GULF COAST BARRIER ISLAND RESTORATION: PUBLIC DEMONSTRATION AND EDUCATION, PRODUCTION PRACTICES FOR THE BEACH PLANT *Iva imbricata*, AND RESTORATION WITH COMPOSITE PLANTINGS

By

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This document is dedicated to everyone who has helped me survive my college career.

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In order to promote plant diversity and increase wildlife habitat, residents, contractors, and local officials need exposure to the benefits of using more than one plant species for dune restoration. This was accomplished through a demonstration planting, an educational kiosk, a brochure, and a website. Education of the public occurred when materials were presented at a variety of meetings, workshops, and events. Workshop participants were aware of the values of dunes but were less knowledgeable about individual plants that grow in the coastal dune system. Ninety percent of the participants gained some knowledge during the workshop. To investigate the effects of stock-plant fertility on cutting production and rooting qualities of *Iva imbricata*, stock-plants were planted into one gal (3.8 L) containers. Plants were fertilized were fertilized with 5.5g, 11g, 15g, and 21g of Osmocote Plus (15N: $9P_2O_5$: $12K_2O$; 8-9 month formulation at 21°C [70°F], Scott Miracle-Grow, Marysville, OH 43041), applied as a topdressing, per pot. Stock-plants were evaluated for shoot growth, total cutting production and rooting characteristics. In Experiment One stock-plant height and width increased as fertility rate increased for all harvests. The total fresh weight of cuttings and number of cuttings produced increased linearly with an increase in fertilizer rate for all harvests. Rooting response differed depending on the time of harvest. Percent rooting did not increase in response to an increase in fertility rate for any harvest period. Fertility rate had an effect on the number of roots per cutting that varied between harvests but did not influence root length. In Experiment Two fertility rate had no effect on stock-plant height and mean cutting weight, but stock-plant width and total fresh weight of cuttings increased as fertility rate increased. Total fresh weight of cuttings and cutting number increased linearly with an increase in fertilizer rate for all harvests. Increased fertility rate had a negative to neutral effect on percent rooting and mean root number but did not affect root length or cutting weight. High levels of fertility, which may be optimal for plant growth and cutting production, may have a negative effect on rooting percentages, root number and root length. *Iva imbricata*, *Panicum amarum*, and *Schizachyrium maritimum* were planted to examine the effect of intermixed composite plantings on transplant survival and sand accumulation. All planting combinations accumulated sand at a rate greater than bare sand controls. Intermixed composite plantings had a negative to neutral effect on plant survival and sand accumulation when compared to monoculture plantings. Plant density increased sand accumulation, however, survival of *Schizachyrium maritimum* decreased as plant density increased.

CHAPTER 1
INTRODUCTION

Coastal dunes are found in almost all latitudes, but many are severely degraded by the exploitation of natural resources, chaotic demographic expansion, and industrial growth (Martinez and Psuty 2004). Coastal dunes exist in a dynamic environment often impacted by tropical storms that erode the shoreline and destroy foredunes (Ehrenfeld 1990). Loss of foredunes can result in storm surge washing over the breadth of the island damaging or destroying island ecosystems (Webb et al. 1997). Restoration of sand dunes is important for the protection of barrier island infrastructure and ecosystems from the further damaging effects of high tides, storm surges, and waves (Dahl et al. 1975). The recovery of barrier island vegetation aids dune building, island stabilization, and provides food and habitat for wildlife (Gore and Schaefer 1993, Snyder and Boss 2002, Swilling et al. 1998).

The coastal dune ecosystem is complex and current restoration practices often do not reestablish that complexity. Changing restoration practices for coastal dunes requires public awareness and support. Garnering public support can be accomplished by extending knowledge gained through research to the public. Through outreach the importance of restoration of coastal dune systems can be conveyed and the need for inclusion of restoration in any successful plan to conserve these coastal systems can be supported.

Before the use of any plant in restoration can become wide spread, production must be economical. Planting stock along with labor required for installation of plants represents one of the major costs of dune restoration and can vary widely by species (Woodhouse 1982). Plants suitable for wide use in restoration of coastal dunes must be economical to produce (Woodhouse 1982). By developing more efficient production practices for species such as *Iva imbricata* Walter [Asteraceae], planting stock costs can be reduced, which in turn will increase *Iva imbricata's* suitability for wide use in restoration projects.

Research into plant-plant interactions and the dynamics that control sand movement and accumulation is key to development of effective restoration and management techniques for dune ecosystems. We examined interactions between three species of dune plants (*Iva imbricata, Panicum amarum* Ell. *var. amarulum* (A.S. Hitchc. & Chase) P.G. Palmer, and *Schizachyrium maritimum* (Chapman) Nash [Poaceae]) and the effect they have on sand movement and accumulation when planted on the beach. This research will increase the information available on how to effectively restore and manage coastal dune ecosystems.

CHAPTER 2
DEMONSTRATION PLANTINGS AT NAVARRE BEACH (SANTA ROSA ISLAND, FL)

In 1995, two major hurricanes impacted the Northwest Florida coast. Since these storms, local home and condominium owners, county governments and contractors have attempted dune restoration. However, government regulations designed to protect endangered sea turtles, such as the Leatherback (*Dermochelys coriacea* (Vandelli), limit or restrict the use of sand fence in the frontal dune position and create the need for restoration with plantings and without sand fence.

