8-11-2012

The Effect of Slope and Media Depth on Growth Performance of Sedum Species in a Green Roof System in Mississippi's Sub-Tropical Climate

Sinan Kordon

The effect of slope and media depth on growth performance of sedum species in a green roof system in Mississippi's sub-tropical climate

By

Sinan Kordon

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Landscape Architecture
in Landscape Architecture
in the Department of Landscape Architecture

Mississippi State, Mississippi

August 2012

The effect of slope and media depth on growth performance of sedum species in a green roof system in Mississippi's sub-tropical climate

By

Sinan Kordon

Approved:

Timothy J. Schauwecker Associate Professor of Landscape Architecture (Director)	Sadik Artunc Professor and Department Head of Landscape Architecture (Committee Member)
Jason Walker Associate Professor of Landscape Architecture (Committee Member)	Michael Seymour Associate Professor of Landscape Architecture (Graduate Coordinator)
George M. Hopper Dean of the College of Agriculture and Life Sciences	

Name: Sinan Kordon

Date of Degree: August 11, 2012

Institution: Mississippi State University

Major Field: Landscape Architecture

Major Professor: Timothy J. Schauwecker

Title of Study: The effect of slope and media depth on growth performance of sedum species in a green roof system in Mississippi's sub-tropical climate

Pages in Study: 87

Candidate for Degree of Master of Landscape Architecture

In recent years, green roofs have become an accepted solution in ecological urban design to mitigate the impacts of impervious surfaces (Berghage, Beattie, Jarrett, Thuring, & Razaei, 2009). An experimental research project was conducted at the Mississippi Agriculture and Forestry Experiment Station (MAFES) Green Infrastructure Research Area at South Farm of Mississippi State University to determine how medium depth and slope gradient on rooftops affect plant cover and survival. Plant cover was monitored monthly by photographing the experimental green roof platforms. Photoshop and AutoCAD software programs were employed to digitize and to calculate plant cover from the images. All recorded data was analyzed with Analysis of Variance (ANOVA) tests. It was determined that the effects of medium depth and slope are statistically significant on plant cover and survival.

DEDICATION

Firstly, I would like to dedicate this thesis to my parents who have been a great resource of motivation and inspiration. They have remained positive and supportive from my first day in the United States. They have also motivated me to push through the final days of thesis writing. My family, you have given me the ability to do things I never thought possible. You all make me want to be a better person and you have helped me to realize my potential. I would also like to dedicate this to my friends who have motivated and helped me with such strong attachment that I feel like I have another set of parents. Finally, I would like to dedicate this work to all my professors who helped to establish my knowledge and my background.

ACKNOWLEDGEMENTS

I would first like to thank Dr. Tim Schauwecker, Sadik Artunc and Jason Walker for being on my committee and for letting me use essential green roof platforms for data collection during this study. Thanks to my friend Onder Tor for helping me to establish a camera mounting frame and to organize my data set for statistical analysis and thanks to my friends Bryce Frost and Burak Malik Kaya for helping me photograph the green roof plants. I would also like to thank to my friend Adef Othan for her support during this study. Special thanks to my professor Sadik Artunc who had started advising me before I came to the United States. He has provided advice throughout my student tenure at both Ohio University and Mississippi State University. He has provided great support and motivation even outside the bounds of class or thesis-related topics.

I also would like to thank Soprema, Colbond USA, ERTH products, and Bell Building Supply for their donations for this study.

Finally, again I would like to thank Dr. Tim Schauwecker, my thesis director, for being supportive, encouraging, and understanding throughout my classwork and thesis writing process. I never could have accomplished this study without all this help.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 Introduction

This study includes the subjects of imperviousness, green roof technology and the effects of medium depth and slope on plant growth performance on rooftops. The purpose of this study was to document how medium depth and rooftop slope affect plant survival and growth performance. This study will also assist in the identification of *Sedum* species that perform well for vegetated roofs in Mississippi's humid sub-tropical climate.

1.2 Background

The research on green roofs started when imperviousness became a serious problem for urban watersheds and other water-related environments (J. G. Lee & Heaney, 2003). Past research has indicated that impervious surfaces highly change the topography, increase volume of runoff, and contaminate water resources because of pollutant wash off (Getter, Rowe, & Andresen, 2007; Rushton, 2001). Furthermore, increasing urban heat island (UHI) effect as well as decreasing air quality and biodiversity have become more common problems in developing cities as a result of rapid increase of impervious surfaces (Susca, Gaffin, & Dell'Osso, 2011).

The impacts of impervious surfaces have demonstrated the need for sustainable stormwater management strategies for urban runoff control (Jia, Lu, Yu, & Chen, 2012).

Conventional runoff control strategies have been developed based on collecting and removing runoff as quickly as possible into piped systems. In contrast, low impact development (LID) methods have been developed to control rainfall where it falls to balance pre-development runoff conditions (Holman-Dodds, Bradley, & Potter, 2003).

Research analyzing the effectiveness of LID approaches has been conducted to mitigate the impacts of impervious surfaces employing Best Management Practices (BMP) such as detention and retention ponds, infiltration basins, porous pavement, bioretention swales and green roofs (Clary et al., 2011; EPA, 2000).

Green roof systems have been developed as a BMP providing greater ecological and sustainable benefits than conventional stormwater management strategies (Berghage et al., 2009). Green roofs provide improved wildlife habitat, better air quality, and more aesthetic stormwater control (Dvorak & Volder, 2010; Oberndorfer et al., 2007).

Researchers have performed various studies to show the direct correlation between vegetation performance and green roof service quality (Dunnett, Nagase, Booth, et al., 2008). There has been expanding research on green roofs for the evaluation of the factors that affect plant cover and survival in order to provide more successful green roof establishment. This issue has not been covered in the literature for Mississippi's humid sub-tropical climate.

1.3 Goals and Objectives

This study was conducted to evaluate the effect of medium depth and slope on plant survival and growth performance in Mississippi's humid sub-tropical climate. Additionally, this study will help with choosing the proper *Sedum* species for future vegetated roof implementations in the southeastern United States by comparing the coverage and survival values of four *Sedum* species: *Sedum album, Sedum spurium 'John Creech', Sedum sexangulare* and *Sedum rupeste 'Angelina'*.

1.4 Site Description

This study was conducted at the Mississippi Agriculture and Forestry Experiment Station (MAFES) Green Infrastructure Research Plots located at the south farm of Mississippi State University in Starkville, MS (33^0 N latitude and 88^0 W longitudes). The research site is approximately 325 feet above sea level (Anders, 2012).

Mississippi's climate is a humid subtropical climate type that exhibits mostly mild winters, long and hot summers, and no repeating wet or dry seasons. Mississippi's climate can cause harsh drought conditions for weeks or months in the summer. Wind and precipitation provide humid, semitropical conditions. The annual temperature ranges from 60^0 F to 67^0 between northern and coastal counties. Temperatures exceed 90^0 F in harsh summer conditions, which are seen usually in July or August. The mean annual statewide precipitation is approximately 56 inches (National Climatic Data Center, 2005).

1.5 Organization of This Study

This paper is organized into a Literature Review chapter, a Materials and Methods chapter, a Results chapter, and a Discussion and Conclusions chapter. The Literature Review introduces current research related to the impacts of imperviousness, green roofs, and the effects of medium depth and slope on vegetation performance. The Materials and Methods chapter explains the experimental process, data collection period, and statistical procedures used for data analysis. The Results chapter introduces the findings of this study and summarizes the results of statistical analysis. The Discussion and Conclusions chapter represents the results of this study comparing and discussing the findings of related studies, and provides recommendations for future studies.

CHAPTER II

LITERATURE REVIEW

After the industrial revolution, increasing population started to result in rapidly developing cities that have numerous effects on natural and urban environments (Abdul-Wahab & Al-Arairni, 2004; Paul & Meyer, 2001). This rapid urbanization has caused an increase in impervious surfaces that have replaced forests, agricultural fields, and urban green spaces (Getter & Rowe, 2006). Impervious surfaces such as parking lots, roadways and roof tops (Rushton, 2001; Wollheim, Pellerin, Vörösmarty, & Hopkinson, 2005) prevent the penetration of rainfall and snowmelt into the soil (Moglen & Kim, 2007) and increase stormwater runoff volume and velocity (Holman-Dodds et al., 2003) while decreasing biodiversity because of pollution of water resources (D. B. Booth, Hartley, & Jackson, 2002).

The concern about imperviousness increased as it started to become an increasing problem for urban watersheds and water-related environments (J. G. Lee & Heaney, 2003). Past research has indicated that impervious surfaces increase the amount of nutrients, metals, pesticides and other pollutants in streams (Paul & Meyer, 2001). Furthermore, urban heat island (UHI) effect and air pollution problems have increased as another serious impact of increasing impervious surfaces (S. Lee & French, 2009).

While traditional stormwater control has been based on collecting and removing excess runoff immediately into pipes, detention basins or streams, low impact development (LID) practices have been developed to control rainfall where it falls to balance pre-development water features (Holman-Dodds et al., 2003). Several studies have been conducted to analyze the effectiveness of various LID practices employing BMPs with the goal of mitigating the impacts of impervious surfaces (EPA, 2000). Green roof technology (the incorporation of plants into rooftop design) has been developed as a BMP to provide more ecological solution for runoff volume reduction (Berghage et al., 2009).

Researchers have started to investigate the social and environmental benefits of green roofs (Alcazar, 2004). The result of these studies show that the use of green roofs improves the energy efficiency of buildings by reducing heating and cooling costs (Alcazar, 2004), improves wildlife habitat and air quality (Oberndorfer et al., 2007), mitigates noise and air pollution and the urban heat island effect (Getter & Rowe, 2008a). In addition, green roof establishment provides more aesthetic stormwater control (Dvorak & Volder, 2010) and numerous business opportunities for the members of the nursery, landscaping, and irrigation system industries (Getter & Rowe, 2006).

Green roof systems are mainly categorized into two types: intensive and extensive (Berndtsson, Bengtsson, & Jinno, 2009; Bliss, Neufeld, & Ries, 2009). Both extensive and intensive green roofs provide a range of ecological, environmental, and aesthetic benefits as well as recreational space (Grant, Engleback, & Nicholson, 2003). Intensive green roofs can be designed as gardens (Berndtsson et al., 2009) with planting medium usually deeper than 15.2 cm (Getter & Rowe, 2006) and can provide more diverse plant communities and landscape elements such as large trees, shrubs, and paved walkways (Bliss et al., 2009). In contrast, extensive green roofs, due to shallower substrate depth usually less than15.2 cm (Getter & Rowe, 2006), provide limited plant diversity such as succulents, herbs, grasses and mosses (Berndtsson et al., 2009).

Another important purpose of green roof studies is to show the close relationship between vegetation performance and the benefits of green roofs. Because green roofs are living structures, the performance of plants plays a crucial role on green roof functions (Dunnett, Nagase, & Hallam, 2008). In another study, it was mentioned that green roof vegetation directly changed hydrological performance of green roofs by affecting interception and evaporation of rainfall as well as storage capacity and transpiration of water (Dunnett, Nagase, Booth, et al., 2008). In addition, the vegetation of green roofs reflects less incoming solar radiation compared to conventional roofs. Due to the high albedo of green roof plants, vegetation decreases surface temperature and heat flux on rooftops which can reduce urban heat island effect in urban environments (Scherba, Sailor, Rosenstiel, & Wamser, 2011).

Past research has shown that factors such as substrate depth and slope gradient influence vegetation performance. Dunnett, Nagase and Hallam (2008) monitored the performance of 15 species over the course of 5 years at 100 mm and 200 mm substrate depth. They found that 14 out of 15 species kept at least 50% of their original numbers at 200 mm substrate depth while 8 out of 15 species maintained 50% of their original numbers at 100 mm depth (Dunnett, Nagase, & Hallam, 2008). Getter and Rowe (2008a) analyzed the effects of 4 cm, 7 cm, and 10 cm media depths on the establishment of 12 *Sedum* species on extensive green roof platforms. Substrate depths of 7 cm and 10 cm highly increased plant growth and cover compared to 4 cm substrate depth. While 10 species did exhibit a significant growth at a 7 cm depth, only 6 species exhibited a significant growth at 4 cm depth. The species at 10 cm performed similarly with the species at 7 cm depth (Getter & Rowe, 2008a). In another study, plants showed higher survival at 5 cm and 7 cm substrate depths compared to species at a 2.5 cm depth (Durhman, Rowe, & Rugh, 2007).

Other green roof studies have focused on the effects of slope ratio on rooftops. Generally, slope factor was studied to evaluate rainfall retention performance of green roofs but not plant growth performance. Thus, research seeking the effects of slope on vegetation performance is relatively rare. However, there are studies examining the relationship between slope ratio and moisture retention which directly influences plant cover and survival (Bousselot, Klett, & Koski, 2011).

These studies showed that a 2% slope exhibited doubled retention capacity compared to a 14 % slope (Berndtsson, 2010). Similarly, it was found that the average retention was a minimum of 76.4 % at a 25% slope and a maximum of 85.6% at a 2% slope (Getter et al., 2007). According to another study, a 2% slope provided a significantly higher retention rate of 70.7% compared to 65.9 % retention at a 6.5 % slope (VanWoert, Rowe, Andresen, Rugh, Fernandez, et al., 2005). It has been mentioned that plants on sloped roofs are more vulnerable to harsh environmental conditions than those on flat roofs because of more solar exposure and less soil moisture (Kuper, 2010). Overall results have shown that deeper medium and shallower slope provide better conditions for vegetation because of higher moisture retention, greater root protection (Durhman et al., 2007), and more nutrients in deeper soils (Olly, Bates, Sadler, & Mackay, 2011).

CHAPTER III

MATERIALS AND METHODS

3.1 Green roof platform set up

This study was conducted with twelve existing green roof platforms constructed by Robert M. Anders, a graduate student, and Jason Walker, Associate Professor, at Mississippi State University. In order to study plant growth performance, these twelve green roof platforms simulating typical extensive green roofs were examined at the Mississippi Agriculture and Forestry Experiment Station (MAFES) Green Infrastructure Research Area at south farm of Mississippi State University in the spring and summer of 2011.

Wood-frame platforms were constructed with 4' x 4' treated pine lumber frames and 8" side walls. Side walls and the interior of green roof platforms were covered with SBS modified bitumen waterproof membrane. All platforms were equipped with *Colbond EnkaRetain & Drain 321* integrated moisture retention mats, and platforms with 33% slope were equipped with *Colbond EnkaMat 7010* soil stabilization layers (Figure 3.1). Each green roof platform was designed with an evacuation gap on the low side and equipped with a gutter system to discharge water from the roof.

Figure 3.1 Wood-frame platforms constructed with treated pine lumber having 4' × 4' internal dimensions and 8" side walls. All green roof platforms were equipped with waterproofing membrane, moisture retention mat and platforms with 33% slope were equipped with a soil stabilizer layer.

Two different substrate depths (4" and 6") and slopes (2% and 33%) were used for the study. Each combination of slope and depth was replicated three times. All roof platforms were named under four different testing model groups; Group (6"-2%), Group (4"-2%), Group (6"-33%), and Group (4"-33) (Table 3.1).

All platforms were placed facing south for maximum solar exposure (Getter & Rowe, 2008a). Six green roof platforms were filled to a 4" depth, and the remaining six platforms were filled to a 6" depth by using ERTH Hydrocks Lightweight Soil Media-Extensive, an engineered green roof growing media. This soil material consisted of 50-80% Hydrocks Rotary Kiln Expanded Clay with component sizes ranging from 3/8 to

3/16 inch. The soil mix also includes 15% nutrient grade compost prepared using a mixture of peanut shells and biosolids, and USGS sand (Anders, 2012).

Table 3.1 All green roof platforms were categorized in four different testing model groups.

Group (6”-2%)	R-1 (6"-2%)	Green roofs with 6 inches medium depth and 2% slope.
	R-2 (6"-2%)	
	R-3 (6"-2%)	
Group (4”-2%)	R-4 (4"- 2%)	Green roofs with 4 inches medium depth and 2% slope.
	R-5 (4"- 2%)	
	R-6 (4"- 2%)	
Group (6”-3%)	R-7 (6"-33%)	Green roofs with 6 inches medium depth and 33% slope.
	R-8 (6"-33%)	
	R-9 (6"-33%)	
Group (4”-3%)	R-10 (4"-33%)	Green roofs with 4 inches medium depth and 33% slope.
	R-11 (4"-33%)	
	R-12 (4"-33%)	

All green roof platforms were equipped with a grid point frame divided into 64 planting points with eight nylon strings vertically and eight nylon strings horizontally spaced 3” from edges and 6” from next planting line (Figure 3.2). Platforms were planted with four *Sedum* species; *Sedum album, Sedum spurium ‘John Creech’, Sedum sexangulare* and *Sedum rupestre ‘Angelina’* (Figure 3.3). *Sedum album,* and *Sedum sexangulare* were identified as being appropriate for green roof applications in the Southeastern United States (Moran, 2004). *Sedum rupestre ‘Angelina’* and *Sedum spurium ‘John Creech’* were preferred depending on recommendations of Nashville Natives (Anders, 2012). Plants were provided from Nashville Natives in Fairview, TN in plug trays with the dimensions of 1.5” x 1.5” x 2.5” for each plug.

Figure 3.2 All green roof platforms were equipped with a grid point frame indicating the planting locations.

Figure 3.3 The four types of *Sedum* species used for this study.

These measurements describe the soil volume of each plug. The vegetation portion of each plug exhibited various plant covers ranging from approximately 6 sq. inch to 9 sq. inch. Plants were planted at the locations identified by the grid point frame (Figure 3.4). Additional irrigation was not applied during the study with the exception of one date in August. All green roof platforms were watered on 31 August, 2011 until a constant volume of runoff exited from downspout for one minute. The purpose of watering the plants was to provide supplemental irrigation for dealing with hot and dry summer conditions.

