STAND PERSISTENCE OF ‘PRESTIGE’ BUFFALOGRASS (*BOUTELOUA DACTYLOIDES*) [SYNONYM *BUCHLOE DACTYLOIDES*] GROWN UNDER SIMULATED GREEN ROOF CONDITIONS DURING SUMMER IN OKLAHOMA

By

MARY KATHRYN BEITZ

Bachelor of Science in Landscape Architecture

Oklahoma State University

Stillwater, OK

2004

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2011

STAND PERSISTENCE OF ‘PRESTIGE’ BUFFALOGRASS (*BOUTELOUA DACTYLOIDES*) [SYNONYM *BUCHLOE DACTYLOIDES*] GROWN UNDER SIMULATED GREEN ROOF CONDITIONS DURING SUMMER IN OKLAHOMA

Thesis Approved:

Dr. Daniel E. Storm

Thesis Adviser

Dr. Dennis L. Martin

Dr. Jason R. Vogel

Dr. Mark E. Payton

Dean of the Graduate College

ACKNOWLEDGMENTS

I would like to thank my advisory team for all that they have done for me throughout this entire process. Dr. Daniel Storm, as my primary advisor, has been through the thick and thin with guidance on procedures, writing, statistics, funding and reminding me to have fun with the process. I would also like to thank Dr. Dennis Martin for all of his advice on Buffalograss and turf research, writing and countless trips to the greenhouse to see if things were on track. And also to Dr. Jason Vogel who provided a voice in writing and experiment planning.

There are many others who have contributed to this project completion. Without the generous contribution of Buffalograss plugs from Wayne Thorson from Todd Valley Farms I would have not been able to plant any grass at all. Also construction of tables, carts, engineering of design elements, and help in setting up the experiment were done by Wayne Kiner and his crew who worked tirelessly until things were done.

Most important is my family for their support of me during this whole process; the house spent listening about grass, rain, vegetation and bugs I’m sure got old, but they always listened. I also thank my grandparents Sid and Laverne Muse who taught me to work hard and encouraged me to dream big; and to my mom Sidney Morgan and dad George Morgan who raised me to be the woman I am today, encouraging me and teaching me to never stop learning. To my husband Adam Beitz who spent hours of his own time to help me build and work in the greenhouse without complaining and giving his support in so many ways that I can’t even count through this process. I can’t wait to see what the next chapter of our lives holds.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

Figure Page

Figure Page

CHAPTER I

INTRODUCTION

Every time we turn on the television or look at the front page of a newspaper, overwhelming environmental problems are looking us in the eye. As the population of the world increases, environmental issues also increase. With more people comes more building. Ongoing suburbanization and urban growth, lawns, roads, and parking lots are replacing meadows, wetlands and forests (Peck et al., 1999; Luckett, 2009). Suburbs started spreading after World War II, but the amount of land taken by urban sprawl jumped 50% from 1980 to the 1990s. By the 1990's, Americans were developing about 850000 hectares a year (Otto et al., 2002). Over 162000 hectares of United States (U.S.) farmland have been lost to urban sprawl each year for the last two decades (Luckett, 2009). The acres of flat roof and pavement contribute to many negative impacts on our world including, depleted water supplies, relocation and possible extinction of plants, animals, and insects, increased traffic, air pollution and rapid loss of farmland and open space (Otto et al., 2002; Snodgrass & Snodgrass, 2006). There are four main areas of environmental concern associated with urban sprawl: increased temperature, air pollution, degraded water quality and availability and decreased biodiversity.

1.1 Environmental Problems

The increase in temperature is not just uncomfortable to those living and working in the city, but can contribute to health related illnesses and even death (Daley, 2010). It affects those in the inner city the most; those with low incomes, the elderly and children. In the 1995 Chicago heat wave there were 739 deaths in five days from heatstroke and respiratory illness (McDonough, 2005; Daley, 2010). Increased air temperature results from flat roof tops and pavement in our expanding cities. These paved areas create the urban heat island. The urban heat island (Figure 1.1) is easily explained in the difference you feel when you stand in a parking lot rather than a country meadow (Daley, 2010). The dark surfaces of the rooftops, roads and parking lots of cities absorb and radiate heat, sometimes causing the daily temperature to raise three to four degrees Celsius (°C) higher than the surrounding area (White & Snodgrass, 2003; McDonough, 2005). For example, New York City is three to five °C warmer than the surrounding suburbs. The temperature in the country of Japan has increased one °C over the past 100 years while Tokyo has increased three °C (McDonough, 2005). In the tropics the heat island is more pronounced; Mexico City is 10 °C warmer than the surrounding area (McDonough, 2005). Dense cities like Chicago and New York City have 60-70% of the total area as dark surfaces absorbing heat (McDonough, 2005). The decrease in vegetation also plays a part in the increased heat in the cities. Vegetation uses water for evapotranspiration, the movement of water from the roots through the plant and discharged through the leaves to the atmosphere in the form of water vapor. This process uses solar energy and cools the leaf surfaces as well as the air around the leaves (Bass, 2001).

Because of the increased temperatures, it takes more energy to cool buildings, thus increasing the electricity demand by 3-8% (Bass, 2001; Daley, 2010). The increase in electricity demand makes power plants work harder burning more fossil fuels, which leads to more greenhouse gas emissions and other pollutants like sulfur dioxide, nitrous oxides and particulates (Bass, 2001; McDonough, 2005). The increased temperature also creates more smog due to vehicle, home and factory pollution and is magnified when chemicals in the air react with heat and sunlight (Bass, 2001; Daley, 2010).

Undeveloped land is valuable for more than recreation and wildlife; open space provides a natural filtering function for water (Otto et al., 2002). The impervious surfaces not only contribute to higher air temperatures but also decreased water quality, increased water temperature, decrease the ability of water to reach and replenish aquifers, and lead to stormwaters overwhelming drainage systems (Snodgrass & Snodgrass, 2006). There has been a drop in the local water tables and the base flow of streams and rivers in Canada, with up to 95% of the precipitation being discharged directly into bodies of water rather than the slow infiltration into the ground (Peck et al., 1999). Rain that runs off buildings, roads and parking lots picks up pollutants such as pesticides, oil, particulate matter, and heavy metals that enter rivers, lakes, streams and the ocean (Peck et al., 1999; Otto et al., 2002). With the high level of runoff present there is a higher level of erosion adding to the turbidity of the water, and also an increased chance of flooding threatening human life (Peck et al., 1999). Older cities have what is termed "combined sewer overflow systems" (CSOs). CSOs serve around 772 communities comprised of about 40 million people, mostly in the Northeast and Great Lakes Regions of the U.S. (EPA, 2010). These systems move household sewage, commercial sewage, industrial waste water and stormwater to treatment facilities (McDonough, 2005; EPA, 2010). During dry weather, the systems work well, but during rainfall or snow melt the wastewater volume is too high, and it exceeds the processing capacity of the system, causing overflow to spill into waterways (Peck et al., 1999; McDonough, 2005). This overflow doesn't just contain stormwater, but also human and industrial waste, toxic materials, and debris that cause excess nutrients to enter the waterways leading to explosive plant growth and toxic algae blooms (McDonough, 2005; EPA, 2010). Forty-billion gallons of untreated water, containing 20% raw sewage, spills into the waterways of New York City each year due to CSO's (McDonough, 2005).

Urban and suburban landscapes tend to create an imbalance in the natural ecosystem. These imbalances are a result of a number of factors including concentrated human populations, the introduction of impermeable and reflective surfaces, the import of energy from other resources outside of the area and the creation of waste products which cannot be reintegrated into the ecosystem resulting in pollution (Peck et al., 1999). Urban areas offer little refuge for plants and animals. The result is habitat loss or fragmentation of habitats, leading to reduced plant and animal populations and in extreme cases, extinction. Conserving the land means conserving biodiversity. Protecting biodiversity is not just protecting wildlife and nature, it is protecting natural systems that purify water, cycle oxygen and carbon, maintain soil fertility and give us food and medicines (Wieditz, 2003).

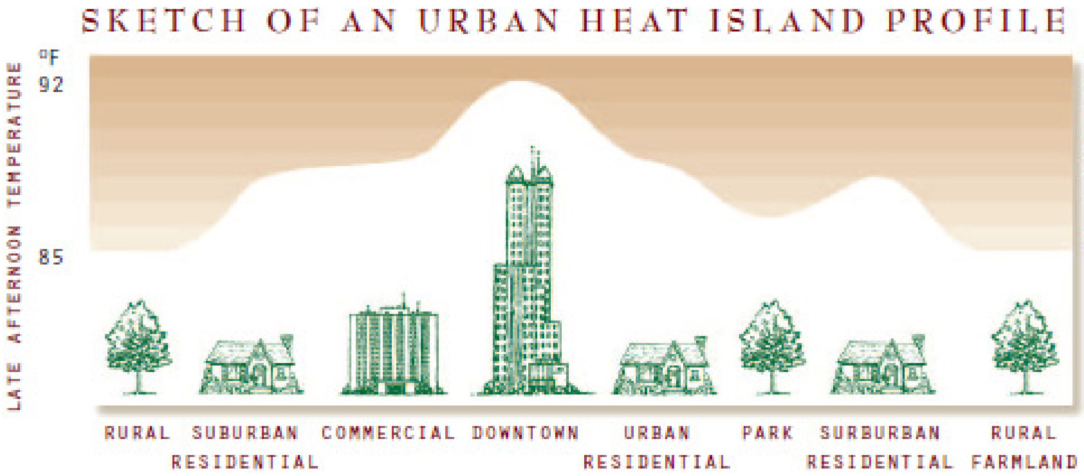


Figure 1.1. The Urban Heat Island (Daley, Richard M. "A Guide to Rooftop Gardening." ***Chicago's Green Rooftops*****. City of Chicago. Web. 13 Oct. 2010. <http://www.cityofchicago.org/content/dam/city/depths/doe/general/GreenBldsRoofsHomes/GuidetoRooftopGardening_v2.pdf>).**

1.2 Problem Statement

Finding effective ways to implement sustainable urban and suburban design is a challenge in our communities. The growing concerns about the environment and the economic costs of development have opened the door for new concepts and technologies in North America, including green roofs (Snodgrass and Snodgrass, 2006). Green roofs alone do not hold the key to solving all of our environmental problems, but the use of green roofs is an effective and attractive way to face environmental challenges of high temperatures and stormwater runoff pollution (McDonough, 2005). Brass (2001) illustrates the effects of green roofs and their benefits on the urban heat island and air quality (Figure 1.2). As shown in Figure 1.2, green roofs can help relieve some of the temperature highs of the urban heat island effect. Planting vegetation on rooftops creates a similar effect as adding vegetation on boulevards and in parking lots;

it reduces the heat-trapping surfaces which lowers temperatures and reduces air pollution (Daley, 2010). If more roofs were greened nationally, then the national energy savings could be in the billions of dollars (Snodgrass & Snodgrass, 2006).

A considerable volume of research has been performed over the last 10 years on green roofs. The technology and techniques are changing rapidly. Although *Sedums* are known for their survivability in harsh conditions, another alternative that this research examined was the use of *Buchloe Dactyloides* ‘Prestige’ (Prestige Buffalograss), a native plant to the plains environment of Oklahoma. The objective of this research was to test the stand persistence of Prestige Buffalograss under simulated green roof conditions in a greenhouse for the harshest months of July and August, where there is little to no rainfall and higher temperatures in central Oklahoma. The following is the research hypothesis and research questions:

H_0: All Prestige Buffalograss green roof irrigation treatments will result in the same stand presence

H_a: At least one irrigation treatment differs from the others.

Research Questions:

- For average rainfall and temperature conditions, is supplemental irrigation required for central Oklahoma green roofs using Prestige Buffalograss?
- Is evapotranspiration a significant indicator of stand presence over the course of the study?
- Is normalized difference vegetative index (NDVI) a significant indicator of stand presence over the course of the study?
- Will the treatments reach permanent wilting point, during the test period of the experiment?

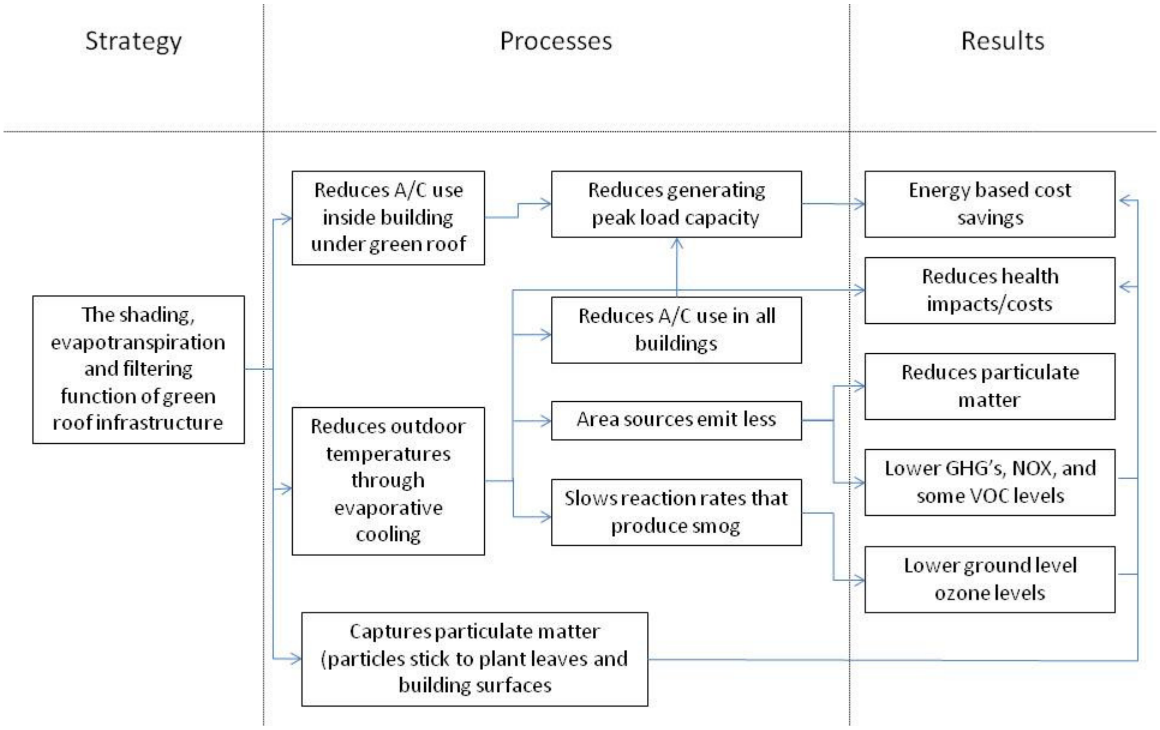


Figure 1.2. Green Roofs and the Benefits to the Urban Heat Island and Air Quality (Bass, Brad. "Examining the Role of Green Roof Infrastructure. "*Green Roof Infrastructure Monitor*" 3.1 (2001): 10-12. Print).

1.3 Outline

This thesis is divided into five chapters, Chapter I is the introduction including the environmental problems facing our world today and the problem statement. Chapter II reviews previous research and experiments on green roofs including a history, types of green roofs, construction, planting media, plants, and green roof benefits. Chapter III describes the three methods used to test the Buffalograss performance on green roofs, while Chapter IV discusses the results obtained from the laboratory tests and analyzed. Chapter V provides recommendations for future research.

CHAPTER II

LITERATURE REVEIW

Green roofs have many benefits that are environmental, economic and psychological. They increase the biological mass of the city, reduce pollutants, improve the microclimate, reduce the heat island effect, reduce energy used by a building, delay stormwater runoff, and provide amenity space for building occupants (Green Roofs for Healthy Cities, 1999).

2.1 Green Roof History

The idea of using plants on rooftops to cool the surroundings and improve aesthetics is not new. The first recorded green roof tops were built in the 4th century. They have been used by many ancient civilizations through time, with the most well known being the Hanging Gardens of Babylon built in the 7th and 8th centuries B.C.E. by Nebuchadnezzar II (Osmundson, 1999). Since the 18th century the Scandinavian countries use sod roofs to provide extra insulation in the cold, wet climates. Scandinavian immigrants that came to the U.S. and Canada brought the idea of sod roofs with them (Dunnett & Kingsburry, 2004). Sod roofs, together with layers of birch bark and twigs or straw, worked well in the rain and moist temperature climates. The birch bark functioned as the sealing membrane, and the twig layer worked as drainage.

The turf was used as insulation and to protect the lower roof layers from wind and sunlight that would reduce the life span of the bark (Dunnett & Kingsburry, 2004).

Germany's first green roofs in urban areas were an unintentional innovation in the 1880's. Berlin was growing quickly with rows of apartment buildings being built. The traditional roofing of tar was flammable and the fear of a fire destroying blocks at a time lead roofers to use other materials. The German roofer Koch, developed a tar covered roof with sand and gravel on top. These materials became a growing media for random seeds in the air; soon there were volunteer plants growing on roofs. In the 1980's students found 50 remaining Koch roofs. After 100 years and two World Wars the roofs had remained water proof (McDonough, 2005).

2.2 Green Roof Types

There are several different types of green roofs: extensive, intensive, brown roofs and semi-extensive green roofs. Extensive green roofs, shown in Figure 2.1, were rarely seen in the U.S. before 2000, and were mostly found on private homes or occasional office buildings (Snodgrass & Snodgrass, 2006). They were usually inaccessible to the public, planted with drought resistant plant species with a light weight thin layer of growing media, about 5.1-15.2 cm in depth, only adding about 73.2-146 kg m^{-2} onto the roof structure (White & Snodgrass, 2003; Snodgrass& Snodgrass, 2006). Early in the development of extensive roofs the growing media was composed of crushed waste and other materials from the building site. Recycling the waste reduced the need for transportation and disposal, and provided drainage in the media (British Council for Offices, 2003). The plants must tolerate extreme conditions, temperature, wind and drought due to the exposed rooftop (Peck et al., 1999). Now newer materials are available for the green roof media including, expanded clays and shale, pumice, and volcanic rock that provide pore space and making the soil light weight and increase water holding capacity (Luckett 2009). There was interest in the extensive green roof due to its low weight and minimal care and it gained wider use in the U.S. (Dunnett, 2002). Extensive roofs are sometimes called ecoroofs. The term ecoroofs was used when describing them in a way that distinguishes them from roofs that may have solar panels, or it was used in climates that experience dry times causing vegetation to turn brown, like in Portland, Oregon (Dunnett & Kingsbury, 2004).

Intensive green roofs, shown in Figure 2.2, are also called roof gardens. They are a green roof that is a park like setting and has a deeper growing media over 15.2 cm, contain trees and shrubs, must account for human occupancy, and have more elaborate plantings that require regular maintenance and an irrigation system (Oberlander et al., 2002; Snodgrass & Snodgrass, 2006). The increased depth of the growing media means that the intensive green roof weighs about 36.4-68.2 kg per square meter (Daley, 2010). Increased amounts of growing media allow greater variety of plantings that can be installed. Special engineering reinforcement must be in place due to the increased weight of the growth media, plants and structures to allow accessibility (Dunnett, 2002).

Semi-extensive green roofs, shown in Figure 2.3, are a combination of an extensive and an intensive green roof. The soil depth is greater than an extensive green roof so there is a greater loading capacity of the building is needed. But due to the deeper soils they can accommodate a wider plant selection due to the increased depth of growing media of up to 20.3 cm; and may or may not be accessible (Dunnett & Kingsbury, 2004).

The last category of green roofs is called a brown roof (Figure 2.4). Brown roofs are buildings that use soil and rock from the site demolition and place it on the roof without plantings (McDonough, 2005). They are primarily created for biodiversity, aiming to recreate brownfield conditions. They are usually colonized over time by native plants from windblown seeds and provide habitat for many invertebrates and birds (Dunnett and Kingsbury, 2004; McDonough, 2005).

Another technology that is emerging in the U.S. is the vertical garden or green wall (Figure 2.5); growing plants on or up against the façade of a building (Peck et al., 1999). While a vertical garden is not a green roof, it is another area of emerging research that provides some of the same benefits of a green roof. Like a green roof it will block the movement of dust and dirt particles and filter them out of the air, provide pockets of cool air around the building, insulate and protect the structure (Peck et al., 1999). The vertical garden could impact the environment more than a green roof due to the walls of the building being more than four times the area of the roof (Peck et al., 1999).

Figure 2.1. Extensive Green Roof on the Cook + Fox offices, New York, New York. "Greenroofs.com Projects - Cook Fox Architects LLP." *Greenroofs.com: The Resource Portal for Green Roofs*. The Greenroof Projects Database, 2010. Web. 18 July 2011. <http://www.greenroofs.com/projects/pview.php?id=670>.