Candidates for dune restoration include plants that are easily introduced, thrive in blowing sand, trap sand well, and are relatively free of pests. Restoration projects often rely heavily on Sea Oats (*Uniola paniculata* L. [Poaceae]) as it is the dominant grass of foredunes in the southeast (Woodhouse 1982). Although there are other plants that make substantial contributions to the geographical region, none are widely planted because they fail to meet one of the above criteria (Woodhouse 1982). In order to promote plant diversity and increase wildlife habitat, residents, contractors and local officials need exposure to the benefits of using more than one plant species in dune restoration projects. This is evident as 100% of calls to the Santa Rosa County extension office concerning dune plantings involved customers wanting information on how to plant only Sea Oats (personal communication C. Verlinde, September, 2003).

Gulf Bluestem (*Schizachyrium maritimum* (Chapman) Nash [Poaceae]), Bitter Panic grass (*Panicum amarum* Ell. *var. amarulum* (A.S. Hitchc. & Chase) P.G. Palmer

[Gramineae]), Sea Oats (*Uniola paniculata*), and Beach Elder (*Iva imbricata* Walter [Asteraceae]) are four western Gulf coast species commonly found in the frontal dune zone of barrier islands (Craig 1991). Two of these four coastal species (Beach Elder and Gulf Bluestem) have been the subject of propagation and production research and protocol development. Developed protocols were published to facilitate increased production of local populations of these coastal plants (Thetford and Miller 2004a, b). Although interactions among these four coastal dune species are not well understood, facilitation among plants in temperate and tropical dune systems has been documented (Franks 2003a, b, Martinez 2003). Facilitation between species in composite plantings may increase transplant survival and growth, rate of dune growth and diversity of plants available for wildlife.

This project was aimed at achieving two goals. The first goal was to increase coastal awareness and stewardship. This was accomplished through an educational kiosk at the demonstration planting site, a brochure, and a website. In addition, a traveling program was developed for use at homeowner associations, civic organizations, planning board meetings and coastal workshops. The program included samples of recommended plants and a “how to” slide show. In addition, a survey was used at these meetings to gage pre and post program knowledge about plant diversity in dune restoration (Figure 1). The second goal was to gather preliminary data (plant height, plant width, plant survival) about dune plant interactions. Preliminary data was to be used to test and refine planting methods for use in a full-scale experiment planted the following summer. This data was not collected due to the loss of the plantings as a result of overwash from hurricane Ivan (16, September 2004). The objective of the full-scale experiment was to determine if composite plantings of Gulf Bluestem, Bitter Panic grass, Sea Oats and Beach Elder might facilitate dune formation in a frontal dune zone in the absence of fencing, and to examine the role facilitation and competition play in successful plant establishment.

This project was completed through a series of partnerships between WFREC faculty, Santa Rosa County Sea Grant Extension Agent, Christina Verlinde, Escambia County Sea Grant Extension Agent, Andrew Diller and Okaloosa County Sea Grant Extension Agent, Scott Jackson M.S. graduate student Josiah Raymer and additional local stakeholders. Stakeholders included: Gulf Islands National Seashore, Santa Rosa County Board of County Commissioners, Navarre Beach Leaseholders Association, Santa Rosa County 4-H Youth, and the Pensacola Bay Area Environmental Education Coordination Team (with representatives from Florida Department of Environmental Protection, West Florida Regional Planning Council, University of West Florida, Northwest Florida Water Management District and additional civic and government organizations).

The physical portion of the project (beach planting) was planted (17, May 2004) with the help of University of Florida staff, the Santa Rosa County Extension Office, and local 4-H volunteers. After which, deliverables for the project were developed. Deliverables produced for this project included a trifold brochure (Figures 2 and 3) and a Power Point presentation that were utilized by the extension service to educate the public about the project and issues affecting the dune ecosystem. A poster presented in a kiosk at the study site exposed beach visitors to the project and helped explain the purpose of the demonstration plots. Dune restoration signs donated by Santa Rosa County were placed at the demonstration site and a website containing all of the information about the project (pictures, plant information, trifold brochure, and power point presentation) was made available for anyone wishing to learn more (http://wfrec.ifas.ufl.edu/extension/dunes).

This project aimed to educate the public about issues facing the dune ecosystem and how these issues affect them. Education of the public occurred when materials were presented at a variety of meetings, workshops, and events. These included 75 residents at two Navarre Beach Leaseholders Association meetings where the project was discussed and brochures were distributed. Additionally the project was presented to 15 participants of a Coastal Restoration Workshop where pre and post program surveys were completed by each participant. A poster was presented and brochures were distributed at several events including, Earthday at the Zoo April 2005 (100 people), Seagrass Awareness Festival March 2005 (200 people), and the Coastal Encounters event Oct. 2005 (300 people). Brochures were also distributed through a local eco-tourism business on the beach.

