dean, Bill B. 1994. *Managing the Potato Production System*. Food Products Press, New York, NY.
- Delanoy, L., C. Schaupmeyer, and J. Hollinger. 2003. Potato – Organic and pesticide free production. Guide to Commercial Potato Production on the Canadian Prairies. Western Potato Council.
- Delate, Kathleen, Michael Duffy, Craig Chase, Ann Holste, Heather Friedrich, and Noreen Wantate. 2003. An economic comparison of organic and conventional grain crops in a long-term agroecological research (LTAR) site in Iowa. *Amer. J. of Alternative Agr.* 18(2): 59-69.
- Dimitri, Carolyn and Catherine Greene. 2002. Recent growth patterns in the U.S. organic foods market. United States Department of Agriculture (USDA) Agriculture Information Bulletin no. AIB777.
- Dimitri, C., and L. Oberholtzer. 2006. A brief retrospective on the U.S. organic sector: 1997 and 2003. *Crop Management* 17 May 2007. <<http://www.plantmanagementnetwork.org/pub/cm/symposium/orgamics/Dimitri/>>.

- Diver, Steve. 1999. Biodynamic farming and compost preparation; alternative farming systems guide. 18 June 2007. <[www.attra.ncat.org](http://www.attra.ncat.org)>. pp.1-20.
- Doll, E.C., D. R. Christenson, and A.R. Wolcott. 1971. Potato yields as related to nitrate levels in petioles and soils. *Amer. Potato J.* 48:105-112.
- Drinkwater, L.E., P. Wagoner, and M. Sarrantonio. 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* 396:262-265.
- Drinkwater, L.E., D.K. Letourneau, F. Workneh, A.H.C. van Bruggen, C. Shennan. 1995. Fundamental differences between conventional and organic tomato agroecosystems in California. *Ecol. Applications* 5(4):1098-1112.
- Eggert, F.P., C.L. Kahrman. 1984. Organic farming: current technology and its role in sustainable farming. *Am. Soc. Agron.* 46:97-109.
- El-Tarabily, Khaled A., Amr H. Nassar, Giles E. St. J. Hardy, and Krishnapillai Sivasiththamparam. 2003. Fish Emulsion as a food base for rhizobacteria promoting growth of radish (*Raphanus sativus* L. var. *sativus*) in a sandy soil. *Plant and Soil* 252:397-411.
- Enviro-Briefs, 2005. No. 1. Crop plants take up (absorb) nutrients only in inorganic form. 15 May 2007. <[www.ppi-ppic.org/enviro-briefs](http://www.ppi-ppic.org/enviro-briefs)>.
- Evans, William B., Kenneth W. Hood, Keri L. Paridon, and Peter M. Hudson. 2005. Organic vegetable yield and economics show promise in a Mississippi trial. American Society for Horticultural Science (ASHS). Annual Conference. July 18-21, 2005. Las Vegas, NV. (abstr.)
- Faulkner, E.H. 1943. *Plowman's Folly*. Grosset & Dunlap. New York.
- Food and Agriculture Organization (FAO), 2007. Why Potato? Food and Agriculture Organization of the United Nations. 13 May 2007. <<http://www.potato2008.org/en/aboutiyp/index.html>>.
- Fertilization Systems in Organic Farming, 1997. Elaboration of standards from site-specific fertilization systems in organic farming in Europe based on long-term field experiments. FERSY (Fertilization Systems in Organic Farming). 14 May 2007. <<http://www.ibdf.de/v1/fersy.htm>>.
- Flynn, R.P., C.W. Wood, E.A. Guertal. 1995. Lettuce response to composted broiler litter as a potting substrate component *J. Am. Soc. Hortic. Sci.* 120:964-970.

Friedman, Diana. 2001. Transitioning to organic production. Pub. Sustainable Action Network (SAN) of the Sustainable Agriculture Research and Education (SARE) program. 16 May 2007. <[www.sare.org/bulletin/organic](http://www.sare.org/bulletin/organic)>

Garcia, C., C.E. Alvarez, A. Carracedo, and E. Iglesias. 1989. Soil fertility and mineral nutrition of a biodynamic avocado plantation in Tenerife. *Biol. Agric. Hort.* 6:1-10.

Gareau, Stephen E. 2004. Analysis of plant nutrient management strategies: Conventional and alternative approaches. *Agri. Human Values* 21:347-353.

Gaskell, M., B. Fouche, S. Koike, T. Lanini, J. Mitchell, and R. Smith. 2000. Organic vegetable production in California-science and practice. *HortTechnology* 10(4):609-713.

Gent, M.P.N., W.H. Elmer, K.A. Stoner, F.J. Ferrandino, J.A. LaMondia. 1998. Growth, yield, and nutrition of potato in fumigated or non-fumigated soil amended with compost and straw mulch. *Compost Sci. Util.* 6:45-56.

Gent, M.P.N. 2002. Growth and composition of salad greens as affected by organic compared to nitrate fertilizer and by environment in high tunnels. *J. Plant Nutr.* 25(5):981-998.

Glover, J.D., J.P. Reganold, and P.K. Andrews. 2000. Systematic method for rating soil quality of conventional, organic, and integrated apple orchards in Washington state. *Agri., Ecosystems, and Environ.* 80:29-45.

Granatstein, David. 2002. Organic farming continues to expand. *Agrichemical and Environmental News*. July 2002, Issue No. 195. Washington State University Cooperative Extension.

Granatstein, David. 2000. Alternative markets for fruit: organic and IFP. Center for Sustainable Agriculture and Natural Resources. 16th Annual Postharvest Conference, Yakima, WA March 14-15. Washington State University. 18 May 2007. <<http://postharvest.tfrec.wsu.edu/pgDisplay.php?article=PC2000M>>

Granatstein, D., A. Stone, C. Williams, C. Miles, D. Bezdicek, and C. Perillo. 2004. Organic farming research in the pacific northwest: Challenges, opportunities, and outlook. In: Brian Baker, Sean L. Swezey, David Granatstein, Steve Guldan, and David Chaney. *Organic Farming Compliance Handbook*. Western Region USDA SARE, Utah State University.

Greene, Catherine, R. 2001. U.S. Organic farming emerges in the 1990's: Adoption of certified systems. U.S. Department of Agriculture, Economic Research Service, Resource Economics Division, *Agriculture Information Bulletin* No. 770.

Greene, Catherine and Carolyn Dimitri. 2003. Organic Agriculture: Gaining Ground. Amber Waves, United States Department of Agriculture (USDA) Economic Research Service (ERS). 16 May 2007.

<<http://www.ers.usda.gov/AmberWaves/Feb03/Findings/OrganicAgriculture.htm>>.

Hall, Charles, Richard Edwards, Jeff Johnson. 2001. A Guide to Marketing Organic Produce. Texas Agricultural Extension Service. 9 June 2007.

<[www.sustainable.tamu.edu/publications/organicproduce.intro.html](http://www.sustainable.tamu.edu/publications/organicproduce.intro.html)>.

Harris, P.M. (ed.) 1978. Water. The potato crop. Chapman & Hall, London.

Harris, P. M. 1992. Mineral nutrition, p. 162-213. In: P.M. Harris (ed.) The potato crop: The scientific basis for improvement. Chapman & Hall, New York.

Harrison Jr., H.F., D.M. Jackson, A.P. Keinath, T.C. Pullaro, P.C. Marino. 2004. Comparison of cowpea, soybean and velvetbean cover crop mulches for broccoli production. HortTechnology 14:484-487.

Havlin, J.L., J.D. Beaton, S.L. Tisdale, and W.L. Nelson. 1999. Soil fertility and fertilizers: An introduction to nutrient management. 6<sup>th</sup> ed. Prentice Hall, Englewood Cliffs, N.J.

Heckman, Joseph. 2006. A History of Organic Farming – Transitions from Sir Albert Howard's War in the Soil to the USDA National Organic Program.

Renewable Agr. Food Systems 21(3):143-150. April 5 2007.

Full-text: Weston A. Price Foundation. <<http://www.westonaprice.org/farming/history-organic-farming.html>>.

Helms, Douglas, Anne B.W. Effland, Patricia J. Durana (eds.). 2002. Profiles in the History of the U.S. Soil Survey. Iowa State Press, Ames, Iowa.

Hepperly, Paul. 2005. Feed the soil, not the plant. The New Farm website.

<[http://www.newfarm.org/columns/research\\_paul/2005/1105/feedsoil.html](http://www.newfarm.org/columns/research_paul/2005/1105/feedsoil.html)>.

Hima, B.L., Cavigelli, M.A., Teasdale, J.R., Lu, Y.C. 2005. A comparative economic analysis of the farming systems project in Beltsville, MD (abstr.) 18 April, 2007.

<[http://www.ars.usda.gov/research/publications/Publications.htm?seq\\_no\\_115=181118](http://www.ars.usda.gov/research/publications/Publications.htm?seq_no_115=181118)>

Hochmuth, G.J. and E.A. Hanlon. 2000. Commercial Vegetable Fertilization Principles. Circular 225-E, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Hutchinson, C.M., E.H. Simonne, G.J. Hochmuth, D.N. Maynard, W.M. Stall, S.M. Olson, S.E. Webb, T.G. Taylor, S.A. Smith. 2006. Potato Production in Florida.

University of Florida/IFAS Extension Digital Information Source (EDIS) publication. 16 May 2007. <<http://edis.ifas.ufl.edu/CV131>>.

Ingham, Steven C., Melody A. Fanslau, Rebecca A. Engel, Jeffrey R. Breuer, Jane E. Breuer, Thomas H. Wright, Judith K. Reith-Rozelle, and Jun Zhu. 2005. Evaluation of fertilization-to-planting and fertilization-to-harvest intervals for safe use of noncomposted bovine manure in Wisconsin vegetable production. *J. Food Protection* 68(6):134-1142.

Jetter, Karen and Timothy D. Paine, 2004. Consumer preferences and willingness to pay for biological control in the urban landscape. *Biological Control* 30:312-322.

Jetter, Karen. 2005. Economic framework for decision making in biological control. *Biological Control* 35:348-357.

Joern, B.C., and M.L. Vitosh. 1995. Influence of applied nitrogen on potato. Part I. Yield, quality and nitrogen uptake. *Amer. Potato J.* 72(1):51-63.

Johnson-Maynard, J. and M. Morra. 2002. Application of Brassica meal for disease control and improved nitrogen fertility in organic farming systems. 18 May 2007. <<http://soils.ag.uidaho.edu/swm/organic.htm>>.

Kirschenmann, Fred. 2004. A brief history of sustainable agriculture. *The Networker* 9(2). Science and Environmental Health Network. 9 April 2007. <[http://www.sehn.org/Volume\\_9-2.html](http://www.sehn.org/Volume_9-2.html)>

Kleinkopf, G.E. 1983. Potato. Crop water relations. J.D. Teare and M.M. Peet (ed.). Wiley & Sons, New York.

Klepper, Robert, William Lockeretz, Barry Commoner, Michael Gertler, Sarah Fast, Daniel O'Leary, and Roger Blobaum. 1977. Economic performance and energy intensiveness on organic and conventional farms in the Corn Belt: a preliminary comparison. *Amer. J. Agri. Economics* 59(1):1-12.

Klonsky, Karen. 2000. Forces impacting the production of organic foods. *Agriculture and Human Values* 17:233-243.

Klonsky, Karen and Laura Tourte. 1998. Organic Agriculture Production in the United States: Debates and Directions. *Amer. J. Agr. Econ.* No. 5.