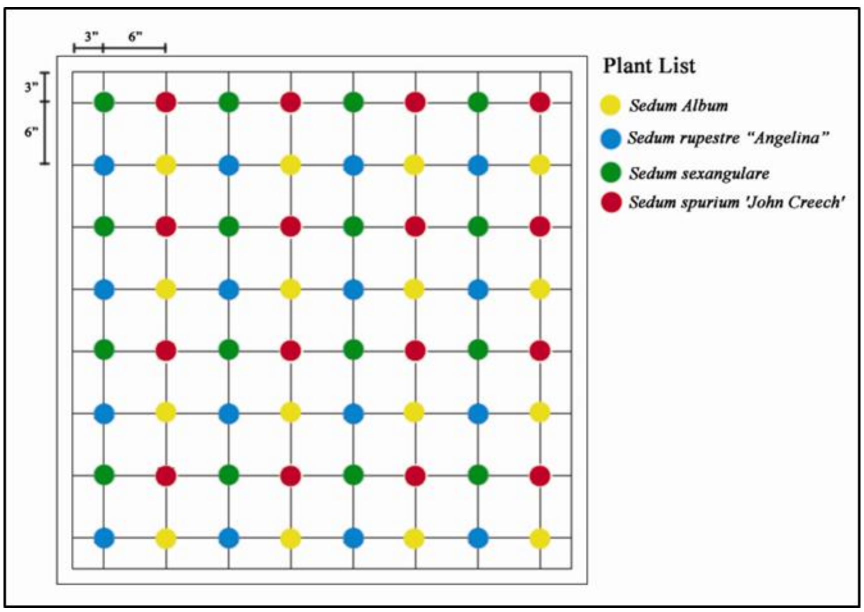

Figure 3.4 Unscaled simulation displaying plant locations and order on the platforms.

3.2 Measurement of Plant Growth

Vegetation cover measurement techniques that have been used for previous research were evaluated to provide accurate measurements. It was noted that traditional plant cover measurement techniques are usually based on visual estimations that may result in high variation and that have bias ranging from 13% to 90% (Luscier, Thompson, Wilson, Gorham, & Dragut, 2006). Past research has shown that image-based techniques using Geographical Information Systems (GIS) or similar digitizing software provide more reliable, unbiased estimations for plant cover measurements (Benavides & Sastre-De Jesús, 2009; D. T. Booth, Cox, Meikle, & Zuuring, 2008). In addition, photographing techniques provide easy classifying and archiving opportunities as well as a better visual understanding for the public (Crimmins & Crimmins, 2008).

Because conventional plant cover measurements may require more observers and time in the field and may exhibit more variation due to different observers, photographing and image-based digitizing methods were used for this study to achieve faster and more accurate plant cover calculations.

In order to evaluate the plant growth performance, another wood frame with 4’×4’ internal dimensions was constructed as a base for a camera mounting stand. The base of the camera mounting frame was divided into 64 points with the same method used for the grid planting frame to point the actual planting locations (Figure 3.5).

A Canon SX-130IS 12.1- megapixel digital camera, with an image stabilizer lens, was integrated on the top of the frame with a 1 sq. ft. base. The base was placed to an elevation of 6’3” above from the center of the vegetation level. To minimize shadows in the images, photos were captured at afternoon hours before the sunset or a paperboard was used (D. T. Booth et al., 2008). To provide images with higher quality, the camera was set up to self-timer mode to capture ten photos consecutively. This step was repeated for each green roof platform. A number tag was put on each roof platform to label the plots during photographing.

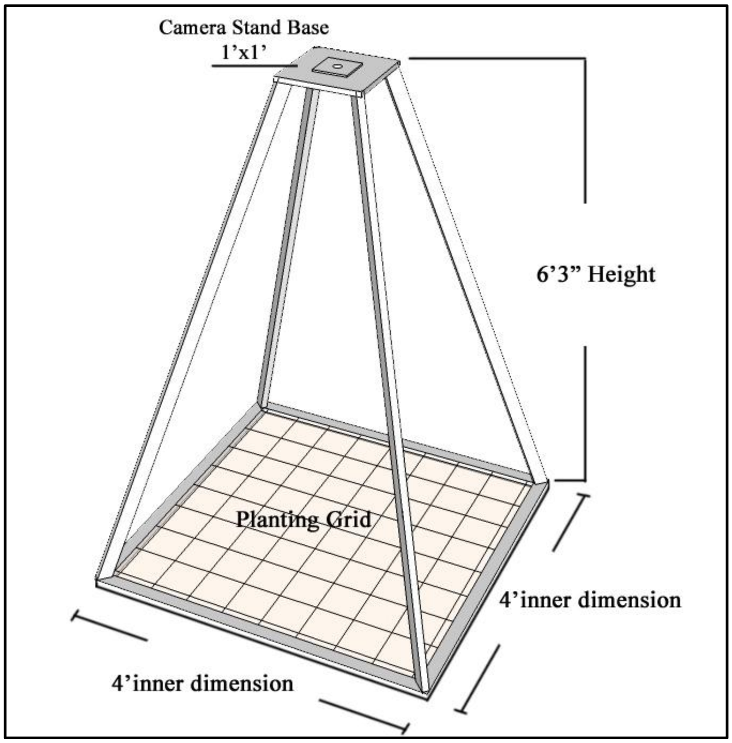

Figure 3.5 Unscaled simulation of camera mounting frame.

Plant growth performance was monitored once per month during the 5 months from July to November, 2011. After photographing, the images were transferred to a computer for the selection of images with the highest quality. Photoshop software was used to crop unwanted spaces in the images. Then, AutoCAD software was employed to resize the images to their actual sizes. Plant coverage was digitized by outlining plant covers in images with closed end polygons (Figure 3.6). Drawing and area calculating tools of AutoCAD software were employed to measure the plant covers by species using 1:1 scaled images.

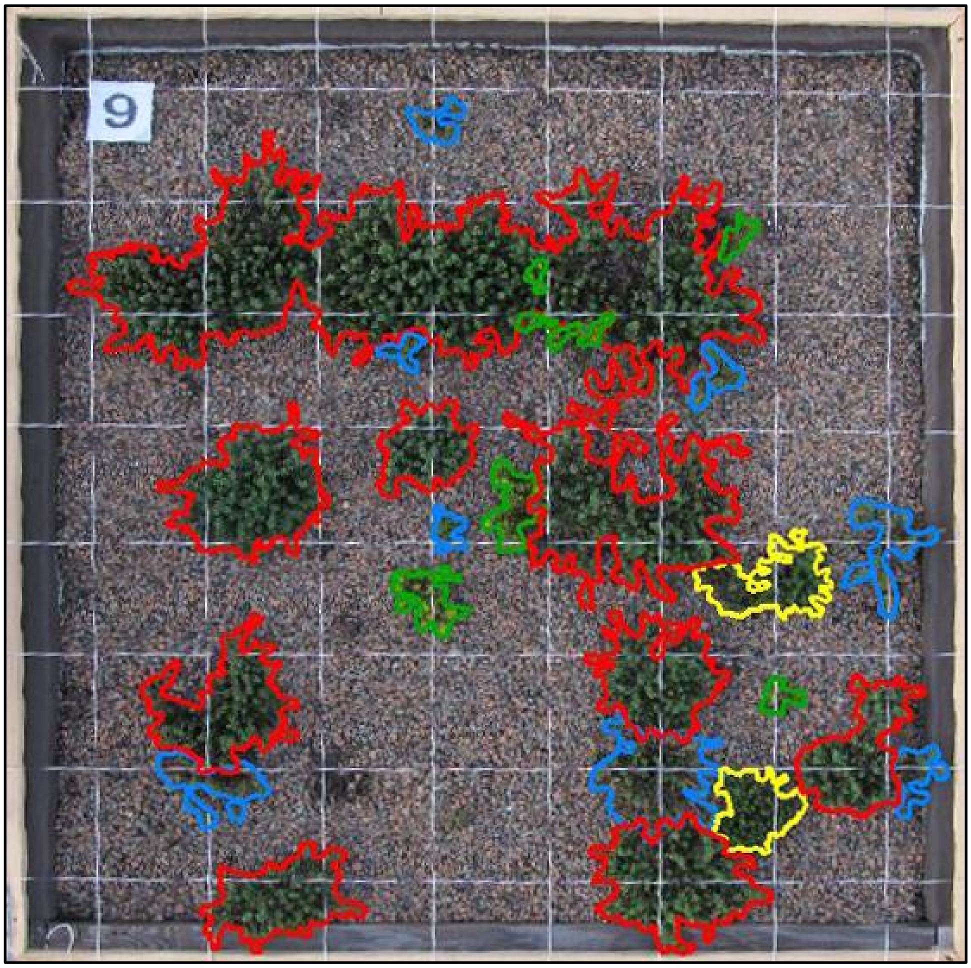

Figure 3.6 Plant cover, digitized by outlining plant covers in images with closed end polygons. Each color represents a different plant species.

The whole area of the platforms (16 sq. ft.) was constant for each green roof platform. This green roof surface area represents a 100% coverage including vegetation cover and bare substrate surface. To calculate relative plant cover by species for each green roof platform the following equation was used:

$$RPC = (MPC) / (GRSA) \times 100 \tag{3.1}$$

Where;

RPC = Relative Plant Cover

MPC = Measured Plant Cover

GRSA = Green Roof Surface Area (16 sq ft.)

3.3 Plant Survival

To calculate plant survival, images of all green roof platforms were compared to a simulation image displaying the planting locations and order (Figure 3.5). Each planting location identified by the grid frame was checked to determine whether species were still present or not. Based on grid points, the numbers of the plants by species were counted, and the percent plant survival by species for each platform group was calculated with the following equation:

$$PPS = (NPS) / 48 \times 100 \quad (3.2)$$

Where;

PPS = Percent Plant Survival

NPS = Number of the Plants by Species

48 = Plants on each platform group

The percentage of plant survival for all platforms was calculated with the following equation:

$$TPPS = (TPNS) / 192 \times 100 \quad (3.3)$$

Where;

TPPS = Total Percent Plant Survival

TNPS = Total Number of the Plants by Species

192 = Plants on all platforms

3.4 Statistical Methods

All collected data were analyzed with single factor and two factor Analysis of Variances (ANOVA) tests (α=0.05) by using SAS software to compare responses of plant cover and survival to independent variables of 4”- 6” medium depths and 2% - 33% slopes.

3.4.1 Analysis of Plant Growth Performance

Plant growth performance was evaluated with the analysis of mean percent plant cover for each green roof platform group. Data for plant growth performance were analyzed using ANOVA test to evaluate the main effects and possible interactions among the independent variables measurement date (MD), substrate depth (SD), and slope ratio (SR) on the dependent variable plant growth performance.

3.4.1.1 The Comparison of Measurement Dates

First of all, one way ANOVA test was employed to evaluate the effects of five measurement dates on plant growth performance using model (3.4).

$$\text{Plant Cover} = \mu + MD + \varepsilon \qquad (3.4)$$

Where:

μ = Mean

MD = Measurement Date

ε = Error

3.4.1.2 The Comparison of Substrate Depth and Slope Ratio

In order to document the effects of the independent variables medium depth and slope ratio on the dependent variable plant cover, a total of 60 samples demonstrating the percent plant cover for each platform over the five months, were analyzed (Table 4.1). The analyzed independent variables were substrate depths of 4" and 6" and slopes of 2% and 33%. Each combination of medium depth and slope includes three replications. Thus, a complete 2×2 factorial experiment with 3 replications per combination was conducted. A two-factor ANOVA general linear model procedure was performed using the full model (3.5) to analyze the main effects and interaction factors on the plant growth performance individually.

$$PPC = \mu + SD + SR + SD*SR + \varepsilon \qquad (3.5)$$

Where:

PPC = Percentage of Plant Coverage

μ = Mean

SD = Substrate depth (inch)

SR = Slope Ratio (%)

* = Indicates a test for interaction between/and among the variables.

ε = Error

This ANOVA result indicated that the two-factor interaction was not statistically significant. Therefore, the reduced models (3.6) and (3.7) were employed separately to explore the effects of substrate depth and slope ratio, respectively.

3.4.1.3 Analysis of Substrate Depth

Firstly, substrate depths of 4" and 6" were analyzed by employing the single factor ANOVA test with reduced model (3.6). Slopes of 2% and 33% were compared for each medium depth of 4" and 6" separately.

$$PPC = \mu + SD + \varepsilon \quad (3.6)$$

Where:

μ = Mean

SD = Substrate depth (inch)

ε = Error

3.4.1.4 Analysis of Slope Ratio

Slopes of 4” and 6” were analyzed with single factor ANOVA test by using reduced model (3.7). Medium depths of 4” and 6” were compared for each slope ratio of 2% and 33% separately.

$$PPC = \mu + SR + \varepsilon \quad (3.7)$$

Where:

PPC = Percentage of Plant Coverage

μ = Mean

SR = Slope Ratio (%)

ε = Error

3.4.1.5 Analysis of Platform Groups of (6”-2%) versus (4’-33%) and (6”-33%) versus (4”-2%)

Since the dependent variables medium depth and slope were completely different for the combination of platform groups of (6”-2%) and (4”-33%) or (6”-33%) and (4”-2%), the platform groups were paired. The paired platform groups of (6”-2%) versus (4”-33%) and (6”-33%) versus (4”-2%) were analyzed individually to evaluate the differences in terms of percent plant cover.

A single factor ANOVA test was employed for the analysis of platform groups by using the full model (3.8).

$$PPC = \mu + PG + \varepsilon \qquad (3.8)$$

Where:

PPC = Percentage of Plant Coverage

μ = Mean

PG = Platform Group

ε = Error

3.4.2 Analysis of Plant Survival

Survival of plant species was analyzed by calculating the mean percentage of survival on the platforms at the end of the first full growing season in November, 2011. The independent variables were platform groups (PG): (6”-2%), (4”-2%), (6”-33%), and (4”-33%) and plant species (PS): *Sedum album, Sedum rupestre ‘Angelina’, Sedum sexangulare,* and *Sedum spurium ‘John Creech’.*

A complete 4×4 factorial experiment with three replications per combination was conducted to evaluate percent plant survival on each green roof platform. Each platform group includes three green roof platforms. Therefore, a total of 48 samples were analyzed.

A two-factor ANOVA general linear model procedure was performed using the full model (3.9) to analyze main effects and interaction factors on the variable percent plant survival individually.

$$PPS = \mu + PG + PS + PG*PS + \varepsilon \qquad (3.9)$$

Where:

PPS = Percentage of Plant Survival

μ = Mean

PG = Platform Group

PS = Plant Species

* = Indicates a test for the interaction between/and among the variables.

ε = Error

This ANOVA test indicated that the two-factor interaction was not statistically significant at the 0.05 significance level. Therefore, the reduced models (3.10) and (3.11) were employed separately to explore the effects of the independent variables plant species and platform groups on the dependent variable percent plant survival.

3.4.2.1 Comparison of Plant Species

Plant species were analyzed using reduced model (3.10. Four types of platform groups were compared for each plant species separately.

$$PPS = \mu + PS + \varepsilon \qquad (3.10)$$

Where;

PPS = Percentage of Plant Species

μ = Mean

PS = Plant Species

ε = Error

3.4.2.2 Comparison of Platform Groups

Platform groups were analyzed using reduced model (3.11). Four plant species of *Sedum album, Sedum rupestre 'Angelina', Sedum sexangulare,* and *Sedum spurium 'John Creech'* were compared for each platform groups separately.

$$PPS = \mu + PG + \varepsilon \qquad (3.11)$$

Where;

PPS	= Percentage of Plant Species
μ	= Mean
PG	= Platform Groups
ε	= Error

CHAPTER IV

RESULTS

4.1 Introduction

This chapter includes the results and the assessments of analysis to evaluate the effects of measurement date, substrate depth, slope ratio, and plant species on plant cover and survival. These results include various numeric data, tables and graphics that allow better understanding for green roof developers to design and implement a successful green roof in Mississippi's climate.

The analysis of plant cover was conducted based on the data set in the Table 4.1, demonstrating the mean percentages of plant covers over the five months. Although measurement date did not have a significant effect on plant cover, other factors such as substrate depth, slope, and plant species all had a significant effect on total plant cover.

Table 4.1 Mean Percentage of Plant Cover on Each Green Roof Platform Over the Five Months

	7/30/2011		8/30/2011		9/30/2011		10/30/2011		11/30/2011	
	2% Slope	**33% Slope**	**2% Slope**	**33% Slope**	**2% Slope**	**33% Slope**	**2% Slope**	**33% Slope**	**2% Slope**	**33% Slope**
4"	20.775	13.263	12.050	9.688	16.838	14.481	36.494	26.556	44.044	27.375
Medium	26.813	11.656	18.850	10.063	26.494	18.769	45.575	28.056	50.656	34.550
Depth	13.500	11.719	9.475	8.794	13.006	12.656	22.950	19.331	32.881	22.794
6"	48.775	32.481	48.875	23.731	60.613	27.625	69.688	36.038	70.050	36.838
Medium	61.688	39.525	55.225	27.200	64.106	34.056	75.975	44.238	72.431	42.631
Depth	32.569	23.188	29.163	18.981	41.500	26.300	58.231	35.444	59.525	37.400

4.2 Results of Plant Cover

4.2.1 Measurement Dates

Based on the single factor ANOVA test, the difference between measurement dates was not statistically significant. The mean percentage of plant cover was 28% in July, the beginning of the data collection period. It is notable that plants exhibited an initial decrease in cover in August and subsequent increase in the following months. The least mean percentage of plant cover 22.67% was monitored in August and other mean percent plant cover values were 29.7% for September and 41.55% for October. Plant species reached the greatest plant cover of 44.26% in November, 2011 at the end of the 5 months period (Figure 4.1).