The long-term impact of this project will be an increased awareness of some of the issues affecting barrier islands. Measurable impacts of the program were evident from the results of the pre- and post program tests administered at the Coastal Restoration Workshop. Among the 15 participants, 10 completed both pre- and post program tests. Results of the pretest indicated 100 percent of the participants were aware that dunes provide habitat for animals, protect the mainland from storms, and naturally undergo change (Table 1). The pretest also indicated that 100 percent of participants were aware that dunes are formed by sand that is trapped by plants. This high level of knowledge suggests many of the participants were highly knowledgeable about stewardship and the function sand dunes play in the coastal dune ecosystem (questions 1 and 2). Eighty percent of the participants also understood the concept of a monoculture suggesting that the participants were somewhat knowledgeable about concepts pertaining to plant diversity (question 3). This percentage did not increase in the post test and indicates that understanding of the concept of monoculture was not increased by the workshop. Only 30 percent of the participants knew about the basic flowering characteristics for Beach Elder prior to the workshop, and 60 percent knew about the basic flowering characteristics of Gulf Bluestem indicating that participants were less knowledgeable about individual plants that grow in the coastal dune system (questions 4 and 5). Knowledge about individual plants was increased by the workshop and was reflected in the increase in correct answers during the post test, which rose to 80 percent for Beach Elder and 70 percent for Gulf Bluestem. When post program test scores were compared to the pre program test scores there was a 16% difference in test scores. Ninety percent of the participants gained some knowledge during the workshop. An additional impact of this work was an increase in calls to the extension office asking where to get the plants described in the brochure and on the web site and how to volunteer for dune restoration projects. (personal communication C. Verlinde, October 2005).

On September 19, 2004 Hurricane Ivan came ashore on Santa Rosa Island and destroyed the physical portion of the project (demonstration plantings and kiosks). The pamphlets, presentations, and website are still available and at this point there are plans to replant the study on Navarre Beach once renourishment efforts are completed.

Please take a moment to fill out this survey before and after the Dune Restoration Presentation. The information will be used to determine whether we are meeting the goals of this program. Thanks in advance!!!!!

Please circle your answers.

1. Why are dunes important?

   A. Provide habitat for birds, reptiles and mammals
   B. Protect the mainland and coastal development from storms
   C. Part of a natural changing environment of a barrier island
   D. All of the above

2. Dunes are formed when:

   A. It rains
   B. Mice live near them
   C. Sand is trapped among plants leaves, stems and roots
   D. When a sea turtle nests

3. A monoculture is:

   A. A single grain of sand
   B. Where only 1 species of plant is utilized (sea oat turf)
   C. An exotic plant
   D. None of the above

4. Which dune plant has small lavender flowers that occur in late summer?

   A. Gulf bluestem
   B. Bitter panicum
   C. Sea oats
   D. Beach elder

5. The seed head of this plant has dense silvery hairs.

   A. Bitter panicum
   B. Sea oats
   C. Gulf bluestem
   D. Beach elder

Name____

Figure 1. Preprogram and postprogram survey used to evaluate change in knowledge of coastal restoration workshop participants.

Figure 2. Backside of Beachgoers Guide to Sand Dunes trifold brochure created for demonstration project.

Do you know your Beach Plants?

Plants used in this restoration project occur naturally along coastal dunes throughout the Gulf Coast. Dune plants are adapted to the harsh conditions of the beach such as temperature extremes, saltwater spray and soil (mostly sand) that is low in nutrients and moisture. Plants in the dune system trap sand, which stabilizes dunes and promotes dune formation. For more information on the plants used in this project check out... http://wfrec.ifas.ufl.edu/extension/dunes or visit the project sites on Navarre Beach at Public Access #7, 8, 10, and 11.

Beach elder (*Iva imbricata*) has sparse, woody, upright stems and fleshy narrow bright green leaves. Small lavender flowers occur in late summer. Beach elder accumulates sand rapidly and produces low rounded dunes.

Bitter panicum (*Panicum amarum*) is a tall, clumping, perennial grass with large, wide, silver/blue leaves. The upright growth form will stand out when compared to other species growing on the dunes.

How are dunes formed?

Coastal dunes are formed when sand is trapped around the stems, leaves and roots of plants in the vegetated areas of the beach.

Why are dunes important?

The sand dune system along Florida beaches helps protect the mainland and buildings from the force of tropical storms and hurricanes. The dune system absorbs the energy of storm waves.

Why use different plants to restore dunes?

Along the Gulf of Mexico, many different species of plants naturally occur on the dune system. Beach areas rich with many different species offer a diversity of plant sizes and forms and thus more opportunities for trapping sand. By imitating this richness in species, dunes can be restored in a natural way that may also benefit animal species that use the dunes for food or shelter.

Gulf bluestem (*Schizachyrium maritimum*) is a creeping, perennial grass easily identified by silvery blue leaves. The seed heads, which mature in late summer are distinguished by dense silvery hairs.

Sea oats (*Uniola paniculata*) is the dominant plant occurring on dunes and is crucial in the growth and maintenance of coastal dunes. It is a creeping, perennial grass, with narrow leaves and tall prominent flower spikes, which appear in early fall. The seed heads look like spiked oats. It has an extensive underground stem and root system, and burial by sand stimulates sea oats growth!

Figure 3. Frontside of Beachgoers Guide to Sand Dunes trifold brochure created for demonstration project.