Knudsen, M.T., N. Halberg, J.E. Olesen, J. Byrne, V. Iyer, and N. Toly. 2006. Global trends in agriculture and food systems. In: N. Halberg, A.H. Fjelsted, M.T. Knudsen, and E.S. Kristensen, eds. *Global Development of Organic Agriculture – Challenges and Prospects*. 1:1-48. CABI publishing.

Kramer, Sasha B., John P. Reganold, Jerry D. Glover, Brendan J. Bohannon, and Harold A. Mooney. 2006. Reduced nitrate leaching and enhanced denitrifier activity and efficiency in organically fertilized soils. *Proceedings of the National Academy of Sciences of the United States of America*. PNAS 103: 4522-4527.

Kristiansen, Paul, Acram Taji, and John Reganold. 2006. *Organic agriculture: A global perspective*. Comstock Pub. Ithaca, NY.

Krug, H. 1997. Environmental influences on development, growth, and yield, p. 191-180. In: H.C. Wein (ed.). *The Physiology of Vegetable Crops*. CAB International. Wallingford, U.K.

Kuepper, George and Lance Gegner. 2004. *Organic crop production overview*. Fayetteville, AR: ATTRA - National Sustainable Agriculture Information Service, National Center for Appropriate Technology (NCAT). Full-text: ATTRA/NCAT. 10 May 2006. <<http://attra.ncat.org/attra-pub/summaries/organiccrop.html>>.

Kuiper, Juliette. 2000. A checklist approach to evaluate the contribution of organic farms to landscape quality. *Agr. Ecosystems Environ.* 77:143-156.

Lang, Susan S. 2005. Organic farming produces same corn and soybean yields as conventional farms, but consumes less energy and no pesticides, study finds. *Cornell University News Service*. 21 May 2006. <<http://www.news.cornell.edu/stories/July05/organic.farm.vs.other.ssl.html>>.

Lockeretz, William (ed.) 1983. *Environmentally Sound Agriculture*. Fourth International Conference of the International Federation of Organic Agriculture Movements, Cambridge, MA, August 18 to 20, 1982. Praeger Pub.

Lockeretz, W., G. Shearer, and D.H. Kohl. 1981. Organic farming in the Corn Belt. *Science*. 211:540-546.

Lockie, Stewart, Krtisten Lyons, Geoffrey Lawrence, and Darrin Halpin. 2006. *Going organic, mobilizing networks for environmentally responsible food production*. CABI Pub. Cambridge, MA, USA.

Lotter, Donald W. 2003. Organic agriculture. *J. Sustainable. Agr.* 21(4):59-128.

Mader, Paul, Andreas Fliebbach, David Dubois, Lucie Gunst, Padruot Fried, and Urs Niggli. 2002. Soil fertility and biodiversity in organic farming. *Science* 296(5573):1694-1697.

Madden, J. Patrick. 2008. The early years of the LISA, SARE, and ACE programs, reflections of the founding director. 16 January 2008. <[http://wsare.usu.edu/about/index.cfm?sub=hist\\_concept](http://wsare.usu.edu/about/index.cfm?sub=hist_concept)>



Martini, Elizabeth A., Jeffrey S. Buyer, Dennis C. Bryant, Timothy K. Hartz, and R. Ford Denison. 2003. Yield increases during the organic transition: improving soil quality or increasing experience? *Field Crops Research* 86:255-266.

Meyer, Roland D. and Daniel B. Marcum. 1998. Potato yield, petiole nitrogen, and soil nitrogen response to water and nitrogen. *Agron. J.* 90:420-429.

Mitchell, Jeff, Mark Gaskell, Richard Smith, Calvin Fouche, Steven T. Koike. 2000. Soil management and soil quality for organic crops. Division of Agriculture and Natural Resources, Univ. of CA at Davis. Pub.7248.

Mondy, Nell I. and Robert L. Koch. 1978. Influence of nitrogen fertilization on potato discoloration in relation to chemical composition. 1. Lipid, potassium, and dry matter content. *J. Agricultural Food Chemistry* 26(3).

Munoz, F., R.S. Mylavarapu, and C.M. Hutchinson. 2005. Environmentally responsible potato production systems: a review. *J. Plant Nutr.* 28:1287-1309.

Nagel, David. 2003. Commercial production of irish potatoes in Mississippi. Mississippi State University Extension Service Information Sheet # 1507.

Newton, Jon. 2004. *Profitable Organic Farming*. Second Ed. Blackwell Science, Ames, Iowa.

OECD, 2003. *Organic agriculture: Sustainability, markets, and policies*. Organization for Economic Co-Operation and Development (OECD). CABI Pub. Cambridge, Massachusetts.

Organic Consumer Trends Report (OCTR), 2007. Summary. 7 August 2007.  
<[http://www.nmisolutions.com/r\\_organic.html](http://www.nmisolutions.com/r_organic.html)>.

Owen, A.G. and Jones, D.L. 2001. Competition for amino acids between wheat roots and rhizosphere microorganisms and the role of amino acids in plant N acquisition. *Soil Biology and Biochemistry* 33:651-657.

Peavy, W.S., J.K. Grieg. 1972. Organic and mineral fertilizers compared by yield, quality, and composition of spinach. *J. Am. Soc. Hortic. Sci.* 97:718-723.

Peet, Mary. 2001. Sustainable practices for vegetable production in the South. Raleigh, North Carolina State Univ. 17 May 2007.  
<<http://www.cals.ncsu.edu/sustainable/peet/profiles/pppotato.html>>.

Pimentel, David, Paul Hepperly, James Hanson, David Douds and Rita Seidel. 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. *BioScience* 55(7):573-582.

- Plotkin, J.M. 2000. The effects of green manure rotation crops on soil and potato yield and quality. M.S. Thesis, University of Maine.
- Porter, G.A., and J.A. Sisson. 1991. Response of 'Russet Burbank' and 'Shepody' potatoes to nitrogen fertilizer in two cropping systems. *Am. Potato J.* 68:425-443. cvzx
- Prunty, Lyle, and Richard Greenland. 1997. Nitrate leaching using two potato-corn N-fertilizer plans on sandy soil. *Agr. Ecosystems and Environ.* 65:1-13.
- Rabalais, N.N., R.E. Turner, and D. Scavia. 2002. Beyond science into policy: gulf of mexico hypoxia and the mississippi river. *BioScience* 52:129-142.
- Raynolds, Laura T. 2000. Re-embedding global agriculture: The international organic and fair trade movements. *Agr. Human Values* 17:297-309.
- Reganold, J.P. 1988. Comparison of soil properties as influenced by organic and conventional farming systems. *Am. J. Alternative Agric.* 3:144-155.
- Reganold, J.P., A.S. Palmer, J.P. Lockhart, and A.N. Macgregor. 1993. Soil quality and financial performance of biodynamic and conventional farms in New Zealand. *Science.* 260:344-349.
- Ricci, M.D.S.F., V.W.D. Casali, A.M. Cardoso, H.A. Ruiz. 1995. Nutrient contents of two lettuce cultivars fertilized with organic compost [Portuguese]. *Pesquisa Agropecuaria Brasileira.* 30:1035-1039.
- Roberts, W. and Bob Cartwright. 2007. Potato production. Oklahoma State University Cooperative Extension Fact Sheet # 6028.
- Robins, J.S., and C.E. Domingo. 1956. Potato yield and tuber shape as affected by severe soil-moisture deficits and plant spacing. *Agron. J.* 48:488-492.
- Roe, N.E., P.J. Stofella, D. Graetz. 1997. Composts from various municipal solid waste feed-stocks affect vegetable crops. II. Growth, yields, and fruit quality. *J. Am. Soc. Hortic. Sci.* 122:433-437.
- Rosen, Carl J. 1991. Potato fertilization on irrigated soils. University of Minnesota Extension Service. 14 April 2006. <<http://extension.umn.edu/ditribution/crop-systems/DC3425.html>>.
- Rosset, Peter M. 1999. Policy Brief no. 4: The multiple functions and benefits of small farm agriculture, In the context of global trade negotiations. *Food First: The Institute for Food and Development Policy.* p.1-23.

Rossi, Roberto and Dionisio Nota. 2000. Nature and landscape production potentials of organic types of agriculture: a check of evaluation criteria and parameters in two Tuscan farm-landscapes. *Agr. Ecosystems Environ.* 77:53-64.

Rowe, P.R. 1969. Nature, distribution and use of diversity in the tuber bearing *Solanum* species. *Economic Bot.* 4:331-338.

Saleque, M. A., M.J. Abedin, N.I. Bhuiyan, S.K. Zaman, and G.M. Panaullah, 2003. Long-term effects of inorganic and organic fertilizer sources on yield and nutrient accumulation of lowland rice. Soil Science Division, Bangladesh Rice Research Institute.

Saltzman, Sarina, and Bruno Yaron (eds.). 1986. *Pesticides in Soil*. Hutchinson Ross Pub. NY.

Sanderson, J.B., and J.A. MacLeod. 1994. Soil nitrate profile and response of potatoes to fertilizer N in relation to time of incorporation of lupin (*Lupinus albus*). *Canadian J. Soil Sci.* 74:241-246.

Sanchez, Elsa S., Michael D. Orzolek, Jayson K. Harper, and Lynn F. Kime. 2003. Agricultural Alternatives Project. Penn State: College of Agricultural Sciences Agricultural Research and Cooperative Extension.

Sanders D.C. and Nancy G. Creamer. 1996. Commercial potato production in eastern North Carolina. North Carolina State University Cooperative Extension Service. Leaflet no. 22.

Sargent, Steve. 1999. Handling Florida Vegetables: Potato. University of Florida IFAS (Institute of Food and Agricultural Sciences) Extension # SS-VEC-929.

Schexnayder, H. 2006. Personal communication.

Secor, Gary A., Neil C. Gudmestad, Duane A. Preston, and H. Arthur Lamey, 1997. Guidelines for seed potato selection, handling and planting. North Dakota State University Extension Service publication no. 877.

Seyedbagheri, M. 2003. A community based approach to extension in organic agriculture. Western SARE PDP project report. 19 May 2007.  
<<http://wsare.usu.edu/projects/2003/EW99-013.pdf>>

Seyedbagheri, M. 2000. Organic potatoes thrive on composted manure. University of Idaho Extension Impact report. 19 May 2007.  
<[http://extension.ag.uidaho.edu/elmore/pdf\\_files/pota.pdf](http://extension.ag.uidaho.edu/elmore/pdf_files/pota.pdf)>.

Sheperd, M.A., and E.I. Lord. 1996. Nitrate leaching from a sandy soil: The effect of previous crop and postharvest soil management in an arable crop rotation. *J. Agri. Sci.* 127:215-229.

Sieczka, Joseph B. and Robert E. Thornton (eds.) 1993. *Commercial Potato Production in North America*. Revision of American Potato Journal Supplement Vol. 57 and USDA Handbook 267 by The Extension Section of The Potato Association of America. Orono, Maine.

Steiner, R. 1958. *Agriculture: a course of eight lectures*. Biodynamic Agriculture Association. London, England. p. 175.

Stobbelaar, Derk Jan, and Jan Diek van Mansvelt. 2000. The process of landscape evaluation introduction to the 2<sup>nd</sup> special AGEE issue of the concerted action: "The landscape and nature production capacity of organic/sustainable types of agriculture". *Agr. Ecosystems Environ.* 77:1-15.