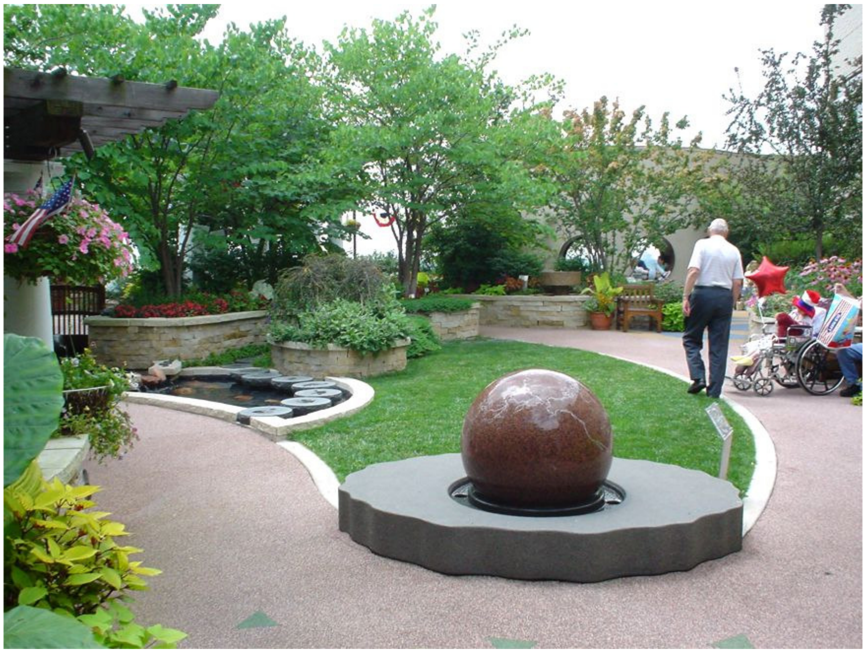


Figure 2.2. Intensive Green Roof on the Olson Family Garden, St. Louis Children's Hospital, St. Louis, Missouri. "Greenroofs.com Projects - Olson Family Garden, St. Louis Children's Hospital." ***Greenroofs.com: The Resource Portal for Green Roofs*****. The Greenroof Projects Database, 2010. Web. 18 July 2011. <http://www.greenroofs.com/projects/pview.php?id=595>.**

Figure 2.3. Semi-Extensive Green Roof, Artist's Rendering of the Songjiang Hotel, Songjiang Hotel, "Greenroofs.com Projects - Songjiang Hotel." *Greenroofs.com: The Resource Portal for Green Roofs*. The Greenroof Projects Database, 2010. Web. 18 July 2011. <http://www.greenroofs.com/projects/pview.php?id=529>.

Figure 2.4. Brown Roof on the Laban Dance Center, London, England, UK. "Greenroofs.com Projects - Laban Dance Centre." *Greenroofs.com: The Resource Portal for Green Roofs*. The Weather Channel, 2010. Web. 18 July 2011. <http://www.greenroofs.com/projects/pview.php?id=549>.

Figure 2.5. Green Wall at the Atlanta Botanical Garden, Atlanta, Georgia. "Greenroofs.com Projects - Atlanta Botanical Garden Edible Garden Green Wall." *Greenroofs.com: The Resource Portal for Green Roofs*. The Greenroof Projects Database, 2010. Web. 18 July 2011. <http://www.greenroofs.com/projects/pview.php?id=1124>.

2.3 Green Roof Construction

In the late 1990's a roof garden was considered no different than a natural garden, but on a rooftop, with all the amenities of a ground level garden (Osmundson, 1999). Green roofs have no equivalent in nature because they are engineered, fabricated systems that create a previously unknown landscape. The plant selection, irrigation, growth media and microclimate are different than ground level gardens (Snodgrass & Snodgrass, 2006).

All types of green roofs require an engineered system (Figure 2.6) to ensure proper function and have the common components of waterproofing, insulation, filtration, drainage, root barrier, planting media, and plant materials (Oberlander et al., 2002; Snodgrass and Snodgrass, 2006). The first layer of any green roof is the deck layer. It is the top of the building’s roof, constructed from concrete, wood, metal, plastic, gypsum, or composite. Buildings with concrete decking are ideal for green roofs because they are stronger and they do not degrade like wood (Snodgrass and Snodgrass, 2006). The next layer is the waterproofing layer and must be 100% water proof. Care must be taken to ensure that there is a durable seal in the water proofing layer (Snodgrass & Snodgrass, 2006). The insulation layer can be placed over the waterproofing layer or under, and is important for energy savings (Snodgrass & Snodgrass, 2006). The root barrier is made from PVC or high density polyethylene sheets, and is used to keep the roots from growing in and compromising the insulation and waterproofing layers (Snodgrass & Snodgrass, 2006). The drainage layer allows the excess water to be removed quickly; proper drainage is needed for the roof and for plant health (Snodgrass & Snodgrass, 2006). The filter layer goes directly below the growing media and separates it from the drainage layer. It is used to keep the soil particles out of the drainage layer to prevent clogging and to keep the planting media in place. (Snodgrass & Snodgrass, 2006). The growing media and plants come last. It is important that all air intakes and venting for air conditioning systems have pollen filters to help keep the building clear of outside allergens (White & Snodgrass, 2003).

The roof load capacity must meet building requirements and all the structures should be built to hold the weight of foot traffic and during saturated conditions (Oberlander et al., 2002). Steel and wood decks typically hold 97.6 – 146 kg of rock ballast per m^2, while a concrete deck may support 195 or more kg m^{-2} (White & Snodgrass, 2003). The live load is considered snow, water, wind, safety factors required for the building’s performance, foot traffic and temporary objects on the roof like furniture, and maintenance equipment (Luckett, 2009). The dead load is the weight of the roof itself with any permanent elements including the roofing layers, permanent mechanical structures for heating and cooling, plants and the water to saturate the growing media (Luckett, 2009).

Slope is also a factor in green roof design and construction. Flat roofs need to have a slight slope to aid in drainage (Luckett, 2009). Most roofing manufacturers recommend a roof slope of 1.04 cm m^{-1} to 2.08 cm m^{-1} to avoid water pooling on a rooftop and aid in drainage (Luckett 2009). Roofs that exceed a slope of 16 cm m^{-1} are considered steep roofs and other design considerations are needed (Luckett, 2009). To keep growing media from sliding down the roof there are manufactured products like compartmentalized honeycomb and grid structures, or constructed in place bracing structures anchored to the roof (Luckett, 2009).

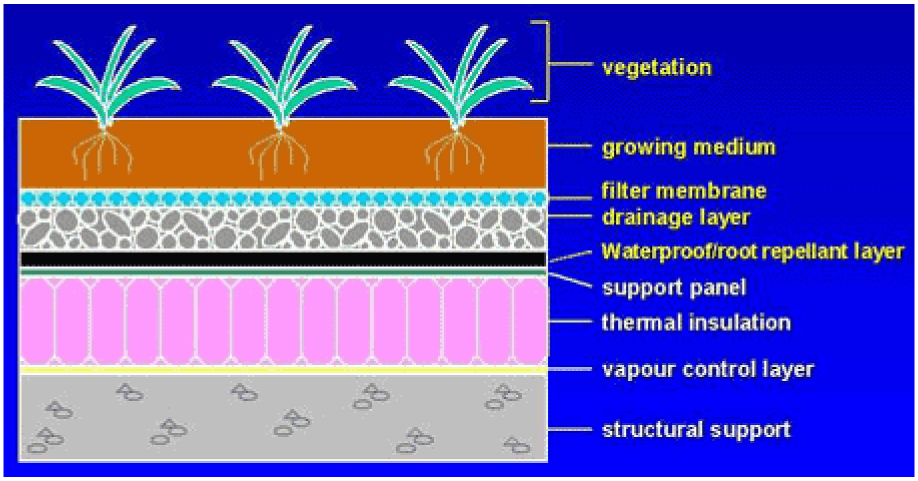


Figure 2.6. Cross Section of the Typical Components of a Green Roof. "About Green Roofs." ***Green Roofs for Healthy Cities*****. Green Roofs for Healthy Cities, 08 Dec. 2009. Web. 18 July 2011. <http://www.greenroofs.org/index.php/about-green-roofs>.**

2.4 Green Roof Media

The planting media supplies and absorbs nutrients and anchors the plants. Green roof growing media needs to be porous and lightweight, a mixture that holds oxygen and water and absorbs and retains nutrients, and provides stability to the root system (Snodgrass & Snodgrass, 2006). It can be made of compost and recycled materials that should reflect the locally occurring material suitable to its location and local wildlife (British Council for Offices, 2003). A typical blend is a ratio of 80% inorganic material and 20% organic compost (Luckett, 2009). The inorganic material generally consists of expanded slate, expanded shale, expanded clay, baked clay, volcanic pumice, sand and crushed clay roofing tiles (Snodgrass & Snodgrass, 2006). The soil is mostly inorganic to help maintain the soil depth and also help keep the media lightweight. Organic matter adds more volume as well as providing nutrients and moisture retention. Organic material may breakdown over a short period of time to a more stable organic matter, so a higher percentage of organic material may result in a loss of depth (Snodgrass & Snodgrass, 2006; Luckett, 2009). A predominately organic media will also have decreased pore space, higher water retention and increased nutrient loss (Snodgrass & Snodgrass, 2006). The mix of 80/20 provides enough organic material to help establish the plants and maintain the desired depth for the life of the green roof. In three to five years the organic material will decompose to a more stable organic matter, but the foliage and roots that come off the plants will decompose, continually recharging the organic matter and maintaining the media depth and contribute to nutrient cycling (Luckett, 2009). Other proportions of growing media mixes are accepted in the field and are determined by the planting materials and weight capacity of the roof (Luckett, 2009). Media depth is also important for success of the green roof to meet its design objectives. Plants available to grow on green roofs are expanded with the increase of growing media depth available and thus soil moisture. As the depth of media increases so does the weight of the roof, and thus there is a tradeoff that balances structural cost with plant selection (Luckett, 2009). Media depth also influences the winter damage on plants. Tests on 5.1 cm media depth show that winter temperatures of the media are lower and have more temperature fluctuations compared to 10.1 cm and 15.2 cm media depths (Boivin et al., 2001).

Moderately pitched roofs (3:12 to 5:12) and steeply pitched roofs (5:12 to 12:12) create variability in water-holding characteristics for the green roof media. The substrate located at the lowest edge will hold more water but have a reduced air space volume. The higher on the roof the more air space and less water available (Snodgrass & Snodgrass, 2006).

2.5 Green Roof Plantings

Roofs can be hostile environments for plants due to the increased wind, heat, rain and shadows from surrounding buildings. Green roof plants will be in direct sunlight all day unless there are adjacent buildings, walls or trees (White & Snodgrass, 2003). Wind speed increases as building height increases--for every ten stories of building the wind speed doubles (Daley, 2010). The increase of the wind increases the moisture loss in the growing media and vegetation (Daley, 2010). Plant seeds can be spread by wind to other rooftops, so special attention should be given that you don’t plant potentially invasive species or weeds (White & Snodgrass, 2003).

The best plants for the roof are low-growing, shallow-rooted perennial plants that are heat, sun, wind, drought, salt, disease and insect tolerant (White & Snodgrass, 2003). The root systems must be fibrous, and the life expectancy of the plant should be long. Also the plants should have low maintenance requirements and be lightweight at maturity (White & Snodgrass, 2003). Plants should be ecologically compatible to the area, fast growing, flame resistant and have low nutrient requirements (White & Snodgrass, 2003). Narrow-leafed evergreens that contain high concentrations of volatile oils should not be used due to their fire hazard (White & Snodgrass, 2003). Diversity is also important in planting plans. Uniform plantings may look great, but any disease, drought or pest can destroy the stand without variety. The more variety in the plantings the more chance that some will survive (Luckett, 2009). Plants should be matched to the rooftop location for their microclimate and their macroclimate, the amount of sun exposure and shadow patterns. There is a learning curve for each climate region to determine which species grow best on an extensive green roof (White & Snodgrass, 2003).

Many different kinds of plants can be used on green roofs including perennials, succulents, grasses, herbs and vines. Each has their benefits and their drawbacks. Herbaceous perennials are great for their aesthetics and have good color, texture and seasonal variability (Snodgrass & Snodgrass, 2006). They do have drawbacks in that they require a deeper media depth than traditionally used on most extensive green roofs. The media required to is higher in nutrients and makes the roof a more hospitable climate for weeds which could crowd out the specified plants (Snodgrass & Snodgrass, 2006). Perennials also take two to three years before they can provide the coverage required to affect a measurable difference in temperature and air quality (Peck et al., 1999). The plant waste can also increase roof load by 0.9 to 2.3 kg per square meter (Snodgrass & Snodgrass, 2006).

Hardy succulents, such as *Sedums* and other plants in the *crassulaceae* family, are the primary plants for media 10.2 cm or less and have the ability to survive drought and wind conditions, store water in their leaves and conserve water through

Crassulacean Acid Metabolism (CAM). Using CAM they can reduce their water loss by opening their stomata at night storing the carbon dioxide for photosynthesis and then closing their stomata during the day, this reduces loss from transpiration (Snodgrass & Snodgrass, 2006). A Michigan State study found that *Sedum* species out performed 18 Michigan natives in every parameter monitored, and in another study found *Sedums* survived 88 days without water (Snodgrass & Snodgrass, 2006). *Sedums* are highly appropriate for green roof use due to their ability to survive in challenging conditions, are not invasive and loved by insects and birds (Snodgrass & Snodgrass 2006). *Sedums* and other succulents also have a large percentage of water in their leaves to help them be fire retardant, and should be used to surround flammable plants to reduce the spread of accidental fire (White & Snodgrass, 2006).

Grasses add motion and texture to the roof and offer vertical elements for birds and insects (Snodgrass & Snodgrass, 2006). They require deeper planting media to accommodate their root systems and they gain a large biomass over time which can affect the weight of the load on the roof and the fire hazard (Snodgrass & Snodgrass, 2006). At certain times of the year their shoots turn straw colored and die, making them unsightly. Grasses need more maintenance so the roof must be accessible for maintenance (Snodgrass & Snodgrass, 2006).

Buffalograss (*Bouteloua dactyloides)* [synonym *Buchloe dactyloides*] is native to the North American Great Plains and is one of the few native turfgrass species (Shearman et al., 2006). Buffalograss and blue gramma grass are the dominant species on the short grass prairie (Cushman & Jones, 1988). The short grass prairie receives 25 to 53 cm of rain a year, with the majority of the rainfall typically falling from May through July (Cushman & Jones, 1988). It has an extensive underground root system that is much larger in proportion to the above-ground part of the plant (Cushman & Jones, 1988); and is a sod forming grass that produces horizontal stems called stolons, or runners, sending out roots and stems of their own (Shearman et al., 2006).

Buffalograss is primarily dioecious, having both male and female parts, and occasionally monoecious (Sherman et al., 2006). In the 1930's Buffalograss was recognized as a grass species with considerable agricultural and conservation importance surviving plowing, overgrazing and drought stress (Shearman et al., 2006). Its dense sod-forming growth makes it a species that helps to prevent wind and water erosion, and has an evapotranspiration rate that is lower than most other turf grasses. Its root system, slow vertical canopy growing rate, leaf hairs, and leaf rolling characteristics help to avoid drought and recover after drought stress more quickly than other turfgrasses (Bowman et al., 1998; Shearman et al., 2006). Initial installation requires as much water as other turf grass lawns, but once established, Buffalograss only require a minimum of 2.5 to 5.1 cm of rain every two to four weeks during the summer (McGinnis; 2008, Dardick, 2009).

The Buffalograss breeding and genetics program at the University of Nebraska-Lincoln (UNL) began in 1984, with the goal to develop the turf-type cultivars with the potential to conserve water and require reduced inputs of fertilizers, pesticides and energy (Shearman et al., 2006). 'Prestige' Buffalograss is a 1997 release from UNL's Breeding Program, a tetraploid, vegetative cultivar that forms a dense turf. Adapted for use in the southern to northern Great Plains, it has an extended period of green foliage cover, greening up early in the spring and staying green longer in the fall and also possessing good winter hardiness. The National Turfgrass Evaluation Program Buffalograss trial run from 1996 to 2000 found that the visual quality of Prestige outranked 15 other types (Shearman et al., 2006). Visual quality incorporates the parameters of color, texture, density, uniformity and live green canopy cover.

2.6 Green Roof Benefits

Green roofs have many benefits that are environmental, economic and psychological.

2.6.1 Environmental Benefits

Green roofs help to mitigate some of the environmental issues we see in our world today such as the urban heat island, stormwater runoff, air pollution and biodiversity loss.

Green roofs can help relieve the temperature highs of the urban heat island effect. Planting vegetation on rooftops creates a similar effect as greening on boulevards and in parking lots, it reduces the heat-trapping surfaces which lowers temperatures and reduces air pollution (Daley, 2010). Plant materials absorb heat, and through evapotranspiration lower the ambient temperature around buildings reducing the urban heat island effect (Oberlander et al., 2002). A typical asphalt roof can reach temperatures of 71 ^{o}C, while a green roof rarely exceeds 27 ^{o}C if there is suitable water available (McDonough, 2005). Constructing green roofs on 50-60% of the rooftops in densely populated cities could help lower the summer temperatures by as much as 9 ^{o}C (Luckett, 2009).

Green roof systems reduce stormwater quantity and can improve quality of the water entering the sewer systems (Peck et al., 1999). Green roofs provide increased stormwater retention due to its permeable surfaces and water stored in plants that will evapotranspirate the water into the air; providing a gradual runoff of the water and less strain on the sewers so they are better able to cope in storms (Oberlander et al., 2002; British Council for Offices, 2003). Green roofs not only retain a portion of the precipitation but also moderate the temperature of the runoff and act as a natural filter to the water that runs off. Heavy metals and nutrients carried by the rain get bound up in the growing media cleaning the runoff before it enters the waste water systems (Peck et al., 1999). Care needs to be taken since fertilizers and decomposing plant materials can increase nutrients in the runoff. (Luckett, 2009).

The plant materials also raise the humidity on the roof and through evapotranspiration and the plant filters airborne particulates (Oberlander et al., 2002). Airborne particulates tend to get trapped in the leaves, branches and stem surface areas of the plants and when it rains the particulates get washed into the growing media keeping them out of the air (Peck et al., 1999).

Developed areas are hostile for plants and animals due to habitat fragmentation, pollution, and increased noise. Green roofs can help create a healthy and functioning habitat in the urban landscape to encourage biodiversity, a common measurement of ecosystem health (McDonough, 2005). Green roofs provide a way to offset the loss of nature in urban areas and replace green space at the street level. They don't replace the ecological value of a destroyed wetland or mature forest, but do provide a suitable habitat (Wieditz, 2003). Plants provide habitat for urban wildlife (Dunnett & Kingsbury, 2004) and access for natural habitats for residential and migratory birds and insects (Oberlander et al., 2002). Extensive green roofs that are not designed for human access are isolated from people and they can be a good undisturbed habitat (Dunnett & Kingsburry, 2004). Some green roofs do not need to be planted to support growth; there are many species that will spontaneously colonize like lichens, mosses, flowering plants, and grasses (Dunnett & Kingsbury, 2004).

2.6.2 Economic Benefits

One of the benefits to green roof installation is decreased energy use in the summer and winter due to the increased insulation provided by the green roof and the evapotranspiration of the plants on the rooftops (Bass, 2001). The green roof provides increased insulation so there is less money spent on heating and cooling (Oberlander et al., 2002). Plants help regulate the interior temperature of the building by trapping an air layer within the plant mass, insulating the building from extreme heat and cold (Peck et al., 1999). The increased use of soil, plants and the trapped layer of air has a secondary benefit, sound insulation; planted areas absorb more sound than hard surfaces (British Council for Offices, 2003).

Green roofs also provide amenity space for users at no land cost for the benefit, with more usable space the value of the property goes up (Oberlander et al., 2004). Attractive community rooftop gardens rather than blank rooftops are a positive selling point for developers (Dunnett & Kingsbury, 2004). They also provide opportunities to grow food, decreasing the travel distance of food, increasing the quality of food and decreasing price of produce for building occupants (Oberlander et al., 2002).

Another benefit of green roofs is that they can provide an increased roof life. If the green roof is constructed properly it will last longer than a standard asphalt roof (Dunnett & Kingsbury, 2004). It has the potential to reduce costs for maintenance of roof membrane due to protection from ultraviolet rays, extreme temperature fluctuations, and maintenance wear and tear (Oberlander et al., 2002). Flat roofs are 50% more at risk to damage after 5 years than a slightly sloped roof. On a flat roof, water tends to pool rather than run off. A properly installed green roof with a drainage layer can keep water from pooling on the roof (Peck et al., 1999).

The Green Roof Infrastructure Technology Demonstration Project in Toronto modeled a scenario of installing green roofs on 6% of the buildings in Toronto over 10 years (Peck, 2003). This study investigated the cost impacts on energy, stormwater and urban agriculture to determine the benefits to the citizens of Toronto. Among the benefits of a lower temperature and a better savings on water and stormwater reductions were the economic benefits of the change in the city infrastructure. This change would provide jobs in supply, manufacture, wholesale, resale, engineering and contracting. (Peck et al., 1999)

2.6.3 Psychological Benefits

Not only do green roofs have environmental and economic, but they have psychological benefits as well. Additions of green space have shown to contribute to increased productivity and well being for those nearby, in part due to biophilia. Biophilia is our deep attachment to, and need for, natural surroundings (Loder, 2003). The variety of sights, smells, and sounds of a garden can add to our quality of life (Oberlander et al., 2002). Research shows that people living in or near parks and other green spaces have fewer health problems than those with little or no access to green space. Outdoor urban spaces with natural amenities also attract neighbors and help to promote stronger social networks (Kellert, 2004). People living in high-density developments are found to get sick less often if they have a balcony or rooftop garden; this is partly due to the additional oxygen, air filtration and humidity control plants provide (Peck et al., 1999). A 2003 study by Snodgrass and Snodgrass (2006) concluded that worker productivity in green buildings to be higher than in less environmentally friendly buildings. The study also indicated that the green building practices such as green roofs are more cost effective in the long run because savings can be measured in areas like declining worker absenteeism and electricity usage (Snodgrass & Snodgrass, 2006). Researchers found that symptoms of sick building syndrome are seen in employees that are not accounted for by actual pollutants; instead they are more related to anxiety, stress or mental fatigue (Palmer-Wilson, 2003).