Table 1. Results of preprogram and postprogram survey taken by ten coastal restoration workshop participants.

		% of responses		Difference Between Pre and Post
Question	**Response**	**Preprogram**	**Postprogram**	**Program Responses**
1	A	100	100	0
	B	0	0	0
	C	0	0	0
	D	0	0	0
2	A	0	0	0
	B	0	0	0
	C	100	100	0
	D	0	0	0
3	A	0	0	0
	B	80	80	0
	C	0	10	10
	D	20	10	-10
4	A	30	0	-30
	B	10	20	10
	C	0	0	0
	D	30	80	50
5	A	20	20	0
	B	0	10	10
	C	60	70	10
	D	0	0	0

CHAPTER 3
EFFECT OF FERTILITY RATE ON CUTTING PRODUCTION OF STOCK-PLANTS OF IVA IMBRICATA: ROOTING CHARACTERISTICS OF CUTTINGS PRODUCED

Introduction

Seacoast Marshelder (*Iva imbricata* Walter [Asteraceae]) (hereafter referred to as *Iva*) is a dominant seashore plant and occurs on coastal dunes throughout the south Atlantic and Gulf region. *Iva* can spread vegetatively and by seed and is the only broad-leaved plant with a potential for building and stabilizing foredunes in the South Atlantic coast of the United States (Woodhouse 1982). *Iva* can grow throughout primary and most secondary successional zones and is occasionally found alone building foredunes but is usually found in combination with one or more dune grasses (Woodhouse 1982). *Iva* is used for dune restoration and stabilization projects (Craig 1991) and has also been identified as an important food for beach mice (Moyers 1996).

Iva is a perennial C3 shrub (Franks 2003), which produces inflorescences at the tips of its stems in the fall. *Iva* has sparse woody stems from one to four feet (30 to 122 cm) tall with fleshy, narrow, lance shaped leaves. Highest rates of seed production on mature plants occur in foredunes while successful seedling establishment occurs in areas of little sand movement and favorable moisture (Woodhouse 1982) causing highest germination rates to occur on open beach or upper marsh in the spring (Colosi and McCormick 1978). *Iva* develops a strong system of rhizomes and roots when buried by soil and produces gently rounded dunes (Craig 1991). These growth characteristics make *Iva* desirable for dune restoration but the timing of seed production in natural regeneration may not provide sufficient plants for restoration and warrants development of efficient propagation and production practices for restoration efforts.

Softwood cuttings of *Iva* stems root readily (Craig 1991) with rooting percentages greater than 90% achievable with or without auxin application for ten cm cuttings collected from native populations (Thetford and Miller 2002). Management of stock-plants in a nursery setting is desirable for producing a reliable and consistent source of cuttings. However, it is not presently known if container production of stock-plants for this purpose is a viable alternative or if stock-plant fertility may have an affect on cutting production, rooting percentage or the quantity or quality of the roots produced. Stock-plant nutritional fertility has been shown to be a factor in the rooting of softwood and hardwood cuttings (Blazich 1988, Veierskov 1988). For example cuttings of *Pelargonium* sp (Geranium) harvested from stock-plants grown under low and medium fertility rates (N, P, K) demonstrated an increase in rooting percentage when compared to high fertility rates (Haun and Cornell 1951, Blazich 1988, Veierskov 1988). A similar response was noted by Preston et al. (1953) when propagating *Rhododendron* sp. (Azalea) maintained under similar fertility rates where low and medium rates demonstrated higher rooting percentages than high fertility rates. Optimum stock-plant nitrogen levels for rooting of cuttings has also been shown to occur below the optimum level for stock-plant growth for *Juniperus virginiana* L. (Eastern Red Cedar) where optimum growth occurred at 100-150 mg/L N while optimum rooting occurred at 20-40 mg/L N (Henry et al. 1992). This previous work demonstrates a need to consider not only the effects of fertilization on the number of cuttings produced, but to also consider the effects of stock-plant fertility on the rooting success of cuttings when optimizing stock-plant fertility rates. Finding an acceptable level of stock-plant fertility to maximize cutting production without sacrificing root quality will lead to better management practices. The objective of the following experiments was to investigate the affects of stock-plant fertility on cutting production and evaluate the rooting qualities of harvested cuttings.

Materials and Methods

Forty-eight stock-plants of *Iva* were planted on both 3 February, 2004 (Experiment One) and 9 July, 2004 (Experiment Two) using eight cm liners transplanted into one gal. (3.8 L) containers. Liners were grown in a pine bark substrate amended with six lbs. (2.7 kg) dolomitic limestone per yd^3 (0.76 m^3). Plants were pruned to eight cm in height seven days after planting (DAP).

Osmocote Plus (15N: $9P_2O_5$: $12K_2O$; 8-9 month formulation at 21°C [70°F], Scott Miracle-Grow, Marysville, OH 43041) was applied as a top dressing at 5.5 g, 11 g, 15 g, and 21 g per pot with 11 g representing the recommended fertility rate for a one gallon plant. Plants were grown in full sun receiving 30 min of overhead irrigation twice daily. The experiment was a completely randomized design consisting of four fertility treatments with 12 single-plant replications.