Stobbelaar, D.J., J. Kuiper, J.D. Mansvelt, and E. Kabourakis. 2000. Landscape quality on organic farms in the Messara valley (Crete): (organic) farms as components in the landscape. *Agr. Ecosystems Environ.* 77:79-93.

Sullivan, Preston. 2003. *Overview of cover crops and green manures: Fundamentals of sustainable agriculture*. ATTRA pub. IP024.

Taylor, Matthew D. and Salvatore J. Locascio. 2004. Blossom-end rot: A calcium deficiency. *J. Plant Nutr.* 27(1):123-139.

Teasdale, John R., Ruth W. Mangum, Jay Radhakrishnan, and Michel A. Cavigelli. 2004. Weed seedbank dynamics in three organic farming crop rotations. *Agron. J.* 96:1429-1435.

Tellarini, Vittorio and Fabio Caporali. 1999. An input/output methodology to evaluate farms as sustainable agroecosystems: an application of indicators to farms in central Italy. *Agri. Ecosystems Environ.* 77:111-123.

Temple, Steve. 2002. *The transition from conventional to low-input or organic farming systems: Soil biology, soil chemistry, soil physics, energy utilization, economics, and risk*. Sustainable Agriculture Research and Extension (SARE) Project Report SW99-008. 18 April, 2007. <[www.wsare.usu.edu](http://www.wsare.usu.edu)>.

Thompson, Homer C. and William C. Kelly. 1957. *Vegetable crops*. 5<sup>th</sup> Edition. McGraw-Hill, New York.

Thorup-Kristensen, K., and N.E. Nielsen. 1998. Modelling and measuring the effect of nitrogen catch crops on the nitrogen supply for succeeding crops. *Plant and Soil* 203:79-89.

USDAa. 2007. National Organic Program (NOP). 12 October 2006. <<http://www.ams.usda.gov/nop/index.html>>.

USDAb. 2007. National Organic Program (NOP). Consumer Brochure. 12 October 2006. <<http://www.ams.usda.gov/nop/Consumers/brochure.html>>.

USDAc. 2007. National Organic Program. CFR Regulatory Text, 7 CFR Part 205, Subpart A — Definitions. § 205.2 Terms defined. 12 October 2006. <<http://www.ams.usda.gov/nop/NOP/standards/DefineReg.html>>.

USDA National Organic Standards Board (NOSB) definition, 2001. Accreditation Committee Reports. Principles of Organic Production and Handling, adopted October, 2001. 11 October 2006. <[http://www.ams.usda.gov/nosb/accredcommRMR/recommendations/princ\\_prod\\_hand\\_final.html](http://www.ams.usda.gov/nosb/accredcommRMR/recommendations/princ_prod_hand_final.html)>.

USDA Study Team on Organic Farming. 1980. Report and Recommendations on Organic Farming. US Gov't Printing Office 1980-0-310-944/96. USDA, Beltsville, MD. July. 94 p.

Van Delden, Arnout. 2001. Yield and growth components of potato and wheat under organic nitrogen management. *Agron. J.* 93:1370-1385.

Vos, J. 1997. The nitrogen response of potato (*Solanum tuberosum* L.) in the field: nitrogen uptake and yield, harvest index and nitrogen concentration. *Potato Research* 40:237-248.

Vos, J. and P.E.L. van der Putten. 2004. Nutrient cycling in a cropping system with potato, spring wheat, sugar beet, oats and nitrogen catch crops. II. Effect of catch crops on nitrate leaching in autumn and winter. *Nutrient Cycling in Agroecosystems* 70(1):23-31.

Waller, Beth e., Casey W. Hoy, Janet L. Henderson, Ben Stinner, Celeste Welty. 1998. Matching innovations with potential users, a case study of potato IPM practices. *Agri, Ecosystems and Environ.* 70:203-215.

Waddell, J.T., S.C. Gupta, J.F. Moncrief, C.J. Rosen, and D.D. Steele. 2000. Irrigation and nitrogen management impacts on nitrate leaching under potato. *Agronomy J.* 91:991-997.

Warman, P.R., K.A. Harvard. 1997. Yield, vitamin, and mineral content of organically and conventionally grown carrots and cabbage. *Agric. Ecosyst, Environ.* 61:155-162.

Welsh, Rick. 1999. Economics of organic grain and soybean production in the midwestern United States. Henry A. Wallace Institute for Alternative Agriculture. Greenbelt, MD.

Wild, Alan. 2003. Soils, land and food, Managing the land during the twenty-first century. Cambridge Univ. Press, Cambridge, MA.

Zinati, Gladis M. 2002a. Transition from conventional to organic farming systems: I. Challenges, recommendations, and guidelines for pest management. *HortTechnology* 12(4):606-610.

Zinati, Gladis M. 2002b. Transition from conventional to organic farming systems: II. Summary of discussion session and recommendations for future research. *HortTechnology* 12(4):611-612.

Zinati, Gladis M. 2002c. Proceedings of the workshop: Pest management during transition from conventional to organic farming. *HortTechnology* 12(4):587-589.

Zublena, J.P., J.V. Baird, and J.P. Lili. 1991. Nutrient content of fertilizer and organic materials. *Soil Facts*. North Carolina State University at Raleigh Cooperative Extension Service. AG-439-18.

## **CHAPTER. 3 TRANSITIONING TO ORGANIC: FERTILITY MANAGEMENT IN POTATO PRODUCTION**

### **3.1. Introduction**

Organic farming is one of the fastest growing segments of U.S. agriculture over the past decade (Dimitri and Greene, 2002). The growth in organic retail sales has been about 20 percent annually since 1990. This growth is due to price premiums, niche markets, reduced chemical inputs, perceived health benefits, and its position as an environmentally friendly alternative growing system (Dainello, 2000). Increased consumer demand along with the growth in direct marketing opportunities indicates that it is important to understand organic production and to ascertain whether organic production, for the wholesale or retail markets, can be productive and sustainable in Louisiana.

Organic crop production in Louisiana is a small, but increasingly important segment of the fruit and vegetable industry in the state. Presently there are over 330 certified organic acres in Louisiana and several new organic farms (H. Schexnayder personal communication). There appears to be significant growth potential in Louisiana as the states' organic growers fill only a portion of the market niche. Currently, very little data on the production and feasibility of organic vegetable production is available in the southern United States, let alone Louisiana. Limited research has been conducted in other areas of the country and the research results are often not transferable to the local climatic conditions and soils. Research investigating organic vegetable crops production practices is needed due to the lack of research in the Gulf South region. Potato was chosen because it is economically important both in the U.S. and worldwide, and is a

world staple crop, able to grow in an array of environments. Potato originated in the Andean mountains of South America, but grows well in southeastern Louisiana; the variety 'Red LaSoda' was chosen as it was developed by the LSU AgCenter and is adapted to Louisiana growing conditions (Boudreaux, 2005; Dean, 1994). Potato is low in sodium, provides 6% of the USRDA of protein, 50% of the recommended daily value of vitamin C, around 8% of the recommended daily value for iron, copper, magnesium, phosphorous, folic acid, and thiamin, 15% of the USRDA of Vitamin B6, plus they are a great source of dietary fiber (Dean, 1994; Sargent 1999; Sieczka and Thornton, 1993).

For Louisiana varieties, the recommended soil pH is 5.5-6.0, or if scab is a problem, 4.8-5.2. Application of 50-100 lbs (23-45 kg) of nitrogen per acre at planting is recommended and 100-150 lbs (45-68 kg) of phosphorous and potassium per acre at planting (Boudreaux, 2005; Hutchinson et al., 2006). A sidedress of 50-100 lbs (23-45kg) of nitrogen per acre is recommended between the time the crop marks the row and is 20-25 cm in height for a total of 200 lb/A of nitrogen (Boudreaux, 2005; Hutchinson et al., 2006).

Production of red-skinned potatoes is usually intended for the fresh market, as opposed to a processing facility for chipping (Sargent 1999). Fresh market organic potatoes fetch a price premium and can be more profitable than conventionally grown potatoes. The organic market is growing, and many farmers are transitioning to organic production to realize higher profits or for economic survival (Cacek and Lagner, 1986). In the 1990's, consumer demand for organic products rose. Currently, approximately one third of the U.S. population annually purchases organic foods. (Emerich, 1995; Greene,



2001; Hartman Group, 1997). Not only produce, but a widening range of organic goods can be found at supermarkets, high-end restaurants and convenience stores, not just natural or health food stores (Greene, 2001; Allen and Kovach, 2000). Organic farming is becoming increasingly popular due to price premiums and high-value markets for organic products (Greene 2001). There is also the notion that organic food is healthier, tastier and more environmentally sound, along with reducing inputs and energy, warranting further research (Klepper et al., 1977; Hartman-Group, 1997).

One study found, organic farming came out ahead economically as compared to conventional farming (Cacek and Lagner, 1986). Wholesale markets comprise approximately 80% of the organic market while direct to consumer is 13% and retail at around 7% (Walz, 1999). Natural food stores are the main outlets for organically produced goods and sales have increased 20% annually since the 1980's (Emerich, 1995). Farmer's markets and CSA's (Community Supported Agriculture) subscription programs are two principal avenues for the direct to consumer market (Hinrichs, 2000; Lotter, 2003). These niche markets allow producers to gain premium price for their product, and in the case of the CSA's, allows the farmers to shift some of the cost burden to the consumer (Brumfield et al., 2000). Consumer education and willingness to share in the responsibility of production is an integral part of the organic farming movement (Allen and Kovach, 2000). Consumers are increasingly interested to know where their food comes from and how it got there. Globalization of organics is arguably counter to the goals of organic growing, goals such as local food, which doesn't rely on long-distance transportation and supports local economies and farmers (Klonsky, 2000).

Adoption of organic agriculture would increase net farm income, but this would be a likely result of decreased exportation and increased consumer expense (Olson et al., 1982). Despite the lack of marketing infrastructure and the ongoing debate as to whether organic agriculture is upholding its holistic, ecologically sensitive, and sustainability principals, the organic market is strong and supported by wealthy, influential consumers and is expected to remain a rising sector of agriculture in the United States (Allen and Kovach, 2000; Greene, 2001).

Research examining nitrogen fertilizer in organic vegetable production is important, as nitrogen fertilizers are often one of the limiting factors in crop production and large amounts of nitrogen fertilizer are needed for adequate crop growth (Dean 1994; Rosen 1991). Whether or not nitrogen is limiting depends upon weather, fertilizer source, and N mineralization. Organic fertilizers such as green manures decompose rapidly and are high in mineral N; both of these traits are important in nutrient absorption (van Delden, 2001). Commercial potato cultivars often require higher rates of nitrogen (Dean, 1994; Harris, 1978; Rosen, 1991; Rowe, 1969). Band application of fertilizer is recommended. This should be done at planting to avoid leaching (Dahnke, et. al. 1992), or as the crop needs it (Carolus, 1937). Split applications of fertilizer are also highly recommended (Hutchinson et al., 2006; Meyer et. al. 1998). Studies in both conventional and organic potato production have shown that increases in tuber yield can be achieved by a split-rate fertilizer treatment rather than a single at-planting or pre-planting treatment (Errebhi et al. 1998; Joern and Vitosh, 1995; Prunty and Greenland, 1997; Rosen, 1991). This study employed both band and split fertilizer applications.