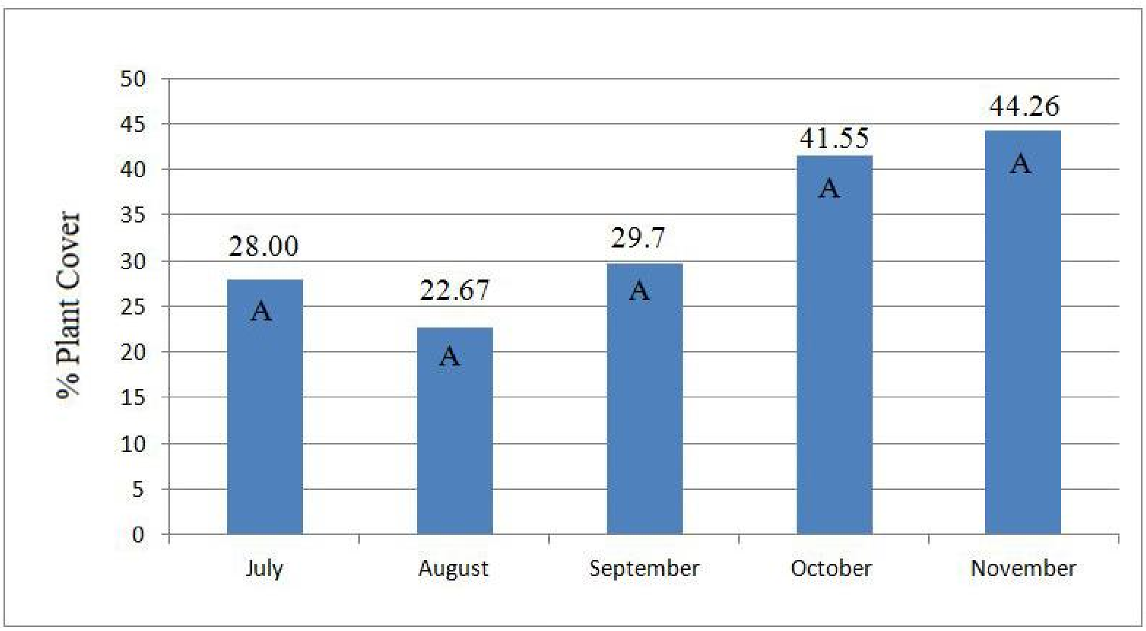

Figure 4.1 Mean percentage of plant cover over the five months. Bars with the same letter are not statistically different. (LSD= 25.467, P-value = 0.351, α= 0.05).

The supplemental irrigation helped the plants for dealing with unusual hot and dry weather conditions. By the end of the August, plants started expanding their covers on all green roof platforms. Test results show that hot and dry climatic conditions can be critical on plant cover and survival.

4.2.2 Substrate Depth versus Slope Ratio

The general linear module procedure showed that the significance level for the interaction between substrate depth and slope ratio was not statistically different. Therefore, the independent variables substrate depth and slope ratio were analyzed separately by using one-way ANOVA test.

4.2.2.1 4” Substrate Depth

The independent variable 4” substrate depth was analyzed and two different slopes 2% and 33% were compared. Based on a one-way ANOVA test, 2% slope and 33% slope did not exhibit a significant difference in plant cover at a 4” substrate depth. Figure 4.2 indicates that platforms with 2% slope provided greater plant cover than those with 33% slope. The mean percent plant cover values were 26.02 % and 17.98 % for the platforms with 2% slope and 33% slope, respectively.

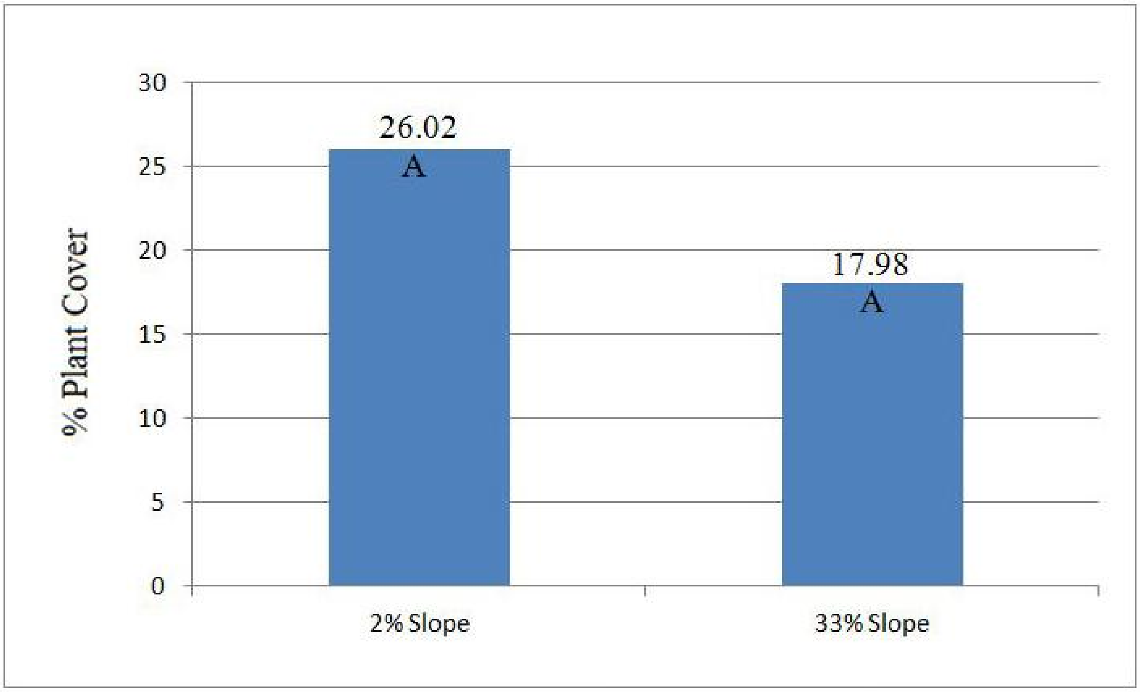

Figure 4.2 Mean percentage of plant cover at 4" medium depth. Bars with the same letter are not statistically different. (LSD= 15.09, P-value = 0.254, α=0.05)

4.2.2.2 6" Substrate Depth

As opposed to 4" substrate depth, two different slopes 2% and 33% provided significantly different plant cover values at 6" substrate depth. Platforms with 2% slope exhibited significantly greater plant cover than the platforms with 33% slope. The mean percent plant cover values were 56.56% and 32.37% for 2% slope and 33% slope respectively (Figure 4.3). All plant species responded similarly to different substrate depths. Shallower slope provided better conditions at two different substrate depths (4" and 6") for plant cover.

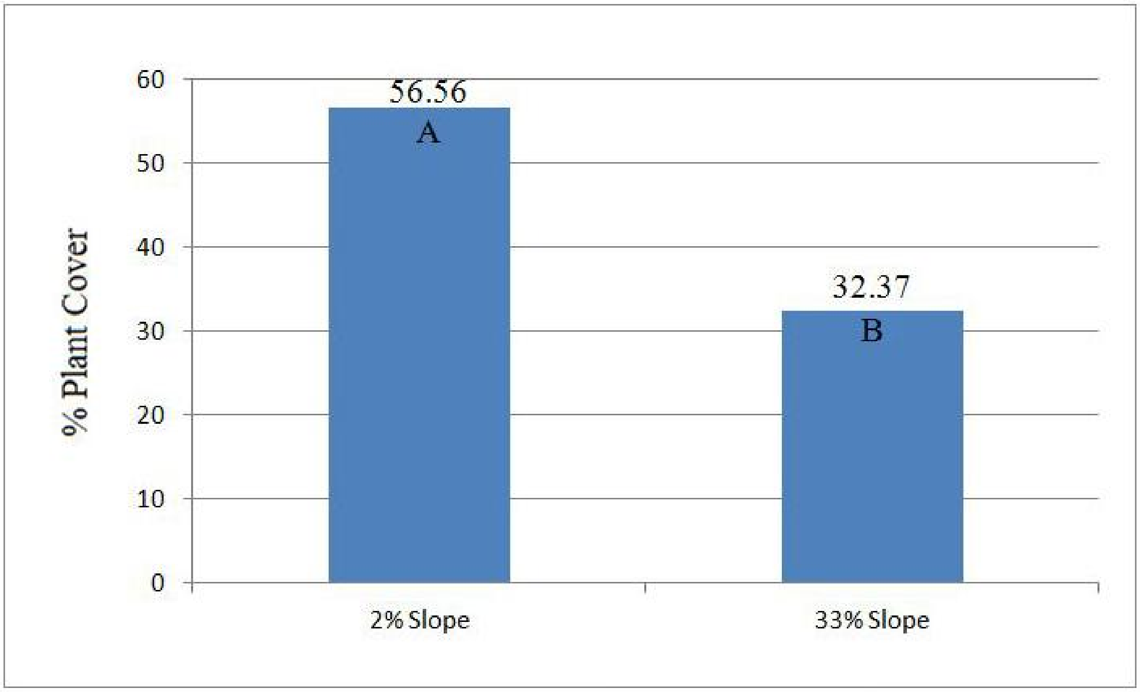

Figure 4.3 Mean percentage of plant cover at 6” medium depth. Bars with different letters are statistically different. (LSD= 13.121, P-value = 0.002, α=0.05).

4.2.2.3 2% Slope

The independent variable 2% slope was analyzed. The effects of 4” and 6” medium depths on plant cover were compared. Test results demonstrated that medium depths of 4” and 6” provided significantly different plant cover at 2% slope. Plants on the platforms with 6” medium depth exhibited statistically higher plant cover than those with 4” medium depth (Figure 4.4). The mean percent plant cover values were 56.56% and 26.02% for 6” and 4” substrate depths respectively.

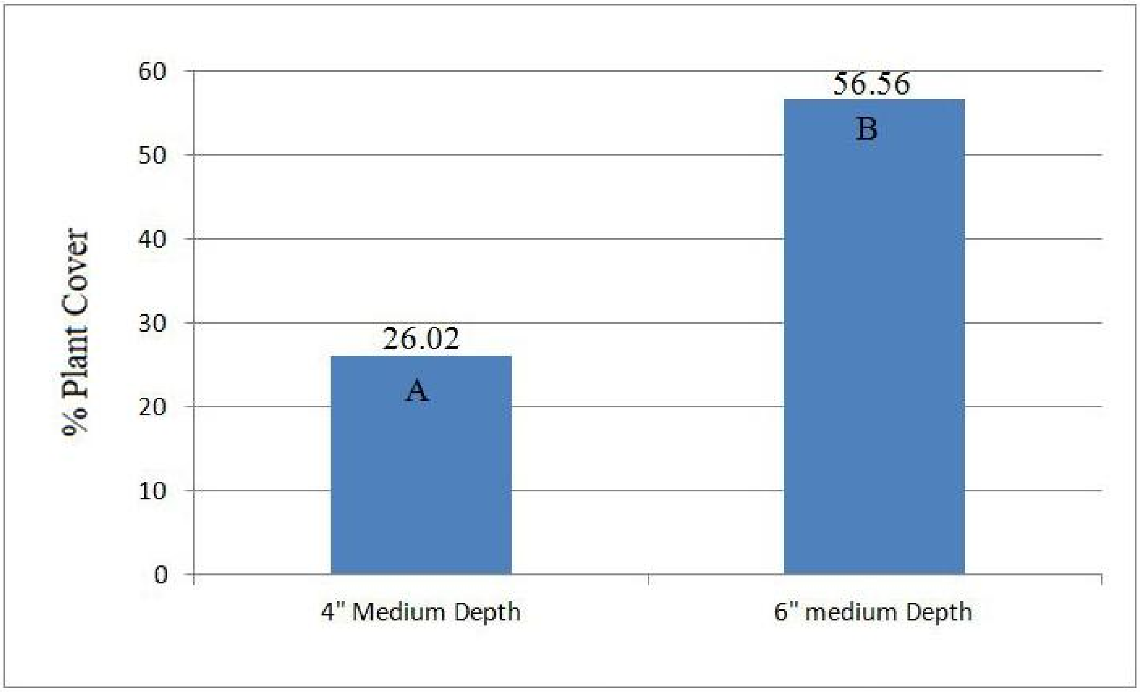

Figure 4.4 Mean percentage of plant cover at 2% slope. Bars with different letters are statistically different. (LSD= 16.861, P-value = 0.003, α=0.05).

4.2.2.4 33% Slope

Similar to 2% slope, platforms with 4” and 6” substrate depths exhibited significant difference in cover at a 33% slope. Platforms with 6” medium depth provided approximately two times higher plant cover than those with 4” medium depth at 33% slope. The mean percent plant cover values were 32.37% and 17.98% for 6” and 4” medium depths, respectively (Figure 4.5).

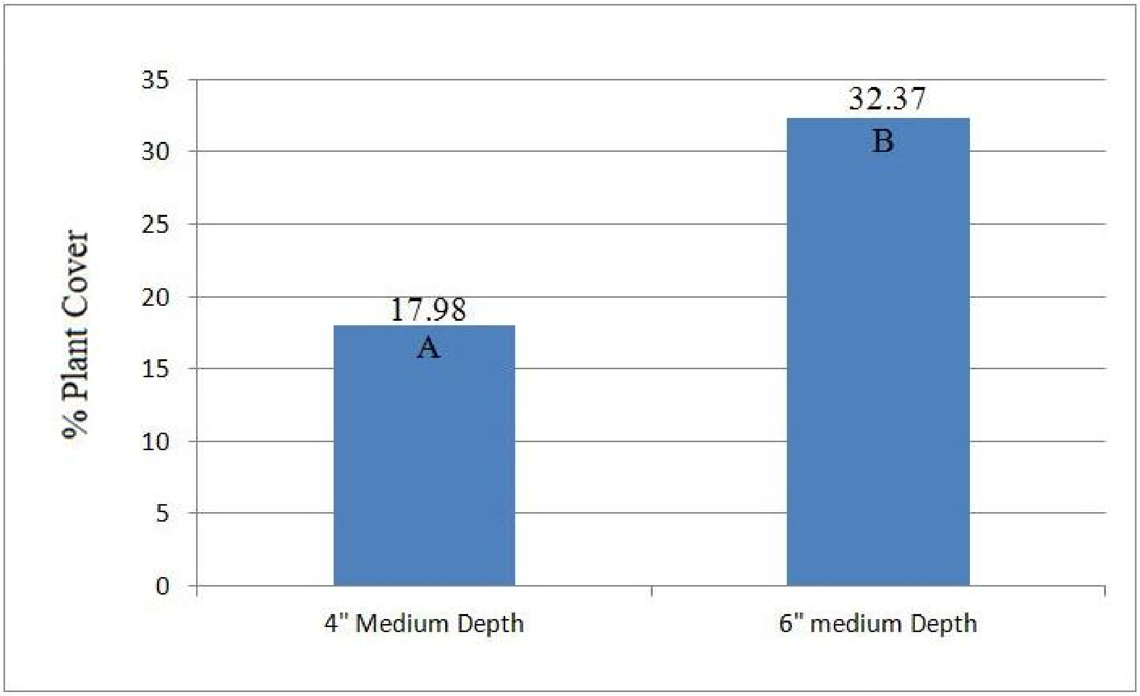

Figure 4.5 Mean percentage of plant cover at 33% slope. Bars with different letters are statistically different. (LSD= 10.762, P-value = 0.015, α=0.05).

4.2.3 Analysis of Platform Groups

4.2.3.1 (6”-2%) versus (4”-33%) and (6”-33%) versus (4”-2%)

The comparison results indicated that the (6”-2%) and (4”-33%) platform groups demonstrated a significant difference in plant cover. While platform group (6”-2%) produced 56.56 % mean plant cover, platform group (4”-33%) produced only 17.98% plant cover (Figure 4.6).

On the other hand, although (6”-33%) and (4”-2%) platforms provided different plant cover values, this difference was not significant. The mean percentages of plant cover values were 32.37% and 26.02% for (6”-33%) and (4”-2%) platform groups, respectively (Figure 4.7).

Test results show that plant species used in this study (*Sedum album, Sedum spurium 'John Creech', Sedum sexangulare,* and *Sedum rupestre 'Angelina'*) are more sensitive to different substrate depths and more tolerant to different slopes. Different substrate depths caused significant changes in plant cover at all slopes. However, different slopes did not exhibit a significant difference in plant cover at 4" medium depth (Figure 4.2). It is notable that substrate depth is more critical on plant cover than slope for these plant species in Mississippi's humid sub-tropical climate.