Experiment One was initiated using dormant liners while Experiment Two was initiated during the growing season. First harvest was conducted when all of the stock-plants in the experiment had sufficient growth to collect at least four 10 cm cuttings. The first harvest of cuttings from each experiment began 114 and 49 DAP respectively. Stock-plants were evaluated for shoot growth (stock-plant height and width) and total cutting production at each of 4 harvest dates [114,146, 175, and 206 DAP for Experiment One and 49, 79, 108, and 136 DAP for Experiment Two.]. Each plant was measured for maximum shoot height and width (mean of two perpendicular widths) and all tip cuttings 10 cm in length harvested. The total number and total weight (g) of cuttings collected from each plant was recorded and the stock-plants were cut back to a height of 20 cm.

Rooting characteristics of cuttings were quantified utilizing a sub-sample of four cuttings randomly selected from the pool of cuttings taken from each stock-plant at each harvest. Cutting were stripped of leaves two cm above the base and a fresh cut made prior to treatment with Hormodin-1, 1000 mg/L IBA (indole-3-butyric acid) auxin rooting powder (OHP, Inc., Mainland, PA 19451). Each rooting experiment contained four cuttings from each of the 12 stock-plants representing each of the four fertilizer treatments for a total of 192 cuttings. However, the first harvest of Experiment Two did not yield sufficient cuttings so no rooting data are available for that date. All rooting experiments were arranged in a randomized complete block design with each of the 12 blocks containing 16 cuttings. Bench position was used as a blocking factor to account for differences in environmental conditions along the length of the greenhouse bench.

Cuttings were inserted two cm deep into 72 cell plug flats filled with Fafard #4M Mix (40% peat, 35% vermiculite, 25% bark) (Conrad Fafard, Inc., Agawam, MA 01001). Cuttings were randomly placed under intermittent mist operating at four seconds of mist every ten min from 7:00 A.M. to 8:00 P.M. with bottom heat of 80°F.

Cuttings were evaluated for rooting 14 days after sticking and the roots washed free of propagation substrate. Root number (primary roots emerging from the cutting) and length of the longest root (cm) were recorded for each cutting.

Mean fresh weight of cuttings was calculated for each stock-plant using total fresh weight of all cuttings harvested divided by total number of cuttings harvested. A plant growth index was calculated for each stock-plant using plant height and width ((mean width + ht)/2) to evaluate the combined effects of changes in height and width and monitor overall changes in plant growth form. Rooting percentage was calculated based on the number of cuttings rooted from each stock-plant. An estimate of total root length was calculated as the product of root number and root length to estimate the combined effects of root number and root length.

Data were analyzed for treatment affects using the general linear models procedure of SAS (SAS Institute Inc. 2000-2004).

Results and Discussion

Stock-plant growth and cutting production were influenced by the rate of fertilizer applied but responses were not consistent across harvest times or between the two experiments. This trend was also true for rooting percentage and measures of root quality. The two experiments had differing responses, which were thought to be a result of seasonal growth effects associated with the timing of the two experiments. Hence, data for the two experiments are presented separately.

Experiment One

Stock-plant growth and cutting production

The main effects of fertility and harvest both had a significant effect on stock-plant size as shown by changes in height, width and growth index (Table 1). There were significant interactions between the effects of fertility and harvest for all variables except stock-plant width. Pearson correlation coefficients indicate stock-plant height and width were not correlated although both were highly correlated with growth index ($r = 0.858$ and 0.816 respectively).

Stock-plant height increased as fertility rate increased for all harvests (Figure 1). There was a significant decrease in stock-plant height for all harvest periods when fertility rate decreased to 5.5 g, a rate representing half the recommended rate of 11 g. Prior to the first harvest of cuttings plant height followed a classic fertilizer growth response curve and maximum height was achieved between the rates of 11 g and 15 g. However, after first harvest plant height did not differ between the 11 g, 15 g, and 21 g fertilizer rate.

Stock-plant width increased as fertility rate increased for all harvests (Figure 2). There was a significant decrease in stock-plant width for all harvest periods when fertility rate decreased to 5.5 g. Plant width did not differ between the 11 g and 15 g, however, and there was a significant increase in plant width when the fertility rate was increased to the 2-times recommended rate of 21 g when compared to the recommended rate.

Fertilizer rate had a significant effect on stock-plant growth index resulting in an increase in plant growth index as fertilizer rate increased (Figure 3). This response was particularly evident prior to the first harvest of cuttings when the greatest differences in stock-plant size were evident and followed a classic quadratic fertilizer growth response curve (Figure 3). When fertilizer was applied at half the recommended rate of 11 g there was a 35% decrease in plant growth index while fertilizer applied at twice the recommended rate of 11 g resulted in a 13% increase in plant growth index. After the initial harvest of cuttings plant growth index did not differ among plants fertilized with 11 and 15 g of Osmocote. The data suggests nearly a 2x application of the recommended rate is necessary to affect a significant increase in plant growth index for *Iva* stock-plants.

Although hedging of stock-plants reduced height to 20 cm following each successive harvest of cuttings, stock-plant growth index (Figure 1) increased with each successive harvest ($P < 0.0001$). The effects of increasing stock-plant width resulted in a 5% increase in growth index from harvest one to the harvest four.