Due to the lack of research on organic vegetable production in the Deep South, the objectives of this study were first, to investigate the effect of different rates of organic, USDA National Organic Program (NOP) certified fertilizer, compared to a control with no fertilizer application and a treatment of fish emulsion as the sole source of fertilizer, on yield. Secondly, the study intended to evaluate the economic feasibility of Louisiana organic potato production under different organic fertility treatments. These objectives were met using a commercial organic fertilizer with a commercial recommended rate of nitrogen and comparing this rate to a half and a double rate of the same fertilizer, a treatment with no fertilizer added and a treatment fertilized with fish emulsion.

### **3.2. Materials and Methods**

Field studies were conducted at a 0.2 hectare (half-acre) organic research plot at the LSU AgCenter Burden Center in Baton Rouge, Louisiana over two years, in the winter/spring growing seasons. The study investigated the impact of different organic fertilizer treatments on the production of ‘Red LaSoda’ potatoes. ‘Red LaSoda’ potato was developed by Louisiana State University and has a high yield of oblong, red skinned tubers and is good for tablestock (Boudreaux, 2005). This cultivar is resistant to mosaic virus, is a mutant of the ‘LaSoda’ cultivar, which is a hybrid of the ‘Triumph’ and ‘Katahdin’ cultivars and similar to the ‘Pontiac’ cultivar, and is adapted to all south and early northern areas (The Potato Association of America, 2008). Plots consisted of 4-row beds, on 1.2 meter (4’) centers, 5.5 meters (18’) long. Certified, commercial potato seed pieces (28-56 g) were planted 7.6 cm (3”) deep, with 23 cm (9”) in-row spacing by hand using planting poles. Five fertilizer treatments were studied, with 4 replications, using a randomized complete block design.

Previous research reported the benefits of compost and cover crops (Munoz et al. 2005; Plotkin, 2000). In December 2005, compost supplied by the LSU AgCenter Caligari Center was spread on site at a rate of 2.24 metric tons per hectare (one ton per acre). On May 18, 2006 a cover crop of soybeans and Austrian winter pea was planted. The soy was planted with a seeder and drilled in a double row while the Austrian winter pea was broadcast over the plots. Soybean was chosen as the legume to fix nitrogen into the soil and add organic matter; buckwheat, a non-legume, was planted to suppress weeds, add biomass and improve soil tilth. (Clark, 2001; Harrison et al. 2004; Sullivan 2003). Both species were planted at a rate of 360 lb/acre. A garden mix for legume inoculant was incorporated with the cover crop seeds and the plots were irrigated after planting.

Different preplant fertilizer treatments were applied at a 15 cm depth in the center of the row by hand before planting. Four weeks after planting a sidedress application was distributed on the side of the row at different rates. The fertilizer treatments consisted of a 0.5x, 1x, 2x rate of a commercial organic pre-plant fertilizer (8-5-5 NPK ratio, Nature Safe, Cold Spring, KY), as well as a control, with no fertilizer applied over the growing season, and fish emulsion (Table 3.1). The 1x rate was equivalent to 100 lbs N/acre (112 kg N/ha) applied preplant and 100 lbs N/acre applied as a sidedress for a total rate of 200 lbs N/A (224 kg N/ha). Two hundred lbs total N/acre is the conventional, commercial recommended rate for potato production (Boudreaux, 2005). Nature Safe 8-5-5 NPK ratio is a USDA NOP certified, OMRI listed organic commercial pelleted fertilizer

containing feather, meat, bone and blood meals, sulfate of potash, yeast, sugars, carbohydrates and humus. Nature Safe 13-0-0 NPK ratio is also a USDA NOP certified, OMRI listed organic commercial pelleted fertilizer containing feather, meat, and blood meal, sugars, carbohydrates and humus.

At the start of each growing season, the field was tilled to eliminate weeds. Nature Safe fertilizer was placed in furrows in the center of the rows on September 6, 2006 and February 15, 2007 in varying amounts, according to treatment (Table 3.1). After reshaping beds, potato seed pieces were planted 7.6 cm deep by hand using planting poles on September 7, 2006 and February 16, 2007. The field was watered with overhead sprinklers after planting. On October 5 and March 19, plants were sidedressed with organic fertilizer (13-0-0 NPK ratio, Nature Safe, Cold Spring, KY). Fertilizer was applied in a band on the sides of the raised beds and the field cultivated to incorporate the fertilizer. The next day, fish emulsion was sprayed on designated plots at the recommended commercial rate (29.5 mL per 3.8 L of water per 0.4 hectares). Liquid fish fertilizer (5-2-2 NPK ratio, Agro-K, Minneapolis, MN) was applied by backpack sprayer and evenly distributed while walking at 3 miles per hour. Fish emulsion was applied every 2 weeks for 10 weeks for a total of 5 applications, following label directions. In the spring, a few seed pieces that did not sprout were replaced on March 8, 2007. Throughout the growing period, weed control was accomplished by cultivation as needed. Insect and disease presence was monitored and pest pressure did not require commercial organic pesticide application. Average rainfall each season was around thirteen inches and overhead

irrigation was used as needed, once a month during the growing season at a rate of 2.54 cm/0.4 ha.

**Table 3.1. Commercial, organic, nitrogen fertilizer rates and treatments for Spring and Fall planted *Solanum tuberosum* ‘Red LaSoda’ potatoes grown in Louisiana**

<b>Treatment<sup>c</sup></b>	<b>N Preplant</b>	<b>N Sidedress</b>	<b>Total N</b>
	lb/acre		
0	0	0	0
0.5	49	51	100
1	98	102	200
2	195	205	400
Fish Emulsion	0	66	66

<sup>z</sup>Treatments 0.5, 1, and 2 were a combination of preplant (8-5-5, Nature Safe) and sidedress (13-0-0, Nature Safe); fish emulsion (5-2-2, Agro K) was applied 5 times following label directions during the growing season.

**Table 3.2. Nitrogen content of Nature Safe organic fertilizer**

	<b>8-5-5</b>	<b>13-0-0</b>
Ammoniacal	0.30%	0.19%
Water insoluble N	6.80%	12.04%
Water soluble N	0.90%	0.77%
Calcium	4.50%	2.00%
Sulfur	1.00%	1.25%
Amino Acid content	50.10%	75.40%

Plots were harvested on December 11, 2006 and May 16, 2007. A commercial potato harvester was used and tubers were hand graded, weighed, counted and packed in the field. Grading was done with a grading board (wooden board with two different size

diameter holes for grades one and two); categories included 1's, 2's and culls based on USDA guidelines (U.S. Dept. of Agriculture, 1972).

Foliar samples and plant growth data were taken every 30 days over the 90-day growing period. Foliar sampling were done in the spring and involved cutting 40 newly formed leaves from the middle rows of every plot and drying them at 15.5° C for one week. Plant tissue was then analyzed by the Soil Testing and Plant Analysis lab at Louisiana Agricultural Center using nitric acid to dissolve the samples and analyze by inductively coupled plasma (ICP) spectrometry. Soil samples were taken at the start of each growing season. A soil testing probe was used and a minimum of ten 5oz. subsamples were taken for every plot, mixed, and sent off for analysis. Soil samples were analyzed for calcium, copper, magnesium, potassium, phosphorous, sodium, sulfur and zinc, and soil pH. Soil analysis was also done at the Soil Testing and Plant Analysis lab at Louisiana Agricultural Center using nitric acid to dissolve the samples and inductively coupled plasma (ICP) spectrometry along with a Mehlich 3 blank. Plant growth data collection included measuring height and width of two plants per plot at 1, 2, and 3 months. Additional data collection included a destructive harvest of two plants from each treatment plot and measuring leaf area as well as dry weight of the above ground and below ground portions of the plant and calculating specific leaf area (SLA), leaf area ratio (LAR), and leaf area index (LAI). Leaf area measurements involved cutting the above ground portion of the plant where the herbaceous material meets the

tuber from the below ground portion and passing the leaves through a leaf area machine (Delta-T Devices, Cambridge, England) obtaining leaf area index. The shoots and tubers were then placed in a dryer at 15.5° C for two weeks. Dry weight measurements were taken using an electronic balance, obtaining above and below ground biomass.

All data was subjected to an analysis of variance and means separated using Tukey's test at  $P \leq 0.05$ . For the five plant growth variables, multivariate analysis of variance was done. The main effect was not significant for treatment. Harvest was analyzed using PROC GLM with five levels of treatment for total market weight with Tukey adjusted means for comparison.

### **3.3 Results and Discussion**

#### **3.3.1 Fall 2006 Results**

For the fall growing season there was a significant difference in potato plant height between organic fertilizer treatments (Table 3.3). In contrast, organic fertilizer treatments did not affect potato plant width, leaf area, above or below ground biomass, shoot to root ratio, specific leaf area, leaf area ratio or marketable yield for the fall growing season. The fish emulsion treatment had a higher plant height than all the commercial organic fertilizer treatments while the 0.5x (100 lb/acre of N) rate of organic fertilizer had the lowest plant height. The 2x (400 lb/acre of N) rates and the control were comparable, and plant height for the 1x (200 lb/acre of N) rate was less than the plant height for 2x and control rates, but greater than the 0.5x rate (Table 3.3).



**Table 3.3. Effect of different commercial organic fertilizer rates on plant growth of *Solanum tuberosum* 'Red LaSoda' potatoes during the fall growing season at 30 and 60 days after planting.**

Treatment <sup>z</sup>	Plant height		Plant width		Tuber dry wt.		Shoot dry wt.		Shoot/Tuber ratio	
	30	60	30	60	30	60	30	60	30	60
	-----cm-----		-----cm-----		-----g-----		-----g-----		-----g-----	
0	15.3a <sup>y</sup>	24.2a	14.1	30.4	2.2	4.3	4.6	21.2	3.4	12.7
100	12.7b	21.6a	12.5	29.4	1.6	3.5	1.7	21.9	1.7	12.7
200	14.7a	22.6a	13.9	31.1	2.6	4.3	1.9	15.4	2.3	9.8
400	15.4a	26.8a	14.5	31.7	2.4	2.7	3.8	19.4	3.1	11.1
Fish Emulsion	15.6a	32.4b	14.4	37.2	2.4	4.7	3.8	32.7	3.1	18.7

<sup>z</sup>Fertilizer treatments in total lb N/A and were a combination of preplant (8-5-5, Nature Safe), sidedress (13-0-0, Nature Safe), and fish emulsion (5-2-2, Agro-K).

<sup>y</sup>Within a single column, values followed by a different letter are significantly different, values without a letter are not significantly different at  $P \leq 0.05$  (Tukey's HSD mean separation test).

**Table 3.3. (Continued)**

Treatment <sup>z</sup>	Leaf Area Index		SLA <sup>x</sup>		LAR <sup>w</sup>	
	30	60	30	60	30	60
	-----cm <sup>2</sup> -----		-----		-----	
0	362.3	1679.4	80.7	58.2	52.7	50.2
100	106.5	1616.1	61.1	74.3	32	63.3
200	96.3	1335	49.4	81.9	20.7	64.7
400	301.6	1197.9	66.8	68.4	40.3	59.5
Fish Emulsion	251.7	3032.8	65.5	84.6	38.1	73.8

<sup>z</sup> Fertilizer treatments in total lb N/A and were a combination of preplant (8-5-5, Nature Safe), sidedress (13-0-0, Nature Safe), and fish emulsion (5-2-2, Agro-K).