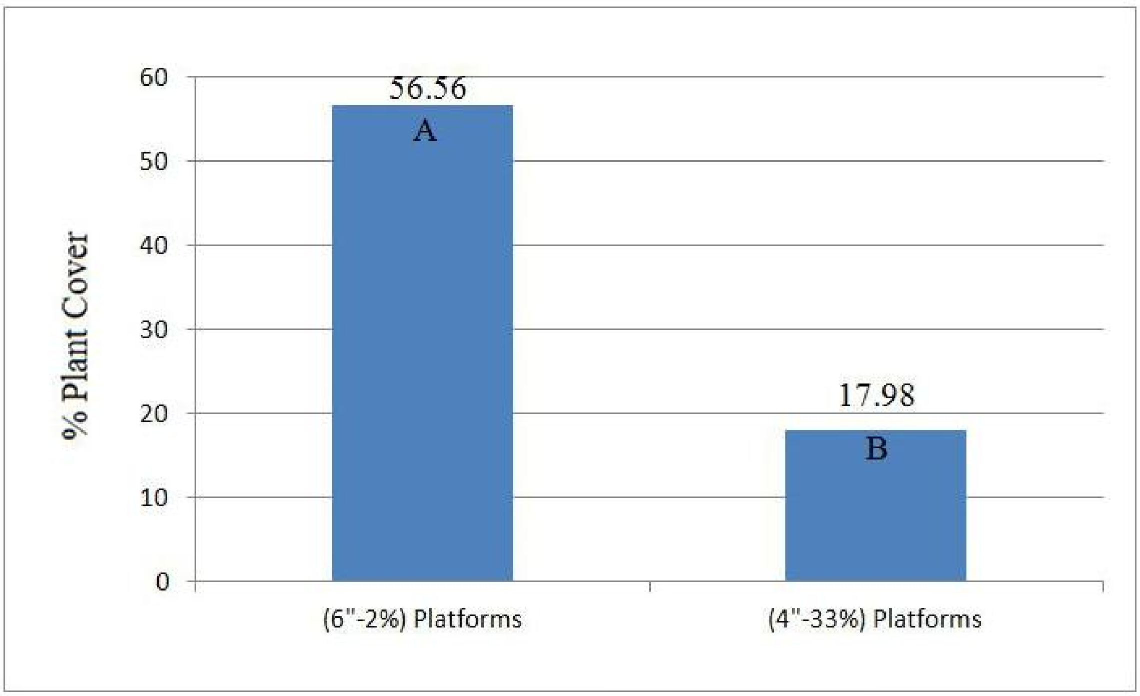

Figure 4.6 Mean percentage of plant cover on the platform groups with different independent variables. Bars with different letters are statistically different. (LSD= 13. 985, P-value < 0.001, α=0.05).

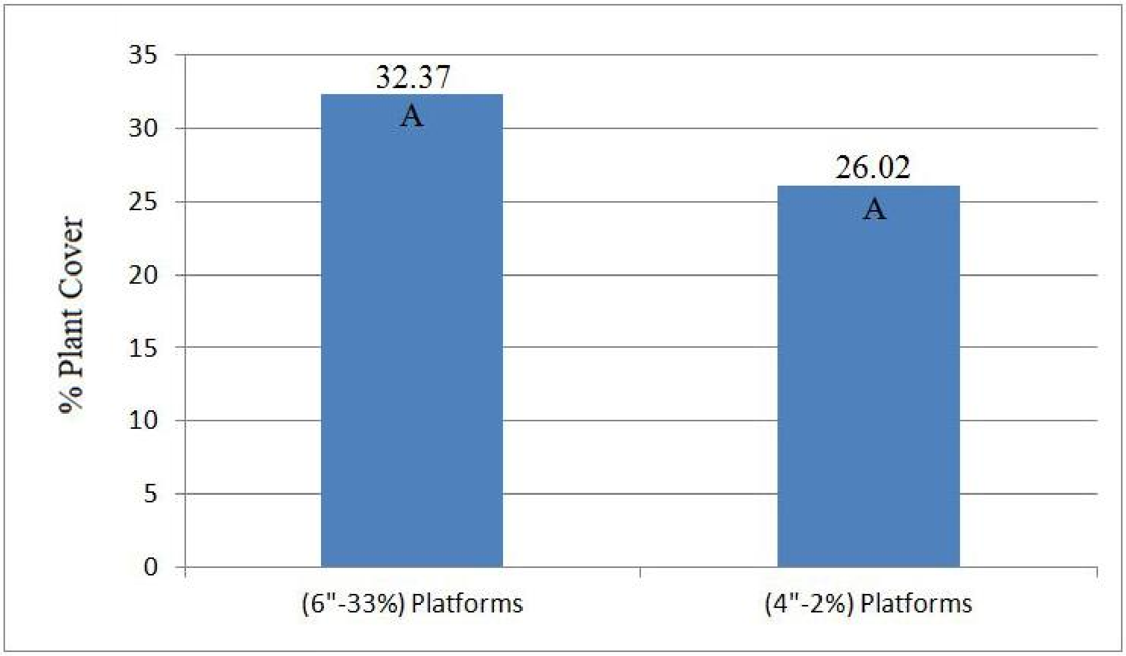

Figure 4.7 Mean percentage of plant coverage on the platform groups with different independent variables. Bars with the same letter are not statistically different. (LSD= 14.301, P-value = 0.335, α=0.05).

4.2.4 Analysis of Plant Species

After planting, the initial vegetation cover for each plant was various ranging from 6 sq. inch to 9 sq. inch, approximately 5.2 % of total coverage. Plant species exhibited a significant difference in mean percent plant cover over the 5 months. The mean percentages of plant covers by species were 28.42%, 2.5%, 1.61%, and 0.69% for *Sedum album, Sedum spurium 'John Creech', Sedum sexangulare,and Sedum rupestre 'Angelina',* respectively (Figure 4.8). *Sedum album* provided the highest plant cover on all platform groups, and *Sedum spurium 'John Creech'* was the species that performed the second highest plant cover. *Sedum rupestre 'Angelina'* and *Sedum sexangulare* exhibited the lowest plant covers on all platforms over the five months. Not surprisingly, all plant species performed their highest plant covers values on (6”-2%) platforms and the lowest plant covers values on (4”-33%) platforms. *Sedum sexangulare* was completely dead on (4”-33%). In addition, *Sedum rupestre ‘Angelina’ and Sedum spurium ‘John Creech’* were almost non-existent on this platform group.

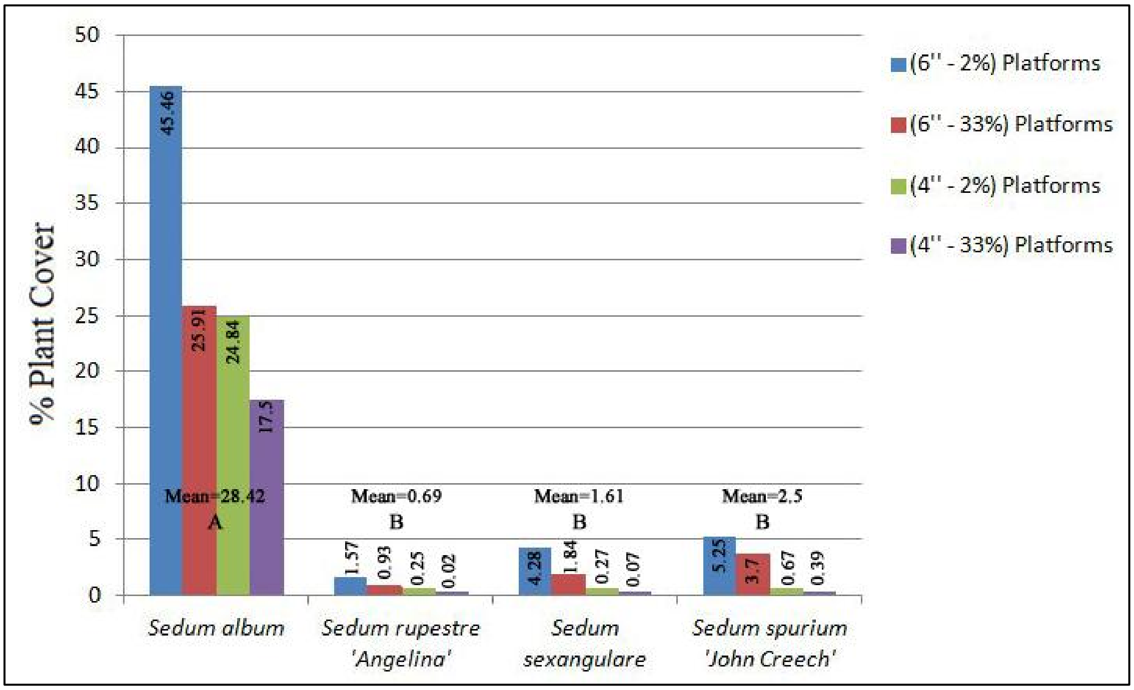

Figure 4.8 Mean percentages of plant covers by species on the platform groups. Groups with different letters are statistically different. (LSD= 9.521, P-value < 0.01, α=0.05).

The overall test results showed that *Sedum album* provided significantly higher vegetation cover compared to other *Sedum* species. 6” substrate depth and 2% slope were the other factors that provided greater plant cover compared to 4” substrate depth and 33% slope. All plant species were more sensitive to medium depth compared to slope. Thus medium depth played a more critical role on total plant cover than slope.

4.3 Results of Plant Survival

The analysis of plant survival was conducted based on Table 4.2 demonstrating the percentage of plant survival. Based on the ANOVA test, interaction between platform groups and plant species was not statistically different. Therefore, the independent variables plant species and platform groups were analyzed respectively to determine the percentage of plant survival by species and by platform groups.

4.3.1 The Analysis of Plant Species

4.3.1.1 *Sedum album*

A total of 192 *Sedum album* were planted on experimental green roof platforms. At the end of the first full growing season, it was recognized that only (6"-2%) and (4"-33%) platform groups exhibited a significant difference in survival for *Sedum album*. The mean percent plant survival values of *Sedum album* among the platform groups were 91.67%, 79.17%, 81.25%, and 58.33% for (6"-2%), (4"-2%), (6"-33%), and (4"-33%) platform groups, respectively (Figure 4.9). *Sedum album* maintained at least 58.33% of its original numbers on (4"-33%) platforms. *Sedum album* exhibited the highest survival value with 91.67% on (6"-2%) platforms.

Table 4.2 Percentage of Plant Survival for Each Plant species on Each Platform Group

Platform Groups	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
Group (6"-2%)	93.75	31.25	31.25	56.25
	93.75	18.75	62.5	62.5
	87.5	0	6.25	31.25
Group (4"-2%)	87.5	0	0	12.5
	93.75	12.5	6.25	31.25
	56.25	18.75	0	12.5
Group (6"-33%)	87.5	12.5	6.25	25
	87.5	0	18.75	37.5
	68.75	25	18.75	43.75
Group (4"-33%)	56.25	0	0	6.25
	68.75	6.25	0	0
	50	0	0	0

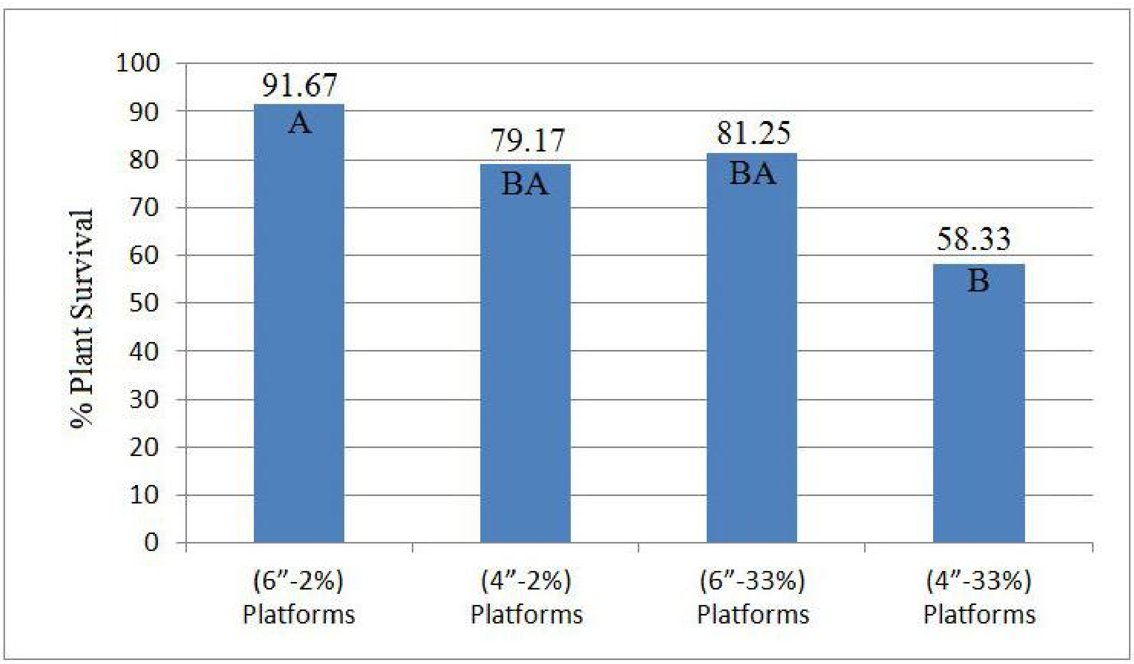

Figure 4.9 Mean percentage of plant survival for *Sedum album* among the platform groups. Bars with the same letter are not statistically different. (LSD= 23.536, P-value = 0.06, α=0.05).

4.3.1.2 *Sedum rupestre 'Angelina'*

Although the mean percent plant survival of *Sedum rupestre 'Angelina'* differed among different platform groups, this difference was not significant. The mean percent plant survival values of *Sedum rupestre 'Angelina'* were 16.66%, 10.41%, 12.5%, and 2.08% for (6"-2%), (4"-2%), (6"-33%), and (4"-33%) platform groups, respectively (Figure 4.10). *Sedum rupestre 'Angelina'* maintained at most 16.66 % of its original number on (6"-2%) platform group. Shallower medium and higher slope caused approximately 84 % decrease to 2.08% on (4"-33%) platforms. Figure 4.10 also demonstrates that *Sedum rupestre 'Angelina'* is more sensitive to slope than to medium depth.

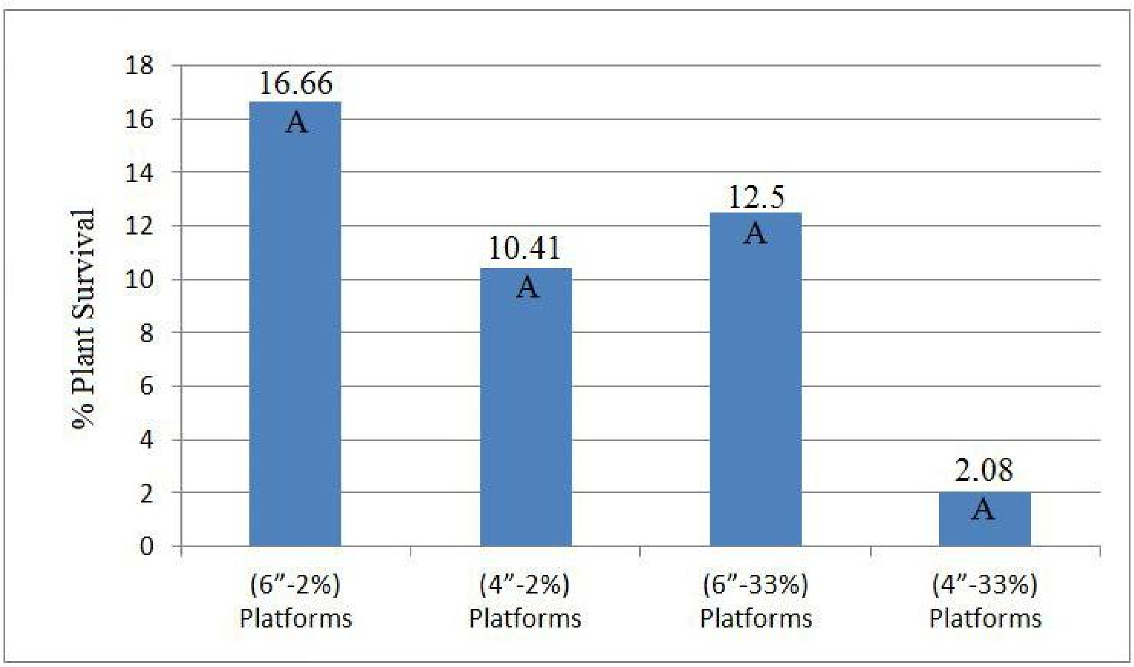

Figure 4.10 Mean percentage of plant survival for *Sedum rupestre 'Angelina'* among the platform groups. Bars with the same letter are not statistically different. (LSD=21.215, P-value = 0.487, α=0.05).

4.3.1.3 *Sedum sexangulare*

The separation result of plant survival for *Sedum sexangulare* was not significant between (4”-2%), (6”-33%), and (4”-33%) platform groups and between (6”-2%) and (6”-33%) platform groups. However (6”-2%) platforms exhibited significantly higher survival values than (4”-2%) and (4”-33%) platform groups. The mean percent survival values for *Sedum sexangulare* were 33.3%, 14.58%, 2.08%, and 0% for (6”-2%), (6”-33%), (4”-2%), and (4”-33%) platform groups, respectively (Figure 4.11). Although higher slope was effective on survival percentages, shallower medium significantly decreased the percent survival and played a more critical role than slope for *Sedum sexangulare*.

4.3.1.4 *Sedum spurium ‘John Creech’*

The mean percent plant survival values of *Sedum spurium ‘John Creech’* among different platform groups were 50%, 18.75, 35.41%, and 2.08 for (6”-2%), (4”-2%), (6”-33%), and (4”-33%) platform groups, respectively (Figure 4.12). The difference among these percentages was statistically significant between (6”-2%) and (4”-2%) platform groups and between (6”-2%) and (4”-33%) platform groups. It was also different between (6”-33%) and (4”-33) platform groups but not between (6”-2%) and (6”-33%) platform groups and between (4”-2%) and (6”-33%). While *Sedum spurium ‘John Creech’* maintained 50% of its original number on (6”-2%) platforms, it maintained only 2.08% of its original number on (4”-33%) platform group. Shallower substrate and higher slope caused a 95.8% significant decrease in survival. It was also understood that medium depth plays a more critical role than slope on plant survival of *Sedum spurium ‘John Creech’*.