CHAPTER III

METHODOLOGY

The experiment was performed on Prestige buffalo grass plugs in a 60/40 media mix under simulated average July and August conditions for Stillwater, Oklahoma. A greenhouse was used to control the environmental conditions, such as day length, temperature and irrigation.

3.1 Experimental Design

The testing was conducted at the Biosystems and Agricultural Engineering Green House, north of West Virginia Avenue, Stillwater, OK 74074, 36º17'13" North, 97º05'33" West. The size of the greenhouse was 21.9 m by 9.1 m, running East and West with a maximum height of 4.3 m. The tables with the experiment boxes were aligned east to west in the center of the greenhouse to avoid temperature extremes at the edges of the greenhouse that may occur with the colder outdoor temperatures. The test was performed from November 14, 2010 to February 14, 2011.

3.1.1 Green Roof Construction

Sixteen boxes with dimensions of 54.6 cm x 99.1 cm x 12.7 cm were used to establish the plant material. Each box had 19 drainage holes with a diameter of 0.6 cm.

The drainage holes were not covered with geotextile to stop media from moving through the holes so as to mimic common practice of extensive roofing systems with shallower soils. Planting boxes were elevated off the ground on tables with wire tops to encourage drainage and allow for measuring over the course of the experiment.

3.1.2 Establishing Plants

Typical extensive green roofs have a growing media mix of 80% inorganic material and 20% organic (Luckett, 2009). A 60/40 mix was selected based on a 2009 Michigan State Study performed by Luckett (2009) showing that this ratio was better suited for native plants for improved plant survival and growth. The mix consisted of 60% inorganic lava rock (0.04 m^3 per planting box) and 40% compost (0.03 m^3 per planting box). The compost was a mix of 1/3 pine bark much (0.01 m^3) and 2/3 Hu-More (0.02 m^3). Hu-More is produced by Humalfa, a company in Shattuck, Oklahoma, and is comprised of humus, alfalfa and cotton burs. The total moisture content of the growing media of lava rock and compost averaged 0.461 m^3 m^{-3}. The choice of lava rock was based on findings from a Southern Illinois University Edwardsville study showing the top two inorganic materials during the first year of growth were pumice and lava rock (Luckett, 2009). The 60/40 growing media of lava rock and compost was mixed in a concrete mixer and placed at 11.4 cm depth in each of the 16 boxes.

The 'Prestige' Buffalograss plugs were planted 20.3 cm on center in each box (Figure 3.1). Prestige Buffalograss (*Bouteloua dactyloides* 'Prestige') [synonym *Buchloe dactyloides* 'Prestige'] was chosen for this experiment due to its resistance to drought stress, low evapotranspiration rates, and high visual quality (Shearman et al., 2006). The plugs were received from Todd Valley Farms in Mead, Nebraska.

During the first two weeks the grass was irrigated daily, gradually moving to irrigation schedule of every three days. Buffalograss plugs were planted on April 23, 2010 and allowed to grow for five months before testing. Growth was enhanced by using Miracle Grow 12-4-8 liquid fertilizer. This fertilizer was applied at 270 kg ha^{-1}, with primary nutrients applied at 33 kg ha^{-1} for N, 11 kg ha^{-1} for P_2O_5 and 22 kg ha^{-1} for K_2O. This was applied four times during the establishment period, June 9, August 25, September 28, and once more one week before the start of the experiment on November 10, 2010. Fertilizer application also replaced nutrients that may have been lost through the heavy irrigation over the establishment period. Fertilizer was also added on February 2, 2011 (day 80) during the experiment. The grass was cut on November 6, 2010 to start the test plots to the same height and biomass for the experiment.

Due to testing in a greenhouse environment, the Buffalograss was exposed to insects that would not normally be an issue in the outdoor environment. In this case the plants were most likely being eaten by a gall midge or a fly, the larval stage of which acted as a stem borer. Also some evidence of spider mite damage was present. Figure 3.2 shows some of the damage to the stems from insects intercepting water before it could reach the leaf surface. Thus all boxes were sprayed with Bayer Advanced Complete Brand Insect Killer for Soil and Turf Ready-to-Spray insecticide on October 4, 2010 before the experiment started and December 12, 2010 (day 28 of the study) and February 6, 2011 (day 84 of the study) when many of the boxes were in unexplained decline. The insecticide was applied at a rate of 60 g per application. The active ingredients were Imidacloprid (common chemical name Merit Insecticide) and B-cyfluthrin (common chemical name Temp Ultra Insecticide). Spray was given from an end of the hose sprayer with pre-mixed insecticide. The declining boxes appeared to recover quickly.

Figure 3.1. Experimental Box Showing Buffalograss Plugs First Planted in Media Mix.

Photographer: Richard Grantham 9/29/2010
Great Plains Diagnostic Network
Copyright 2010 Oklahoma State University

Figure 3.2. Insect damage to Buffalograss (Richard Grantham 9/29/2010, Great Plains Diagnostic Network, 2010).

3.1.3 Testing Procedure

The Buffalograss green roof modules were monitored for a total of 92 days in a greenhouse setting. The 16 boxes were split into four treatments with four repetitions in each treatment (Figure 3.3.A). The four treatments were irrigated differently during the first 60 days, followed by a 32 day recovery period. The temperatures in the greenhouse mimicked the average July and August temperatures for Stillwater, Oklahoma (Table. 3.1). The months of July and August were selected because they represent the highest monthly average temperatures and lowest monthly average rainfall in Stillwater, Oklahoma.

The irrigation schedule was based on the number of days between rain events using historical rainfall data obtained from the US National Oceanic and Atmospheric Administration (NOAA) National Weather Service Cooperative Observer Network (COOP) network (National Weather Center, 2009). Weather data were obtained for the Stillwater, Oklahoma station, COOP ID 34501 from January 1, 1950 through October 28, 2009. Data from September 1957, September 2002, October 2002, and February 2008 came from the station in Perkins, Oklahoma, COOP ID 347003, due to errors in collection in Stillwater. A “rainfall event” was defined when a rainfall total exceeding 0.6 cm was measured for a single day. Based on professional judgment this threshold of 0.6 cm was selected because at this depth rainwater can start being taken up and used by the plants. To determine the number of days between rainfall events for the different treatments rainfall data from July and August were isolated. All days with rainfall above 0.6 cm were determined and the days in between those events were counted. The number of days between rainfall were graphed and basic statistics were analyzed using a statistical program, Minitab (Figure 3.4). Minitab is a trademark of Minitab Inc, State College PA. The mean period between rainfall events was eight days. Therefore, the median irrigation frequency set at eight days, and high and low frequency irrigation was set at four days and twelve days. A control of no irrigation was also used for the last treatment.

Based on the Minitab output, four of the boxes received no irrigation during the course of the 60 day testing period. They were labeled NW01 to NW04. Four of the boxes were irrigated at the mean number of days between rainfall events based on a threshold of 0.6 cm, i.e. every eight days, and were labeled 8D01 to 8D04. There was a 65% chance that rainfall would occur every eight days. Four were irrigated at half of that time, or every four days. There was a 47% chance of the days between rainfall events in this category; they were labeled 4D01 to 4D04. The other four are irrigated every 12 days where there was a 78% chance of rainfall; they were labeled 12D01 to 12D04 (Table 3.2).

Irrigation time was set at 45 seconds. Field capacity was reached at any point between 30 and 45 seconds. At each appointed irrigation time the boxes were irrigated until the soil media reached field capacity, which was estimated at the time when water drained from the bottom box holes. The field capacity of the soil was measured using boxes of the mixed soil media without Buffalograss planted. These boxes were irrigated until water drained from the bottom box and then weighed. The boxes were weighed again 24 hours after the first weighing, which is defined as field capacity.

After the 60 day testing period all boxes were given 32 days to recover with regular irrigation every four days. Boxes were not grouped together based on irrigation days, but placed randomly around the table. Placement was decided based on picking the number of the box out of a hat. Final project layout is shown in Figure 3.3 including fan placement and light height (Figure 3.3.B, 3.3.C, and 3.3.D).

Temperatures in the greenhouse were maintained with two Dayton heater units, Model 3E230B distributed by Granger in Lake Forest Illinois, with a normal output of 150,000 BTU/hr. One Enerco model H5125N6, manufactured by Enerco Inc. of Cleveland, Ohio, with an output of 125,000 BTU/hr was added December 15, 2010 to aid in heating during the colder winter months. Representing average July and August conditions for central Oklahoma, the temperature in the greenhouse was set for the average high of 35 ^{O}C in the day, an average low of 21 ^{O}C at night, and with a two hour transition of an average of the high and low, 28 ^{O}C (National Weather Center, 2010). Programmable thermostats from Hunter Inc., a Medwing Company in Memphis, Tennessee, were used to automatically adjust the temperatures at the different times of the day (Table 3.3).

Day length was mimicked in this experiment by using artificial lighting. Manufactured by Hydro Farm Horticultural Products, three Daystar growing lamps with 1000 W high pressure Sodium bulbs were connected to Xtrasun power supply by an All System cord set. The Daystar growing lamps, Xtrasun power supply and All System cord set are products of Hydro Farm from Hydro Farm Central in Grand Prairie, Texas, The lights were hung 1.83 m above the plants to provide a 2.44 m by 2.44 m coverage area per light. The lights were spaced 2.13 m apart with a 0.31 m overlap to provide a total coverage area of 6.40 m by 2.44 m, which was used to illuminate the 6.1 m by 2.44 m plant boxes (Figure 3.4). A 15 hour day length was selected to represent the mid- to late-summer conditions of July and August for Stillwater, Oklahoma. The cover materials on the greenhouse was a Sun Select UVA Clear Film that allowed 90% light in and provided 20% diffusion.

Wind is a major factor in the plant's need for water, so simulated wind was provided by four Feature Comfort stand fans from the Geneva Comfort Industrial Group.

Two fans were placed at the east end of the table blowing over the boxes, and two fans were placed at the west end of the table drawing the air away from the plants. Prior to the start of the experiment each box was measured for average wind speed using a Kestrel 350 Pocket Weather Meter from the Nielsen-Kellerman company in Boothwyn, Pennsylvania, placed 13 cm above the top of the box 33cm from each end and held for one minute, gathering two readings per box. This process was repeated three times for a total of six readings per box and the average of each box taken.

Atmospheric measurements were taken throughout the experiment to characterize the growing conditions. Temperature, relative humidity and dew point in the testing area of the greenhouse were measured every hour using a 12-bit Onset HOBO Temperature/Relative Humidity Data Logger U12-011from the Onset Computer Corporation of Pocasset, Massachusetts, hanging three ft above the turfgrass canopy. Incoming radiation was measured every hour at two points on the table by an Onset HOBO silicon pyranometer smart sensors, S-LIB-M003 from the Onset Computer Corporation of Pocasset, Massachusetts, with the data stored on an Onset microstation H21-002. Net shortwave radiation was measured manually at each box every four days using one pyranometer facing up and the other hanging 10.2 cm above the test box. Soil temperature readings were taken every hour using an Onset Air/Water/Soil Temperature Sensors with 20’ cables, TMC20-HD, with a 12-bit Onset HOBO Data Logger with four external input channels, U12-006 from the Onset Computer Corporation of Pocasset, Massachusetts. One temperature probe was used per treatment in 4D-04 (Box 2), 8D-01 (Box 3), 12D-04 (Box 1), and NW-04 (Box 4).

Evapotranspiration of each box was calculated based on the change in weight of each box every four days from day 4 to day 92. An LW Measurements LSS-400 portable scale (180 kg capacity, readability 0.05 kg), from LW Measurments, LLC in

Santa Monica, California, was used to weight each box and determine water loss since the last measurement. The weight loss was then changed to cm of water lost at each weigh in and defined as the evaportranspiration since the last weighing. On the days the boxes are irrigated, a weight was taken before and after irrigating.

To determine the volumetric water content of the soil, four subsamples for the soil mix were used. Soil was collected and weighed at saturation and each sample dried for 36 hours and weighed again. Volumetric water content is determined by using both the wet and dry weight of the soil, and is equal to the wet weight minus the dry weight divided by the dry weight.

To characterize the amount of water lost daily from the soil media only, five boxes of soil media were used. Soil media was mixed, placed in the boxes and weighed before irrigating. The boxes were then weighed immediately after irrigating and 24 hours after irrigating.

To quantify the plant health, biomass was measured using a Greenseeker spectrometer from NTech Industries in Ukiah, California, 505 hand held data collection device that measures normalized difference vegetative index (NDVI). NDVI is a common measurement of plant health; the more chlorophyll a plant has the higher the biomass. With a higher biomass the plant absorbs more red light and will reflect more near infrared light. The larger the percentage live green canopy cover, also an indication of plant health, of the Buffalograss the higher the NDVI reading. The sensor uses an interal illumation and releflectance reasing are taken. The width of the sensor is approximatly 61 cm when held 81 cm over the vegetation (Trimble Agriculture, 2011). NDVI readings was taken every four days from day 0 to day 88 with the mean NDVI recorded manually.

Table 3.1. Average Monthly Temperatures and Rainfall for Stillwater, Oklahoma for the Period 1950 to 2009 ("Tables and Charts of Monthly Climatological Averages." *National Weather Service Southern Region Homepage*. 24 Nov. 2009. Web. 07 July 2011. <http://www.srh.noaa.gov/oun/climate/getnorm.php?id=stwo2>.).

Month	**Average High Temperature (^{O}C)**	**Average Low Temperature (^{O}C)**	**Average Rainfall (mm)**
January	8	-6	33.0
February	12	-3	41.1
March	17	3	81.8
April	22	8	87.6
May	26	14	137
June	31	19	110
July	34	22	68.3
August	34	21	77.5
September	30	16	105
October	24	9	81.5
November	16	3	65.3
December	10	-3	44.2

Table 3.2. Irrigating Frequency Descriptions for Each Treatment.

Box Labels	Time Between Irrigation (Days)	Probability of Rainfall Event (%)
NW01 to NW04	0	N/A
4D01 to 4D04	4	47
8D01 to 8D04	8	65
12D01 to 12D04	12	78

Table 3.3. Programmed Time and Temperature for Greenhouse Experiment.

Start Time	End Time	Average Set Temperature, ºC
6 AM	8 AM	28
8 AM	8 PM	35
8 PM	10 PM	28
10 PM	6 AM	21

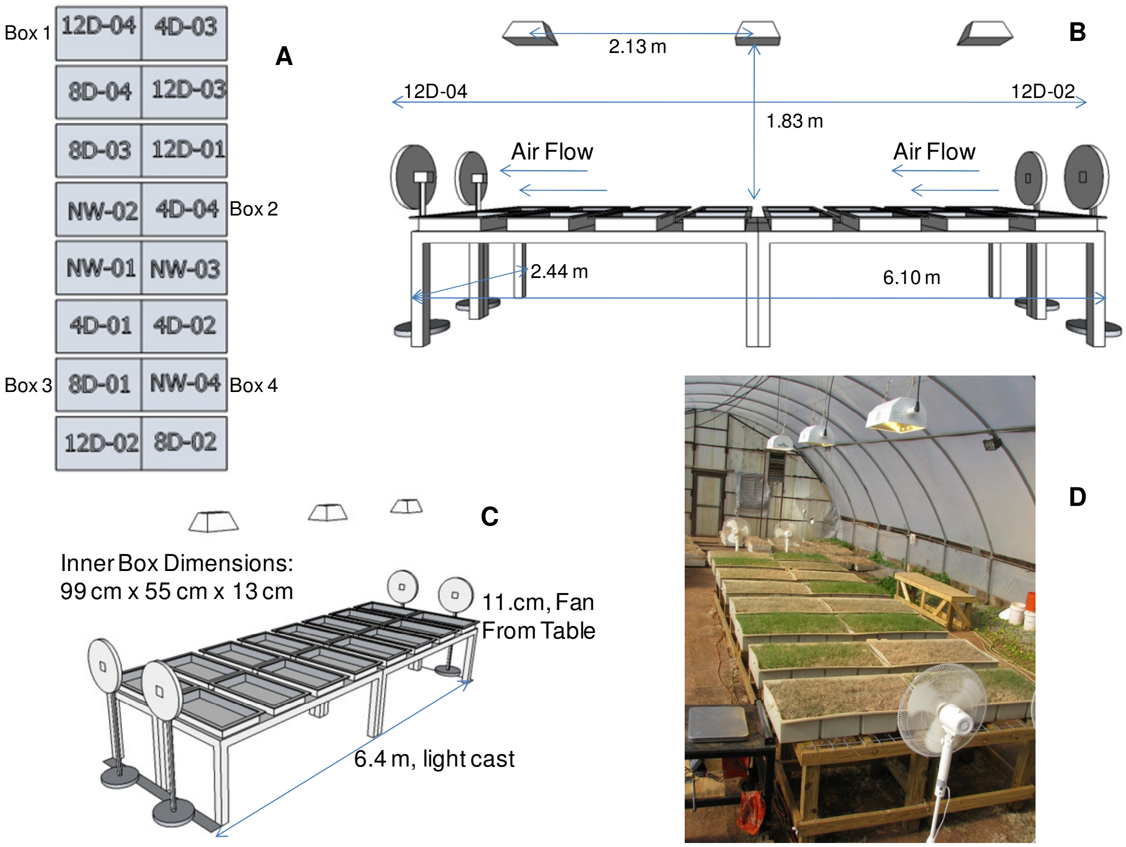


Figure 3.3. Experimental Layout in the Greenhouse.

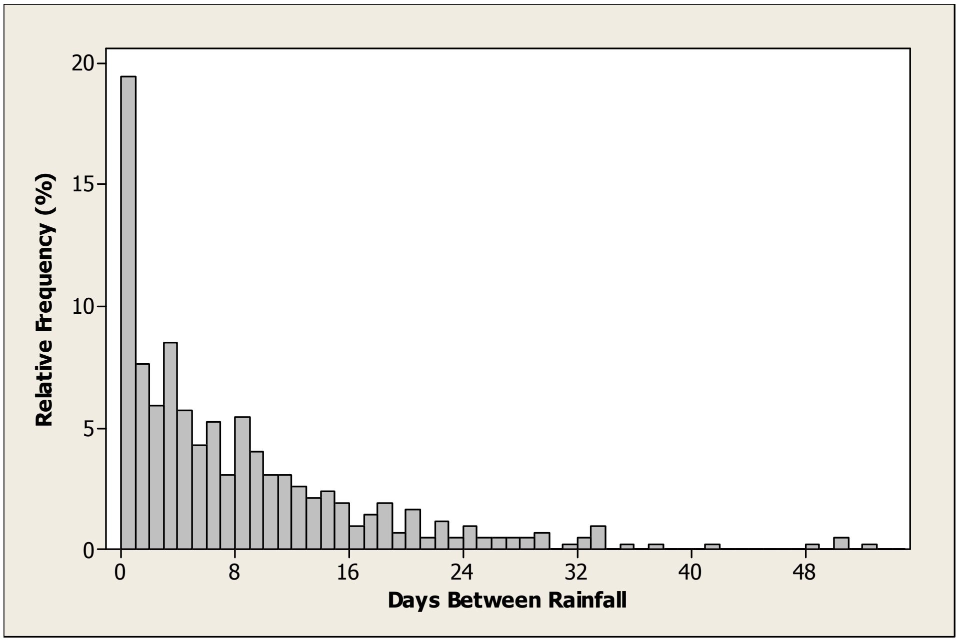


Figure 3.4. Histogram of the Number of Days between Rainfall Events for a 0.6 cm Rainfall Threshold for Stillwater, Oklahoma for the Years 1950 to 2009.

CHAPTER IV

RESULTS AND DISCUSSION

This research was performed to determine the stand presence of Prestige Buffalograss under average July and August temperatures and rainfall conditions. Environmental parameters were measured throughout the experiment. To determine stand presence evapotranspiration and NDVI were used as indicators.

4.1 Environmental Parameters

Environmental parameters, which included air temperature, soil temperature, relative humidity, and solar radiation, were collected hourly over the course of the experiment. Figure 4.1 illustrates the high and low daily temperatures in the greenhouse over the course of the experiment. The average high maintained was 37 ºC, higher than the target average 35 ºC of July and August for Stillwater, Oklahoma. The average low was 16 ºC, 5 ºC less than the average target July and August low for Stillwater, Oklahoma. On December 14, 2010 (day 30) there was a significant drop in the greenhouse temperature that resulted in a low less than 0 ºC. The outside low was 4 ºC and the heaters were not adequate. On December 15, 2011 (day 31), the Enerco heater was installed to maintain the target temperatures for the remainder of the experiment. The other parameters recorded hourly were relative humidity (Figure 4-2) and solar radiation (Figure 4-3). Soil temperature is shown in Figure 4.4. The soil temperature also was low on December 14, 2010 (day 30) due to the unusually low greenhouse temperature.

The initial low solar radiation values during the first day of the study were due to the absence of the supplemental lighting resulting from a power loss. The average wind speed for experiment was 3.2 km per hour (Table 4.1), which was lower than average Stillwater, Oklahoma conditions. The monthly average for wind in Stillwater, Oklahoma in July was 7.4 km per hour, while the monthly average for August was 3.5 km per hour (National Weather Service, 2009). The results for the wind measurements in the greenhouse are in Figure 4.5. Data for the volumetric water content are shown in Table 4.2. The weight of the five boxes at each weighing and the evapotranspiration is shown in Table 4.3. The average evaporation for the soil only boxes was 2.64 cm, while the average evapotranspiration with the Buffalograss was 3.70 cm. The increase in evapotranspiration in the Buffalograss boxes was the result of transpiration from the plants. Table 4.1 provides a brief summary of the environmental descriptive statistics: temperature, soil temperatures, relative humidity, solar radiation and wind speed.