<sup>y</sup>Within a single column, values followed by a different letter are significantly different, values without a letter are not significantly different at  $P \leq 0.05$  (Tukey's HSD mean separation test).

<sup>x</sup>SLA specific leaf area= leaf area/leaf dry weight

<sup>w</sup>LAR leaf area ratio= leaf area/total plant weight

**Table 3.4. Effect of different rates of commercial organic fertilizer on *Solanum Tuberosum* 'Red LaSoda' potato yield in hundred weight per acre of graded potatoes harvested during the fall growing season.**

Treatment <sup>z</sup>	Tuber number		Tuber weight		Total Marketable yield cwt/A
	cwt/A		cwt/A		
	no. 1's	no. 2's	no. 1's	no. 2's	
<b>0</b>	76.3	19.3	13.0	1.0	85.1
<b>100</b>	50.5	21.5	8.9	0.9	59.4
<b>200</b>	70.5	20.3	11.9	1.0	78.3
<b>400</b>	81.5	31.3	15.1	1.6	101.4
<b>Fish Emulsion</b>	70.0	15.3	13.3	0.7	84.5

<sup>z</sup>Treatments in total lb N/A and were preplant (8-5-5, Nature Safe), combined with a sidedress (13-0-0, Nature Safe), and fish emulsion (5-2-2, Agro-K) application.

Units			
To convert U.S. to SI,		To convert SI to U.S.,	
multiply by	U.S. unit	SI unit	multiply by
2.54	inch(es)	cm	0.3937
1.1209	lbs./acre	kg•ha <sup>-1</sup>	0.8922
1.1209	cwt/acre	quintals/ha	0.8922

### 3.3.2. Spring 2007 Results

The results for the spring growing season indicated that there were differences in plant height, specific leaf area and leaf area ratio due to treatment (Table 3.5). No differences in plant width, leaf area index, aboveground (shoot) biomass, belowground (root) biomass or shoot/root ratio were significant (Table 3.5). Differences in plant height were evident 8 and 12 weeks after planting and the 100 lbs. N/acre, 400 lbs. N/acre and the fish emulsion treatments were significantly taller than the control and 200 lbs. N/acre rates. The 100 lbs., 200 lbs., and the fish emulsion had the largest specific

leaf area and were significantly higher than the control and the 400 lbs. N/acre rate.

These rates, along with the control, also had a larger LAR than the 400 lbs. N/acre rate treatment.

Field observations noted differences between the control treatment and the fertilized treatments. The control, where no fertilizer was applied, was more chlorotic than the fertilized treatments. The control treatment was healthy however, signifying that nitrogen was available in the soil. No noticeable differences were noted between the 100 lbs., 200 lbs., and 400 lbs N/acre rate. The fish emulsion treatments had foliage that was the deepest green among all the treatments.

There were differences in marketable yield due to treatment (Table 3.6). The 400 lbs. N/acre rate of organic fertilizer and the fish emulsion marketable yield rates were significantly different while the marketable yield of the control, 100 lbs., and the 200 lbs. N/acre treatments were similar. Marketable yield ranged from 123 cwt/acre for the 400lbs. treatment to 153 cwt/acre for the 100 lbs. treatment. The fish emulsion treatment averaged 185 cwt/acre.

In general, foliar nutrition was adequate to high, as shown in Table 3.7. Magnesium (Mg), Manganese (Mn) and copper (Cu) levels were higher than recommended levels. Nitrogen (N), potassium (K), zinc (Zi), and manganese (Mn) levels were highest in the 400 lbs. N/acre (Table 3.7). In the soil analysis, potassium levels were deficient as compared to recommended levels but K levels significantly increased in percentage in the soil over the 90 day growing period (Table 3.8). The lowest yields were found with the 400 lbs. N/acre rate, the rate that is double the recommended amount

of nitrogen per acre. Low yields in this treatment could possibly be due to nutrient toxicity, though several treatments had high levels of minerals. Copper toxicity can be a problem, as it does accumulate in the soil, resulting in lower yields and is toxic to beneficial soil organisms (Kuepper and Sullivan, 2004). One study reported a decrease in root and leaf biomass with high levels of copper when growing corn. (Mocquot et al., 1996). In another study, increased potato yields were found with zinc and boron micronutrient applications, but not copper or manganese (Rosen, 1991). Manganese toxicity in potato can also be a problem, especially in acidic soils, resulting in necrotic areas on leaves (lower than pH 4.8) (Rosen, 1991). Soil tests indicate an increase in potassium (K) and zinc (Zn) from before planting to post harvest, that was not affected by fertilizer treatment (Table 3.8). There were no observed pest problems although the fields were scouted periodically. Problems associated with potato growing were absent; no control measures were used.

### **3.3.3 Fall 2006 and Spring 2007 Yield Discussion**

There were differences in 'Red LaSoda' potato marketable yield with organic fertilizer treatments for the spring growing season although there were no differences in marketable yield for the fall. As shown in Table 3.4., potato yields for the fall season (59 to 101 cwt/acre) were lower than reported average commercial conventional yields (100 to 200 cwt/acre) (Boudreaux, 2005). The fall is not the normal growing season for potatoes in Louisiana and a killing frost occurred two weeks prior to harvest. As shown

**Table 3.5. Effect of different commercial organic fertilizer rates on plant growth of *Solanum tuberosum* 'Red LaSoda' potatoes during the spring growing season at 30, 60, and 90 days after planting.**

Treatment <sup>z</sup>	Plant height			Plant width			Shoot biomass			Tuber biomass			Shoot/Tuber ratio		
	30	60	90	30	60	90	30	60	90	30	60	90	30	60	90
	cm			cm			g			g			g		
Control	11 <sup>y</sup>	30	32 b	15	38	33	1.78	16.19	33.31	4.27	6.39	5.08	4.27	6.39	5.07
100	8	37	41 a	13	49	35	3.13	17.23	28.76	3.47	8.65	4.00	3.47	8.65	4.01
200	9	31	38 ab	14	47	37	2.45	17.26	32.28	3.45	6.14	4.98	3.45	6.14	4.97
400	12	33	35 ab	20	38	38	2.91	18.21	31.87	4.44	8.61	3.77	4.43	8.61	3.77
<b>Fish Emulsion</b>	10	38	41 a	16	46	37	2.57	11.03	32.52	2.93	3.74	4.80	2.93	3.74	4.80

<sup>z</sup>Treatments in total lbs N/A and were preplant (8-5-5, Nature Safe), combined with sidedress (13-0-0, Nature Safe), and fish emulsion (5-2-2, Agro-K).

<sup>y</sup>Within a single column, values followed by a different letter are significantly different and values without a letter are not significant at  $P \leq 0.05$  (Tukey's HSD mean separation test).

**Table 3.5. (Continued) Effect of different commercial organic fertilizer rates on plant growth of *Solanum tuberosum* 'Red LaSoda' potatoes during the spring growing season at 30, 60, and 90 days after planting.**

Treatment <sup>z</sup>	Leaf Area Index Average			Specific Leaf Area (SLA)			Leaf Area Ratio (LAR)		
	30	60	90	30	60	90	30	60	90
	cm <sup>2</sup>								
Control	87.29 <sup>y</sup>	1133.29	1880.11	49.18	69.99	56.44 ab	14.44	50.18	48.98 b
100	210.21	1525.25	1867.48	67.21	88.54	64.93 a	31.85	58.95	56.99 a
200	129.27	1214.84	1684.20	52.79	70.41	52.17 b	21.9	51.93	45.19 b
400	184.79	1259.94	1796.95	63.61	69.19	56.39 ab	25.17	46.98	50.42 ab
<b>Fish Emulsion</b>	140.40	720.13	1585.49	54.63	65.32	48.76 b	25.53	48.77	42.48 b

<sup>z</sup>Treatments in total lb N/A and were preplant (8-5-5, Nature Safe), combined with sidedress (13-0-0, Nature Safe), and fish emulsion (5-2-2, Agro-K).

<sup>y</sup>Within a single column, values without a letter are not significant at  $P \leq 0.05$  (Tukey's HSD mean separation test).

**Table 3.6. Effect of different rates of commercial organic fertilizer on *Solanum Tuberosum* 'Red LaSoda' potato yield in pounds of graded potatoes harvested during the spring growing season.**

Treatment <sup>z</sup>	Tuber Number		Tuber Weight		Total Marketable yield cwt/A
	No. 1's	No. 2's	No. 1's	No. 2's	
	<b>0</b>	55.8 ab	20.4 ab	16.5 ab	
<b>100</b>	60.0 ab	23.5 ab	19.5 ab	1.7 ab	152.6 ab
<b>200</b>	66.0 ab	22.4 ab	17.5 ab	1.4 ab	144.1 ab
<b>400</b>	52.5 b	19.6 b	7.5 b	0.7 b	122.7 b
<b>Fish Emulsion</b>	73.3 a	28.7 a	19.8 a	2.0 a	185.3 a

<sup>z</sup>Treatments in total lb N/A and were preplant (8-5-5, Nature Safe), combined with sidedress (13-0-0, Nature Safe), and fish emulsion (5-2-2, Agro-K).

<sup>y</sup>Within a single column, values followed by same letter are not significantly different at  $P \leq 0.05$  (Tukey's HSD mean separation test).

Units			
To convert U.S. to SI,		To convert SI to U.S.,	
multiply by	U.S. unit	SI unit	multiply by
2.54	inch(es)	cm	0.3937
1.1209	lbs./acre	kg•ha <sup>-1</sup>	0.8922
1.1209	cwt/acre	quintals/ha	0.8922

**Table 3.7. Plant tissue analysis for spring planted *Solanum tuberosum*, 'Red LaSoda' potato at approximately 30 inches in height on a dry weight basis.**

Status <sup>z</sup>	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
	-----Percent-----						-----Parts per million-----					
<b>Deficient</b>	<3.0	0.2	3.5	0.6	0.3	0.25	40	30	30	20	5	0.1
<b>Adequate</b>	3.0-6.0	0.2-0.8	3.5-6.0	0.6-2.0	0.3-0.6	0.25-0.50	40-150	30-60	30-60	20-60	5.0-10	0.1-0.2
<b>High</b>	>6.0	0.8	6	2	0.6	0.5	150	60	60	60	10	0.5
<b>Treatment<sup>y</sup></b>												
<b>Control</b>	5.16 c <sup>x</sup>	0.32	2.83 ab	2.12 a	1.28 a	0.49	174.8	116.17c	27.07 b	37.56	41.07	<0.1
<b>100</b>	5.42 bc	0.32	2.64 b	1.68 ab	1.03 b	0.46	162.73	138.85 bc	27.59 ab	33.73	30.18	<0.1
<b>200</b>	5.56 abc	0.31	3.02 ab	1.72 ab	1.02 b	0.46	143.32	204.69 b	30.25 ab	37.52	31.42	<0.1
<b>400</b>	5.94 a	0.29	3.07 a	1.58 b	0.97 b	0.45	135.19	297.48 a	32.54 a	38.03	30.04	<0.1
<b>Fish Emulsion</b>	5.60 ab	0.33	2.79 ab	1.78 ab	1.04 ab	0.45	171.86	116.58 c	30.27 ab	40.09	32.95	<0.1

<sup>z</sup>Data for deficient/adequate range and high nutrient status for potato from Hutchinson et al., 2004.

<sup>y</sup>Treatments in lb N/acre and were preplant (8-5-5, Nature Safe), combined with sidedress (13-0-0, Nature Safe), and fish emulsion (5-2-2, Agro-K).