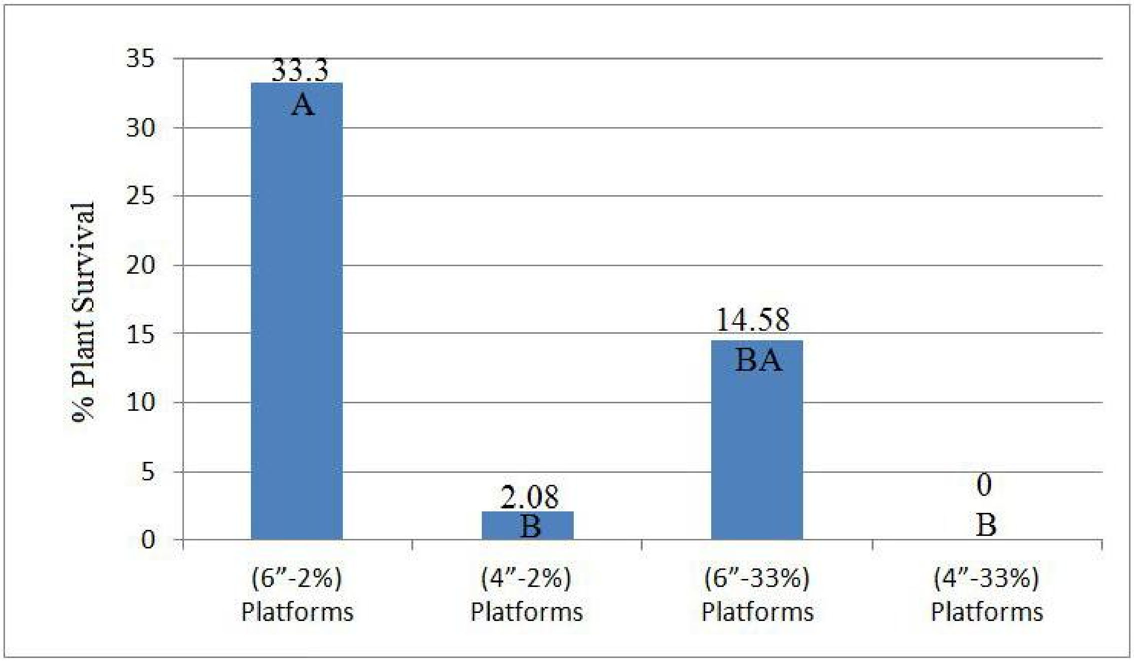

Figure 4.11 Mean percentage of plant survival for *Sedum sexangulare* among the platform groups. Bars with the same letter are not statistically different. (LSD=27.598, P-value = 0.079, α=0.05).

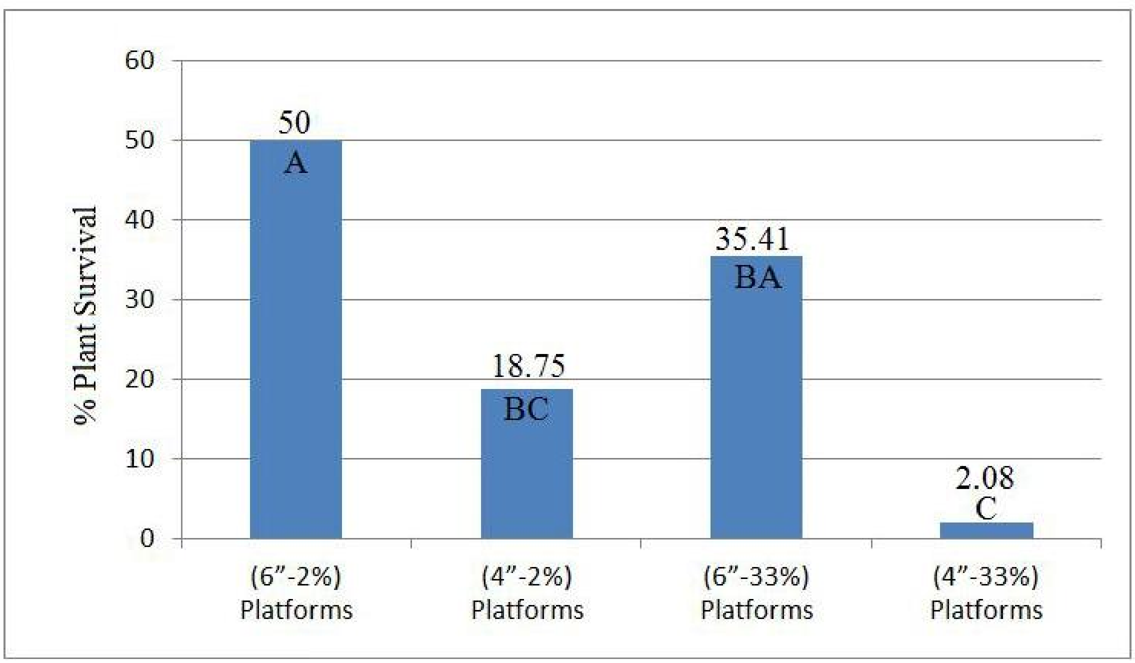

Figure 4.12 Mean percentage of plant survival for *Sedum spurium ‘John Creech’* among the platform groups. Bars with the same letter are not statistically different. (LSD=20.941, P-value = 0.003, α=0.05).

4.3.2 Analysis of Platform Groups

4.3.2.1 Platform group (6”-2%)

Plant survival values by species were compared for each green roof platform group. Platform group (6”-2%) exhibited a significant difference in plant survival among plant species. The mean percent survival values were 91.67%, 50%, 33.3%, 16.67% for *Sedum album, Sedum spurium ‘John Creech’, Sedum sexangulare,* and *Sedum rupestre ‘Angelina’,* respectively (Figure 4.13). *Sedum album* exhibited significantly higher plant survival compared to the other species. *Sedum spurium ‘John Creech’, Sedum sexangulare, and Sedum rupestre ‘Angelina’* did not exhibit a difference in plant survival.

4.3.2.2 Platform group (4”-2%)

Plant species *Sedum album, Sedum spurium ‘John Creech’, Sedum sexangulare,* and *Sedum rupestre ‘Angelina’* produced 79.17%, 18.75%, 2.08%, and 10.42% plant survival, respectively (Figure 4.14). The difference between *Sedum spurium ‘John Creech’, Sedum sexangulare,* and *Sedum rupestre ‘Angelina’* was not significant but *Sedum album* exhibited significantly higher survival than these three species. All plant species decreased in numbers on (4”-2%) platforms, compared to (6”-2%) platforms. The most significant decrease occurred for *Sedum sexangulare*. While it provided 33.3% survival on (6”-2%) platform group, it provided only 2.08% survival on (4”-2%) platform group.

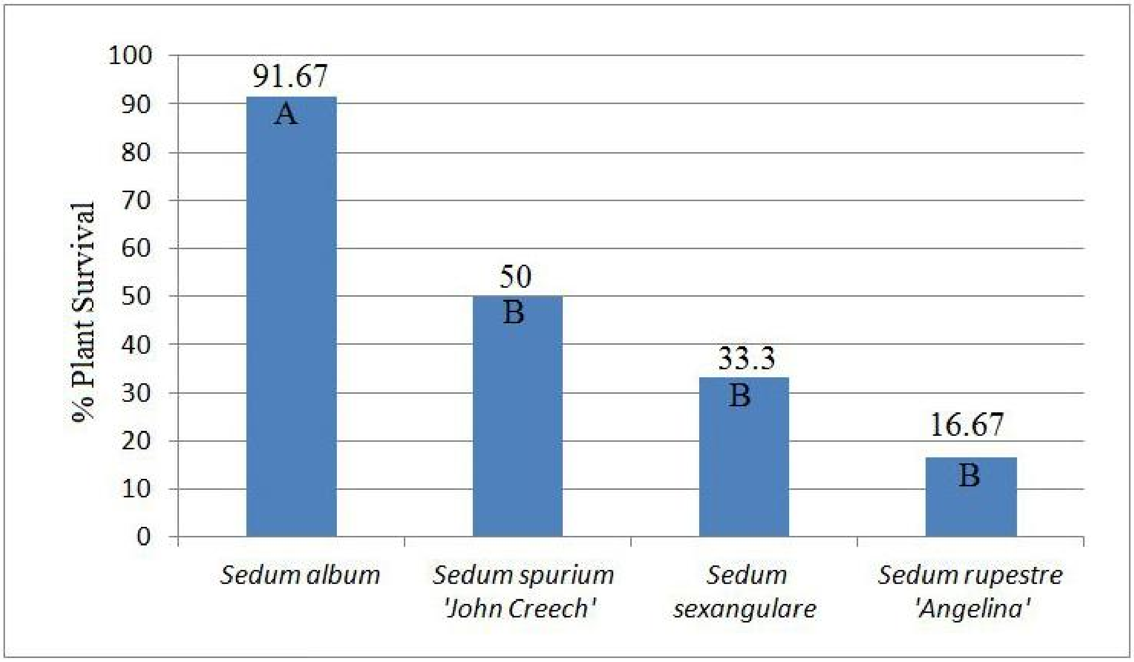

Figure 4.13 Mean percentage of plant survival on (6”-2%) platforms. Bars with the same letter are not statistically different. (LSD=34.309, P-value = 0.005, α= 0.05).

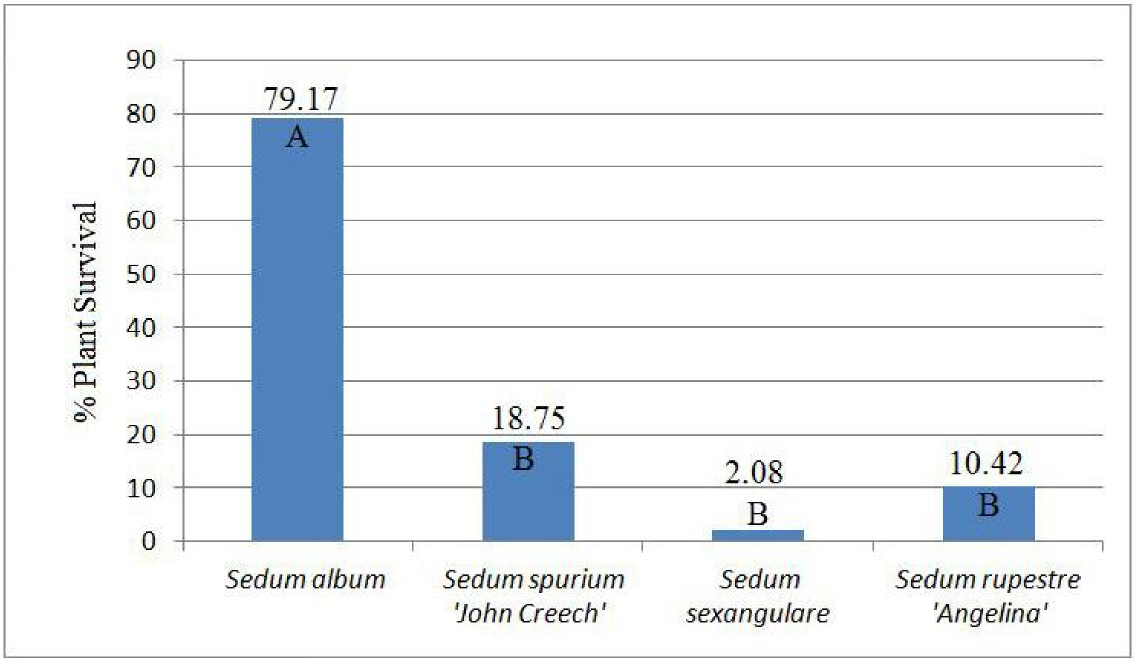

Figure 4.14 Mean percentage of plant survival on (4"-2%) platforms. Bars with the same letter are not statistically different. (LSD=23.536, P-value < 0.001, α=0.05).

4.3.2.3 Platform group (6"-33%)

Platform group (6"-33%) exhibited a significantly different plant survival for different *Sedum* species. *Sedum album, Sedum spurium 'John Creech', Sedum sexangulare,* and *Sedum rupestre 'Angelina'* performed 81.25%, 35.41%, 14.58%, and 12.5% plant survival, respectively (Figure 4.15). The percent survival values of *Sedum album* and *Sedum spurium 'John Creech'* were different from any other species. However, *Sedum sexangulare, and Sedum rupestre 'Angelina'* did not differ between each other. *Sedum album* exhibited significantly higher plant survival compared to the other three species on (6"-33%) platforms.

4.3.2.4 Platform group (4”-33%)

All plant species exhibited their lowest percent survival values on (4”-33%) platforms compared to other platform groups. Plant species *Sedum album, Sedum spurium ‘John Creech’, Sedum sexangulare,* and *Sedum rupestre ‘Angelina’* performed 58.33%, 2.08%, 0%, and 2.08% survival, respectively. The difference between *Sedum album* and other species was significant, but the other three species did not differ significantly (Figure 4.16). Similar to the results of other platform groups, *Sedum album* exhibited the highest plant survival on (4”-33%) platforms. *Sedum spurium ‘John Creech’, and Sedum rupestre ‘Angelina’* were about completely dead, and *Sedum sexangulare* was the only species that could not survive on this platform group.

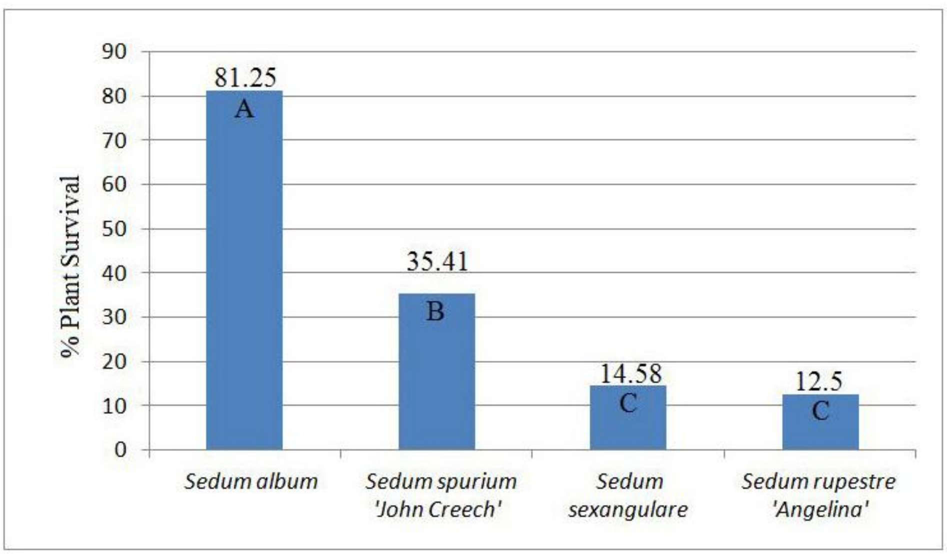

Figure 4.15 Mean percentage of plant survival on (6”-33%) platforms. Bars with the same letter are not statistically different. (LSD=19.217, P-value < 0.001, α= 0.05).

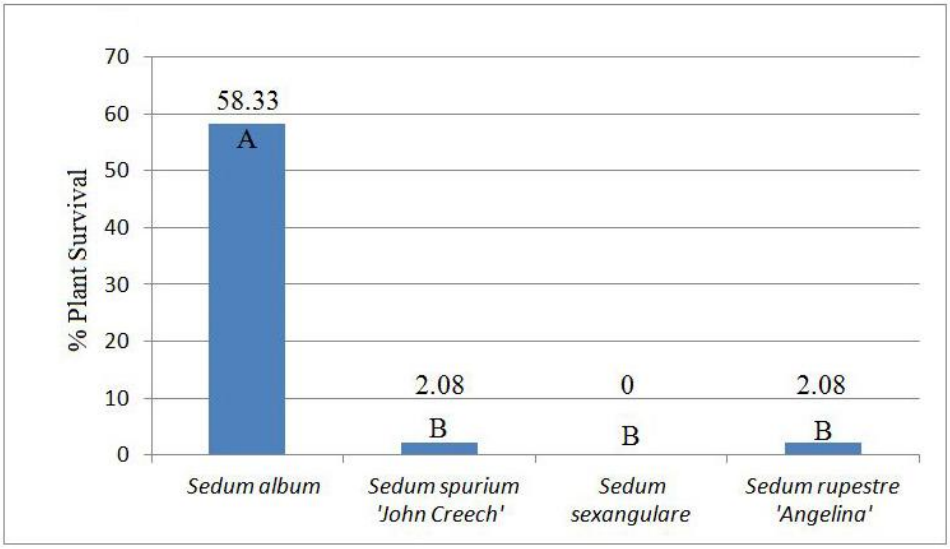

Figure 4.16 Mean percentage of plant survival on (4”-33%) platforms. Bars with the same letter are not statistically different. (LSD=10.191, P-value < 0.001, α= 0.05)

The overall test results showed that *Sedum album* exhibited greater survival values compared to other *Sedum* species at all green roof platforms regardless of medium depth or slope. In addition, (6”-2%) platforms provided highest survival percentages for all plant species compared to other platform groups (Figure 4.17). By the end of the first full growing season, mean percent survival values were 77.6%, 26.6%, 12.5%, and 10.4% for *Sedum album, Sedum spurium ‘John Creech’, Sedum sexangulare,* and *Sedum rupestre ‘Angelina’,* respectively (Figure 4.18).