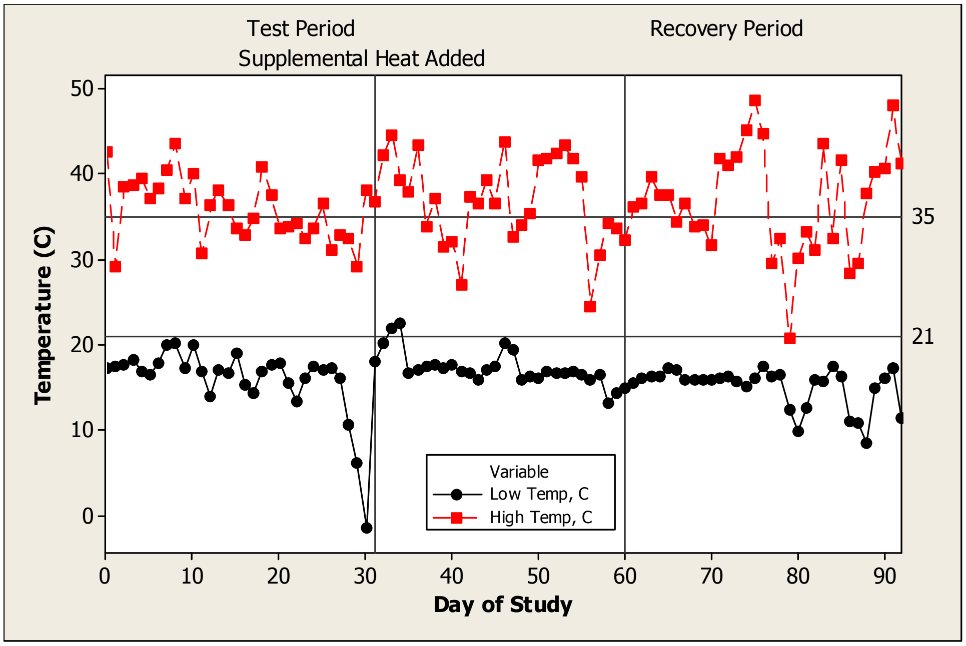


Figure 4.1. High and Low Daily Temperatures over a 0-60 Days Test Period, and a 60-92 Days Recovery Period in a Greenhouse Study (Additional Heater Added on day 31 to keep the indoor temperatures at the average for July and August).

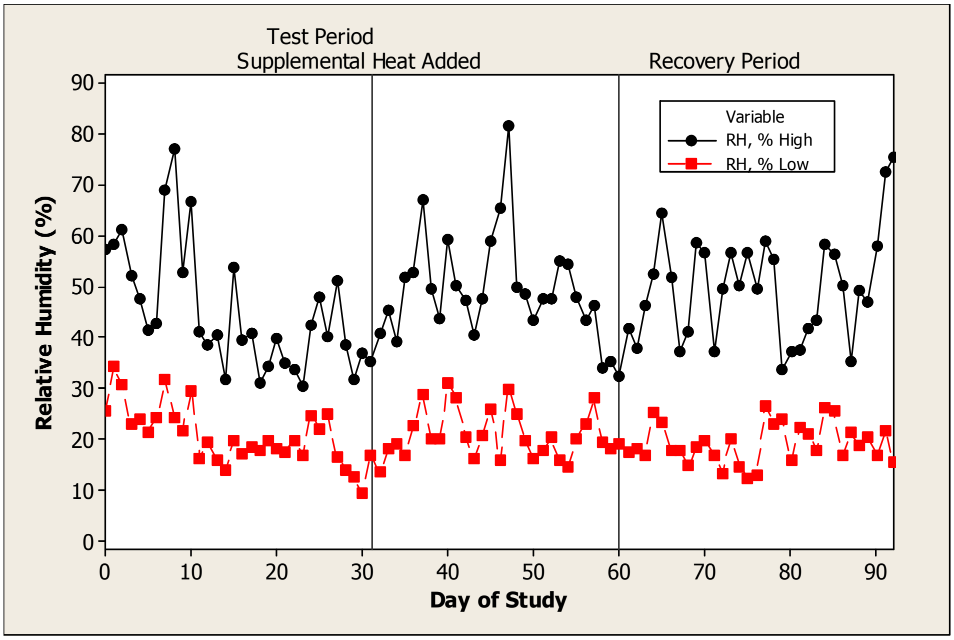


Figure 4.2. High and Low Daily Relative Humidity over a 0-60 Days Test Period, and a 60-92 Days Recovery Period in a Greenhouse Study (Additional Heater Added on day 31 to keep the indoor temperatures at the average for July and August).

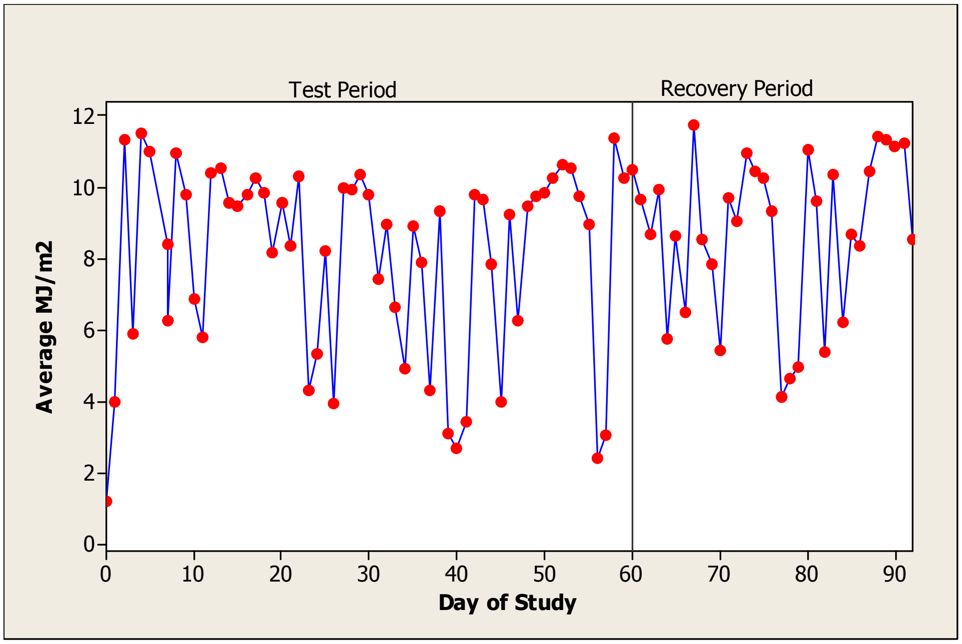


Figure 4.3. Average Daily incoming Solar Radiation over a 0-60 Days Test Period, and a 60-92 Days Recovery Period in a Greenhouse Study.

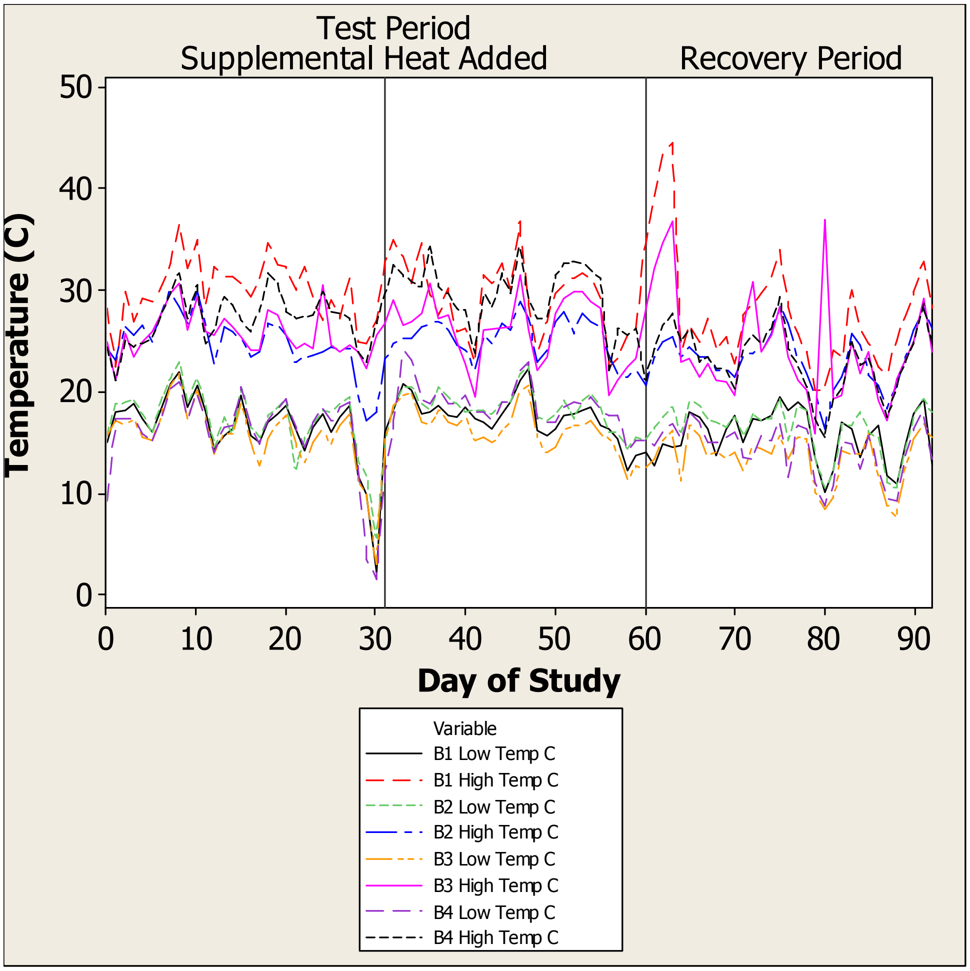
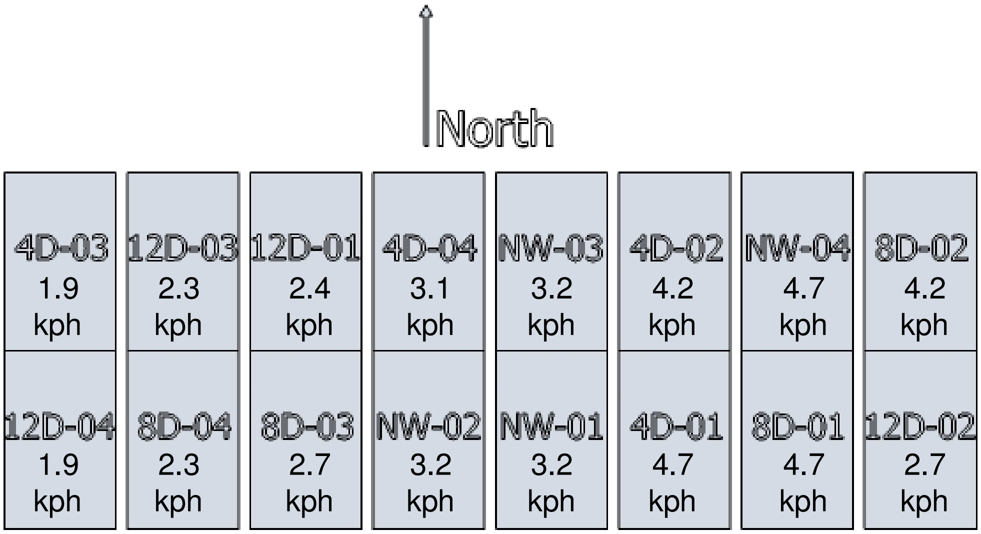


Figure 4.4. High and Low Daily Box Temperatures for Each Treatment during the 0-60 Days Test Period, and a 60-92 Days Recovery Period in a Greenhouse Study (Additional Heater Added on day 31 to keep the indoor temperatures at the average for July and August).



4D-03 1.9 kph	12D-03 2.3 kph	12D-01 2.4 kph	4D-04 3.1 kph	NW-03 3.2 kph	4D-02 4.2 kph	NW-04 4.7 kph	8D-02 4.2 kph
12D-04 1.9 kph	8D-04 2.3 kph	8D-03 2.7 kph	NW-02 3.2 kph	NW-01 3.2 kph	4D-01 4.7 kph	8D-01 4.7 kph	12D-02 2.7 kph

Figure 4.5. Average Wind Speed per Box over Buffalograss Turf in Greenhouse Experiment.

Table 4.1. Greenhouse Descriptive Environmental Statistics over a 0-60 Days Test Period, and a 60-92 Days Recovery Period in a Greenhouse Study.

Variable	Mean	Median	Standard Deviation	High	Low
Temperature (°C)	24.8	24.0	7.74	48.5	$^{-}1.41$
High Temperature (°C)	36.6	36.6	5.11	48.5	20.8
Low Temperature (°C)	16.0	16.5	3.11	22.5	$^{-}1.41$
Relative Humidity (%)	33.1	31.4	11.6	81.6	9.41
High Relative Humidity (%)	48.0	47.7	11.0	81.6	30.5
Low Relative Humidity (%)	20.3	19.8	4.85	34.3	9.41
Box 1 Temperature (°C)	22.3	21.9	5.37	44.6	2.18
Box 1 High Temperature (°C)	29.1	29.2	4.49	44.6	20.2
Box 1 Low Temperature (°C)	16.5	17.0	2.90	22.2	2.18
Box 2 Temperature (°C)	20.7	20.7	3.65	29.9	5.54
Box 2 High Temperature (°C)	24.4	29.9	2.69	29.9	16.3
Box 2 Low Temperature (°C)	17.2	17.8	2.75	22.9	5.54
Box 3 Temperature (°C)	19.8	19.4	4.69	36.9	2.93
Box 3 High Temperature (°C)	25.4	24.9	3.92	36.9	15.8
Box 3 Low Temperature (°C)	15.1	15.4	3.00	21.7	2.93
Box 4 Temperature (°C)	21.2	20.1	5.11	34.3	1.40
Box 4 High Temperature (°C)	26.5	26.7	3.97	34.3	15.5
Box 4 Low Temperature (°C)	16.2	17.0	3.63	24.0	1.40
Average Solar Radiation (MJ/m^2)	8.30	9.31	2.59	11.8	1.19
Solar Radiation Sensor 1 (MJ/m^2)	8.36	9.16	2.66	12.42	1.27
Solar Radiation Sensor 2 (MJ/m^2)	8.24	9.12	2.57	12.0	1.11
Wind (km/h)	3.20	2.90	1.31	7.73	1.13

Table 4.2. Soil Moisture Characteristics of Growing Containers.

Container	Saturated Weight (g)	Container Weight (g)	Dry Weight (g)	Volumetric Water Content (%)
B01	332	9.0	241	39.2
B02	299	9.0	203	49.2
B03	349	9.0	247	43.1
B04	392	9.0	259	52.9

Table 4.3. Water Lost from Boxes for Soil Only.

Container	Container Weight (kg)	Container and Soil Dry (kg)	Container and Soil Saturated (kg)	Container and Soil 24 hours (kg)	Water Lost * (kg)	Water Lost (cm)
S1	11.2	62.4		72.7	1.9	0.35
S2	11.7	58.5	69.4	67.6	1.8	0.33
S3	11.5	56.9	68.2	67.5	0.7	0.13
S4	11.1	52.8	61.8	61.2	0.6	0.10
S5	10.8	51.0	61.2	60.2	1.0	0.19

* Difference between the saturated soil weight and the soil weight 24 hours later

4.2 Evapotranspiration

Average daily evapotranspiration was measured by weighting water lost per box over a four day period. Figure 4.6 shows the average evapotranspiration for each treatment. The evapotranspiration for each box is shown in Appendix C. The amount of cumulative water added to each box is shown in Figure 4.7. The boxes irrigated every four days had a greater average evapotranspiration rate compared to the irrigated every twelve day treatment and the no water treatment. As the twelve day treatment and no water treatment went into a decline, less water was released from the soil due to evapotranspiration. When comparing the irrigation treatments to one another using a two-way ANOVA, during the test period it was found that at an α=0.05 the day was significant to the outcome as was treatment type (Table 4.4). The Tukey's Comparison showed that the irrigation treatments were not statistically similar to one another. (Table 4.5).

A two-way ANOVA was also run for the recovery period. Based on an $\alpha=0.05$, day was also significant for the recovery period, as was treatment (Table 4.6). The Tukey's Comparison showed that the twelve day irrigation treatment was statistically similar to the no water irrigation treatment (Table 4.7). The mean for the treatments showed that the every four day irrigation treatment had a lower evapotranspiration rate in the recovery period, while the every eight day, twelve day and no water irrigation treatments had a raise in the mean rate. This was likely due to the increased water available to the plants during the recovery. A one-way ANOVA on day 92 of the experiment showed that evapotranspiration for the irrigation treatment was significantly different at an $\alpha=0.05$ ($P>0.001$). A Tukey's Comparison (Table 4.8) showed that the every four and eight day, the every eight day and twelve day, and the every twelve day and no water irrigation treatments were statistically similar.

Table 4.4. Analysis of Variance P-Values for Evapotranspiration during the 0-60 day Test Period, Based on Day of the Experiment and Irrigation Treatment.

Source	P-Value
Day	<0.001
Treatment	<0.001

Table 4.5. Tukey's Comparison of Evapotranspiration (ET) per Treatment during the 0-60 Day Test Period using an α=0.05 (N/A days between irrigation represents the controls with no water added to the boxes after test began).

Days Between Irrigation	Mean ET (cm/day)	Multiple Comparison Results			
4	11.1	A			
8	6.06		B		
12	3.70			C	
N/A	1.86				D

Table 4.6. Analysis of Variance P-Values for Evapotranspiration during the 60-92 day Recovery Period, Based on Day of the Experiment and Irrigation Treatment.

Source	P-Value
Day	<0.001
Treatment	<0.001

Table 4.7. Tukey's Comparison of Evapotranspiration (ET) per Treatment during the 60 to 92 Day Recovery Period using an α=0.05 (N/A days between irrigation represents the controls with no water added to the boxes after test began).

Days Between Irrigation	Mean ET (cm/day)	Multiple Comparison Results		
4	10.0	A		
8	7.77		B	
12	5.44			C
N/A	4.50			C

Table 4.8. Tukey's Comparison of Evapotranspiration (ET) Day 92 only α=0.05 (N/A days between irrigation represents the controls with no water added to the boxes after test began).

Days Between Irrigation	Mean ET (cm/day)	Multiple Comparison Results		
4	10.2	A		
8	9.59	A	B	
12	7.18		B	C
N/A	6.13			C

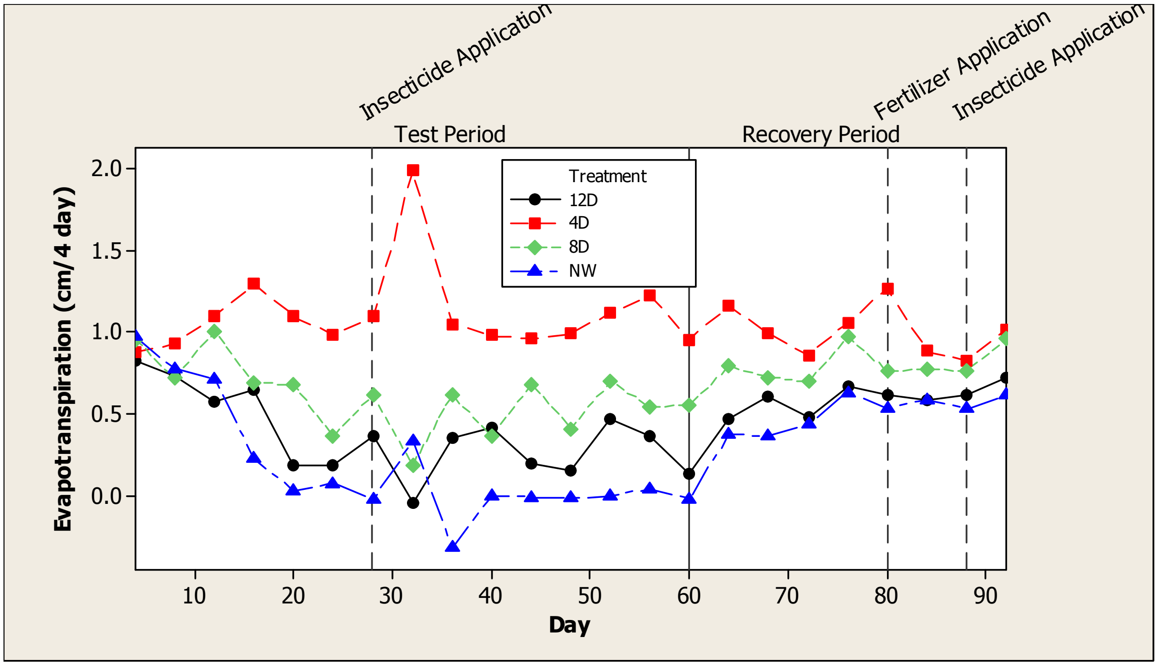


Figure 4.6. Average Four Day Evaporation per Treatment over a 0-60 Days Test Period, and a 60-92 Days Recovery Period in a Greenhouse Study. Insecticide Applied Days 28 and 84 when Evidence of Insects Appeared. Miracle Grow Fertilizer Applied on Day 80 when Plants in Decline. (4D = Irrigate Every 4 Days, 8D = Irrigate Every 8 Days, 12D = Irrigate Every 12 Days, NW = No Days Irrigated).