<sup>x</sup>Within a single column, values followed by a different letter are significantly different, values without a letter are not significantly different

**Table 3.8 Initial and post-planting soil analysis for spring planted *Solanum tuberosum* 'Red LaSoda'**

	P	K	Ca	Mg	S	Zn	Cu	Na
	-----%-----					-----ppm-----		
0 days	35.29 a	29.77 a	1.50 a	2.50 a	19.48 a	3.70 a	0.88 a	1457.09 a
90 days	32.81 a	42.88 b	1.50 a	2.50 a	17.74 a	7.45 b	0.88 a	1283.33 a

in Table 3.6, the spring season yields (123 to 153 cwt/acre) were comparable to average yields (100 to 200 cwt/acre) of conventionally grown potatoes as reported by the Louisiana Cooperative Extension Service (Boudreaux, 2005). It appears that the nitrogen fertilizer levels in the organically managed research plots were not limiting as potato yields were not affected by fertilizer rate in the fall, and yields were within the average yields range for the spring season.

The yields at the 400 N lb/acre rate were lower than the other treatments. Excessive manganese was found for the 400 N lb/acre, though toxicity symptoms were not expressed in the foliage and this is usually only problematic at a low soil pH (< 4.5) (Davis, 1996). The pH of the soil was approximately 6.5. Rather than mineral toxicity, accelerated vegetative growth due to excessive nitrogen may have led to a decrease in yields at the 400 lbs N/A rate. Vegetative growth as opposed to tuber growth may be the cause of lower yields at the 400 lbs N/acre rate (Mills and Jones, 1979; Stroehlein and Oebker, 1979). These results may be due to excess nitric acid, as the organic fertilizer has high levels of nitrogen. As the organic fertilizer breaks down, it mineralizes and releases nitric acid, which at elevated levels can be toxic to many plants, especially those in the Solanaceae family (Thomas, 2007). This could lead to lower yields as similar results have been reported in Canada using Nature Safe products in field trials with various crops (Thomas, 2007).

The plots treated with fish emulsion had the highest yields. The fish emulsion treatment had the lowest amount of nitrogen per acre (66 lbs./A) and had the highest yields. Fish emulsion has been shown to be an effective replacement for inorganic



fertilizers. One study reported that plant growth enhanced by bacterial and actinomycete isolates was most apparent when fish emulsion was used as a nutrient base. In this study, the bacterial and actinomycete isolates seemed to use fish emulsion as a source of nutrients and precursor for plant growth regulators (PGRs) such as auxins, gibberellins, and cytokinins (El-Tarabily et al., 2003). The reason for the lack of yield response between the control, 100 lbs. and 200 lbs. N/acre rates in the spring growing season to organic fertilizer is unclear. A possible explanation for this lack of difference is that the field research plot had been managed organically for several years and practices to build up soil organic matter and fertility levels were conducted. Commercially produced compost, primarily composed of horse manure and sawdust, was applied at a rate of one ton per acre to the field one year prior to the fall planting. In addition, in the summer of 2006 an organic cover crop was grown and then incorporated into the field. The cover crop was a combination of 360 lbs of soybean per acre planted in double rows atop the bed, and 360 lbs. of Austrian winter pea, broadcast between rows. Both species were coated with a legume inoculant to maximize nitrogen fixation. Research shows that cover cropping is a successful means of reducing fertilizer input and is often part of a structured BMP (Best Management Practices) system designed for economic and environmental efficiency (Abdul-Baki and Teasdale, 1993; Drinkwater et al., 1998; Randall and Schmitt, 1993). In one corn study, soybean and clover sown together as a green manure provided adequate nitrogen and yields were higher than conventionally fertilized corn. When N fertilizer was added, yield responses were eliminated, suggesting

yield increases were due to nitrogen and not some other factor such as crop rotation (Oyer and Touchton, 1990).

Diversity in a production system is beneficial. A study comparing a system incorporating cover crops and compost had higher pools of mineralizable nitrogen in the soil than one relying solely on commercial nitrogen fertilizer (Sanchez et al., 2001). Efficient use of nitrogen can result in a constant, adequate supply of nitrogen to the plant through recycling of nitrogen in the system, and thus, reduced fertilizer input requirement (Abdul-Baki and Teasdale, 1993; Sanchez et al., 2001). Regular use of green manures will result in long-term benefits (McGuire, 2003). In some cases, the use of green manures provides excess nitrogen, but is less wasteful due to more efficient use of nitrogen in a cover cropping system as compared to nitrogen fertilizers (Garrity and Becker, 1994; George et al., 1998). Rising prices and increasing regulation of commercial synthetic fertilizers has led to a need for more research on the traditional and effective practice of cover cropping as a replacement for mineral N (Abdul-Baki and Teasdale, 1993). Not only do green manures supply adequate and efficient nitrogen to the crop, they maintain soil fertility and retain soil nitrogen, cutting costs in the long run (Drinkwater et al., 1998). Compost and cover cropping likely supplied adequate nitrogen to the potato crop in the study, resulting in a lack of differences in plant growth due to treatment.

### **3.4 Economics of Potato Production**

Local markets set price premiums, but the price for organic fresh market produce premium is usually about 55% more than conventional (The New Farm, 2007). Price premiums in the wholesale market range from 10% to 30% more for organic produce (Sok and Glaser, 2001). The average wholesale price received by growers for conventional potatoes is \$7.06/cwt. Conventional, fresh market potatoes are sold for \$10.36/cwt and processing potatoes are \$5.39/cwt. (Economic Research Service, 2007); based on this percentage (55%) organic potatoes could possibly sell for up to \$16.06/cwt. at a farmer's market. The Rodale Institute reports that on average, the fresh market price for a 50lb. bag of conventional potatoes is \$20 and \$35 for a 50lb. sack of fresh market organic potatoes (The New Farm, 2007). Organic production is largely geared towards fresh markets, natural foods stores and conventional food stores. Unfortunately, national statistics on organic retail sales are not available from the USDA (Dimitri and Greene, 2002).

The current study suggests that the use of commercial organic fertilizer in a potato production system in Louisiana is viable. The cost of organic fertilizer ranged from \$100 per acre (1 ton compost per acre) for the control treatment due to the cost of compost (Caligari Center, 2007) to \$432/acre for the 200 N lbs./acre commercial organic fertilizer treatment and \$863/acre for the 400 N lbs./acre commercial organic fertilizer treatment. Both of these latter prices include the cost of compost (Table 3.9). Negative net benefits were realized for the 400 lbs./acre treatment, making this the least profitable treatment of the study (Table 3.9). Fish emulsion was one of the most expensive forms of fertilization

in this study at \$425 per acre when applied at 55 gallons of product per acre. Used in combination with compost the input cost for this fertilization treatment is \$525/acre. Recommended fertilizers for conventional potato production cost around \$166 per acre, plus \$52 per acre for pesticides for a total of approximately \$218 per acre in Louisiana (Hinson and Boudreaux, 2007). The cost of commercial organic fertilizers is about \$214 per acre more than a conventional production system and the total direct expenses and varying cost for the organic treatments were higher than the estimated cost for conventional potato production. Due to higher organic price premiums (\$20 for a 50 lb. sack of conventional fresh market potatoes and \$35 for a 50 lb. sack of organic fresh market potatoes as of 2007), the organic production systems had higher gross benefits and net benefits 2 to 3 times higher than a conventional production system (Table 3.9). Break-even price is the price a producer must receive for a product to recover the costs related to production of the product. Higher break-even prices are also associated with organic production treatments, although expected price premiums would offset the break-even price.

The current study did not require any pesticide applications. Potential inputs in an organic potato system would be timely sprays of neem oil and *Bacillus thuringiensis* for pest management. As of 2007, one-time application of neem oil would cost \$55/acre and *Bacillus thuringiensis* would cost \$20/acre for a total organic pesticide cost of \$75/acre. While the organic pesticide cost is more than conventional pesticides, they may be unnecessary, as in this study. If an application of these organic pesticides were necessary, net benefits in an organic system would still exceed those in a conventional

system as the pesticide cost is a relatively small portion, less than 3 percent, of the varying costs.

Fish emulsion used alone as a fertilizer was an acceptable production treatment, even with the higher cost associated with application labor and product expense. The difference in cost between a conventional growing system and one using fish emulsion as the sole source of fertilizer is about \$200/acre (Table 3.9). If compost is used, the difference in price is about \$300/acre. With price premiums, it is economically viable to use fish emulsion as the sole source of fertilizer as the fish emulsion treatment had the highest gross and net benefit and the breakeven price is less than a dollar more than conventional production systems. Without price premiums, the fish emulsion treatments were the only treatments in the study that retained higher than conventional gross and net benefits.

Compost is relatively inexpensive (\$100/ton) (Caligari Center, 2007) and this study suggests that compost alone as a fertilizer for potatoes (control treatment, 130 lbs/acre yield) is also a feasible treatment as the control had higher net and gross benefit and similar breakeven price to conventional (Table 3.9). In this study total yield (144 lbs/acre) for the 200 lbs N/acre treatment was comparable to conventional production, which is based on 200 lbs N/acre using synthetic fertilizers. The fish emulsion treated plots had relatively higher yields (185 lbs/acre). In general, the results of this study indicate that input costs are higher in an organic production system, but with price premiums, gross and net benefits are higher (Table 3.9). The use of cover cropping and compost likely decreases the requirement for commercial fertilizers (Delatea and

Cambardella, 2004; Drinkwater et. al. 1998; Oyer and Touchton, 1990; Sanchez et. al. 2001). More research is needed to adjust organic fertilizer recommendations based on cover crops and compost use in an organic production system.

**Table 3.9. Varying costs, gross and net benefits, additional varying costs and benefits and breakeven price per acre for *Solanum tuberosum* 'Red LaSoda' potatoes in 2007 (Louisiana State University Agricultural Center).**

Treatment <sup>z</sup>	Cost of fertilizer <sup>z</sup>	Total direct expenses	Varying costs <sup>y</sup>	Gross benefits <sup>x</sup>	Net benefits <sup>w</sup>	Breakeven price <sup>v</sup>
				\$		
<b>Control</b>	100	1655	1755	4650	2795	13.19
<b>100</b>	216	1770	1986	5320	3334	13.06
<b>200</b>	432	1986	2417	5040	2623	16.78
<b>400</b>	864	2418	3281	4305	-1024	26.68
<b>Fish Emulsion</b>	525	2080	2606	6475	3869	14.08
<b>Conventional<sup>u</sup></b>	218	1773	1990	3000	1010	13.27

<sup>z</sup>Treatments in total lb N/A and were preplant (8-5-5, Nature Safe), combined with sidedress (13-0-0, Nature Safe), and fish emulsion (5-2-2, Agro-K).

<sup>y</sup>Varying costs equals cost for fertilizer plus total direct expenses.

<sup>x</sup>Gross benefits equals total yield (Control yielded: 133 lbs/acre, 100 rate: 153 lbs./acre, 200 rate : 144 lbs/acre, 400 rate: 123 lbs./acre, Fish Emulsion: 185 lbs/acre, and Conventional used for comparison: 150 lbs/acre) multiplied by potato unit prices.

<sup>w</sup>Net benefits equals gross benefits minus varying costs.

<sup>v</sup>Breakeven price equals varying costs divided by total yield.