Fertility rate as well as time of harvest had a significant effect on the total fresh weight of cuttings removed from each plant ($P < 0.0001$, Table 2). The total fresh weight of cuttings increased linearly with an increase in fertilizer rate for all harvests (Figure 4). Total fresh weight of cuttings decreased 35% from harvest one to harvest three before increasing 27% from harvest three to harvest four for the 11 g rate.

Fertility rate had a significant effect on cutting number ($P < 0.0001$). The number of cuttings produced per stock-plant increased linearly with increasing rate of fertility for all harvests (Figure 5). The number of cuttings produced at the recommended rate per stock-plant increased with each successive harvest ($P < 0.0001$), resulting in an increase of 93% from harvest one to harvest four (Figure 5). Pearson correlation coefficients indicate that the number of cuttings produced was not correlated with plant height ($r = 0.2539$) or index ($r = 0.5733$) but was highly correlated with plant width ($r = 0.74923$) across harvests. This suggests stock-plant width has a greater positive effect on increases in cutting production than stock-plant height and that managing stock-plants in a fashion that increases width will result in an increase in cutting production.

Fertility rate as well as time of harvest had a significant effect on individual cutting weight ($P < 0.0001$). The weight of individual cuttings increased linearly with an increase in fertilizer rate for harvests one and two (Figure 5). Cutting weight was 53-56% greater at harvest one than at other harvests when averaged across fertility rates

(Figure 6). At the time of the first and second harvests, cutting weight increased 24% and 10% with a doubling of the fertility while cutting weight did not differ at 2x the recommended rate at the third and fourth harvests.

Rooting percentages and quality

The main effects of fertility and time of harvest were significant for most measured rooting variables (Table 3). An interaction was present between the main effects of fertility and time of harvest for all measured variables indicating the rooting response differed depending on the time of harvest.

Percent rooting was influenced by fertility rate ($P = 0.0035$) and the time of harvest ($P < 0.0001$) (Figure 7). Percent rooting did not increase in response to an increase in fertility rate for any harvest period. Harvests one and four had rooting percentages between 88% and 100% for all fertility levels. Rooting percentages for harvest period two declined linearly as fertility level increased and ranged from 79% at the lowest rate to 54% at the highest rate. Rooting percentages for harvest period three declined linearly as fertility level increased and ranged from 63% at the lowest rate to 35% for the highest rate. Increasing fertility rate of *I. imbricata* stock-plants does not increase the rooting percentage of harvested cuttings.

Fertility rate had a significant effect on the number of roots per cutting ($P = 0.016$) but did not influence root length ($P = 0.0772$) (Figures 8 and 9). During harvest period one root number declined linearly as fertility rate increased and ranged from 8.6 roots per cutting at the lowest rate to 6.3 roots per cutting at the highest rate. Root number did not differ in response to fertility rate for harvests two through four with 4.3 to 6.9 roots produced per cutting.

Fertility rate as well as time of harvest had a significant effect on root index (P = 0.0151 and $P < 0.0001$)(Table 3). Root index decreased linearly as fertility rate increased for harvest one (Figure 10). Root index then began to increase linearly as fertility rate increased for harvest four.

Experiment Two

Stock-plant growth and cutting production

The main effects of fertility and time of harvest both had a significant effect on stock-plant width and growth index but did not have a significant effect on stock-plant height (Table 1). There were no significant interactions between the effects of fertility and harvest for height, width or growth index (Table 1). Pearson correlation coefficients indicate stock-plant height and width were not correlated although width was highly correlated with growth index (r = 0.7803).

Fertility rate had no effect on stock-plant height (Figure 11) but decreases in stock-plant height following each harvest of cuttings indicate plant regrowth was affected by the time of harvest ($P < 0.0001$). Stock-plant fertility did have a significant effect ($P < 0.0001$) on stock-plant width (Figure 12). Compared to the standard rate of 11 g, there was a significant decrease in stock-plant width for all harvest periods when fertility rate decreased to 5.5 g. Stock-plant width at the 5.5 g rate of fertilizer remained nearly constant following each successive harvest of cuttings. Stock-plant width increased with each subsequent harvest of cuttings when fertilizer was applied at the recommended rate or greater. However, stock-plant width did not differ among plants fertilized at 11 g, 15 g, or 21 g rates.

Fertility rate ($P < 0.0001$) and time of harvest (P =0.0004) both had a significant effect on plant growth index. Plant growth index demonstrated a linear or quadratic increase as fertilizer rate increased. The greatest increase in plant index occurred from 5.5 g to 11 g and no significant increase in plant index was evident when the fertilizer rate was doubled to 21 g. (Figure 13). The data suggest that even a 2x fertility rate does not increase stock-plant growth index compared to the recommended rate.

Fertility rate as well as time of harvest had a significant effect on the total fresh weight of cuttings removed from each plant ($P < 0.0001$)(Table 2). The total fresh weight of cuttings increased linearly with an increase in fertilizer rate for all harvests (Figure 14). Total fresh weight of cuttings increased 178% from harvest one to harvest four for the 11 g rate. Total fresh weight of cuttings decreased 23% from harvest two to harvest three causing an interaction between fertilizer rate and harvest period.