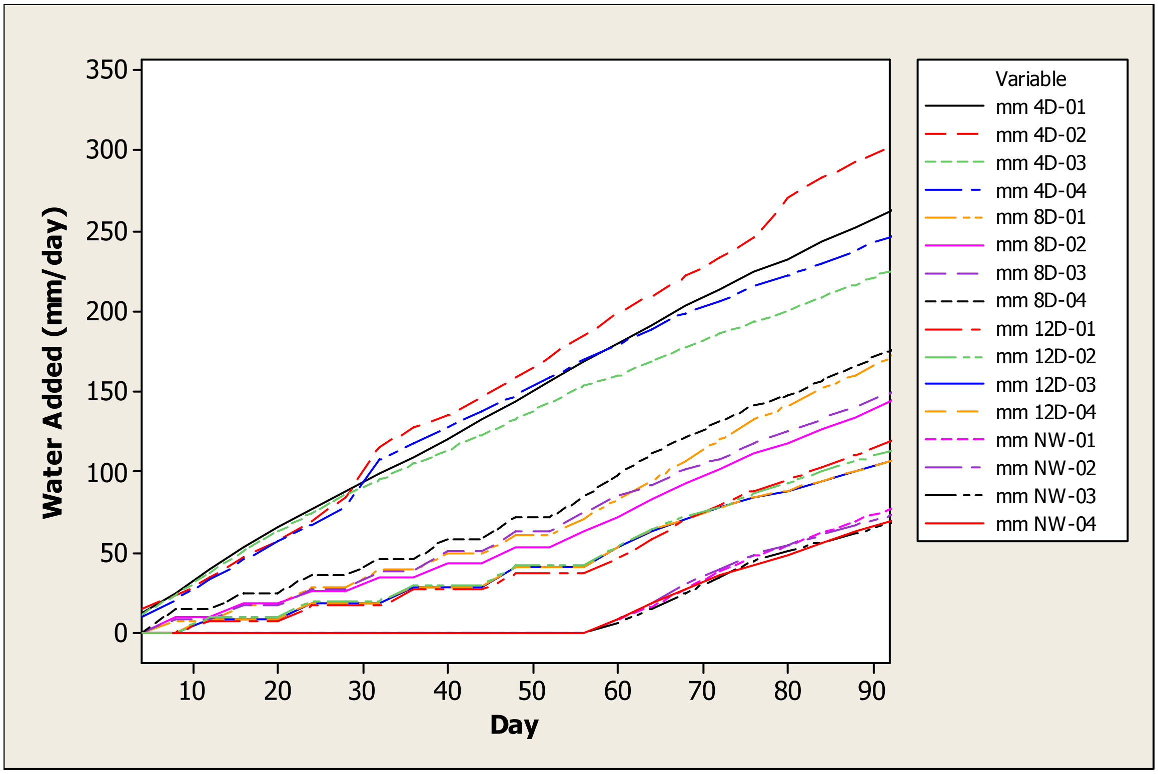


Figure 4.7. Accumulated Water Added per Treatment over a 0-60 Days Test Period, and a 60-92 Days Recovery Period in a Greenhouse Study (4D = Irrigate Every 4 Days, 8D = Irrigate Every 8 Days, 12D = Irrigate Every 12 Days, NW = No Days Irrigated).

4.3 NDVI

NDVI is a common measurement of plant health; the more chlorophyll a plant has the higher the biomass (Canada Center for Remote Sensing, 2005). With a higher biomass the plant absorbs more red light and will reflect more near infrared light. Figure 4.8 shows the NDVI per box in each treatment, illustrating the variability in the NDVI for each treatment, as well as the time period. The NDVI for the every four day irrigation treatment increases and peaks at day 24, and declines until the insecticide spray on day 28. This decline was likely due to the insect damage to the plants. The boxes in the twelve day irrigation treatment and the eight day irrigation treatment showed higher

NDVI in the recovery period with the increase in irrigation frequency. The no water treatment did not show improvement during the recovery period; the stand was already beyond permanent wilting point.

When comparing the irrigation treatments using a two-way ANOVA during the test period, at an $\alpha=0.05$ day was a significant variable as was treatment type (Table 4.9). The Tukey's Comparison showed that the every twelve day irrigation treatment and the no water irrigation treatment were statistically similar, while the every four day and every eight day irrigation treatments were not statistically similar to any other irrigation treatment (Table 4.10).

A similar two-way ANOVA was also run for the recovery period. Based on an $\alpha=0.05$, day was not a significant variable during the recovery period, but treatment was still significant (Table 4.11). The Tukey's Comparison showed that none of the treatments were statistically similar during the recovery period (Table 4.12). A one-way ANOVA for NDVI for day 88 of the experiment showed that the irrigation treatment was significant at an $\alpha=0.05$ ($P>0.001$). A Tukey's Comparison (Table 4.13) showed that the every four and every eight day treatments, and the every twelve and no water irrigation treatments were statistically similar.

Table 4.9. Analysis of Variance P-Values for NDVI during the 0-60 day Test Period, Based on Day of the Experiment and Irrigation Treatment.

Source	P-Value
Day	<0.001
Treatment	<0.001

Table 4.10. Tukey's Comparison of NDVI per Treatment during the 0-60 Day Test Period using an α=0.05 (N/A days between irrigation represents the controls with no water added to the boxes after test began).

Days Between Irrigation	Mean NDVI (cm/day)	Multiple Comparison Results		
4	0.580	A		
8	0.212		B	
12	-0.074			C
N/A	-0.112			C

Table 4.11. Analysis of Variance P-Values for NDVI during the 60-88 day Recovery Period, Based on Day of the Experiment and Irrigation Treatment.

Source	P-Value
Day	0.204
Treatment	<0.001

Table 4.12. Tukey's Comparison of NDVI per Treatment during the 60 to 88 Day Recovery Period using an α=0.05 (N/A days between irrigation represents the controls with no water added to the boxes after test began).

Days Between Irrigation	Mean NDVI (cm/day)	Multiple Comparison Results			
4	0.630	A			
8	0.381		B		
12	-0.200			C	
N/A	-0.429				D

Table 4.13. Tukey's Comparison of NDVI Day 88 only α=0.05 (N/A days between irrigation represents the controls with no water added to the boxes after test. began)

Days Between Irrigation	Mean NDVI (cm/day)	Multiple Comparison Results		
4	0.591	A		
8	0.483	A	B	
12	-0.092			C
N/A	-0.430			C

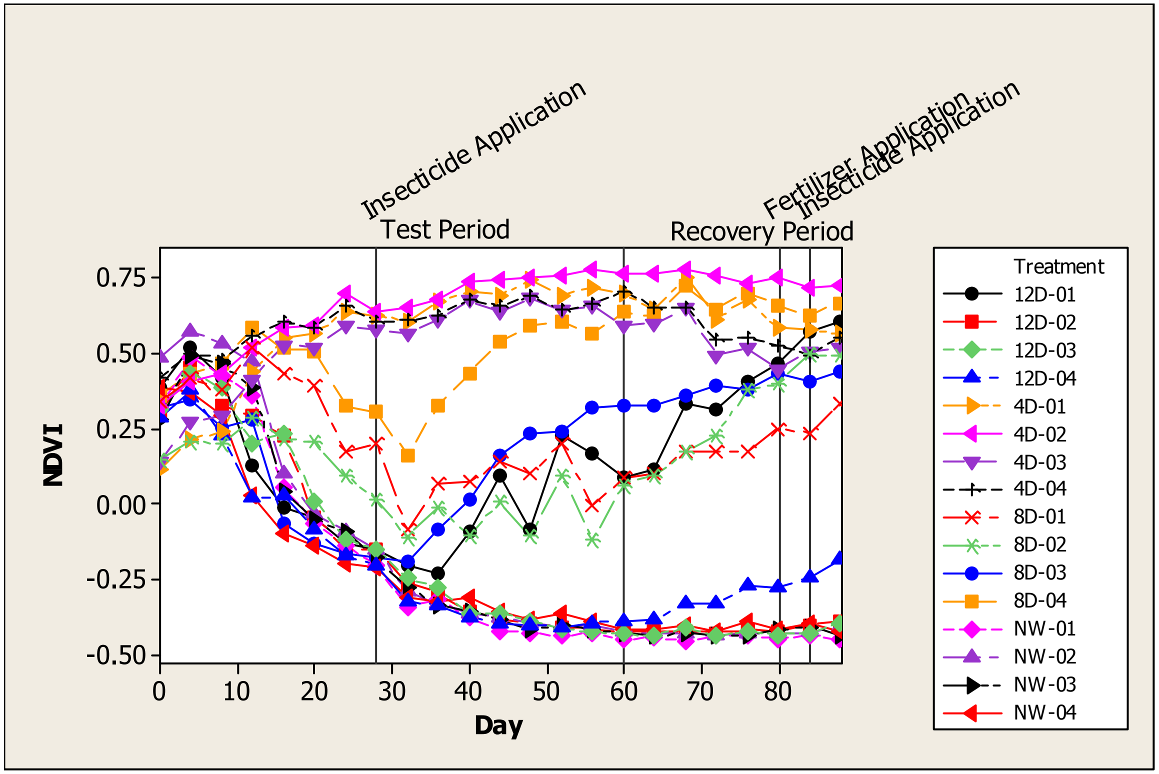


Figure 4.8. Every Four Day NDVI per Box over a 0-60 Days Test Period, and a 60-92 Days Recovery Period in a Greenhouse Study. Insecticide Applied Days 28 and 84 when Evidence of Insects Appeared. Miracle Grow Fertilizer Applied on Day 80 when Plants in Decline. (4D = Water Every 4 Days, 8D = Water Every 8 Days, 12D = Water Every 12 Days, NW = No Days Irrigated).

4.4 Discussion

The results of this study were based on average rainfall and temperature conditions for Stillwater, Oklahoma; and will vary due to temperatures and rainfall with higher and lower than average conditions.

The Buffalograss irrigated every four days performed the best overall in the study. In Figure 4.9 box 4D-04 is shown over time in the project. This box and two other boxes in the four day irrigation treatment showed decline in the recovery period. It should be noted that the primary intent of the recovery period was to determine which boxes reached permanent wilting point.

Using a rainfall cutoff threshold of 0.6 cm, the average number of days between rainfall events in Oklahoma was eight days. The boxes irrigated every eight days performed well in the study, with box 8D-04 outperforming all the eight day treatments. Figure 4.10 shows atypical box 8D-04 and its performance over time, while Figure 4.11 shows the performance of box 8D-01, a typical box for the treatment. Any decline during the course of the study could be attributed to the insects in the greenhouse.

The next treatment group was the twelve day irrigation. Overall this treatment did not perform well, but no box was found to have complete death. Box 12D-01 did seem to outperform the rest of the treatment after spraying for insects on day 28. Figure 4.12 shows the atypical box 12-01 over the course of the project, while Figure 4.13 shows a more typical box 12-04. All boxes did start to show some leaf re-growth during the recovery period, but the greening areas were sparse.

The last treatment was not irrigated at all during the 60 day test period. This treatment did not perform well, and all boxes were found to be dead at the end of the test period. The boxes in the no water treatment started to get very light green by day 16, and were completely brown by days 28 and 32. Some of their decline may be attributed to the insect problem, but after insecticide application they never recovered. Figure 4.14 shows Box NW-02 over time.

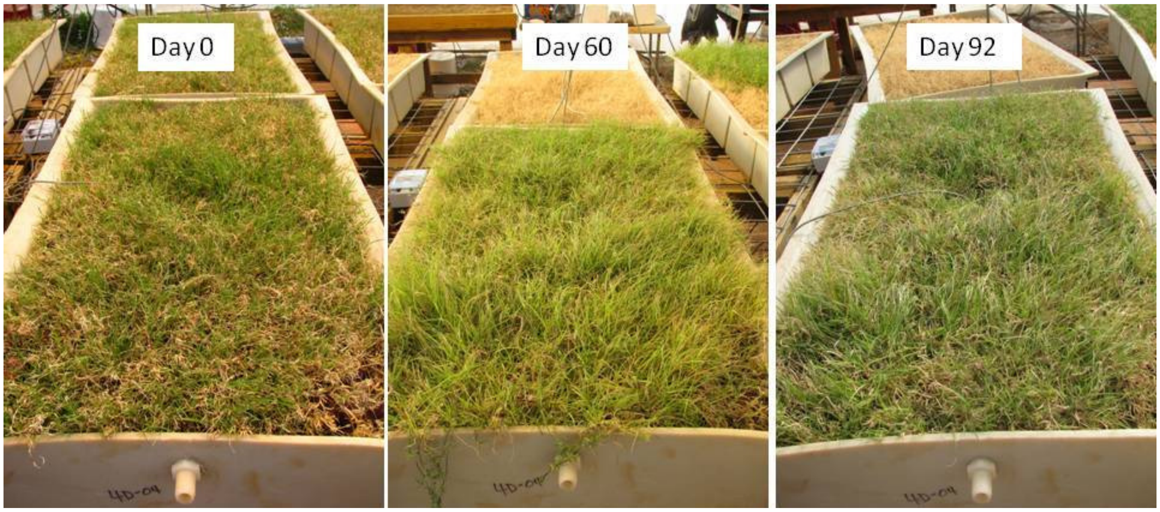


Figure 4.9. Box 4D-04, Irrigated every Four Days, on Day 0, Day 60, and Day 92 (Typical results for the boxes irrigated every four days).

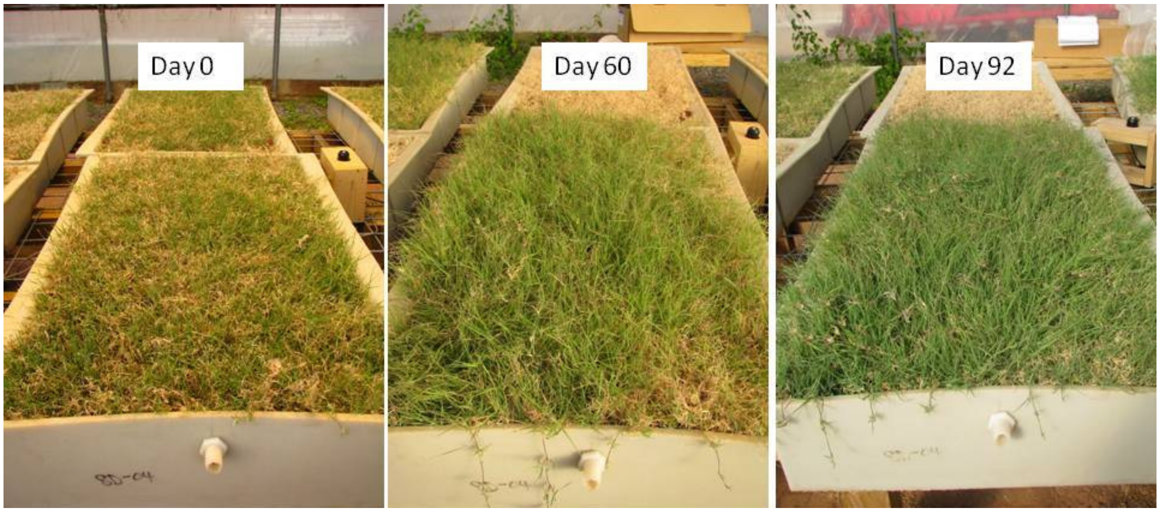


Figure 4.10. Box 8D-04, Irrigated every Eight Days, on Day 0, Day 60, and Day 92 (Atypical results for the boxes irrigated every eight days).

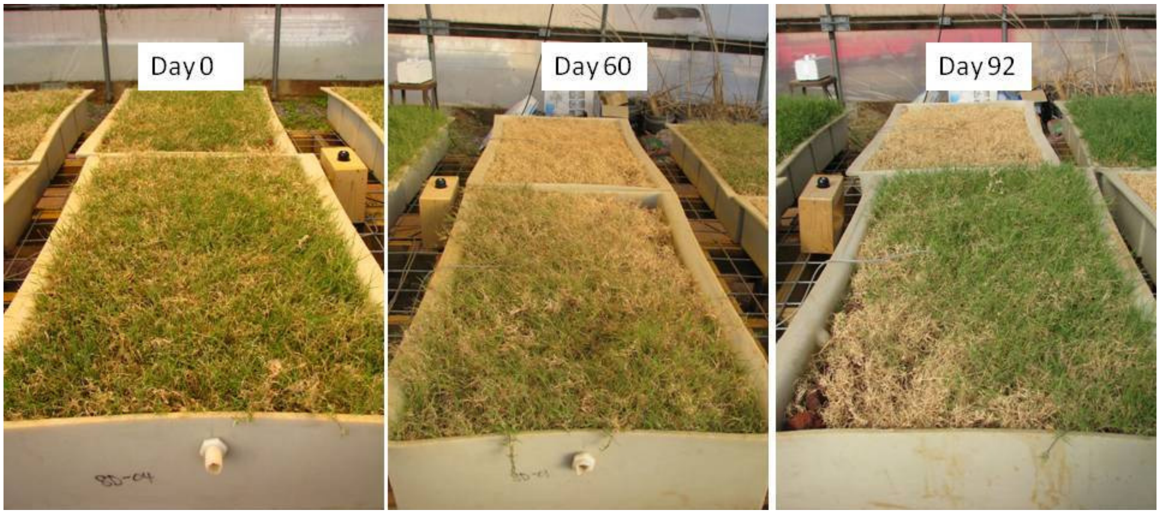


Figure 4.11. Box 8D-01, Irrigated every Eight Days, on Day 0, Day 60, and Day 92 (Typical results for the boxes irrigated every eight days).

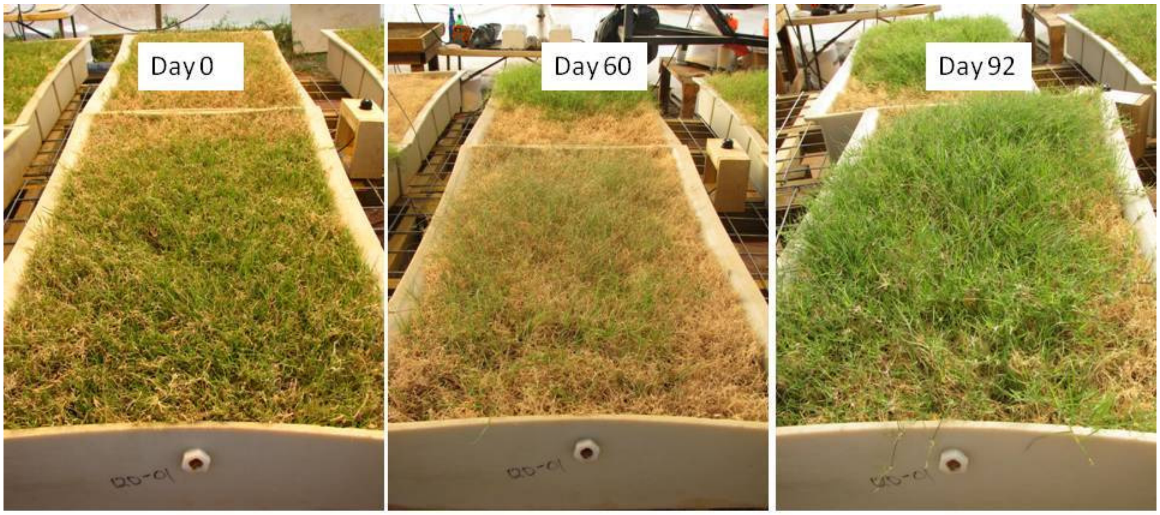


Figure 4.12. Box 12D-01, Irrigated every Twelve Days, on Day 0, Day 60, and Day 92 (Atypical results for the boxes irrigated every 12 days).

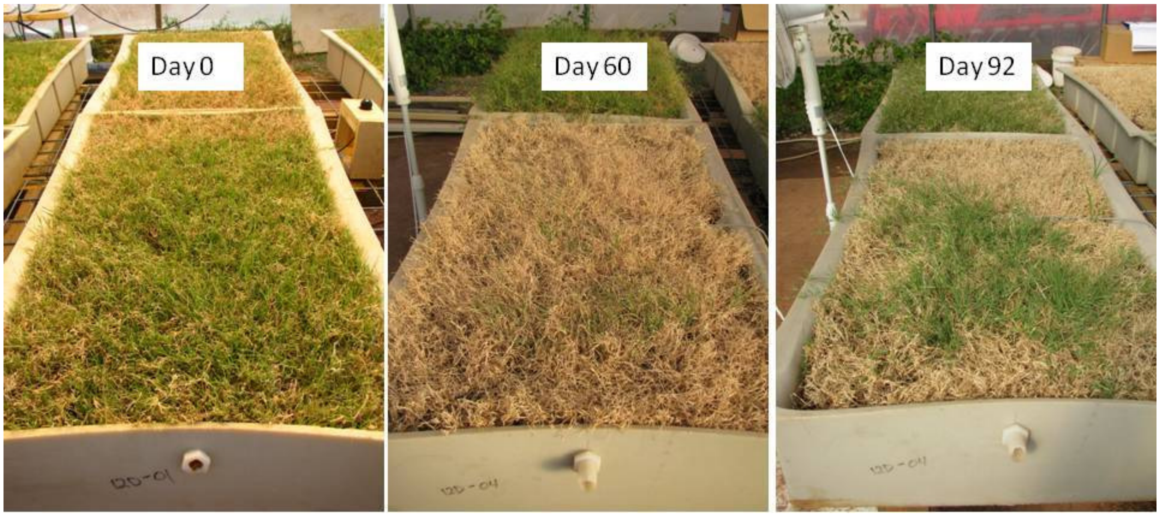


Figure 4.13. Box 12D-04, Irrigated every Twelve Days, on Day 0, Day 60, and Day 92 (Typical results for the boxes irrigated every 12 days).