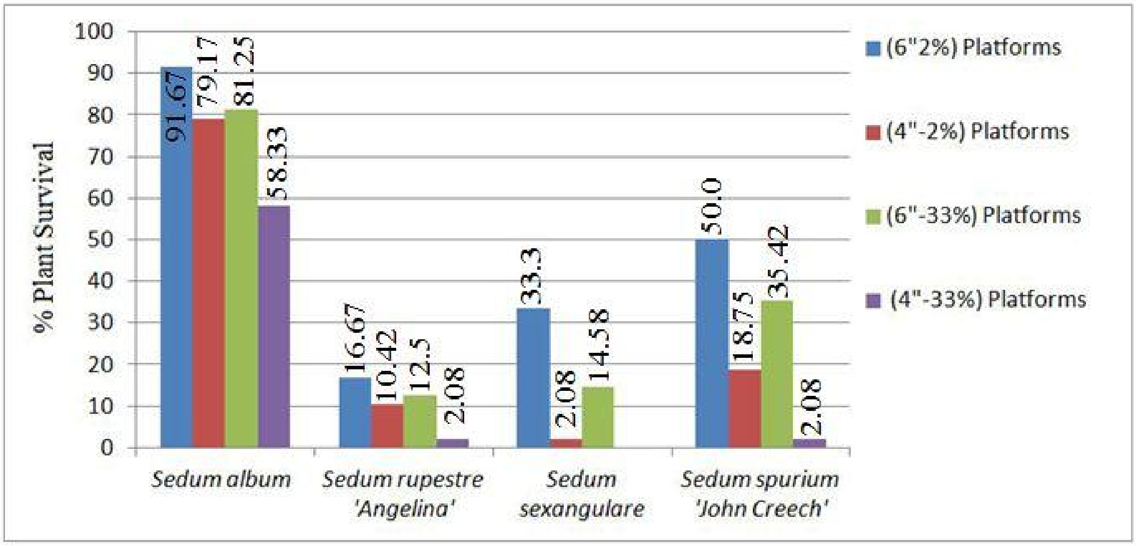

Figure 4.17 Comparison of the survival of each plant species on each platform group.

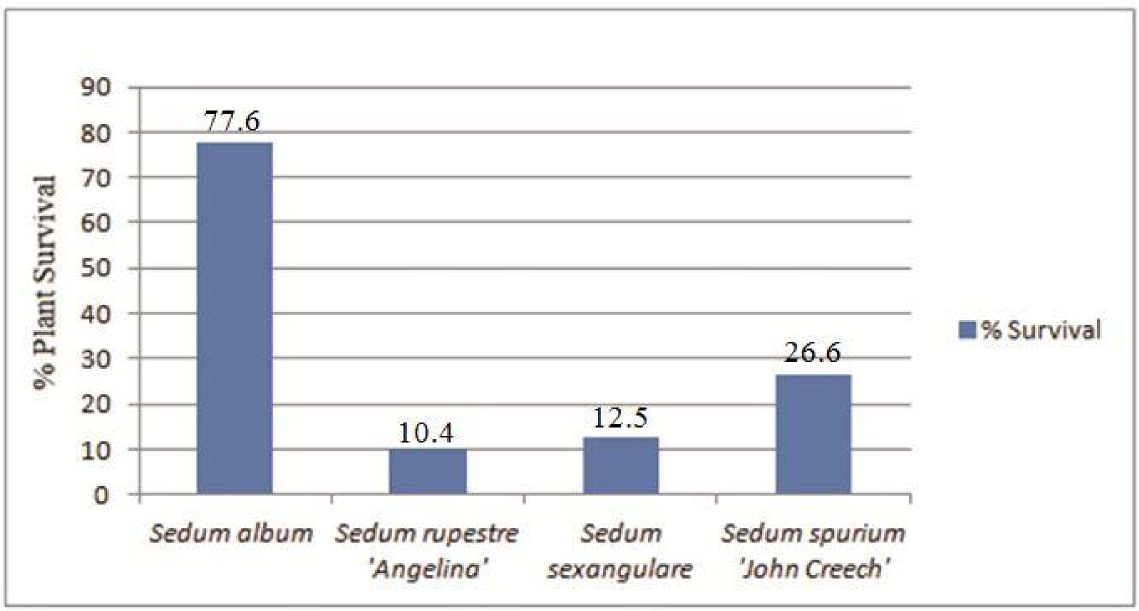

Figure 4.18 Mean percentage of the survival for each plant species by the end of the first full growing season.

CHAPTER V

DISCUSSION AND CONCLUSION

5.1 Introduction

This chapter includes a restatement of the purpose of this study and an examination of the limitations of this study. This chapter also compares the results with related studies and discusses similarities and differences. Finally, this chapter gives suggestions for future studies and concludes with the explanation of the relationship between this study and the landscape architecture profession.

5.2 Restatement of Study Purpose

The main purpose of this study was to understand the effects of substrate depth and slope ratio on plant cover and survival for extensive green roof implementations. This study compared four *Sedum* species with regard to survival and cover in Mississippi's humid sub-tropical climate.

In order to evaluate the effects of substrate depth and slope on plant cover and survival, twelve green roof platforms simulating extensive green roofs were examined at the MAFES Green Infrastructure Research Area at Mississippi State University. Plant cover was monitored once per month during five months of the 2011 growing season by photographing the plants. Photoshop and AutoCAD software were employed for the calculation of plant cover and survival. All data were analyzed with SAS software by using Analysis of Variance (ANOVA) tests.

5.3 Discussion of Results

The effects of each independent variable (measurement date, substrate depth, slope, and plant species) on plant cover and survival are discussed in the following sections in the same context because all of these variables have relatively the same effects on both plant cover and survival. At the end of this section a general discussion is represented for the findings of this study.

5.3.1 The Effects of Measurement Date on Plant Cover and Survival

Initial plant cover was approximately 6-9 sq. inch for each species which equals approximately 5% total coverage for each green roof platform. In July 2011 at the beginning of the measurement period, green roof platforms reached at least 12.2% mean total coverage on (4”-33%) platforms and at most 50.87% mean total coverage on (6”-2%) platforms. Green roof platforms did not exhibit a significant difference in plant cover over the five months from July to November, 2011. Plant cover decreased in August, presumably because plants were exposed to the highest annual mean temperatures, usually seen in July or August (National Climatic Data Center, 2005). Plants were irrigated on 31 August, 2011 because of changes in plant color and decrease in cover and visual quality of plants. Then plants exhibited an increase in cover and better visual quality for the following months. Although the purpose of this study was not to evaluate the effects of irrigation on vegetation performance, this result was notable to share. Presumably, additional irrigation helped plants to better tolerate difficult late summer conditions and to survive for the rest of the growing season. The findings of another study support this hypothesis. It was found that additional irrigation provided a significant benefit for vegetation performance (Dunnett & Nolan, 2004). *Sedum acre, Sedum reflexum,* and *Sedum kamtschaticum ellacom-bianum* reduced their biomass in un-watered plastic pots compared to frequently watered treatments over a period of 4 months (Durhman, Rowe, & Rugh, 2006).

This study included a 5 month monitoring period. Although total cover was not significantly different over the five months, some species were completely dead on some platforms by the end of the study. The species composition will continue to change over time. Other studies have found significant differences between measurement dates. For example, 23 succulent plant species did not exhibit a significant difference in the first growing season (Rowe, Getter, & Durhman, 2012), but by the end of the second growing season, some species produced significant growth and consequently *Sedum dasyphyllum 'Burnatii', Sedum dasyphyllum 'Lilac Mound', Sedum diffusum, Sedum hispanicum,* and *Sedum kamtschaticum* were recommended for greater plant cover on extensive green roofs. It was notable that at the end of the seventh growing season, *Sedum sediforme, Sedum dasyphyllum 'Burnati', Sedum dasyphyllum 'Lilac Mound', Sedum diffusum,* and *Sedum hispanicum* had totally disappeared and were removed from the recommended plant list (Rowe et al., 2012). This example of a long term study showed the necessity for similar studies in different climates to evaluate plant cover results and recommend plant species.

5.3.2 Effects of Substrate Depth and Slope on Plant Cover and Survival

Without exception, all test results showed that platforms with deeper soil provided more species and plant cover than those with shallower soil. Plant cover was less at 4" medium depth compared to 6" medium depth in August, presumably because plants suffered when exposed to high annual mean temperatures in shallower media. This result was consistent with the findings of Boivin et al. (2001). They found that significantly higher temperature fluctuation occurred at 2 inch medium depth compared to 4 or 6 inches, resulting in reduced water and minerals in media, (Boivin, Lamy, Gosselin, & Dansereau, 2001). Similarly, Durhman et al. (2007) found that plants in 2.5, 5.0, and 7.5 cm soil provided 47%, 74%, and 96% coverage, respectively. In addition, Dunnett, Nagase, and Hallam (2008) found that 200 mm soil depth provided greater survival, diversity and cover compared to 100 mm medium depth. Furthermore, Getter and Rowe (2008a) indicated that while six plant species produced near zero plant growth at a 4 cm medium depth, only 2 species did not exhibit any growth at a 7 cm medium depth. All of these results can be explained with the amount of retained water and nutrients in deeper substrates. Deeper medium provides greater water retention which reduces possible drought and provides more minerals and phytohormones that regulate plant growth on green roofs (Boivin et al., 2001; Olly et al., 2011). Therefore, researchers mostly recommended deeper substrate for green roof implementations.

On the other hand, Rowe et al. (2012) found in Michigan's climate that deeper substrate was not beneficial for some species such as *Sedum acre,* and *Sedum album 'Bella d'Inverno'*. *Sedum acre,* and *Sedum album 'Bella d'Inverno'* exhibited greater coverage at 2.5 cm substrate compared to 5.0 cm and 7.5 cm substrates at the end of the seventh growing season (Rowe et al., 2012). In contrast, deeper substrate provided higher plant cover and survival values for all plant species used in this study in Mississippi. These differences may be a result of the effects of different soil moisture and temperature or other dominant plant species. For example, while 6” medium may provide the ideal moisture for the species in southern climates, only 2.5 cm (approximately 1 inch) may be enough for the same plant species and deeper substrates may provide more than enough moisture which can be harmful for green roof plants in northern climates. The current green roof research that compares green roofs in different climates is not enough to explain the exact reasons for these differences.

The effect of slope on plant cover and survival is another important factor for green roof plant performance. As mentioned in Chapter 2, slope has mostly been studied for the evaluation of stormwater retention performance on green roofs. Thus, research discussing the direct effects of slope on plant cover and survival is very rare. However, due to the effects of slope on the amount of retained water and nutrients in green roof soil, it is possible to predict the effects of slope on plant cover as well. Past research has shown that green roofs with shallower slope provide greater runoff retention capacity compared to roofs with higher slope (Berndtsson, 2010; Getter et al., 2007; VanWoert, Rowe, Andresen, Rugh, Fernandez, et al., 2005). Therefore green roofs with shallower slope can provide more moisture and nutrients than those with higher slope (Boivin et al., 2001; Olly et al., 2011). Although there is not enough research supported with statistical analysis, it can be expected that shallower slopes should provide greater plant cover compared to higher slopes.

As expected, green roof platforms with 2% slope provided more plant species and greater plant cover compared to the platforms with 33% slope. Especially at 6” medium depth, platforms with 2% slope provided significantly higher plant cover than the platforms with 33% slope. This was a consistent result with the findings of another green roof study conducted by Martin (2007) at Woodland Park Zoo in Seattle, WA. It was found that *Allium cernuum, Arctostaphylos uva-ursi*, common species in South California, exhibited a significant decrease in cover and survival on slopes higher than 15% compared to shallower slopes (Martin, 2007). Similarly, Jones et al. (2008) found that green roofs with shallower slope provided more diverse vegetation and plant cover at shallower slope. As opposed to this study, it was also found that some plant species such as *Sedum acre* and *Sedum divergens* provided greater coverage on green roofs with higher slope (Jones et al., 2008). All of these findings showed that different plant species responded differently at various slopes in different climates.

Past green roof research has shown that medium depth and slope affect vegetation performance, but research that is discussing which variable is more critical is not enough. This study compared the effects of medium depth versus slope on vegetation performance to evaluate which variable is more effective in Mississippi’s climate. Although (4”-2%) platforms have shallower slope, (6”-33%) platforms provided greater plant cover values due to deeper substrate. While (6”-33%) platforms exhibited 32.37% plant cover, (4”-2%) platforms exhibited 26.02% plant cover (Figure 4.7). Although the difference between these two values was not significant, this result showed that deeper substrate (6”) eliminated the drawbacks of higher slope (33%) and increased plant cover at a higher slope. The comparisons of medium depth versus slope showed that medium depth plays a more critical role on plant cover and survival than slope for *Sedum album, Sedum spurium 'John Creech', Sedum sexangulare* and *Sedum rupestre 'Angelina'* in Mississippi's climate.

This study and other green roof studies comparing the performance of plant species were conducted with mixed or randomly-planted experimental green roofs. All plant species grew together with other green roof plants. Therefore competition between plant species may be another effective factor on total plant cover and survival on rooftops. Although performance of green roof plants grown alone and with others has not been statistically analyzed and compared in past research, Dunnett and Nolan (2004) mentioned this issue. They noted that reduced performance of *Dianthus deltoides* and *Sedum acre* may be a result of competition between plant species. In addition, Durhman et al. (2007) found that some species such as *Sedum dasyphyllum 'Burnatii', Sedum dasyphyllum 'Lilac Mound',* and *Sedum sediforme* did not exhibit an increase in cover regardless of medium depth. It was also noted that it may be linked to competition between green roof plants because more vigorous plants can provide faster initial growth and coverage which may affect performance of other species.

Similar to other studies, plant competition may be an issue that needs to be discussed for the (6"-2%) platforms in this study. This is because on (6"-2%) platforms *Sedum album* exhibited a dominant coverage which may reduce plant cover and survival performance of other species. Although *Sedum album* still exhibited the highest coverage and survival values on other platform groups, it was less competitive because it decreased in cover and numbers and left enough space for other species' growth. Although *Sedum album* was less competitive on other platform groups, other species presumably could not increase both their cover and survival because of shallower medium depth and higher slope. All of this means that plant species might have exhibited different coverage and survival percentages if they were grown alone, and in addition to medium depth and slope, plant competition could be another factor that affects species performance on rooftops.

5.3.3 Plant Species Response to Substrate Depth and Slope

Previous studies agree that *Sedums* have been commonly used plant species for extensive green roof implementations because of their long term drought tolerance and survival ability in shallow soils without rainfall or additional irrigation (Bousselot et al., 2011; Butler & Orians, 2011; Durhman et al., 2006; Emilsson, 2008; Getter & Rowe, 2008a, 2008b; Monterusso, Rowe, & Rugh, 2005; Rowe et al., 2012; VanWoert, Rowe, Andresen, Rugh, & Xiao, 2005). In this study, *Sedum album* was the only species that supported this general idea. *Sedum album* maintained at least 58.33% and at most 91.67% of its original numbers on (4” -33%) and (6”-33%) platforms, respectively. *Sedum album* also provided the highest plant cover at all depths and slopes. *Sedum spurium ‘John Creech’,* was the species that provided the second highest percentages of survival and coverage. It maintained at most 50.00% of its original numbers on (6”-2%) platforms, but it could not survive on two (4”-33%) platforms out of three. On the other (4”-33%) platform, it survived but the coverage was very weak. *Sedum sexangulare* was the only species completely disappeared on (4”-33%) platforms; however, it still provided higher mean percent plant cover than *Sedum rupestre ‘Angelina’.*

Because there is no study that includes all of these four *Sedum* species, it was not possible to compare their performance all together in another study. However they were studied individually in different studies. Getter and Rowe (2008a) found that while *Sedum rupestre 'Angelina'* did not exhibit significant increase in cover *Sedum sexangulare* and *Sedum spurium 'John Creech'* achieved significant increase in cover at a 4.0 cm (approximately 1.5 inch) medium depth in Michigan's climate . However *Sedum sexangulare* and *Sedum spurium 'John Creech'* did not show high survival and coverage values at 4" medium depths in Mississippi's climate. In another study conducted in central and eastern North Carolina, *Sedum album* and *Sedum sexangulare* were recommended because of their high growth rates (Moran, 2004). Similarly, in our study *Sedum album* established much higher coverage and survival than other species, but *Sedum sexangulare* did not provide enough cover and survival to be recommended in Mississippi's climate.

Overall results showed that the same plant species respond differently to different medium depths and slopes in different climates. Based on the findings at the end of the five months, this study offers different plant recommendations for use on extensive green roofs in Mississippi's climate. At (6"2%) and (6"-33%) platforms, although *Sedum spurium 'John Creech', Sedum sexangulare,* and *Sedum rupestre 'Angelina'* provided less plant survival and coverage than *Sedum album*, all these species can be recommended for richer vegetation. At (4"-2%) and (4"-33%) platforms, *Sedum album* can be recommended without any concern, but *Sedum spurium 'John Creech',* may be too risky to be recommended. Although *Sedum sexangulare,* and *Sedum rupestre 'Angelina'* are still present with the exception of *Sedum sexangulare* on (4"-33%) platforms, these two species are not recommended for 4" medium depths regardless of slope because these two species were almost absent on these green roof platforms. These plant species were recommended only based on the findings of this study by the end of the first full growing season. Long term responses of plant species should be monitored and evaluated for successful green roof implementations.

Either the results of this study or the results of other studies showed that proper plant species, media depth, slope, length of study, and climate are notable factors that affect conclusions when evaluating plant cover and survival on green roofs. All of these variables can influence plant cover and survival differently when one of these variables is changed because each of them exhibits an individual effect on vegetation performance.

5.4 Conclusion

The results of this study indicated that medium depth, slope and plant species all affect plant cover and survival. This study also showed the necessity of long term studies because it covers only a five month monitoring period. The results of this study are applicable to Mississippi's humid sub-tropical climate and other locations with similar climates.

5.5 Limitations

First, it is important to understand how substrate depth and slope affect plant cover and survival. These factors affect soil moisture and temperature which have a direct relationship with plant cover and survival. Past research has evaluated the effects of soil moisture and temperature on vegetation performance on green roofs. Surprisingly, it was found that increased substrate depth did not provide a significant benefit in vegetation performance without additional irrigation (Dunnett & Nolan, 2004). The significant growth was monitored on water applied platforms. They also noted that deeper substrates would provide greater vegetation performance because of higher moisture retention capacity. Thus, Dunnett and Nolan (2004) suggested that water availability is the main effect on plant growth instead of medium depth itself.