Fertility rate ($P < 0.0001$) had a significant effect on the number of cuttings harvested. Cutting number increased linearly as fertility rate increased (Figure 15). Reducing the fertilizer rate to 5.5 g resulted in a 29% to 48% decrease in cutting production. However, increasing the fertilizer rate above 11 g did not increase the number of cuttings produced per plant. Cutting number also differed with the time of harvest ($P < 0.0001$). Cutting number began to increase by the third harvest of cuttings and then began to decrease at the fourth harvest. Fertility rate did not have a significant effect on mean cutting weight ($P = 0.3750$) but cutting weight did increase from harvest one to harvest four ($P < 0.0001$)(Figure 16).

Rooting percentages and quality

The main effects of fertility and time of harvest were significant for most rooting variables (Table 3). An interaction was also present between the main effects of fertility and harvest for all rooting variables indicating the rooting response differed depending on the time of harvest.

Percent rooting was influenced by fertility rate (*P* = 0.0269) and the time of harvest (*P* < 0.0001) (Figure 17). Rooting percentages for cuttings collected during harvest two remained above 90% regardless of the level of stock-plant fertility. However, at subsequent harvests, rooting percentages began to decrease for cuttings taken from plants receiving less that 21 g of fertilizer. At harvest three rooting percentages indicate a linear increase as the rate of stock-plant fertility increased resulting in a 28% decrease in rooting percentage from the 21 g rate to the 5.5 g rate. Rooting percentages further decreased as fertility rate decreased at harvest four and ranged from 64% to 83%.

Both fertility rate (*P* = 0.0059) and time of harvest (*P* < 0.0001) had a significant effect on mean root number (Table 3). At harvest two the number of roots per cutting initially increased as stock-plant fertilizer rate increased but this trend became reversed by the fourth harvest (Figure 18). The number of roots per cutting for harvest period two was 21% to 63% higher than root number for subsequent harvests. Root number per cutting decreased through harvest period four and cuttings from stock-plants fertilized at 11 g had 5.2 roots per cutting by harvest four.

Mean root length was not affected by the rate of stock-plant fertilizer treatment (*P* = 0.2079), however root length did differ with the time of harvest (*P* < 0.0001). Root length was significantly higher during harvest two compared to subsequent harvests (Figure 19). Root length decreased from 10 to 12 roots per cutting at harvests two to only two roots per cutting at harvest four. The similar decreases in root number and root length are also reflected in the root index (Figure 20). The effects of stock-plant fertility and time of cutting harvest on root index resembles the response of root number more than root length.

Fertility rate as well as time of harvest had a significant effect on root index (P = 0.0008 and $P < .0001$)(Table 3). Root index increased linearly as fertility rate increased for harvest two but had no effect for harvests three and four (Figure 20). Root index was 286% to 913% higher at harvest two than at harvests three and four showing a dramatic reduction in root index from period two to four.

Discussion

The effect of fertility rate on plant growth before the first harvest of cuttings from both Experiments one and two exhibited a classic growth response curve in response to an increase in fertilizer rate (Figures 3 and 13). In both experiments, the greatest increase in growth occurred when the rate of Osmocote increased from the 5.5 g to 11 g. The rate of growth slowed but continued to show an increase when the rate of Osmocote increased from 11 g to 15 g. *Iva* growth rate did not increase when the rate of Osmocote was increased from 15 g to 21 g. This trend was exhibited for both plant height and plant width (Figures 1, 2, 11, and 12). These results indicate the growth rate of *Iva* can be increased with the application of Osmocote up to the 15 g rate but no additional benefit in growth can be achieved with further increases in the rate of fertilization. Maximizing plant growth with the application of 11 to 15 g of Osmocote will allow for shorter grow out times in a nursery production system, which will in turn increase the numbers of plants that can be produced in a given time period while reducing production costs.

After the first harvest of cuttings for both experiments, increases in plant height in response to fertilizer slowed while plant width continued to increase in response to an increase in fertility rate. In addition, width also increased with each successive harvest and was highly correlated with an increase in the number of cuttings produced. Cutting production has also been shown to increase with successive harvests in *Antirrhinum*, *Chrysocephalum*, *Diascia*, *Lavendula*, *Osteospermum*, and *Verbena* in response to hedging. This shows that hedging stock-plants results in an increase in cutting number (Faust and Grimes 2005). Faust and Grimes (2005) also found that increasing the hedging height in successive harvests maximized cutting production. *Iva* stock-plants were hedged to a constant height in our experiments but further increases in the number of cuttings produced may have been realized with successive increases in stock-plant height following each successive harvest. Over a 23 week period cutting quantity and quality of *Scaevola* cuttings has been shown to increase over time as N fertilization concentration increased from 100 to 300 mg/L (Gibson 2003). Similarly, stock-plants of *Pelargonium* sp. have been shown to produce low numbers of cuttings at a 50 mg/L rate while producing higher numbers of cuttings at the 100 mg/L, 200 mg/L, and 400 mg/L rates (Ganmore-Neuman and Hagiladi 1990, 1992).