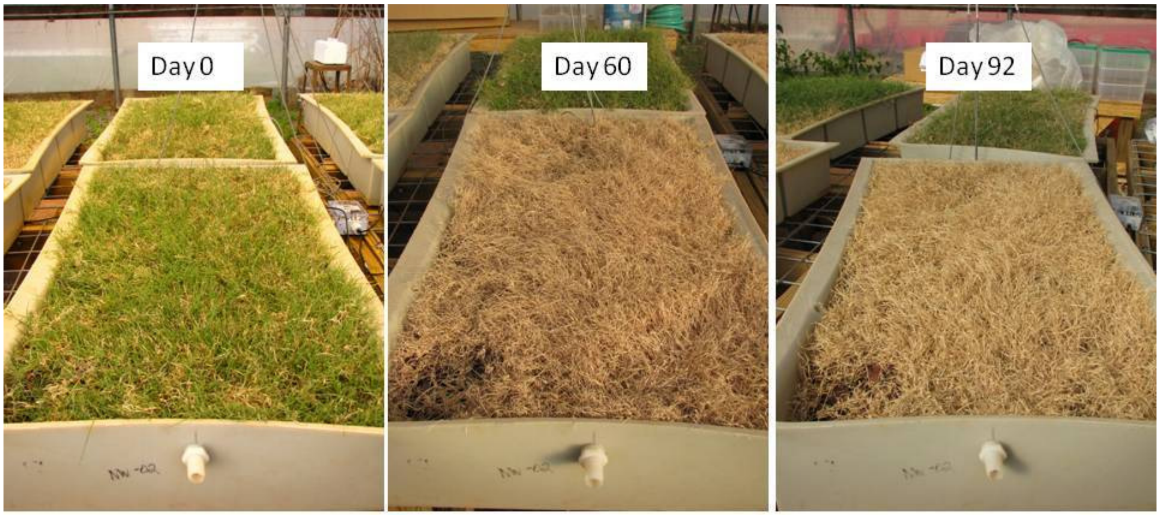


Figure 4.14. Box NW-02, Not Watered Treatment, on Day 0, Day 60, and Day 92 (Typical results for the boxes not irrigated).

CHAPTER V

CONCLUSIONS AND RECOMENDATIONS FOR FURTHER RESEARCH

5.1 Conclusions

For average temperature conditions for Stillwater, Oklahoma, the irrigation treatments on the Prestige Buffalograss did not result in the same stand presence. Using evapotranspiration and NDVI as indicators, there was a significant effect of irrigation frequency on Buffalograss persistence. The no watering treatment reached permanent wilting point, and due to the performance of the twelve day and no watering treatments, supplemental irrigation will be required for green roofs in central Oklahoma. Based on these experiments, rainfall will be required at least every twelve days in order to maintain a green roof Buffalograss stand.

Buffalograss is a desirable species to use on a green roof given its high drought tolerance and its low growth rate. However, as the Buffalograss stand persistence declines, the greater the fire risk. To help reduce the fire danger on a rooftop, a periodic prescribed burn or mowing with removal of clippings is recommended. If clippings are removed, supplemental fertilization may be required.

5.2 Recommendations for Further Research

1. Move the testing outside and perform a year round study to see how it responds to the actual climate conditions rather than a short term simulated environment depths and types.

2. Test Buffalograss for its winter tolerance and possible root freezing in different media depths and types.
3. Begin testing other Oklahoma native grasses and perennials in simulated and non-simulated conditions.
4. Test the effect of different media depths and types on rain retention, filtering, and insulating properties.

REFERENCES

"About Green Roofs." *Green Roofs for Healthy Cities*. Green Roofs for Healthy Cities, 08 Dec. 2009. Web. 18 July 2011. <http://www.greenroofs.org/index.php/about-green-roofs>.

Bass, Brad. "Examining the Role of Green Roof Infrastructure." *Green Roof Infrastructure Monitor* 3.1 (2001): 10-12. Print.

Boivin, Marie-Anne, Marie-Pierre Lamy, Andre Gosselin, and Blanche Dansereau. "Effect of Artificial Substrate Depth on Freezing Injury of Six Herbaceous Perennials Grown in a Green Roof System." *Hort Technology* 11.3 (2001). Print.

Bowman, Daniel C., Dale A. Devitt, David R. Huff, and W. Wally Miller. "Comparative Evapotranspiration of Seventeen Buffalograss (Buchloe dactyloides (Nutt.) Engelm.) Genoypes." *Journal of Turfgrass Management* 2.4 (1998). Print.

Cushman, Ruth Carol, and Stephen R. Jones. *The Shortgrass Prairie*. Boulder, CO: Pruett Pub., 1988. Print.

Daley, Richard M. "A Guide to Rooftop Gardening." *Chicago's Green Rooftops*. City of Chicago. Web. 13 Oct. 2010. <http://www.cityofchicago.org/content/dam/city/depts/doe/general/GreenBldsRoofsHomes/GuidetoRooftopGardening_v2.pdf>.

Dardick, Karen. "Lean and Green: Replace That Thirsty Lawn with These Water-thrifty Ground Covers." *San Diego Union-Tribune* [San Diego] 28 June 2009, Real Estate sec. Print.

Dunnett, Nigel, and Noël Kingsbury. *Planting Green Roofs and Living Walls*. Portland, Or.: Timber, 2004. Print.

Dunnett, Nigel. "Up on the Roof." *The Garden* May 2002: 380-83. Print.

England. British Council for Offices. *Green Roofs Research Advice Note*. 2003. Print.

"EPA - NPDES FAQs." *U.S. EPA ColdFusion Server*. U.S. Environmental Protection Agency. Web. 01 Mar. 2010. <http://cfpub.epa.gov/npdes/faqs.cfm?program_id=5>.

"Glossary of Remote Sensing Terms." *Canada Centre for Remote Sensing / Centre Canadien De Télédétection*. 21 Nov. 2005. Web. 07 July 2011. <http://www.ccrs.nrcan.gc.ca/glossary/index_e.php?id=1938>.

"Green Roofs for Healthy Cities." *The Green Roof Monitor* 1.1 (1999): 1-4. Print.

"Greenroofs.com Projects - Atlanta Botanical Garden Edible Garden Green Wall." *Greenroofs.com: The Resource Portal for Green Roofs*. The Greenroof Projects Database, 2010. Web. 18 July 2011. <http://www.greenroofs.com/projects/pview.php?id=1124>.

"Greenroofs.com Projects - Cook Fox Architects LLP." *Greenroofs.com: The Resource Portal for Green Roofs*. The Greenroof Projects Database, 2010. Web. 18 July 2011. <http://www.greenroofs.com/projects/pview.php?id=670>.

"Greenroofs.com Projects - Laban Dance Centre." *Greenroofs.com: The Resource Portal for Green Roofs*. The Weather Channel, 2010. Web. 18 July 2011. <http://www.greenroofs.com/projects/pview.php?id=549>.

"Greenroofs.com Projects - Olson Family Garden, St. Louis Children's Hospital." *Greenroofs.com: The Resource Portal for Green Roofs*. The Greenroof Projects Database, 2010. Web. 18 July 2011. <http://www.greenroofs.com/projects/pview.php?id=595>.

"Greenroofs.com Projects - Songjiang Hotel." *Greenroofs.com: The Resource Portal for Green Roofs*. The Greenroof Projects Database, 2010. Web. 18 July 2011. <http://www.greenroofs.com/projects/pview.php?id=529>.

Kellert, Stephen R. "Beyond LEED: From Low Environmental Impact to Restorative Environmental Design." *Green Roof Infrastructure Monitor* 6.1 (2004): 1+. Print.

Loder, Angela. "Green Roof Infrastructure Helps to Implement Goals of Smart Growth." *Green Roof Infrastructure Monitor* 5.2 (2003): 18-19. Print.

Luckett, Kelly. *Green Roof Construction and Maintenance*. New York: McGraw-Hill, 2009. Print.

McDonough, William J. . *Green Roofs Ecological Design and Construction*. Atglen, PA: Schiffer, 2005. Print.

McGinnis, Lori. "Buffalograss Advantages Are Deep-rooted." *University of Nebraska-Lincoln Cooperative Extecnsion Connect* 8 (01 May 2008): 8. Print.

Oberlander, Elisabeth Whitelaw, Hahn, Cornelia, Matsuzaki, Eva. Canada. Public Works and Government Services. *Introductory Manual for Greening Roofs*. [Ottawa]: Public Works and Government Services Canada, 2002. Print.

Osmundson, Theodore. *Roof Gardens: History, Design, and Construction*. New York: W.W. Norton, 1999. Print.

Otto, Betsy, Katherine Ransel, Jason Todd, Deron Lovaas, Hannah Stutzman, and John Bailey. *Paving Our Way to Water Shortages: How Sprawl Aggravates the Effects of Drought*. [Washington, D.C.]: American Rivers, 2002. Print.

Palmer-Wilson, Kathryn. "Introduction to Horticultural Therapy and Green Roofs." *Green Roof Infrastructure Monitor* 5.1 (2003): 11-12. Print.

Peck, Steven. "Towards an Integrated Green Roof Infrastructure Evaluation for Toronto." *Green Roof Infrastructure Monitor* 5.1 (2003): 4-5. Print.

Peck, Steven W., Chris Callaghan, Monica E. Kuhn, and Brad Bass. *Greenbacks from Green Roofs Forging a New Industry in Canada*. [Ottawa]: Canada Mortgage and Housing Corporation, 1999. Print.

Shearman, R.C., T.P. Riordan, B.G. Abeyo, T.M. Hen-Moss, D.J. Lee, R.E. Gaussoin, O. Gulsen, H. Budak, and D.D. Serba. "Buffalograss: Tough Native Turfgrass." *Turfgrass and Environmental Reasearch Online* 5.21 (2006): 1-13. Print.

Snodgrass, Edmund C., and Lucie L. Snodgrass. *Green Roof Plants: a Resource and Planting Guide*. Portland, Or.: Timber, 2006. Print.

"Tables and Charts of Monthly Climatological Averages." *National Weather Service Southern Region Homepage*. 24 Nov. 2009. Web. 07 July 2011. <http://www.srh.noaa.gov/oun/climate/getnorm.php?id=stwo2>.

"User Guide: Geenseeker 505 Handheld Sensor." Trimble Agriculture. Web. 18 July 2011. <http://trl.trimble.com/docushare/dsweb/Get/Document-493091/>.

White, John W., and Edmund Snodgrass. *Extensive Greenroof Plant Selection and Characteristics*. Chicago: Greening Rooftops for Sustainable Communities, 2003. Print.

Wieditz, Ireen. "Urban Biodiversity - An Oxymoron?" *Green Roof Infrastructure Monitor* 5.1 (2003): 9-10. Print.

APPPENDIX A

Experimental Daily Raw Data for Each Box

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
0	11/14/2010	4D-01	0.112	320.6	50.6		130.3
0	11/14/2010	4D-02	0.327	173.1	44.4		151.7
0	11/14/2010	4D-03	0.138	135.6	60.6		119.5
0	11/14/2010	4D-04	0.423	220.6	65.6		145.6
0	11/14/2010	8D-01	0.343	311.9	46.9		142.6
0	11/14/2010	8D-02	0.145	208.1	50.6		147.5
0	11/14/2010	8D-03	0.322	314.4	53.1		120.7
0	11/14/2010	8D-04	0.362	358.1	54.4		140.0
0	11/14/2010	12D-01	0.388	220.6	60.6		122.3
0	11/14/2010	12D-02	0.306	311.9	43.1		140.8
0	11/14/2010	12D-03	0.317	135.6	65.6		140.2
0	11/14/2010	12D-04	0.287	358.1	51.9		133.3
0	11/14/2010	NW-01	0.321	320.6	46.9		144.1
0	11/14/2010	NW-02	0.488	314.4	56.9		140.3
0	11/14/2010	NW-03	0.279	173.1	48.1		144.9
0	11/14/2010	NW-04	0.385	208.1	51.9		121.0
1	11/15/2010	4D-01				127.6	
1	11/15/2010	4D-02				147.4	
1	11/15/2010	4D-03				116.8	
1	11/15/2010	4D-04				142.1	
1	11/15/2010	8D-01				138.7	
1	11/15/2010	8D-02				142.6	
1	11/15/2010	8D-03				117.8	
1	11/15/2010	8D-04				137.7	
1	11/15/2010	12D-01				119.9	
1	11/15/2010	12D-02				136.9	

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
1	11/15/2010	12D-03				137.5	
1	11/15/2010	12D-04				130.5	
1	11/15/2010	NW-01				139.6	
1	11/15/2010	NW-02				136.7	
1	11/15/2010	NW-03				138.3	
1	11/15/2010	NW-04				115.5	
2	11/16/2010	4D-01				125.4	
2	11/16/2010	4D-02				145.4	
2	11/16/2010	4D-03				114.3	
2	11/16/2010	4D-04				139.8	
2	11/16/2010	8D-01				135.4	
2	11/16/2010	8D-02				140.0	
2	11/16/2010	8D-03				115.5	
2	11/16/2010	8D-04				132.9	
2	11/16/2010	12D-01				117.6	
2	11/16/2010	12D-02				131.0	
2	11/16/2010	12D-03				135.2	
2	11/16/2010	12D-04				127.8	
2	11/16/2010	NW-01				137.9	
2	11/16/2010	NW-02				133.3	
2	11/16/2010	NW-03				136.6	
2	11/16/2010	NW-04				114.4	
3	11/17/2010	4D-01				123.0	
3	11/17/2010	4D-02				140.3	
3	11/17/2010	4D-03				113.2	
3	11/17/2010	4D-04				137.0	
3	11/17/2010	8D-01				132.3	
3	11/17/2010	8D-02				137.9	
3	11/17/2010	8D-03				110.8	
3	11/17/2010	8D-04				131.5	
3	11/17/2010	12D-01				114.1	
3	11/17/2010	12D-02				131.4	
3	11/17/2010	12D-03				132.1	
3	11/17/2010	12D-04				125.6	
3	11/17/2010	NW-01				135.5	
3	11/17/2010	NW-02				129.7	
3	11/17/2010	NW-03				136.6	
3	11/17/2010	NW-04				112.3	
4	11/18/2010	4D-01	0.217	165.6	68.1	121.4	135.5

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m2)	Outgoing Radiation (W/m2)	Weight (lbs)	Weight after water (lbs)
4	11/18/2010	4D-02	0.407	141.9	54.4	137.4	155.0
4	11/18/2010	4D-03	0.275	145.6	54.4	111.6	125.2
4	11/18/2010	4D-04	0.502	120.6	51.9	134.8	146.2
4	11/18/2010	8D-01	0.417	156.1	61.1	130.0	
4	11/18/2010	8D-02	0.210	138.1	44.4	134.6	
4	11/18/2010	8D-03	0.344	126.9	50.6	111.5	
4	11/18/2010	8D-04	0.435	116.9	44.4	129.3	
4	11/18/2010	12D-01	0.517	136.9	59.4	113.1	
4	11/18/2010	12D-02	0.455	173.1	53.1	129.0	
4	11/18/2010	12D-03	0.435	149.4	53.1	130.3	
4	11/18/2010	12D-04	0.377	119.4	48.1	125.0	
4	11/18/2010	NW-01	0.488	204.4	69.4	132.5	
4	11/18/2010	NW-02	0.576	136.9	55.6	127.9	
4	11/18/2010	NW-03	0.492	126.9	48.1	133.7	
4	11/18/2010	NW-04	0.374	103.1	41.9	110.1	
5	11/19/2010	4D-01				131.3	
5	11/19/2010	4D-02				149.0	
5	11/19/2010	4D-03				121.7	
5	11/19/2010	4D-04				143.6	
5	11/19/2010	8D-01				126.6	
5	11/19/2010	8D-02				133.4	
5	11/19/2010	8D-03				108.0	
5	11/19/2010	8D-04				126.1	
5	11/19/2010	12D-01				109.3	
5	11/19/2010	12D-02				124.9	
5	11/19/2010	12D-03				127.4	
5	11/19/2010	12D-04				122.0	
5	11/19/2010	NW-01				130.8	
5	11/19/2010	NW-02				124.4	
5	11/19/2010	NW-03				130.7	
5	11/19/2010	NW-04				106.8	
6	11/20/2010	4D-01				128.2	
6	11/20/2010	4D-02				146.5	
6	11/20/2010	4D-03				118.5	
6	11/20/2010	4D-04				140.9	
6	11/20/2010	8D-01				123.8	
6	11/20/2010	8D-02				132.2	

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
6	11/20/2010	8D-03				105.8	
6	11/20/2010	8D-04				122.7	
6	11/20/2010	12D-01				106.3	
6	11/20/2010	12D-02				123.7	
6	11/20/2010	12D-03				124.9	
6	11/20/2010	12D-04				119.4	
6	11/20/2010	NW-01				127.6	
6	11/20/2010	NW-02				119.6	
6	11/20/2010	NW-03				127.9	
6	11/20/2010	NW-04				104.8	
7	11/21/2010	4D-01				125.5	
7	11/21/2010	4D-02				143.0	
7	11/21/2010	4D-03				116.1	
7	11/21/2010	4D-04				137.7	
7	11/21/2010	8D-01				121.7	
7	11/21/2010	8D-02				128.6	
7	11/21/2010	8D-03				103.7	
7	11/21/2010	8D-04				119.9	
7	11/21/2010	12D-01				103.9	
7	11/21/2010	12D-02				121.4	
7	11/21/2010	12D-03				121.3	
7	11/21/2010	12D-04				117.5	
7	11/21/2010	NW-01				125.0	
7	11/21/2010	NW-02				118.0	
7	11/21/2010	NW-03				124.8	
7	11/21/2010	NW-04				102.9	
8	11/22/2010	4D-01	0.238	411.9	108.1	124.4	139.6
8	11/22/2010	4D-02	0.432	444.4	168.1	141.6	151.2
8	11/22/2010	4D-03	0.297	388.1	168.1	115.3	129.9
8	11/22/2010	4D-04	0.482	235.6	101.9	136.2	149.7
8	11/22/2010	8D-01	0.381	636.1	116.9	121.2	129.8
8	11/22/2010	8D-02	0.199	278.1	105.6	128.9	141.0
8	11/22/2010	8D-03	0.255	406.9	116.9	102.7	112.9
8	11/22/2010	8D-04	0.465	378.1	96.9	118.4	135.7
8	11/22/2010	12D-01	0.421	283.1	113.1	103.1	
8	11/22/2010	12D-02	0.327	175.6	91.9	121.2	
8	11/22/2010	12D-03	0.385	433.2	155.6	121.6	

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
8	11/22/2010	12D-04	0.230	410.6	111.9	116.6	
8	11/22/2010	NW-01	0.429	505.6	134.4	124.5	
8	11/22/2010	NW-02	0.532	329.4	98.1	116.8	
8	11/22/2010	NW-03	0.465	233.1	90.6	124.7	
8	11/22/2010	NW-04	0.295	211.9	85.6	101.3	
9	11/23/2010	4D-01				133.5	
9	11/23/2010	4D-02				146.5	
9	11/23/2010	4D-03				123.8	
9	11/23/2010	4D-04				127.3	
9	11/23/2010	8D-01				127.4	
9	11/23/2010	8D-02				136.4	
9	11/23/2010	8D-03				108.3	
9	11/23/2010	8D-04				129.1	
9	11/23/2010	12D-01				100.2	
9	11/23/2010	12D-02				115.8	
9	11/23/2010	12D-03				117.3	
9	11/23/2010	12D-04				112.6	
9	11/23/2010	NW-01				117.4	
9	11/23/2010	NW-02				111.8	
9	11/23/2010	NW-03				119.7	
9	11/23/2010	NW-04				98.4	
10	11/24/2010	4D-01				130.9	
10	11/24/2010	4D-02				145.8	
10	11/24/2010	4D-03				122.0	
10	11/24/2010	4D-04				140.9	
10	11/24/2010	8D-01				125.6	
10	11/24/2010	8D-02				132.0	
10	11/24/2010	8D-03				105.0	
10	11/24/2010	8D-04				125.9	
10	11/24/2010	12D-01				99.2	
10	11/24/2010	12D-02				114.6	
10	11/24/2010	12D-03				116.5	
10	11/24/2010	12D-04				113.2	
10	11/24/2010	NW-01				118.4	
10	11/24/2010	NW-02				109.8	
10	11/24/2010	NW-03				118.0	
10	11/24/2010	NW-04				97.8	