<sup>u</sup>Not a treatment within the study, figures used for comparison and includes cost of pesticides; Hinson and Boudreaux, 2007

### 3.5 Literature Cited

Abdul-Baki, Aref A., and John R. Teasdale. 1993. A no-tillage tomato production system using hairy vetch and subterranean clover mulches. *HortScience* 28(2):106-108.

Allen, Patricia and Martin Kovach. 2000. The capitalist composition of organic: The potential of markets in fulfilling the promise of organic agriculture. *Agri. and Human Values* 17:221-232.

Boudreaux, James E. 2005, *Commercial Vegetable Production Recommendations*. Louisiana Cooperative Extension Service, Publication 2433.

Brumfield, Robin G., Arbindra Rimal, and Steve Reiners. 2000. Comparative cost analyses of conventional, integrated crop management, and organic methods. *HortTechnology* 10(4):785-793.

Cacek, Terry, and Linda L. Langner. 1986. The economic implications of organic farming. *Am. J. Alternative Agr.* 1(1):25-29.

Caligari Center, 2007. Louisiana State University Agricultural Center, Baton Rouge, Louisiana. Personal communication.

Carolus, R.L. 1937. Chemical estimations of the weekly nutrient level of a potato crop. *Amer. Potato J.* 14:141-153.

Clark, Andy (ed.). 2001. *Managing cover crops profitably*. 3<sup>rd</sup> ed. Handbook Series Book 9. Sustainable Agr. Network, Beltsville, MD.

Dahnke, W.C., C. Fanning, and A. Cattanach. 1992. *Fertilizing Potato*. North Dakota State University Extension Service Pub. #SF-715.

Dainello, Frank J. 2000. *Organic production, opportunity, requirements, and pitfalls*. Risk management Series. Texas A&M Univ., College Station, Texas.

Davis, J.G. 1996. Soil pH and magnesium effects on manganese toxicity in peanuts. *J. Plant Nutr.* 19 (3-4):535-550.

Dean, Bill B. 1994. *Managing the Potato Production System*. Food Products Press, New York, NY.

Delanoy, L., C. Schaupmeyer, and J. Hollinger. 2003. *Potato – Organic and pesticide free production*. Guide to Commercial Potato Production on the Canadian Prairies. Western Potato Council.

- Delatea, Kathleen and Cynthia A. Cambardella. 2004. Agroecosystem performance during transition to certified organic grain production. *Agron. J.* 96:1288-1298.
- Dimitri, Carolyn and Catherine Greene. 2002. Recent growth patterns in the U.S. organic foods market. United States Department of Agriculture (USDA) Agriculture Information Bulletin no. AIB777.
- Drinkwater, L.E., P. Wagoner and M. Sarrantonio. 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* 396. 262-265.
- Economic Research Service, USDA. 2007. Vegetables and Melons Outlook. Potatoes: Acreage, yield, prices, and production, by season, crops year 1998 to date, VGS-324.
- El-Tarabily, Khaled A., Amr H. Nassar, Giles E. St. J. Hardy, and Krishnapillai Sivasiththamparam, 2003. Fish emulsion as a food base for Rhizobacteria promoting growth of radish (*Raphanus sativus* L. var. *sativus*) in a sandy soil. *Plant and Soil* 252:397-411.
- Emerich, Monica. 1995. Industry growth:22.6%. *Natural Foods Merchandiser*. 1(32).
- Errebhi, M., C.J. Rosen, S.C. Gupta, and D.E. Birong. 1998. Potato yield response and nitrate leaching as influenced by nitrogen management. *Agron. J.* 90:10-15.
- Garrity, D.P. and M. Becker. 1994. Where do green manures fit in Asian rice farming systems?, p.1-10. In J.K. Ladha and D.P. Garrity (eds.). *Green manure production systems for Asian ricelands: Selected papers from the International Rice Research Conference*. IRRI, Los Banos, Philippines.
- Greene, Catherine, R. 2001. U.S. Organic farming emerges in the 1990's: Adoption of certified systems. U.S. Department of Agriculture, Economic Research Service, Resource Economics Division, Agriculture Information Bulletin No. 770.
- George, Thomas, Roland J. Buresch, Jagdish K. Ladha, and Gloria Punzalan. 1998. Recycling in situ of legume-fixed and soil nitrogen in tropical lowland rice. *Agron. J.* 90:429-437.
- Harris, P.M. (ed.) 1978. *Water: The Potato Crop*. Chapman & Hall, London.
- Harrison Jr., H.F., D.M. Jackson, A.P. Keinath, T.C. Pullaro, P.C. Marino. 2004. Comparison of cowpea, soybean and velvetbean cover crop mulches for broccoli production. *HortTechnology* 14:484-487.
- Hartman-Group. 1997. *The Evolving Organic Marketplace: A Hartman and New Hope Industry Series Report*. New Hope Communications. Bellevue, WA. <[www.hartman-group.com](http://www.hartman-group.com)>. 17 May 2007.



Hinson, Roger A. and James E. Boudreaux. 2007. 2007 Projected Commodity Costs and Returns: Louisiana Vegetable Crops. Louisiana State University Agricultural Center, Farm Management Research & Extension, Department of Agricultural Economics & Agribusiness. A.E.A. Information Series No. 246.

Hinrichs, C.C. 2000. Embeddedness and local food systems: notes on two types of direct agricultural market. *J. of Rural Studies*. 16(3):295-303.

Hutchinson, C.M., E.H. Simonne, G.J. Hochmuth, D.N. Maynard, W.M. Stall, S.M. Olson, S.E. Webb, T.G. Taylor, S.A. Smith. 2006. Potato Production in Florida . University of Florida/IFAS Extension Digital Information Source (EDIS) publication. May 16 2007. <<http://edis.ifas.ufl.edu/CV131>>.

Joern, B.C., and M.L. Vitosh. 1995. Influence of applied nitrogen on potato. Part I. Yield, quality and nitrogen uptake. *Amer. Potato J.* 72(1):51-63.

Klepper, Robert, William Lockeretz, Barry Commoner, Michael Gertler, Sarah Fast, Daniel O'Leary, and Roger Blobaum. 1977. Economic performance and energy intensiveness on organic and conventional farms in the corn belt: a preliminary comparison. *Amer. J. Agri. Economics* 59(1):1-12.

Klonsky, Karen. 2000. Forces impacting the production of organic foods. *Agriculture and Human Values* 17:233-243.

Kuepper, George and Preston Sullivan. 2004. Organic alternatives for late blight control in potatoes. ATTRA publication #IP131.

Lotter, Donald W. 2003. Organic Agriculture. *J. Sustainable. Agr.* 21(4).

McGuire, Andy. 2003. Using Green Manures in Potato Cropping Systems. Washington State University Cooperative Extension, Grant-Adams area.

Meyer, Roland D. and Daniel B. Marcum. 1998. Potato yield, petiole nitrogen, and soil nitrogen response to water and nitrogen. *Agron. J.* 90:420-429.

Mills, H.A. and J.B. Jones, Jr. 1979. Nutrient deficiencies and toxicities in plants: Nitrogen. *J. Plant Nutr.* 1:101-122.

Mocquot, B., J. Vangronsveld, H. Clijsters, and M. Mench. 1996. Copper toxicity in young maize (*Zea mays* L.) plants: effects on growth, mineral and chlorophyll contents, and enzyme activities. *Plant and Soil* 182(2):287-300.

Munoz, F., R.S. Mylavarapu, and C.M. Hutchinson. 2005. Environmentally responsible potato production systems: a review. *J. Plant Nutr.* 28:1287-1309.

The New Farm. 2007. Organic price report. The Rodale Institute.  
<<http://www.newfarm.org/opx/>>

Olson, K.D., J. Langley, E.O. Heady. 1982. Widespread adoption of organic farming practices: Estimated impacts on U.S. agriculture. *J. Soil Water Conservation*. 37(1):41-45.

Oyer, L.J. and J.T. Touchton. 1990. Utilizing legume cropping systems to reduce nitrogen fertilizer requirements for conservation-tilled corn. *Agron. J.* 82:6.

Plotkin, J.M. 2000. The effects of green manure rotation crops on soil and potato yield and quality. M.S. Thesis, University of Maine.

Prunty, Lyle, and Richard Greenland. 1997. Nitrate leaching using two potato-corn N-fertilizer plans on sandy soil. *Agr. Ecosystems Environ.* 65: 1-13.

Randall, G.W. and M.A. Schmitt. 1993. Best management practices for nitrogen use statewide in Minnesota (Clean Water Series). University of Minnesota Extension Service, pub. No. FO-06125-GO.

The Potato Association of America (PAA). 2008. Red LaSoda. The University of Maine.  
<<http://www.umaine.edu/PAA/webbuy/Varieties/redlasoda.htm>>

Rosen, Carl J. 1991. Potato fertilization on irrigated soils. Univ. of Minnesota Extension Service. <<http://extension.umn.edu/ditribution/crop-systems/DC3425.html>>. 15 May 2007.

Rowe, P.R. 1969. Nature, distribution and use of diversity in the tuber bearing *Solanum* species. *Economic Bot.* 4:331-338.

Sanchez, Jose E., Thomas C. Wilson, Kadir Kizilkayac, Elaine Parkera and Richard R. Harwood. 2001. Enhancing the mineralizable nitrogen pool through substrate diversity in long term cropping systems. *Soil Sci. Soc. Am. J.* 65(5):1442 -1447.

Sargent, Steve. 1999. Handling Florida Vegetables: Potato. University of Florida IFAS (Institute of Food and Agricultural Sciences) Extension # SS-VEC-929.

Sieczka, Joseph B. and Robert E. Thornton (eds.) 1993. Commercial Potato Production in North America. Revision of American Potato Journal Supplement Vol. 57 and USDA Handbook 267 by The Extension Section of The Potato Association of America. Orono, Maine.

Sok, Emy and Lewrene Glaser. 2001. Tracking wholesale prices for organic produce. U.S. Department of Agriculture, Economic Research Service. *Agricultural Outlook*, October.

Stroehlein, J.L. and N.F. Oebker. 1979. The effects of nitrogen and phosphorus on yields and tissue analysis of chili peppers. *Comm. Soil Sci. Plant Anal.* 10:551-563.

Sullivan, Preston. 2003. Overview of cover crops and green manures: Fundamentals of sustainable agriculture. ATTRA pub. IP024.

Thomas, Steve. 2007. Griffin Industries, Inc. Nature Safe Fertilizers. Personal communication.

USDA. 1972. United States Standards for Grades of Potatoes. USDA, AMS, Washington, D.C. 20402.

Van Delden, Arnout. 2001. Yield and growth components of potato and wheat under organic nitrogen management. *Agron. J.* 93:1370-1385.

Walz, E. 1999. Third Biennial National Organic Farmers' Survey. Santa Cruz, CA: Organic Farming Research Foundation. 124 p. <[www.ofrf.org](http://www.ofrf.org)>. 5 April 2007.