In another study, it was also found that plant roots were exposed to significantly higher temperature fluctuation (43.5^0 F) at 2 inch substrate compared to (40.3^0 F) at 4 inch and (38.7^0 F) at 6 inch substrates. Therefore, Stonecrop species were exposed to more freezing injury because of severe temperature fluctuations in shallower substrates (Boivin et al., 2001).

Similar to the findings of past research, deeper substrate and shallower slope provided greater coverage and higher survival in this study as expected, but soil moisture and temperature data were not documented. Thus, it was not possible to statistically explain why deeper soil and shallower slope increased plant cover and survival. For this reason, it would be more beneficial to have soil moisture and temperature data to better understand close relationship between medium depth, slope, soil moisture, temperature, plant cover, survival, and to determine water use rates of vegetation on different platform groups and irrigation frequency if needed.

Second, it would be beneficial to have a wide range of *Sedum* and other plant species to identify more green roof plant species for Mississippi's climate. Furthermore, the data collection period could be longer to evaluate plant cover and survival for long term success. Each of these limitations could be addressed with additional equipment for soil moisture and temperature data measurements, green roof platforms and plants for the evaluation of other plant species, time for long-term studies, and financial support.

Third, a mistake was made with monitoring the plants. The first monitoring photographs were conducted at noon time. Green roof platforms were exposed to direct sun light resulted in very bright spots on plants at higher level and bare ground. Direct sun light and plants at higher level caused very dark shadows on the plants at lower level. These situations reduced the visibility of plants at lower level and caused adjustment and focus problems for the camera and resulted in decreased image quality. Also, they caused confusion in the identification of plants in the images. This problem was solved by using a paper board to eliminate bright spots and to provide an equally-shaded area for the whole platform surface.

5.6 Recommendations for Future Studies

First of all it is recommended that green roof studies evaluating the effects of substrate depth and slope should be improved in Mississippi's climate. Future studies should consider the issues mentioned as limitations of this study. Especially soil moisture and temperature data should be considered for future studies because these data will provide more knowledge about the soil moisture, gradient and its effects on cover and survival. These additions will surely increase the complexity of green roof studies but will provide better knowledge for local designers and researchers for designing more successful green roofs in Mississippi.

Future studies would also include more diverse plant species to recommend more green roof plants and to provide more diverse vegetation on Mississippi's green roofs because monoculture vegetation is more susceptible to disease or insects that target an individual species (Getter & Rowe, 2008a). To provide more diverse vegetation, plant species should be grown together and separately in the same study to understand competition between species and to identify dominant species. Rainfall data should also be considered for future studies because green roofs play a crucial role on runoff control and knowing stormwater retention capacity of plant species would provide valuable knowledge for green roof designers and researchers.

5.7 Green Roofs for Landscape Architecture Profession

As a part of huge impervious surfaces, useless and impermeable spaces on roof tops have a great potential for mitigating stormwater runoff, air and noise pollution, and urban heat island effect in urban environments. Instead of traditional stormwater management practices, more sustainable methods providing ecological, environmental, and aesthetic benefits are becoming more common to mitigate the effects of impervious surfaces, and green roofs have been developed as one of these methods.

Landscape architects can play a crucial role in mitigating impervious surfaces on rooftops and to increase the benefits of these useless spaces because landscape architects have the ability of designing any space surrounding the community by considering the ecological, environmental and aesthetic potential of the space. Knowing how substrate depth and slope affect vegetation performance and knowing which plant species perform better on rooftops will provide valuable knowledge for landscape architects and other designers to increase the functions and service quality of rooftops.

Results discussed in this study showed that deeper substrate and shallower slope can significantly increase plant cover and survival, but the difference between (6”-33%) platforms and (4”-2%) platforms was not significant in terms of total cover and survival. Findings of this study also identified *Sedum* species that performed well in Mississippi’s climate. These results provide valuable knowledge for local green roof designers when considering construction costs and expectations of clients. All components of green roof design such as soil mix, substrate depth, slope, and plant species should be carefully brought together with the purpose of providing optimum green roof design. Responses of these components to local climatic conditions must be understood by designers.

REFERENCES

Abdul-Wahab, S. A., & Al-Arairni, A. (2004). Environmental considerations in urban planning. International Journal of Environmental Studies, 61(5), 527-537.

Alcazar, S. S. (2004). Greening the dwelling: A life cycle energy analysis of green roofs in residential buildings. Master's, University of Toronto.

Anders, R. M. (2012). Extensive green roofs in Mississippi: An evaluation of stormwater retention under local climatic conditions. Master's Thesis, Mississippi State University.

Benavides, J. C., & Sastre-De Jesús, I. (2009). Digitized images provide more accuracy and efficiency to estimate bryophyte cover. The Bryologist, 112(1), 12-18. doi: 10.1639/0007-2745-112.1.12

Berghage, R. D., Beattie, D., Jarrett, A. R., Thuring, C. E., & Razaei, F. (2009). Green roofs for stormwater runoff control (Government Documents Internet Resource Report No.: EPA/600/R-09/026.). Cincinnati, OH: National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency. Retrieved from http://www.epa.gov/nrmrl/pubs/600r09026/600r09026.pdf.

Berndtsson, J. C. (2010). Green roof performance towards management of runoff water quantity and quality: A review. Ecological Engineering, 36(4), 351-360. doi: 10.1016/j.ecoleng.2009.12.014

Berndtsson, J. C., Bengtsson, L., & Jinno, K. (2009). Runoff water quality from intensive and extensive vegetated roofs. Ecological Engineering, 35(3), 369-380. doi: 10.1016/j.ecoleng.2008.09.020

Bliss, D. J., Neufeld, R. D., & Ries, R. J. (2009). Storm water runoff mitigation using a green roof. Environmental Engineering Science, 26(2), 407-418. doi: 10.1089/ees.2007.0186

Boivin, M. A., Lamy, M. P., Gosselin, A., & Dansereau, B. (2001). Effect of artificial substrate depth on freezing injury of six herbaceous perennials grown in a green roof system. HortTechnology, 11(3), 409-412.

Booth, D. B., Hartley, D., & Jackson, R. (2002). Forest cover, impervious-surface area, and the mitigation of stormwater impacts. JAWRA Journal of the American Water Resources Association, 38(3), 835-845. doi: 10.1111/j.1752-1688.2002.tb01000

Booth, D. T., Cox, S. E., Meikle, T., & Zuuring, H. R. (2008). Ground-cover measurements: Assessing correlation among aerial and ground-based methods. Environmental Management, 42(6), 1091-1100. doi: 10.1007/s00267-008-9110-x

Bousselot, J. M., Klett, J. E., & Koski, R. D. (2011). Moisture content of extensive green roof substrate and growth response of 15 temperate plant species during dry down. HortScience, 46(3), 518-522.

Butler, C., & Orians, C. M. (2011). Sedum cools soil and can improve neighboring plant performance during water deficit on a green roof. Ecological Engineering, 37(11), 1796-1803. doi: 10.1016/j.ecoleng.2011.06.025

Clary, J., Quigley, M., Poresky, A., Earles, A., Strecker, E., Leisenring, M., & Jones, J. (2011). Integration of Low-Impact Development into the International Stormwater BMP Database. Journal of Irrigation & Drainage Engineering, 137(3), 190-198. doi: 10.1061/(asce)ir.1943-4774.0000182

Crimmins, M. A., & Crimmins, T. M. (2008). Monitoring plant phenology using digital repeat photography. Environmental Management, 41(6), 949-958. doi: 10.1007/s00267-008-9086-6

Dunnett, N., Nagase, A., Booth, R., & Grime, P. (2008). Influence of vegetation composition on runoff in two simulated green roof experiments. Urban Ecosystems, 11(4), 385-398.

Dunnett, N., Nagase, A., & Hallam, A. (2008). The dynamics of planted and colonising species on a green roof over six growing seasons 2001-2006: Influence of substrate depth. Urban Ecosystems, 11(4), 373-384.

Dunnett, N., & Nolan, A. (2004). The effect of substrate depth and supplementary watering on the growth of nine herbaceous perennials in a semi-extensive green roof. Acta Horticulturae(643), 305-309.

Durhman, A. K., Rowe, D. B., & Rugh, C. L. (2006). Effect of watering regimen on chlorophyll fluorescence and growth of selected green roof plant taxa. HortScience, 41(7), 1623-1628.

Durhman, A. K., Rowe, D. B., & Rugh, C. L. (2007). Effect of substrate depth on initial growth, coverage, and survival of 25 succulent green roof plant taxa. HortScience, 42(3), 588-595.

Dvorak, B., & Volder, A. (2010). Green roof vegetation for North American ecoregions: A literature review. Landscape and Urban Planning, 96(4), 197-213. doi: 10.1016/j.landurbplan.2010.04.009

Emilsson, T. (2008). Vegetation development on extensive vegetated green roofs: Influence of substrate composition, establishment method and species mix. Ecological Engineering, 33(3–4), 265-277. doi: 10.1016/j.ecoleng.2008.05.005

EPA. (2000). Low impact development (LID) a literature review (Government Documents Internet Resource. Report No.: EPA-841-B-00-005). Washington, D.C.: United States Environmental Protection Agency, Office of Water. Retrieved from http://www.epa.gov/owow/nps/lid/lid.pdf.

Getter, K. L., & Rowe, D. B. (2006). The role of extensive green roofs in sustainable development. HortScience, 41(5), 1276-1285.

Getter, K. L., & Rowe, D. B. (2008a). Media depth influences sedum green roof establishment. Urban Ecosystems, 11(4), 361-372. doi: 10.1007/s11252-008-0052-0

Getter, K. L., & Rowe, D. B. (2008b). Selecting plants for extensive green roofs in the United States (Vol. July, pp. 9): Michigan State University. Retrieved from http://www.hrt.msu.edu/greenroof/PDF/08%20GetterRoweExtensionBulletin.pdf.

Getter, K. L., Rowe, D. B., & Andresen, J. A. (2007). Quantifying the effect of slope on extensive green roof stormwater retention. Ecological Engineering, 31(4), 225-231. doi: 10.1016/j.ecoleng.2007.06.004

Grant, G., Engleback, L., & Nicholson, B. (2003). Green roofs: Their existing status and potential for conserving biodiversity in urban areas (Research Report, No:498): English Nature.

Holman-Dodds, J. K., Bradley, A. A., & Potter, K. W. (2003). Evaluation of hydrologic benefits of infiltration based urban storm water management. JAWRA Journal of the American Water Resources Association, 39(1), 205-215. doi: 10.1111/j.1752-1688.2003.tb01572.x

Jia, H., Lu, Y., Yu, S. L., & Chen, Y. (2012). Planning of LID–BMPs for urban runoff control: The case of Beijing Olympic Village. Separation and Purification Technology, 84(0), 112-119. doi: 10.1016/j.seppur.2011.04.026

Jones, T., Liptan, T., Cunningham, C., Dobson, L., Dunlap, I., & Elkin, D. (2008). Ecoroof plant report (Vol. September). Portland,OR: Environmental Services City of Portland.

Kuper, R. (2010). The tipping point: How roof design and location affect Temple University's sloped green roof. Landscape Architecture, 100, 50-61.

Lee, J. G., & Heaney, J. P. (2003). Estimation of urban imperviousness and its impacts on storm water systems. Journal of Water Resources Planning and Management, 129(5), 419-426. doi: 10.1061/(asce)0733-9496(2003)129:5(419)

Lee, S., & French, S. P. (2009). Regional impervious surface estimation: an urban heat island application. Journal of Environmental Planning and Management, 52(4), 477-496. doi: 10.1080/09640560902868207

Luscier, J. D., Thompson, W. L., Wilson, J. M., Gorham, B. E., & Dragut, L. D. (2006). Using digital photographs and object-based image analysis to estimate percent ground cover in vegetation plots. Frontiers in Ecology and the Environment, 4(8), 408-413. doi: 10.1890/1540-9295(2006)4[408:udpaoi]2.0.co;2

Martin, M. A. (2007). Native plant performance on a Seattle green roof. Master's Thesis, University of Washington. Retrieved from http://www.wsl.ch/info/mitarbeitende//martinm/pdf/MSc_thesis.

Moglen, G. E., & Kim, S. (2007). Limiting imperviousness. Journal of the American Planning Association, 73(2), 161-171.

Monterusso, M. A., Rowe, D. B., & Rugh, C. L. (2005). Establishment and persistence of Sedum spp. and native taxa for green roof applications. HortScience, 40(2), 391-396.

Moran, A. C. (2004). A North Carolina field study to evaluate greenroof runoff quantity, runoff quality, and plant growth. Master's Thesis, North Carolina State University, Raleigh,NC. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-0942268559&partnerID=40&md5=dc14cb77ecc66f618b15f2520a97c081.

National Climatic Data Center. (2005). Climate of Mississippi (Government Documents Internet Resources. Accessed on 4 April 2012): National Climatic Data Center. Retrieved from http://cdo.ncdc.noaa.gov/climatenormals/clim60/states/Clim_MS_01.pdf.

Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R. R., Doshi, H., Dunnett, N., . . . Rowe, B. (2007). Green roofs as urban ecosystems: Ecological structures, functions, and services. BioScience, 57(10), 823-833. doi: 10.1641/b571005

Olly, L. M., Bates, A. J., Sadler, J. P., & Mackay, R. (2011). An initial experimental assessment of the influence of substrate depth on floral assemblage for extensive green roofs. Urban Forestry & Urban Greening, 10(4), 311-316. doi: 10.1016/j.ufug.2011.07.005

Paul, M. J., & Meyer, J. L. (2001). Streams in the urban landscape. Annual Review of Ecology and Systematics, 32, 333-365.

Rowe, D. B., Getter, K. L., & Durhman, A. K. (2012). Effect of green roof media depth on crassulacean plant succession over seven years. Landscape and Urban Planning, 104(3–4), 310-319. doi: 10.1016/j.landurbplan.2011.11.010

Rushton, B. T. (2001). Low impact parking lot design reduces runoff and pollutant loads. Journal of Water Resources Planning and Management, 127(3), 172.

Scherba, A., Sailor, D. J., Rosenstiel, T. N., & Wamser, C. C. (2011). Modeling impacts of roof reflectivity, integrated photovoltaic panels and green roof systems on sensible heat flux into the urban environment. Building and Environment, 46(12), 2542-2551. doi: 10.1016/j.buildenv.2011.06.012

Susca, T., Gaffin, S. R., & Dell'Osso, G. R. (2011). Positive effects of vegetation: Urban heat island and green roofs. Environmental Pollution, 159(8–9), 2119-2126. doi: 10.1016/j.envpol.2011.03.007

VanWoert, N. D., Rowe, D. B., Andresen, J. A., Rugh, C. L., Fernandez, R. T., & Xiao, L. (2005). Green roof stormwater retention: Effects of roof surface, slope, and media depth. Journal of Environmental Quality, 34(3), 1036-1044.

VanWoert, N. D., Rowe, D. B., Andresen, J. A., Rugh, C. L., & Xiao, L. (2005). Watering regime and green roof substrate design affect sedum plant growth. HortScience, 40(3), 659-664.

Wollheim, W. M., Pellerin, B. A., Vörösmarty, C. J., & Hopkinson, C. S. (2005). N retention in urbanizing headwater catchments. Ecosystems, 8(8), 871-884

APPENDIX A

STATISTICAL ANALYSIS OF PLANT GROWTH PERFORMANCE

Table A.1 ANOVA general linear model procedure for mean percent plant cover over the five months.

The General Linear Model Procedure

Dependent Variable: Mean Percentage of Plant Cover

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Months	4	1368.871814	342.217953	1.20	0.3519
Error	15	4282.917013	285.527801		
Corrected Total	19	5651.788827			

R-Square	Coeff Var	Root MSE	Mean
0.242202	50.83879	16.89757	33.23755

Source	DF	Type I SS	Mean Square	F Value	Pr > F
month	4	1368.871814	342.217953	1.20	0.3519

Source	DF	Type III SS	Mean Square	F Value	Pr > F
month	4	1368.871814	342.217953	1.20	0.3519

Table A.2 ANOVA general linear model procedure for mean percent plant cover over the five months.

The General Linear Model Procedure

Dependent Variable: Mean Percentage of Plant Cover

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Substrate Depth	3	4146.964709	1382.321570	14.70	<.0001
Error	16	1504.824118	94.051507		
Corrected Total	19	5651.788827			

R-Square	Coeff Var	Root MSE	Mean
0.733744	29.17789	9.698016	33.23755

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Substrate Depth	1	2523.268801	2523.268801	26.83	<.0001
Slope Ratio	1	1298.031056	1298.031056	13.80	0.0019
SD*SR	1	325.664851	325.664851	3.46	0.0812

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Substrate Depth	1	2523.268801	2523.268801	26.83	<.0001
Slope Ratio	1	1298.031056	1298.031056	13.80	0.0019
SD*SR	1	325.664851	325.664851	3.46	0.0812

Table A.3 ANOVA general linear model procedure for mean percent plant cover among platform groups with 4" substrate depth.

The General Linear Model Procedure

Dependent Variable: Mean Percentage of Plant Cover

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Slope Ratio	1	161.676368	161.676368	1.51	0.2543
Error	8	857.331998	107.166500		
Corrected Total	9	1019.008366			

R-Square	Coeff Var	Root MSE	Mean
0.158660	47.04378	10.35213	22.00530

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Slope Ratio	1	161.6763681	161.6763681	1.51	0.2543

Table A.4 ANOVA general linear model procedure for mean percent plant cover among platform groups with 6” substrate depth.