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
11	11/25/2010	4D-01				127.4	
11	11/25/2010	4D-02				142.3	
11	11/25/2010	4D-03				118.6	
11	11/25/2010	4D-04				136.9	
11	11/25/2010	8D-01				121.0	
11	11/25/2010	8D-02				131.2	
11	11/25/2010	8D-03				103.6	
11	11/25/2010	8D-04				123.4	
11	11/25/2010	12D-01				98.5	
11	11/25/2010	12D-02				111.3	
11	11/25/2010	12D-03				115.1	
11	11/25/2010	12D-04				112.5	
11	11/25/2010	NW-01				115.9	
11	11/25/2010	NW-02				108.4	
11	11/25/2010	NW-03				116.1	
11	11/25/2010	NW-04				96.7	
12	11/26/2010	4D-01	0.437	369.4	96.9	125.5	143.2
12	11/26/2010	4D-02	0.517	454.4	150.6	140.4	153.7
12	11/26/2010	4D-03	0.416	285.6	128.1	116.5	132.5
12	11/26/2010	4D-04	0.557	405.6	170.6	135.8	150.2
12	11/26/2010	8D-01	0.517	394.4	109.4	120.3	
12	11/26/2010	8D-02	0.284	381.4	153.1	130.2	
12	11/26/2010	8D-03	0.280	383.1	100.6	102.7	
12	11/26/2010	8D-04	0.584	438.1	113.1	118.3	
12	11/26/2010	12D-01	0.126	418.1	163.1	97.9	106.7
12	11/26/2010	12D-02	0.293	440.6	95.6	110.8	122.1
12	11/26/2010	12D-03	0.202	438.1	144.4	114.5	124.5
12	11/26/2010	12D-04	0.023	423.1	95.6	112.1	120.6
12	11/26/2010	NW-01	0.362	446.9	106.9	115.5	
12	11/26/2010	NW-02	0.470	465.6	119.4	106.7	
12	11/26/2010	NW-03	0.385	371.9	140.6	114.1	
12	11/26/2010	NW-04	0.028	381.9	135.6	96.9	
13	11/27/2010	4D-01				138.4	
13	11/27/2010	4D-02				151.9	
13	11/27/2010	4D-03				128.7	
13	11/27/2010	4D-04				147.8	
13	11/27/2010	8D-01				115.5	

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
13	11/27/2010	8D-02				128.1	
13	11/27/2010	8D-03				101.3	
13	11/27/2010	8D-04				117.8	
13	11/27/2010	12D-01				106.6	
13	11/27/2010	12D-02				117.9	
13	11/27/2010	12D-03				122.2	
13	11/27/2010	12D-04				119.7	
13	11/27/2010	NW-01				114.9	
13	11/27/2010	NW-02				104.6	
13	11/27/2010	NW-03				112.3	
13	11/27/2010	NW-04				96.9	
14	11/28/2010	4D-01				135.0	
14	11/28/2010	4D-02				154.5	
14	11/28/2010	4D-03				123.9	
14	11/28/2010	4D-04				143.4	
14	11/28/2010	8D-01				117.7	
14	11/28/2010	8D-02				107.1	
14	11/28/2010	8D-03				103.9	
14	11/28/2010	8D-04				119.4	
14	11/28/2010	12D-01				105.4	
14	11/28/2010	12D-02				115.5	
14	11/28/2010	12D-03				122.0	
14	11/28/2010	12D-04				118.4	
14	11/28/2010	NW-01				114.4	
14	11/28/2010	NW-02				104.8	
14	11/28/2010	NW-03				112.1	
14	11/28/2010	NW-04				81.8	
15	11/29/2010	4D-01				128.9	
15	11/29/2010	4D-02				137.9	
15	11/29/2010	4D-03				118.5	
15	11/29/2010	4D-04				138.0	
15	11/29/2010	8D-01				112.5	
15	11/29/2010	8D-02				122.7	
15	11/29/2010	8D-03				97.6	
15	11/29/2010	8D-04				110.8	
15	11/29/2010	12D-01				103.8	
15	11/29/2010	12D-02				112.2	

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
15	11/29/2010	12D-03				115.9	
15	11/29/2010	12D-04				115.9	
15	11/29/2010	NW-01				113.0	
15	11/29/2010	NW-02				103.6	
15	11/29/2010	NW-03				111.4	
15	11/29/2010	NW-04				95.0	
16	11/30/2010	4D-01	0.551	124.4	55.6	126.5	142.9
16	11/30/2010	4D-02	0.587	66.9	35.6	139.8	155.5
16	11/30/2010	4D-03	0.526	71.9	38.1	116.0	132.3
16	11/30/2010	4D-04	0.603	73.1	41.9	135.7	150.3
16	11/30/2010	8D-01	0.433	118.1	49.4	110.7	123.1
16	11/30/2010	8D-02	0.213	75.6	38.1	120.9	130.3
16	11/30/2010	8D-03	-0.062	68.1	36.9	97.8	107.3
16	11/30/2010	8D-04	0.517	80.6	41.9	109.3	121.4
16	11/30/2010	12D-01	-0.015	75.6	36.9	102.7	
16	11/30/2010	12D-02	0.226	113.1	55.6	111.0	
16	11/30/2010	12D-03	0.235	121.9	44.4	113.8	
16	11/30/2010	12D-04	0.026	89.4	39.4	115.4	
16	11/30/2010	NW-01	0.055	123.1	49.4	113.3	
16	11/30/2010	NW-02	0.101	130.6	50.6	103.4	
16	11/30/2010	NW-03	0.044	84.4	34.4	110.4	
16	11/30/2010	NW-04	-0.099	71.9	31.9	95.3	
17	12/1/2010	4D-01				139.6	
17	12/1/2010	4D-02				148.9	
17	12/1/2010	4D-03				127.3	
17	12/1/2010	4D-04				146.2	
17	12/1/2010	8D-01				119.3	
17	12/1/2010	8D-02				126.6	
17	12/1/2010	8D-03				103.9	
17	12/1/2010	8D-04				119.2	
17	12/1/2010	12D-01				102.1	
17	12/1/2010	12D-02				110.1	
17	12/1/2010	12D-03				114.3	
17	12/1/2010	12D-04				114.1	
17	12/1/2010	NW-01				112.9	
17	12/1/2010	NW-02				102.9	
17	12/1/2010	NW-03				110.3	

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
17	12/1/2010	NW-04				94.5	
18	12/2/2010	4D-01				135.0	
18	12/2/2010	4D-02				146.8	
18	12/2/2010	4D-03				124.1	
18	12/2/2010	4D-04				142.6	
18	12/2/2010	8D-01				116.2	
18	12/2/2010	8D-02				124.0	
18	12/2/2010	8D-03				102.8	
18	12/2/2010	8D-04				115.8	
18	12/2/2010	12D-01				101.2	
18	12/2/2010	12D-02				108.5	
18	12/2/2010	12D-03				113.2	
18	12/2/2010	12D-04				113.6	
18	12/2/2010	NW-01				110.5	
18	12/2/2010	NW-02				102.8	
18	12/2/2010	NW-03				109.7	
18	12/2/2010	NW-04				94.9	
19	12/3/2010	4D-01				131.5	
19	12/3/2010	4D-02				144.9	
19	12/3/2010	4D-03				121.8	
19	12/3/2010	4D-04				139.9	
19	12/3/2010	8D-01				113.1	
19	12/3/2010	8D-02				123.4	
19	12/3/2010	8D-03				104.1	
19	12/3/2010	8D-04				113.3	
19	12/3/2010	12D-01				101.1	
19	12/3/2010	12D-02				108.4	
19	12/3/2010	12D-03				113.1	
19	12/3/2010	12D-04				113.1	
19	12/3/2010	NW-01				112.4	
19	12/3/2010	NW-02				102.1	
19	12/3/2010	NW-03				110.8	
19	12/3/2010	NW-04				95.0	
20	12/4/2010	4D-01	0.566	200.6	119.4	129.9	143.9
20	12/4/2010	4D-02	0.595	383.1	160.6	141.3	152.5
20	12/4/2010	4D-03	0.522	419.4	170.6	119.6	134.2
20	12/4/2010	4D-04	0.586	364.4	154.4	137.9	151.2

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
20	12/4/2010	8D-01	0.393	430.6	95.6	112.8	
20	12/4/2010	8D-02	0.209	353.1	144.4	122.1	
20	12/4/2010	8D-03	-0.129	181.9	161.9	102.9	
20	12/4/2010	8D-04	0.509	265.6	180.6	111.9	
20	12/4/2010	12D-01	-0.045	398.1	146.9	100.6	
20	12/4/2010	12D-02	-0.042	425.6	86.9	108.1	
20	12/4/2010	12D-03	0.010	320.6	133.1	112.8	
20	12/4/2010	12D-04	-0.085	175.6	140.6	112.6	
20	12/4/2010	NW-01	-0.066	208.1	130.6	112.6	
20	12/4/2010	NW-02	-0.032	190.6	149.6	102.5	
20	12/4/2010	NW-03	-0.050	421.9	156.9	110.8	
20	12/4/2010	NW-04	-0.141	415.6	151.9	94.9	
21	12/5/2010	4D-01				139.2	
21	12/5/2010	4D-02				149.7	
21	12/5/2010	4D-03				128.7	
21	12/5/2010	4D-04				146.9	
21	12/5/2010	8D-01				110.7	
21	12/5/2010	8D-02				119.3	
21	12/5/2010	8D-03				102.6	
21	12/5/2010	8D-04				109.0	
21	12/5/2010	12D-01				99.2	
21	12/5/2010	12D-02				107.4	
21	12/5/2010	12D-03				111.8	
21	12/5/2010	12D-04				111.6	
21	12/5/2010	NW-01				112.0	
21	12/5/2010	NW-02				102.0	
21	12/5/2010	NW-03				109.2	
21	12/5/2010	NW-04				94.3	
22	12/6/2010	4D-01				135.2	
22	12/6/2010	4D-02				143.0	
22	12/6/2010	4D-03				125.4	
22	12/6/2010	4D-04				143.5	
22	12/6/2010	8D-01				108.9	
22	12/6/2010	8D-02				117.3	
22	12/6/2010	8D-03				102.3	
22	12/6/2010	8D-04				107.7	
22	12/6/2010	12D-01				97.9	
22	12/6/2010	12D-02				107.2	

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
22	12/6/2010	12D-03				111.4	
22	12/6/2010	12D-04				110.6	
22	12/6/2010	NW-01				111.1	
22	12/6/2010	NW-02				102.4	
22	12/6/2010	NW-03				108.7	
22	12/6/2010	NW-04				94.4	
23	12/7/2010	4D-01				133.4	
23	12/7/2010	4D-02				145.3	
23	12/7/2010	4D-03				121.2	
23	12/7/2010	4D-04				141.0	
23	12/7/2010	8D-01				108.5	
23	12/7/2010	8D-02				118.0	
23	12/7/2010	8D-03				101.4	
23	12/7/2010	8D-04				106.8	
23	12/7/2010	12D-01				97.1	
23	12/7/2010	12D-02				107.2	
23	12/7/2010	12D-03				110.9	
23	12/7/2010	12D-04				110.9	
23	12/7/2010	NW-01				112.0	
23	12/7/2010	NW-02				102.1	
23	12/7/2010	NW-03				109.9	
23	12/7/2010	NW-04				94.1	
24	12/8/2010	4D-01	0.638	174.4	81.9	132.1	146.2
24	12/8/2010	4D-02	0.702	409.4	160.6	142.3	157.7
24	12/8/2010	4D-03	0.591	338.1	156.9	120.9	134.3
24	12/8/2010	4D-04	0.661	361.9	150.6	139.7	152.2
24	12/8/2010	8D-01	0.177	228.1	94.4	107.3	119.5
24	12/8/2010	8D-02	0.093	341.9	133.1	117.7	127.1
24	12/8/2010	8D-03	-0.166	161.9	78.1	101.2	113.5
24	12/8/2010	8D-04	0.324	139.4	89.4	106.3	119.8
24	12/8/2010	12D-01	-0.130	403.1	153.1	98.0	109.1
24	12/8/2010	12D-02	-0.149	156.8	58.1	106.2	118.2
24	12/8/2010	12D-03	-0.116	385.6	146.9	110.0	121.8
24	12/8/2010	12D-04	-0.171	215.6	136.9	111.1	120.1
24	12/8/2010	NW-01	-0.135	168.6	74.4	112.1	
24	12/8/2010	NW-02	-0.090	194.4	85.6	102.2	
24	12/8/2010	NW-03	-0.093	374.4	149.4	109.0	

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
24	12/8/2010	NW-04	-0.195	364.4	139.4	93.9	
25	12/9/2010	4D-01				141.4	
25	12/9/2010	4D-02				149.4	
25	12/9/2010	4D-03				130.4	
25	12/9/2010	4D-04				147.9	
25	12/9/2010	8D-01				115.1	
25	12/9/2010	8D-02				124.1	
25	12/9/2010	8D-03				110.6	
25	12/9/2010	8D-04				116.3	
25	12/9/2010	12D-01				106.5	
25	12/9/2010	12D-02				115.2	
25	12/9/2010	12D-03				119.6	
25	12/9/2010	12D-04				118.1	
25	12/9/2010	NW-01				111.1	
25	12/9/2010	NW-02				102.1	
25	12/9/2010	NW-03				109.8	
25	12/9/2010	NW-04				94.6	
26	12/10/2010	4D-01				138.4	
26	12/10/2010	4D-02				148.9	
26	12/10/2010	4D-03				126.9	
26	12/10/2010	4D-04				144.5	
26	12/10/2010	8D-01				113.7	
26	12/10/2010	8D-02				122.7	
26	12/10/2010	8D-03				109.5	
26	12/10/2010	8D-04				114.7	
26	12/10/2010	12D-01				105.3	
26	12/10/2010	12D-02				114.5	
26	12/10/2010	12D-03				118.1	
26	12/10/2010	12D-04				117.3	
26	12/10/2010	NW-01				111.8	
26	12/10/2010	NW-02				102.0	
26	12/10/2010	NW-03				109.7	
26	12/10/2010	NW-04				94.1	
28	12/12/2010	4D-01	0.628	323.1	166.9	133.8	147.1
28	12/12/2010	4D-02	0.640	419.4	175.6	142.2	159.8
28	12/12/2010	4D-03	0.579	359.4	169.4	121.6	135.3
28	12/12/2010	4D-04	0.604	380.6	170.6	140.7	154.5

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
28	12/12/2010	8D-01	0.203	441.9	165.9	111.0	
28	12/12/2010	8D-02	0.018	323.1	146.9	120.6	
28	12/12/2010	8D-03	-0.177	338.1	159.4	107.6	
28	12/12/2010	8D-04	0.305	398.1	165.6	111.2	
28	12/12/2010	12D-01	-0.149	371.9	150.6	103.9	
28	12/12/2010	12D-02	-0.153	353.1	149.4	113.3	
28	12/12/2010	12D-03	-0.151	423.1	150.6	117.6	
28	12/12/2010	12D-04	-0.203	390.6	111.9	117.1	
28	12/12/2010	NW-01	-0.204	393.1	174.4	112.1	
28	12/12/2010	NW-02	-0.152	359.4	150.6	102.0	
28	12/12/2010	NW-03	-0.178	379.4	151.9	109.9	
28	12/12/2010	NW-04	-0.209	410.6	159.4	94.3	
32	12/16/2010	4D-01	0.608	358.1	99.4	134.6	147.6
32	12/16/2010	4D-02	0.655	340.6	144.4	122.3	159.6
32	12/16/2010	4D-03	0.564	341.9	163.1	124.4	135.3
32	12/16/2010	4D-04	0.611	425.6	181.9	120.7	155.5
32	12/16/2010	8D-01	-0.084	309.4	86.9	107.9	121.2
32	12/16/2010	8D-02	-0.109	454.4	174.4	118.7	129.2
32	12/16/2010	8D-03	-0.193	318.1	100.6	104.9	118.7
32	12/16/2010	8D-04	0.159	378.1	105.6	109.8	121.4
32	12/16/2010	12D-01	-0.202	456.9	190.6	106.9	
32	12/16/2010	12D-02	-0.264	385.6	100.6	111.6	
32	12/16/2010	12D-03	-0.247	410.6	164.4	116.5	
32	12/16/2010	12D-04	-0.322	338.1	104.3	119.2	
32	12/16/2010	NW-01	-0.343	303.1	108.1	111.9	
32	12/16/2010	NW-02	-0.293	418.1	120.6	102.0	
32	12/16/2010	NW-03	-0.278	378.1	146.9	93.3	
32	12/16/2010	NW-04	-0.308	436.9	163.1	95.2	
36	12/20/2010	4D-01	0.672	293.1	118.1	135.4	147.9
36	12/20/2010	4D-02	0.682	276.9	113.1	145.7	159.5
36	12/20/2010	4D-03	0.611	229.4	108.1	124.2	136.0
36	12/20/2010	4D-04	0.628	245.6	109.4	142.7	155.1
36	12/20/2010	8D-01	0.067	330.6	126.9	112.4	
36	12/20/2010	8D-02	-0.009	148.1	58.1	121.6	
36	12/20/2010	8D-03	-0.086	254.4	103.1	112.5	
36	12/20/2010	8D-04	0.329	319.4	125.6	114.7	
36	12/20/2010	12D-01	-0.232	346.9	135.6	99.0	111.0

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
36	12/20/2010	12D-02	-0.296	315.6	133.1	109.8	122.1
36	12/20/2010	12D-03	-0.278	340.6	134.4	114.9	127.1
36	12/20/2010	12D-04	-0.336	261.9	98.1	113.6	125.8
36	12/20/2010	NW-01	-0.319	268.1	108.1	111.8	
36	12/20/2010	NW-02	-0.332	246.9	93.1	102.0	
36	12/20/2010	NW-03	-0.335	269.4	108.1	109.8	
36	12/20/2010	NW-04	-0.323	269.9	93.1	93.8	
40	12/24/2010	4D-01	0.708	61.9	20.6	136.5	149.0
40	12/24/2010	4D-02	0.737	61.9	18.1	146.4	155.3
40	12/24/2010	4D-03	0.677	49.4	14.4	125.6	136.1
40	12/24/2010	4D-04	0.679	19.4	6.9	143.4	154.7
40	12/24/2010	8D-01	0.073	71.9	21.9	108.5	121.1
40	12/24/2010	8D-02	-0.105	23.1	8.1	118.4	129.1
40	12/24/2010	8D-03	0.016	79.4	25.6	107.0	121.5
40	12/24/2010	8D-04	0.435	75.6	24.4	109.8	125.1
40	12/24/2010	12D-01	-0.089	83.1	26.9	105.6	
40	12/24/2010	12D-02	-0.359	36.9	13.1	115.9	
40	12/24/2010	12D-03	-0.362	21.9	6.9	122.9	
40	12/24/2010	12D-04	-0.375	24.4	9.4	121.7	
40	12/24/2010	NW-01	-0.376	68.1	25.6	111.8	
40	12/24/2010	NW-02	-0.365	43.1	15.6	101.9	
40	12/24/2010	NW-03	-0.356	20.6	6.9	109.5	
40	12/24/2010	NW-04	-0.311	53.1	18.1	94.3	
44	12/28/2010	4D-01	0.693	93.1	50.6	133.7	149.5
44	12/28/2010	4D-02	0.745	125.6	46.9	147.0	161.8
44	12/28/2010	4D-03	0.639	80.6	34.4	124.7	135.8
44	12/28/2010	4D-04	0.658	111.9	43.1	144.0	156.3
44	12/28/2010	8D-01	0.139	121.9	54.4	112.5	
44	12/28/2010	8D-02	0.005	74.4	26.9	121.7	
44	12/28/2010	8D-03	0.158	149.4	81.9	113.9	
44	12/28/2010	8D-04	0.539	114.4	86.9	116.2	
44	12/28/2010	12D-01	0.093	76.9	30.6	101.9	
44	12/28/2010	12D-02	-0.383	104.4	44.4	113.7	
44	12/28/2010	12D-03	-0.361	125.6	45.6	120.9	
44	12/28/2010	12D-04	-0.394	154.4	64.4	120.4	
44	12/28/2010	NW-01	-0.421	181.9	85.6	111.8	
44	12/28/2010	NW-02	-0.375	135.6	74.4	101.7	

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
44	12/28/2010	NW-03	-0.384	124.4	46.9	110.0	
44	12/28/2010	NW-04	-0.359	74.4	29.4	94.4	
48	1/1/2011	4D-01	0.747	418.1	191.9	136.5	149.5
48	1/1/2011	4D-02	0.751	416.9	165.6	147.8	161.6
48	1/1/2011	4D-03	0.684	338.1	184.4	126.5	138.4
48	1/1/2011	4D-04	0.691	320.6	178.1	145.3	156.6
48	1/1/2011	8D-01	0.104	318.1	141.9	107.9	120.5
48	1/1/2011	8D-02	-0.107	281.9	139.4	117.8	129.3
48	1/1/2011	8D-03	0.231	363.1	119.4	108.8	123.6
48	1/1/2011	8D-04	0.594	375.6	158.1	110.2	125.7
48	1/1/2011	12D-01	-0.087	406.9	175.6	99.2	110.7
48	1/1/2011	12D-02	-0.400	334.4	138.1	112.3	126.0
48	1/1/2011	12D-03	-0.390	315.6	165.6	119.3	134.0
48	1/1/2011	12D-04	-0.402	335.6	121.9	118.9	131.7
48	1/1/2011	NW-01	-0.428	360.6	181.9	112.1	
48	1/1/2011	NW-02	-0.395	358.1	164.4	102.0	
48	1/1/2011	NW-03	-0.416	370.6	163.1	109.9	
48	1/1/2011	NW-04	-0.382	353.1	145.6	94.5	
52	1/5/2011	4D-01	0.694	384.4	164.4	136.1	150.2
52	1/5/2011	4D-02	0.758	294.4	146.9	147.4	162.8
52	1/5/2011	4D-03	0.645	288.1	164.4	125.1	137.0
52	1/5/2011	4D-04	0.645	310.6	156.9	144.3	157.4
52	1/5/2011	8D-01	0.202	306.9	143.1	112.1	
52	1/5/2011	8D-02	0.094	296.9	135.6	122.0	
52	1/5/2011	8D-03	0.239	380.6	139.4	115.1	
52	1/5/2011	8D-04	0.607	341.9	155.6	116.7	
52	1/5/2011	12D-01	0.226	344.4	156.9	105.0	
52	1/5/2011	12D-02	-0.409	318.1	145.6	119.5	
52	1/5/2011	12D-03	-0.416	329.4	161.4	128.4	
52	1/5/2011	12D-04	-0.413	355.6	133.1	127.1	
52	1/5/2011	NW-01	-0.439	378.1	171.9	112.2	
52	1/5/2011	NW-02	-0.405	309.4	156.9	102.4	
52	1/5/2011	NW-03	-0.404	301.9	145.6	109.8	
52	1/5/2011	NW-04	-0.364	279.4	144.4	94.2	
56	1/9/2011	4D-01	0.722	110.6	39.4	134.3	150.1
56	1/9/2011	4D-02	0.777	118.1	44.4	145.5	161.5
56	1/9/2011	4D-03	0.657	76.9	36.9	125.5	138.0