## CHAPTER 4

### CONCLUSIONS AND RECOMMENDATIONS

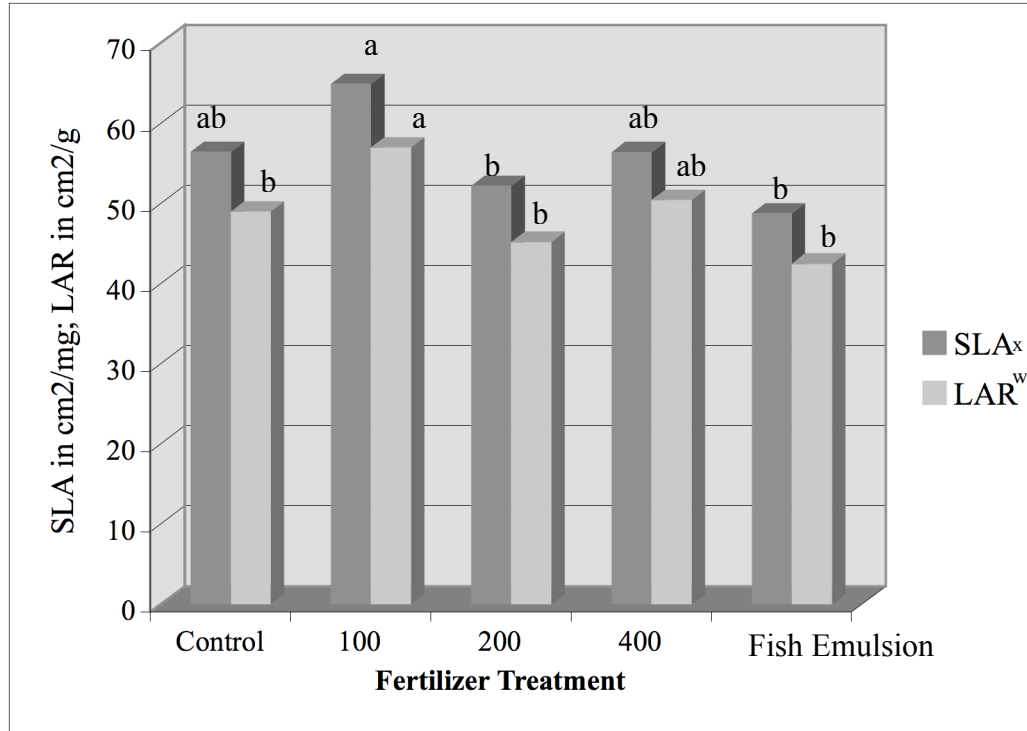
The results from this study suggest that high initial soil fertility levels resulting from compost and cover crop incorporation may have resulted in the lack of response to the different organic fertility treatments in the fall, and the lack of differences between the control, 100 lbs. and 200 lbs. N/acre treatment rates in the spring. Commercial organic fertilizers are expensive and reliance on composting and cover cropping, which are local, sustainable, relatively inexpensive inputs, are often recommended for organic production by small and medium-scale producers. In this investigation, differing organic fertility treatments in the fall did not affect yield, only the spring season resulted in significant differences in yields.

The field had been fallow for eight years previous to the study, allowing beneficial soil microbes to increase in population. Also, the range in fertilizer rates may not have been broad enough in the current study. Nitrogen and other nutrients were probably at adequate levels in the soil; differences in growth and yield between the control, the 100 lbs. and 200 lbs. N/acres rate treatments were not significant. As previously stated, the addition of compost and cover cropping may be a beneficial method of decreasing the use of commercial fertilizers in a cropping system.

This study indicates that organic potato production in Louisiana is viable and profitable. If compared, the use of commercial organic fertilizer is potentially more

expensive than conventional fertilizer along with higher labor inputs for organic production. Due to price premiums (\$20 for a 50 lb. sack of conventional fresh market potatoes and \$35 for a 50 lb. sack of organic fresh market potatoes as of 2007) normally received for organic produce, returns are higher in an organic production system. In this study, the fish emulsion treatment was one of the most costly but profitable production systems, as yields and gross and net benefits were highest and fish emulsion may have a beneficial association with plant growth regulators. Using compost and cover crops for fertilization are the least expensive fertility programs and result in profitable production. Additional research is needed to investigate the expected outcomes of using various cover crops and types and rates of compost in a sustainable organic production system in the Deep South.

**APPENDIX  
SUPPLEMENTARY DATA**



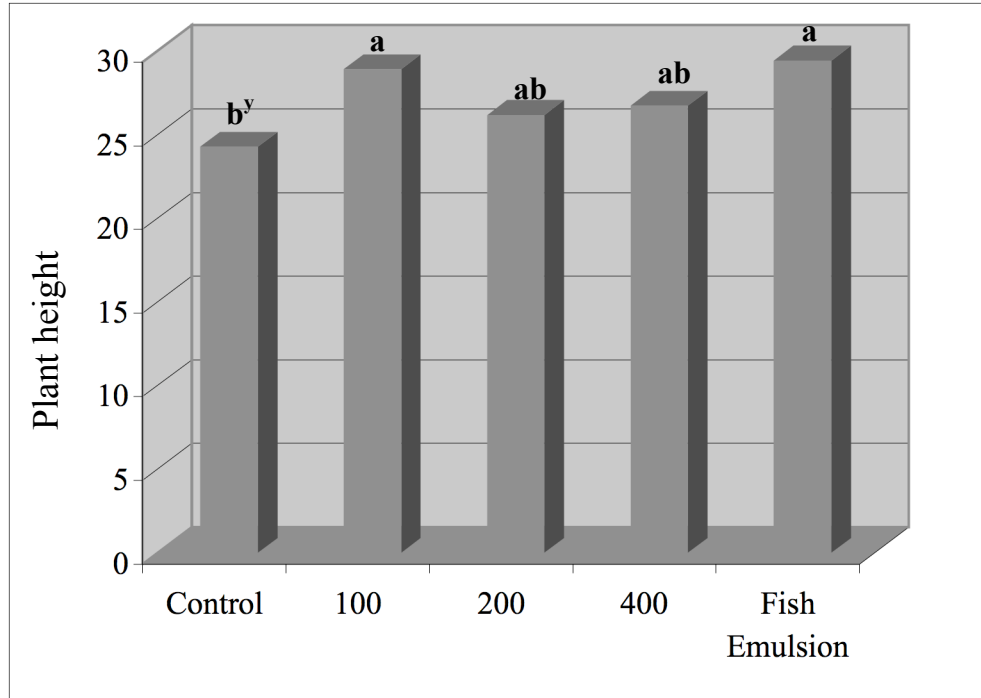
**Figure A.1. The influence of organic Nitrogen fertilizer treatments on spring planted ‘Red LaSoda’ potato specific leaf area (SLA) and leaf area ratio (LAR).**

<sup>z</sup>Treatments in lbs.N/A and were preplant (8-5-5, Nature Safe), sidedress (13-0-0, Nature Safe), and fish emulsion (5-2-2, Agro-K).

<sup>y</sup>Within a single column, bars followed by same letter are not significantly different at  $P \leq 0.05$  (Tukey's HSD mean separation test) according to treatment.

<sup>x</sup>SLA specific leaf area= leaf area/leaf dry weight

<sup>w</sup>LAR leaf area ratio= leaf area/total plant weight.



Fertilizer treatment<sup>z</sup>

**Figure A.2. The influence of organic Nitrogen fertilizer treatments on spring planted ‘Red LaSoda’ potato plant height.**

<sup>z</sup>Treatments in lbs.N/A and were preplant (8-5-5, Nature Safe), sidedress (13-0-0, Nature Safe), and fish emulsion (5-2-2, Agro-K).

<sup>y</sup>Within a single column, bars followed by same letter are not significantly different at  $P \leq 0.05$  (Tukey's HSD mean separation test) according to treatment.

<sup>x</sup>LAR leaf area ratio= leaf area/total plant weight.

**Table A.1. Summary of estimated costs and returns per acre for potato *Solanum tuberosum* (Irish), organic fresh market one-row, equipment, average yield, Louisiana, 2007.**

Item	Unit	Control (compost only, no commercial fertilizer)			200 lbs. N/acre commercial organic fertilizer (Nature Safe)			55 gal/acre commercial organic fertilizer (Agro-K fish emulsion)		
		Price (\$)	Quantity	Amount (\$)	Price (\$)	Quantity	Amount (\$)	Price (\$)	Quantity	Amount (\$)
<b>Income</b>	sack (potato)	35.00	130	5200.00	35.00	150	6000.00	35.00	185.00	7400.00
<b>Total income</b>				5200.00			6000.00			
<b>Direct Expenses</b>										
<b>Hired labor</b>	acre	134.40	1	134.40	134.40	1	134.40	806.40	1	806.40
<b>Pack and Harvest Items</b>	acre	147.00	1	147.00	147.00	1	147.00	147.00	1	147.00
<b>Seed</b>	acre	242.00	1	242.00	242.00	1	242.00	242.00	1	242.00
<b>Harvest Labor</b>	acre	480.00	1	480.00	480.00	1	480.00	480.00	1	480.00
<b>Organic fertilizer</b>	acre	100.00	1	100.00	432.00	1	432.00	525.40	1	525.40
<b>Operator</b>										
<b>Labor</b>	hour	15.30	25.46	389.51	15.30	23.78	363.76	15.30	21.98	336.32
<b>Diesel Fuel</b>	gal	2.10	6.29	13.23	2.10	6.29	13.23	2.10	6.29	13.23
<b>Gasoline</b>	gal	2.30	33.24	76.45	2.30	31.51	72.48	2.30	29.67	68.24
<b>Repair &amp; Maintenance</b>	acre	52.31	1.00	52.31	50.17	1.00	50.17	47.09	1.00	47.09
<b>Interest on Op. Cap.</b>	acre	41.56	1.00	41.56	48.10	1.00	48.10	102.15	1.00	102.15
<b>Total Direct Expenses</b>				1676.46			1983.13			2767.83
<b>Returns Above Direct Expenses</b>										
<b>Total Fixed Expenses</b>				3523.54			4016.87			4632.17
<b>Returns Above Total Specified Expenses</b>										
<b>Total Specified Expenses</b>				118.41			114.08			108.31
<b>Returns Above Total Specified Expenses</b>										
<b>Total Specified Expenses</b>				1794.87			2097.21			2876.14
<b>Returns Above Total Specified Expenses</b>										
<b>Total Specified Expenses</b>				3405.13			3902.79			4523.86
<b>Allocated Cost Items</b>										
<b>Overhead (owner)</b>	acre	56.52		56.52	56.52		56.52	56.52		56.52
<b>Residual Returns</b>				3348.61			3846.27			4467.34



**Table A.2. Problems and recommended control measures for *Solanum tuberosum* 'Red LaSoda' potato**

<b>Problems</b>	Seed decay	Early Blight	Late Blight	scab	Colorado Potato Beetle	aphids	Bacterial soft rot	Grubs and wireworms
<b>Recommended Treatments</b>	adequate drainage	Certified seed potato, sanitation, copper fungicide spray, and compost tea as a foliar spray.	Certified seed potato, sanitation, copper fungicide spray, and compost tea as a foliar spray.	Certified seed, crop rotation, maintain pH below 5.5, Trichoderma	crop rotation, flaming, mulch, trap cropping, spinosad, neem, <i>Beauveria bassiana</i>	Beneficial insects, soap, neem, summer oils, rotenone	Certified seed, copper compounds, compost	Scouting and hand-picking, <i>Bt kurstaki</i> , spinosad

## VITA

Lacey Theresa Dupré was born in Lafayette, Louisiana, in 1981. After high school, she decided to stay in Louisiana to pursue her studies and in May of 2003 she received a Bachelor of Art in the College of Liberal Arts, Sociology and Anthropology from the University of Louisiana at Lafayette. In August of 2005, she began graduate studies under the direction of Dr. Carl E. Motsenbocker to pursue the degree of Master of Science in the field of horticulture, which will be awarded at the August 2008 Commencement.