The General Linear Model Procedure

Dependent Variable: Mean Percentage of Plant Cover

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Slope Ratio	1	1462.019540	1462.019540	18.06	0.0028
Error	8	647.492120	80.936515		
Corrected Total	9	2109.511660			

R-Square	Coeff Var	Root MSE	Mean
0.693061	20.23052	8.996472	44.46980

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Slope Ratio	1	1462.019540	1462.019540	18.06	0.0028

Table A.5 ANOVA general linear model procedure for mean percent plant cover among platform groups with 2% slope.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Cover

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Substrate Depth	1	2330.965563	2330.965563	17.44	0.0031
Error	8	1069.239796	133.654974		
Corrected Total	9	3400.205358			

R-Square	Coeff Var	Root MSE	Mean
0.685537	27.99682	11.56092	41.29370

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Substrate Depth	1	2330.965563	2330.965563	17.44	0.0031

Table A.6 ANOVA general linear model procedure for mean percent plant cover among platform groups with 33% slope.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Cover

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Substrate Depth	1	517.9680900	517.9680900	9.51	0.0150
Error	8	435.5843224	54.4480403		
Corrected Total	9	953.5524124			

R-Square	Coeff Var	Root MSE	Mean
0.543198	29.30294	7.378892	25.18140

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Substrate Depth	1	517.9680900	517.9680900	9.51	0.0150

Table A.7 ANOVA general linear model procedure for mean percent plant cover among platform groups with different independent variables.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Cover

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Platform groups	1	3720.770945	3720.770945	40.47	0.0002
Error	8	735.549440	91.943680		
Corrected Total	9	4456.320385			

R-Square	Coeff Var	Root MSE	Mean
0.834942	25.72642	9.588727	37.27190

Source	DF	Type I SS	Mean Square	F Value	Pr > F
comb	1	3720.770945	3720.770945	40.47	0.0002

Source	DF	Type III SS	Mean Square	F Value	Pr > F
comb	1	3720.770945	3720.770945	40.47	0.0002

Table A.8 ANOVA general linear module procedure for mean percent plant cover among platform groups with different independent variables.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Cover

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Platform Groups	1	100.8761121	100.8761121	1.05	0.3357
Error	8	769.1546900	96.1443363		
Corrected Total	9	870.0308021			

R-Square	Coeff Var	Root MSE	Mean
0.115945	33.57722	9.805322	29.20230

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Platform Groups	1	100.8761121	100.8761121	1.05	0.3357

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Platform Groups	1	100.8761121	100.8761121	1.05	0.3357

Table A.9 ANOVA general linear module procedure for mean percent plant cover among platform groups with different independent variables.

The General Linear Module Procedure

Dependent Variable: Mean percentage of Plant Cover

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2165.160769	721.720256	18.90	<.0001
Error	12	458.351125	38.195927		
Corrected Total	15	2623.511894			

R-Square	Coeff Var	Root MSE	percentage Mean
0.825291	74.37726	6.180285	8.309375

Source	DF	Type I SS	Mean Square	F Value	Pr > F
plant	3	2165.160769	721.720256	18.90	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
plant	3	2165.160769	721.720256	18.90	<.0001

APPENDIX B

STATISTICAL ANALYSIS OF PLANT SURVIVAL

Table B.1 ANOVA general linear model procedure for mean percent plant survival among platform groups.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Survival

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	40731.77083	5818.82440	29.95	<.0001
Error	40	7770.83333	194.27083		
Corrected Total	47	48502.60417			

R-Square	Coeff Var	Root MSE	Mean
0.839785	43.87076	13.93811	31.77083

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Plant Species	3	35462.23958	11820.74653	60.85	<.0001
Platform Group	1	4703.77604	4703.77604	24.21	<.0001
PG*PS	3	565.75521	188.58507	0.97	0.4160

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Plant Species	3	35462.23958	11820.74653	60.85	<.0001
Platform Group	1	4703.77604	4703.77604	24.21	<.0001
PG*PS	3	565.75521	188.58507	0.97	0.4160

Table B.2 ANOVA general linear model procedure for mean percent plant survival of *Sedum album*. The comparison of platform groups.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Survival

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1754.557292	584.852431	3.74	0.0601
Error	8	1250.000000	156.250000		
Corrected Total	11	3004.557292			

R-Square	Coeff Var	Root MSE	Mean
0.583965	16.10738	12.50000	77.60417

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Platform Groups	3	1754.557292	584.852431	3.74	0.0601

Table B.3 ANOVA general linear model procedure for mean percent plant survival of *Sedum rupestre*. The comparison of platform groups.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Survival

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	338.541667	112.847222	0.89	0.4872
Error	8	1015.625000	126.953125		
Corrected Total	11	1354.166667			

R-Square	Coeff Var	Root MSE	Mean
0.250000	108.1665	11.26735	10.41667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Group	3	338.5416667	112.8472222	0.89	0.4872

Table B.4 ANOVA general linear model procedure for mean percent plant survival of *Sedum sexangulare*. The comparison of platform groups.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Survival

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2109.375000	703.125000	3.27	0.0799
Error	8	1718.750000	214.843750		
Corrected Total	11	3828.125000			

R-Square	Coeff Var	Root MSE	Mean
0.551020	117.2604	14.65755	12.5

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Group	3	2109.375000	703.125000	3.27	0.0799

Table B.5 ANOVA general linear model procedure for mean percent plant survival of *Sedum spurium*. The comparison of platform groups.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Survival

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	3863.932292	1287.977431	10.41	0.0039
Error	8	989.583333	123.697917		
Corrected Total	11	4853.515625			

R-Square	Coeff Var	Root MSE	Percentage Mean
0.796110	41.87090	11.12196	26.56250

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Group	3	3863.932292	1287.977431	10.41	0.0039

Table B.6 ANOVA general linear model procedure for mean percent plant survival for (6”-2%) platforms. The comparison of plant species.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Survival

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	9322.91667	3107.63889	9.36	0.0054
Error	8	2656.25000	332.03125		
Corrected Total	11	11979.16667			

R-Square	Coeff Var	Root MSE	Mean
0.778261	38.02795	18.22172	47.91667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Tree_Species	3	9322.916667	3107.638889	9.36	0.0054

Table B.7 ANOVA general linear model procedure for mean percent plant survival for (4”-2%) platforms. The comparison of plant species.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Survival

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	11051.43229	3683.81076	23.58	0.0003
Error	8	1250.00000	156.25000		
Corrected Total	11	12301.43229			

R-Square	Coeff Var	Root MSE	Mean
0.898386	45.28302	12.50000	27.60417

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Tree_Species	3	11051.43229	3683.81076	23.58	0.0003

Table B.8 ANOVA general linear model procedure for mean percent plant survival for (6”-33%) platforms. The comparison of plant species.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Survival

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	9176.43229	3058.81076	29.36	0.0001
Error	8	833.33333	104.16667		
Corrected Total	11	10009.76563			

R-Square	Coeff Var	Root MSE	Mean
0.916748	28.39988	10.20621	35.93750

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Tree_Species	3	9176.432292	3058.810764	29.36	0.0001

Table B.9 ANOVA general linear model procedure for mean percent plant survival for (4”-33%) platforms. The comparison of plant species.

The General Linear Module Procedure

Dependent Variable: Mean Percentage of Plant Survival

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	7304.687500	2434.895833	83.11	<.0001
Error	8	234.375000	29.296875		
Corrected Total	11	7539.062500			

R-Square	Coeff Var	Root MSE	Mean
0.968912	34.64102	5.412659	15.62500

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Tree_Species	3	7304.687500	2434.895833	83.11	<.0001

APPENDIX C

MONITORING DATA BY SPECIES FOR EACH GREEN ROOF PLATFORM

Table C.1 Plants cover data of (6”-2%) Platform Group on 7/30/2011.

7/30/2011 (6"-2%) Platforms					
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	5.402	0.567	0.646	1.190
	% Plant Cover	33.763	3.545	4.035	7.434
2	Plant Cover (sq. ft)	6.252	0.334	2.044	1.240
	% Plant Cover	39.075	2.089	12.774	7.749
3	Plant Cover (sq. ft)	4.448	0.009	0.059	0.694
	% Plant Cover	27.801	0.056	0.372	4.338

Table C.2 Plants cover data of (4”-2%) Platform Group on 7/30/2011.

7/30/2011 (4"-2%) Platforms					
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	3.006	0.038	0.175	0.104
	% Plant Cover	18.789	0.240	1.094	0.652
2	Plant Cover (sq. ft)	3.507	0.065	0.350	0.368
	% Plant Cover	21.922	0.407	2.187	2.297
3	Plant Cover (sq. ft)	1.649	0.134	0.106	0.271
	% Plant Cover	10.304	0.839	0.661	1.695

Table C.3 Plants cover data of (6”-33%) Platform Group on 7/30/2011.

7/30/2011 (6"-33%) Platforms					
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	3.354	0.281	0.434	1.127
	% Plant Cover	20.963	1.758	2.715	7.044
2	Plant Cover (sq. ft)	4.863	0.011	0.826	0.623
	% Plant Cover	30.395	0.072	5.165	3.895
3	Plant Cover (sq. ft)	2.685	0.210	0.365	0.451
	% Plant Cover	16.779	1.312	2.283	2.817

Table C.4 Plants cover data of (4”-33%) Platform Group on 7/30/2011.

7/30/2011 (4"-33%) Platforms					
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	1.868	0.018	0.054	0.183
	% Plant Cover	11.672	0.115	0.337	1.141
2	Plant Cover (sq. ft)	1.638	0.016	0.064	0.145
	% Plant Cover	10.240	0.102	0.403	0.909
3	Plant Cover (sq. ft)	1.540	0.000	0.048	0.288
	% Plant Cover	9.623	0.000	0.299	1.799

Table C.5 Plants cover data of (6”-2%) Platform Group on 8/30/2011.

8/30/2011
(6"-2%) Platforms

Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	5.772	0.518	0.322	1.208
	% Plant Cover	36.074	3.235	2.015	7.553
2	Plant Cover (sq. ft)	5.871	0.273	1.359	1.333
	% Plant Cover	36.695	1.708	8.492	8.328
3	Plant Cover (sq. ft)	4.435	0.000	0.000	0.231
	% Plant Cover	27.716	0.000	0.000	1.447

Table C.6 Plants cover data of (4”-2%) Platform Group on 8/30/2011.

8/30/2011
(4"-2%) Platforms

Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	1.897	0.000	0.000	0.030
	% Plant Cover	11.858	0.000	0.000	0.189
2	Plant Cover (sq. ft)	2.980	0.000	0.000	0.036
	% Plant Cover	18.627	0.000	0.000	0.222
3	Plant Cover (sq. ft)	1.494	0.013	0.000	0.009
	% Plant Cover	9.336	0.078	0.000	0.059

Table C.7 Plants cover data of (6”-33%) Platform Group on 8/30/2011.

8/30/2011 (6"-33%) Platforms					
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	2.521	0.239	0.174	0.862
	% Plant Cover	15.755	1.495	1.090	5.390
2	Plant Cover (sq. ft)	3.388	0.000	0.435	0.529
	% Plant Cover	21.177	0.000	2.718	3.307
3	Plant Cover (sq. ft)	2.258	0.163	0.215	0.401
	% Plant Cover	14.114	1.019	1.345	2.504

Table C.8 Plants cover data of (4”-33%) Platform Group on 8/30/2011.

8/30/2011 (4"-33%) Platforms					
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	1.542	0.000	0.000	0.008
	% Plant Cover	9.638	0.000	0.000	0.049
2	Plant Cover (sq. ft)	1.610	0.000	0.000	0.000
	% Plant Cover	10.063	0.000	0.000	0.000
3	Plant Cover (sq. ft)	1.407	0.000	0.000	0.000
	% Plant Cover	8.796	0.000	0.000	0.000

Table C.9 Plants cover data of (6”-2%) Platform Group on 9/30/2011.

		9/30/2011 (6"-2%) Platforms			
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	7.240	0.594	0.301	1.564
	% Plant Cover	45.249	3.710	1.881	9.773
2	Plant Cover (sq. ft)	6.901	0.300	1.513	1.542
	% Plant Cover	43.130	1.878	9.459	9.639
3	Plant Cover (sq. ft)	6.228	0.000	0.000	0.412
	% Plant Cover	38.926	0.000	0.000	2.574

Table C.10 Plants cover data of (4”-2%) Platform Group on 9/30/2011.

		9/30/2011 (4"-2%) Platforms			
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	2.612	0.000	0.000	0.082
	% Plant Cover	16.325	0.000	0.000	0.515
2	Plant Cover (sq. ft)	4.009	0.077	0.000	0.153
	% Plant Cover	25.059	0.479	0.000	0.956
3	Plant Cover (sq. ft)	2.057	0.024	0.000	0.000
	% Plant Cover	12.858	0.150	0.000	0.000

Table C.11 Plants cover data of (6”-33%) Platform Group on 9/30/2011.

9/30/2011
(6"-33%) Platforms

Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	2.800	0.261	0.090	1.270
	% Plant Cover	17.497	1.629	0.560	7.936
2	Plant Cover (sq. ft)	4.267	0.000	0.339	0.843
	% Plant Cover	26.670	0.000	2.117	5.267
3	Plant Cover (sq. ft)	3.392	0.163	0.213	0.440
	% Plant Cover	21.198	1.019	1.331	2.752

Table C.12 Plants cover data of (4”-33%) Platform Group on 9/30/2011.

9/30/2011
(4"-33%) Platforms

Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	2.237	0.000	0.000	0.080
	% Plant Cover	13.983	0.000	0.000	0.497
2	Plant Cover (sq. ft)	2.994	0.009	0.000	0.000
	% Plant Cover	18.711	0.059	0.000	0.000
3	Plant Cover (sq. ft)	2.006	0.000	0.000	0.019
	% Plant Cover	12.536	0.000	0.000	0.119

Table C.13 Plants cover data of (6”-2%) Platform Group on 10/30/2011.

10/30/2011 (6"-2%) Platforms					
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	9.400	0.414	0.266	1.070
	% Plant Cover	58.753	2.585	1.664	6.688
2	Plant Cover (sq. ft)	9.259	0.190	1.744	0.964
	% Plant Cover	57.872	1.186	10.897	6.022
3	Plant Cover (sq. ft)	9.110	0.000	0.000	0.207
	% Plant Cover	56.935	0.000	0.000	1.295

Table C.14 Plants cover data of (4”-2%) Platform Group on 10/30/2011.

10/30/2011 (4"-2%) Platforms					
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	5.739	0.000	0.000	0.101
	% Plant Cover	35.868	0.000	0.000	0.628
2	Plant Cover (sq. ft)	7.066	0.077	0.000	0.149
	% Plant Cover	44.160	0.484	0.000	0.933
3	Plant Cover (sq. ft)	3.595	0.031	0.000	0.046
	% Plant Cover	22.470	0.192	0.000	0.287

Table C.15 Plants cover data of (6”-33%) Platform Group on 10/30/2011.

10/30/2011
(6"-33%) Platforms

Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	4.709	0.256	0.070	0.731
	% Plant Cover	29.433	1.599	0.437	4.571
2	Plant Cover (sq. ft)	6.023	0.000	0.443	0.612
	% Plant Cover	37.645	0.000	2.768	3.825
3	Plant Cover (sq. ft)	5.039	0.221	0.132	0.280
	% Plant Cover	31.492	1.379	0.825	1.750

Table C.16 Plants cover data of (4”-33%) Platform Group on 10/30/2011.

10/30/2011
(4"-33%) Platforms

Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	4.144	0.000	0.000	0.105
	% Plant Cover	25.901	0.000	0.000	0.654
2	Plant Cover (sq. ft)	4.483	0.005	0.000	0.000
	% Plant Cover	28.022	0.032	0.000	0.000
3	Plant Cover (sq. ft)	3.037	0.000	0.000	0.056
	% Plant Cover	18.980	0.000	0.000	0.348

Table C.17 Plants cover data of (6”-2%) Platform Group on 11/30/2011.

11/30/2011
(6"-2%) Platforms

Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	10.109	0.355	0.328	0.416
	% Plant Cover	63.182	2.218	2.050	2.599
2	Plant Cover (sq. ft)	9.266	0.208	1.680	0.435
	% Plant Cover	57.910	1.301	10.501	2.719
3	Plant Cover (sq. ft)	9.399	0.000	0.023	0.102
	% Plant Cover	58.744	0.000	0.145	0.639

Table C.18 Plants cover data of (4”-2%) Platform Group on 11/30/2011.

11/30/2011
(4"-2%) Platforms

Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	7.017	0.000	0.000	0.029
	% Plant Cover	43.859	0.000	0.000	0.184
2	Plant Cover (sq. ft)	7.865	0.085	0.016	0.139
	% Plant Cover	49.156	0.532	0.100	0.866
3	Plant Cover (sq. ft)	5.128	0.051	0.000	0.082
	% Plant Cover	32.047	0.321	0.000	0.512

Table C.19 Plants cover data of (6”-33%) Platform Group on 11/30/2011.

11/30/2011 (6"-33%) Platforms					
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	5.295	0.216	0.072	0.311
	% Plant Cover	33.095	1.353	0.449	1.942
2	Plant Cover (sq. ft)	6.136	0.000	0.463	0.222
	% Plant Cover	38.349	0.000	2.894	1.385
3	Plant Cover (sq. ft)	5.459	0.211	0.139	0.174
	% Plant Cover	34.121	1.317	0.872	1.089

Table C.20 Plants cover data of (4”-33%) Platform Group on 11/30/2011.

11/30/2011 (4"-33%) Platforms					
Roof	Data	*Sedum album*	*Sedum rupestre 'Angelina'*	*Sedum sexangulare*	*Sedum spurium 'John Creech'*
1	Plant Cover (sq. ft)	4.335	0.000	0.000	0.046
	% Plant Cover	27.091	0.000	0.000	0.286
2	Plant Cover (sq. ft)	5.517	0.011	0.000	0.000
	% Plant Cover	34.481	0.066	0.000	0.000
3	Plant Cover (sq. ft)	3.647	0.000	0.000	0.000
	% Plant Cover	22.792	0.000	0.000	0.000