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
56	1/9/2011	4D-04	0.663	120.6	44.4	143.8	157.3
56	1/9/2011	8D-01	-0.005	63.1	24.4	106.6	1119.0
56	1/9/2011	8D-02	-0.118	86.9	29.4	117.5	128.4
56	1/9/2011	8D-03	0.318	120.6	44.4	107.3	121.2
56	1/9/2011	8D-04	0.564	110.6	41.9	108.6	123.9
56	1/9/2011	12D-01	0.166	71.9	29.4	100.4	
56	1/9/2011	12D-02	-0.415	74.4	29.4	115.2	
56	1/9/2011	12D-03	-0.424	119.4	44.4	125.0	
56	1/9/2011	12D-04	-0.394	114.4	41.9	122.0	
56	1/9/2011	NW-01	-0.429	96.9	38.1	111.3	
56	1/9/2011	NW-02	-0.407	111.9	44.4	101.7	
56	1/9/2011	NW-03	-0.414	109.4	41.9	109.4	
56	1/9/2011	NW-04	-0.389	78.1	29.4	94.1	
60	1/13/2011	4D-01	0.697	169.4	81.9	138.8	151.4
60	1/13/2011	4D-02	0.767	98.1	66.9	146.8	162.5
60	1/13/2011	4D-03	0.592	91.9	88.1	129.3	136.4
60	1/13/2011	4D-04	0.709	169.4	84.4	146.6	157.0
60	1/13/2011	8D-01	0.086	205.6	80.6	112.0	126.5
60	1/13/2011	8D-02	0.063	93.1	43.1	122.4	134.1
60	1/13/2011	8D-03	0.326	178.1	70.6	114.6	127.5
60	1/13/2011	8D-04	0.637	189.4	89.4	117.1	133.3
60	1/13/2011	12D-01	0.086	153.1	71.9	97.9	109.0
60	1/13/2011	12D-02	-0.424	144.4	61.9	114.0	128.4
60	1/13/2011	12D-03	-0.432	200.6	86.9	122.6	137.8
60	1/13/2011	12D-04	-0.390	105.6	66.9	121.7	134.2
60	1/13/2011	NW-01	-0.453	133.1	76.9	112.0	121.2
60	1/13/2011	NW-02	-0.424	166.9	70.6	101.8	111.5
60	1/13/2011	NW-03	-0.432	188.1	78.1	109.6	117.2
60	1/13/2011	NW-04	-0.416	175.6	68.1	94.0	103.6
64	1/17/2011	4D-01	0.647	104.4	38.1	135.6	149.6
64	1/17/2011	4D-02	0.767	94.4	39.4	146.1	160.0
64	1/17/2011	4D-03	0.599	86.9	43.1	125.7	137.1
64	1/17/2011	4D-04	0.653	129.4	51.9	144.5	157.3
64	1/17/2011	8D-01	0.100	94.4	33.1	116.0	130.4
64	1/17/2011	8D-02	0.094	96.9	34.4	126.7	139.5
64	1/17/2011	8D-03	0.324	128.1	49.4	118.2	126.2
64	1/17/2011	8D-04	0.625	88.1	39.4	122.7	138.6

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
64	1/17/2011	12D-01	0.112	105.6	43.1	103.7	118.5
64	1/17/2011	12D-02	-0.427	51.9	23.1	121.6	134.2
64	1/17/2011	12D-03	-0.436	106.9	43.1	132.3	144.0
64	1/17/2011	12D-04	-0.381	86.9	35.6	129.5	140.0
64	1/17/2011	NW-01	-0.444	66.9	28.1	116.3	126.4
64	1/17/2011	NW-02	-0.433	64.4	29.4	106.7	119.3
64	1/17/2011	NW-03	-0.437	100.6	41.9	113.4	123.2
64	1/17/2011	NW-04	-0.419	98.1	35.6	99.0	110.9
68	1/21/2011	4D-01	0.753	268.1	154.4	136.2	150.2
68	1/21/2011	4D-02	0.778	305.6	148.1	148.1	162.0
68	1/21/2011	4D-03	0.650	319.4	141.9	127.2	137.3
68	1/21/2011	4D-04	0.655	306.9	149.4	145.1	156.7
68	1/21/2011	8D-01	0.172	335.6	155.6	118.9	133.4
68	1/21/2011	8D-02	0.171	276.9	120.6	132.5	144.2
68	1/21/2011	8D-03	0.363	251.9	143.1	120.2	131.6
68	1/21/2011	8D-04	0.726	221.9	148.1	128.7	141.1
68	1/21/2011	12D-01	0.334	305.6	140.6	110.9	124.7
68	1/21/2011	12D-02	-0.421	271.9	155.6	127.1	137.3
68	1/21/2011	12D-03	-0.412	351.9	153.1	135.9	145.0
68	1/21/2011	12D-04	-0.333	349.4	161.9	133.9	142.7
68	1/21/2011	NW-01	-0.456	326.9	173.1	122.5	135.9
68	1/21/2011	NW-02	-0.431	259.4	149.4	114.5	128.1
68	1/21/2011	NW-03	-0.431	316.9	146.9	118.0	130.2
68	1/21/2011	NW-04	-0.406	255.6	108.1	107.6	118.1
72	1/25/2011	4D-01	0.616	320.6	113.1	139.3	151.5
72	1/25/2011	4D-02	0.761	259.4	138.1	149.9	163.4
72	1/25/2011	4D-03	0.496	329.4	135.6	128.2	138.0
72	1/25/2011	4D-04	0.546	323.1	144.4	148.1	156.8
72	1/25/2011	8D-01	0.171	365.6	136.9	121.7	136.9
72	1/25/2011	8D-02	0.227	311.9	136.9	137.5	148.0
72	1/25/2011	8D-03	0.392	390.6	155.6	125.5	132.8
72	1/25/2011	8D-04	0.648	405.6	163.1	132.3	143.2
72	1/25/2011	12D-01	0.312	318.1	130.6	118.4	129.7
72	1/25/2011	12D-02	-0.428	378.1	166.9	130.7	137.1
72	1/25/2011	12D-03	-0.438	274.4	139.4	140.5	148.2
72	1/25/2011	12D-04	-0.330	329.4	128.1	137.3	145.4
72	1/25/2011	NW-01	-0.437	395.6	140.6	129.9	142.6

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
72	1/25/2011	NW-02	-0.437	339.4	135.6	123.9	135.4
72	1/25/2011	NW-03	-0.438	349.4	159.4	124.5	135.9
72	1/25/2011	NW-04	-0.424	346.9	151.9	113.3	123.5
76	1/29/2011	4D-01	0.681	311.9	144.4	136.3	149.5
76	1/29/2011	4D-02	0.731	258.1	136.9	148.3	163.0
76	1/29/2011	4D-03	0.517	201.9	133.1	128.1	137.1
76	1/29/2011	4D-04	0.552	343.1	144.1	146.5	157.1
76	1/29/2011	8D-01	0.171	323.1	128.1	121.6	137.1
76	1/29/2011	8D-02	0.378	239.4	89.4	140.7	152.0
76	1/29/2011	8D-03	0.377	395.6	156.9	121.0	132.1
76	1/29/2011	8D-04	0.702	356.9	151.9	131.5	143.6
76	1/29/2011	12D-01	0.409	271.9	126.9	119.9	130.8
76	1/29/2011	12D-02	-0.419	289.4	119.4	130.9	140.9
76	1/29/2011	12D-03	-0.422	338.1	148.1	140.6	148.3
76	1/29/2011	12D-04	-0.274	326.9	144.4	137.1	146.6
76	1/29/2011	NW-01	-0.435	346.9	159.4	133.6	144.9
76	1/29/2011	NW-02	-0.432	374.4	155.6	127.9	138.5
76	1/29/2011	NW-03	-0.436	264.4	120.6	128.2	140.6
76	1/29/2011	NW-04	-0.392	265.6	116.9	117.7	126.1
80	2/2/2011	4D-01	0.585	526.9	194.4	139.1	148.8
80	2/2/2011	4D-02	0.750	516.9	219.4	130.1	159.7
80	2/2/2011	4D-03	0.450	423.1	194.4	128.6	136.4
80	2/2/2011	4D-04	0.529	428.1	180.6	148.7	156.4
80	2/2/2011	8D-01	0.250	509.4	184.4	125.8	135.3
80	2/2/2011	8D-02	0.400	486.9	190.6	145.5	152.7
80	2/2/2011	8D-03	0.436	386.9	223.1	122.2	131.9
80	2/2/2011	8D-04	0.659	428.1	210.6	134.8	142.5
80	2/2/2011	12D-01	0.467	444.4	184.4	122.9	130.2
80	2/2/2011	12D-02	-0.423	596.9	201.9	133.2	140.7
80	2/2/2011	12D-03	-0.434	488.1	200.6	141.8	147.1
80	2/2/2011	12D-04	-0.280	475.6	224.6	139.2	145.7
80	2/2/2011	NW-01	-0.450	499.4	193.1	137.6	145.1
80	2/2/2011	NW-02	-0.429	499.4	194.4	131.7	138.6
80	2/2/2011	NW-03	-0.417	433.1	198.1	134.3	141.2
80	2/2/2011	NW-04	-0.417	515.6	210.6	121.3	127.8
84	2/6/2011	4D-01	0.577	166.9	64.4	137.5	150.0
84	2/6/2011	4D-02	0.720	168.1	66.9	146.3	161.1

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
84	2/6/2011	4D-03	0.504	185.6	65.6	127.9	138.9
84	2/6/2011	4D-04	0.495	154.4	66.9	147.5	157.4
84	2/6/2011	8D-01	0.237	199.4	71.9	124.5	137.5
84	2/6/2011	8D-02	0.498	124.4	54.4	144.8	155.3
84	2/6/2011	8D-03	0.406	166.9	64.4	122.8	131.4
84	2/6/2011	8D-04	0.629	171.9	70.6	133.6	144.3
84	2/6/2011	12D-01	0.574	151.9	60.6	121.7	131.7
84	2/6/2011	12D-02	-0.404	188.1	66.9	133.6	142.5
84	2/6/2011	12D-03	-0.431	183.1	71.9	141.5	148.5
84	2/6/2011	12D-04	-0.245	143.1	58.1	139.0	147.6
84	2/6/2011	NW-01	-0.435	160.6	69.4	137.2	147.3
84	2/6/2011	NW-02	-0.427	148.1	65.6	132.7	140.1
84	2/6/2011	NW-03	-0.411	155.6	65.6	134.1	141.1
84	2/6/2011	NW-04	-0.399	158.1	63.1	120.6	130.2
88	2/10/2011	4D-01	0.564	144.4	95.6	139.7	150.0
88	2/10/2011	4D-02	0.728	171.9	85.6	150.2	162.6
88	2/10/2011	4D-03	0.517	100.6	56.9	129.3	138.2
88	2/10/2011	4D-04	0.555	174.4	90.6	148.8	158.3
88	2/10/2011	8D-01	0.331	198.1	105.6	128.1	138.4
88	2/10/2011	8D-02	0.492	183.1	79.4	146.5	156.5
88	2/10/2011	8D-03	0.440	141.9	84.4	124.4	134.3
88	2/10/2011	8D-04	0.668	133.1	95.6	133.0	144.3
88	2/10/2011	12D-01	0.609	159.4	71.9	123.9	132.6
88	2/10/2011	12D-02	-0.390	211.9	94.4	135.0	142.6
88	2/10/2011	12D-03	-0.398	153.1	69.4	142.1	149.4
88	2/10/2011	12D-04	-0.187	211.9	98.1	139.7	147.6
88	2/10/2011	NW-01	-0.450	209.4	96.9	139.6	147.8
88	2/10/2011	NW-02	-0.412	183.1	98.1	133.3	140.4
88	2/10/2011	NW-03	-0.434	164.4	74.4	137.5	143.5
88	2/10/2011	NW-04	-0.422	194.4	84.4	123.1	131.4
92	2/14/2011	4D-01	0.612	124.4	53.1	137.8	149.6
92	2/14/2011	4D-02		525.6	215.6	147.7	158.0
92	2/14/2011	4D-03	0.497	99.4	44.4	127.8	138.0
92	2/14/2011	4D-04		188.1	74.4	147.3	157.4
92	2/14/2011	8D-01	0.408	143.1	64.4	126.3	139.5
92	2/14/2011	8D-02		456.9	185.6	145.3	157.1
92	2/14/2011	8D-03	0.496	88.1	44.4	123.2	133.2

Day	Date	Box	Green Seeker Average (NDVI)	Incoming Radiation (W/m^2)	Outgoing Radiation (W/m^2)	Weight (lbs)	Weight after water (lbs)
92	2/14/2011	8D-04	0.691	99.4	44.4	133.0	144.0
92	2/14/2011	12D-01	0.653	173.1	70.6	122.0	132.2
92	2/14/2011	12D-02	-0.389	218.1	109.4	134.5	142.2
92	2/14/2011	12D-03	-0.417	155.6	60.6	142.6	149.5
92	2/14/2011	12D-04	-0.075	126.9	49.4	138.9	147.9
92	2/14/2011	NW-01	-0.445	121.9	53.1	138.6	147.4
92	2/14/2011	NW-02	-0.415	109.4	51.9	133.5	140.7
92	2/14/2011	NW-03		358.1	161.6	137.9	145.2
92	2/14/2011	NW-04		483.1	191.9	123.9	131.5

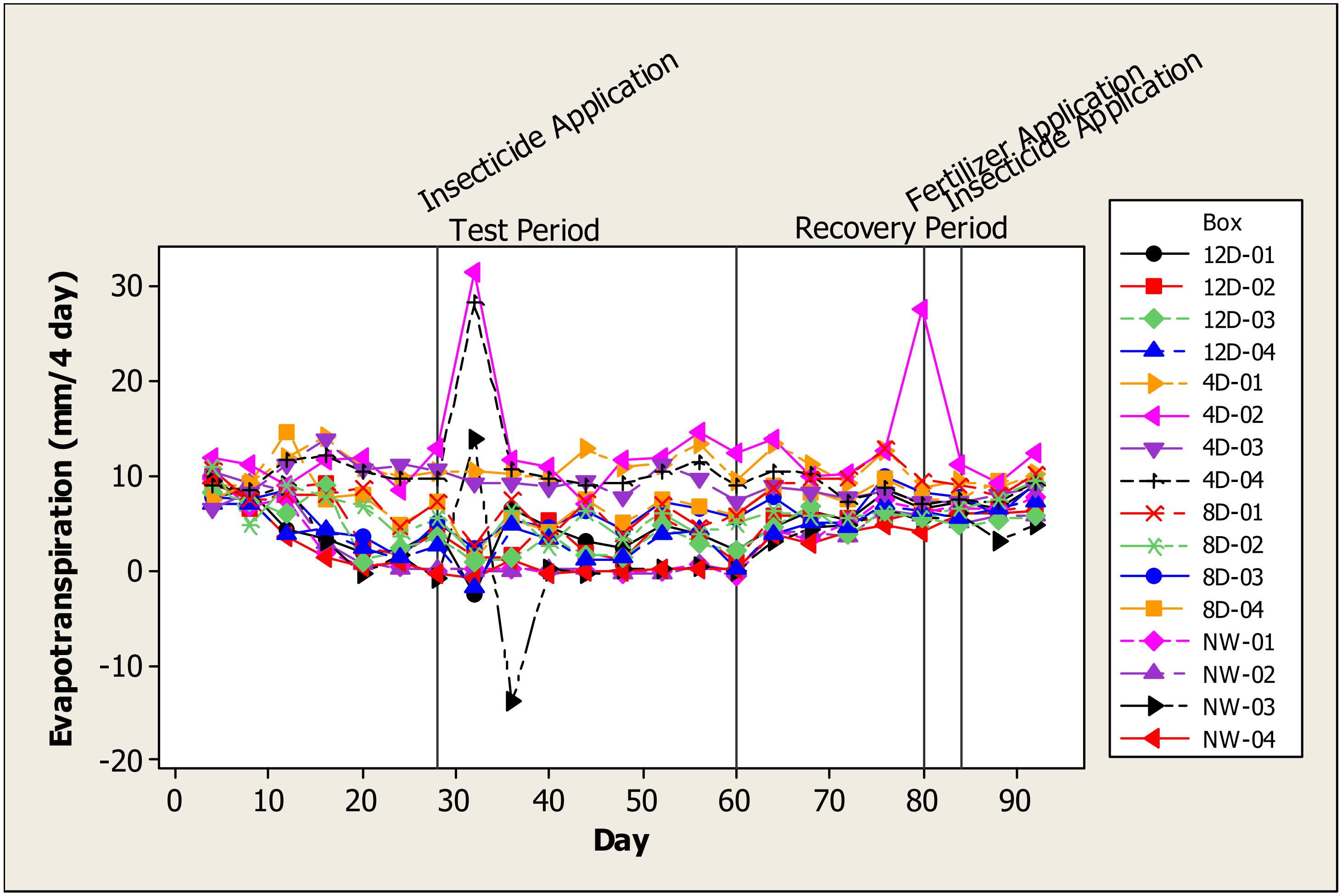
APPENDIX B

Wind Readings for Each Box in the Greenhouse

Cell	Box ID	Reading 1 mph	Reading 2 mph	Reading 3 mph	Average mph	Average Box mph
1	12D-02	1.7	0.8	2.0	1.5	
2	12D-02	2.0	1.9	1.9	1.9	1.7
3	8D-02	4.8	2.5	2.3	3.2	
4	8D-02	0.7	3.3	1.7	1.9	2.6
5	8D-01	2.3	2.7	2.6	2.5	
6	8D-01	3.1	3.0	3.5	3.2	2.9
7	NW-04	4.2	2.6	2.5	3.1	
8	NW-04	1.4	3.5	3.4	2.8	2.9
9	4D-01	3.6	2.8	3.5	3.3	
10	4D-01	2.5	2.4	2.5	2.5	2.9
11	4D-02	3.9	2.8	1.9	2.9	
12	4D-02	1.2	2.7	3.1	2.3	2.6
13	NW-01	2.3	2.5	2.0	2.3	
14	NW-01	1.8	1.7	1.9	1.8	2.0
15	NW-03	2.6	2.3	2.6	2.5	
16	NW-03	0.8	1.7	1.7	1.4	2.0
17	NW-02	2.3	1.8	2.0	2.0	
18	NW-02	2.2	1.7	2.0	2.0	2.0
19	4D-04	2.3	2.3	1.8	2.1	
20	4D-04	1.0	1.8	2.2	1.7	1.9
21	8D-03	1.9	1.3	2.0	1.7	
22	8D-03	1.7	1.4	1.6	1.6	1.7
23	12D-01	2.1	1.6	1.7	1.8	
24	12D-01	0.7	1.5	1.5	1.2	1.5
25	8D-04	1.6	1.3	1.3	1.4	
26	8D-04	1.3	1.4	1.5	1.4	1.4
27	12D-03	1.6	1.6	1.5	1.6	
28	12D-03	0.7	1.2	1.6	1.2	1.4
29	12D-04	1.1	1.3	1.4	1.3	
30	12D-04	1.3	1.2	1.0	1.2	1.2
31	4D-03	1.2	1.4	1.2	1.3	
32	4D-03	0.7	1.3	1.3	1.1	1.2

APPENDIX C

Average Four Day Evapotranspiration per Box over a 0-60 Days Test Period, and a 60-92 Days Recovery period in a Greenhouse Study (4D = Irrigate Every 4 Days, 8D = Irrigate Every 8 Days, 12D = Irrigate Every 12 Days, NW = No Days Irrigated).



VITA

Mary Kathryn (Katie) Beitz

Candidate for the Degree of

Master of Science

Thesis: STAND PERSISTENCE OF ‘PRESTIGE’ BUFFALOGRASS (*BOUTELOUA DACTYLOIDES*) [SYNONYM *BUCHLOE DACTYLOIDES*] GROWN UNDER SIMULATED GREEN ROOF CONDITIONS DURING SUMMER IN OKLAHOMA

Major Field: Environmental Science

Biographical:

Education:

Completed the requirements for the Master of Science in Environmental Science at Oklahoma State University, Stillwater, Oklahoma in July, 2011.

Completed the requirements for the Bachelor of Science in Landscape Architecture at Oklahoma State University, Stillwater, Oklahoma in May, 2004.

Experience:

August 2009 to June 2011: Research and Teaching Assistant, Oklahoma State University. Areas of research included developing turbidity/TSS relationship for stormwater runoff from construction and developments sites, working in EPA Region 3 sampling sediment cores in reservoirs, water sample filtering and testing, preparing and conducting land survey labs and tutoring and advising students in the lab.

September 2008 to September 2009: Landscape Specialist, Covenant Theological Seminary. Designed campus building landscapes, coordinated maintenance crews, maintained grounds.

June 2004 to September 2007: Landscape Architect, Poynter Landscape and Construction. Designed residential landscape plans, prepared presentations for clients using hand and computer graphics and Quick Books estimating, surveyed clients property and prepared the base map.