The strong correlation in Experiment One and weak correlation in Experiment Two between the increase in stock-plant width and the increase in cutting production suggests that managing stock-plants in a manner that increases width will also cause cutting production to increase as fertility level increases. But, similar to plant growth, cutting number did not continue to increase as fertilizer rates were increased above the 15.0 g rate.

Time of harvest had a stronger influence on the weight of individual cuttings than did the rater of fertilizer. When cutting weight is graphed across time (Figure 21) the lowest weights per cutting were evident during the months of June and July and correspond with the period of lowest rooting percentages. Seasonal effects on cutting production and quality have been reported for many crops such as *Pelargonium sp. and*

Cotinus coggygria (Ganmore-Neuman and Hagiladi 1992, Cameron et al. 2005). Work by (Ganmore-Neumann et al. 1992), showed that low irradiance levels during stock-plant growth caused a drop in cutting production while causing an increase in rooting characteristics. Cameron et al. (2005) showed that rooting percentages responded to changes in photoperiod differently according to season. Rooting of cuttings harvested in August were unaffected by short day compared to long day photoperiod while cuttings harvested in September had higher levels of rooting in the long day photoperiod. Changes in light characteristics may have been a factor in the seasonal effect on rooting percentages of cuttings taken from *Iva* stock-plants.

Stock-plant nutrition has been shown to have a significant effect on rooting percentages (Blazich 1988, Veierskov 1988), as was observed in this study. Rooting percentage had an inverse relationship with fertility rate from May through July suggesting that high levels of fertility should be avoided during that period to keep from negatively affecting rooting percentages. High levels of fertility, which may be optimal for plant growth and cutting production, had a negative affect on rooting percentages, root number and root length. This inverse relationship has also been demonstrated in cuttings taken from stock-plants of *Pelargonium* sp, *Rhododendron sp*, and Eastern Redcedar (Haun and Cornell 1951, Preston et al. 1953, Henry et al. 1992). Haun et al (1951), Preston et al (1953), and Henry et al (1992) all found inverse relationships between stock-plant fertilization and rooting percentages in cuttings harvested from stock-plants. With *Iva* this trend was not consistent throughout the season. Higher fertilizer rates had a neutral to positive effect on *Iva* rooting percentage and quality during the months of August through November. This may be a result of the onset of flowering in *Iva*, which is fall flowering, or the onset of dormancy.

The recommended rate of 11.0 g of Osmocote Plus per one-gallon pot produced nearly maximum plant growth and resulted in acceptable rooting percentages throughout the growing season. Optimum rooting percentages occurred from May to early June and August through September, suggesting two optimum harvest periods. Utilizing a stock-plant hedging technique was a successful method for the production of Iva cuttings. Propagators should prune stock-plants to maximize plant width during spring and schedule a harvest of cuttings from May to early June. After this initial harvest of cuttings stock-plants may benefit from a period of growth when rooting percentages are minimal. By scheduling a second harvest during August through September, cutting production will be maximized and cuttings will be propagated at a time when cuttings root at a high percentage. Avoiding harvest and propagation of cuttings when rooting percentages will be at their lowest will improve propagation success and increase production efficiency.

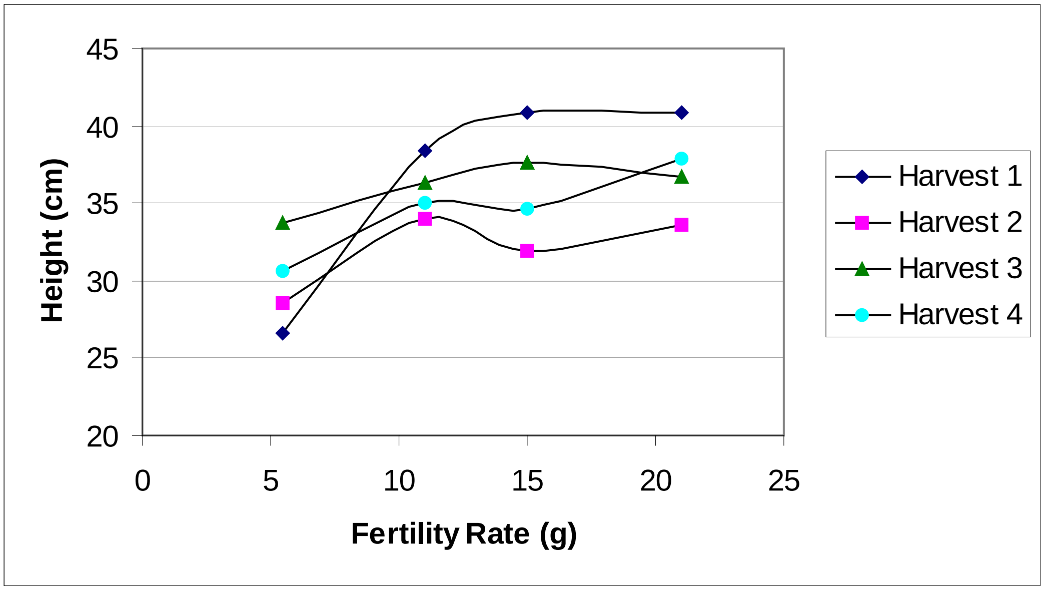

Figure 4. Plant height by fertility rate, and month of harvest for Experiment One. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

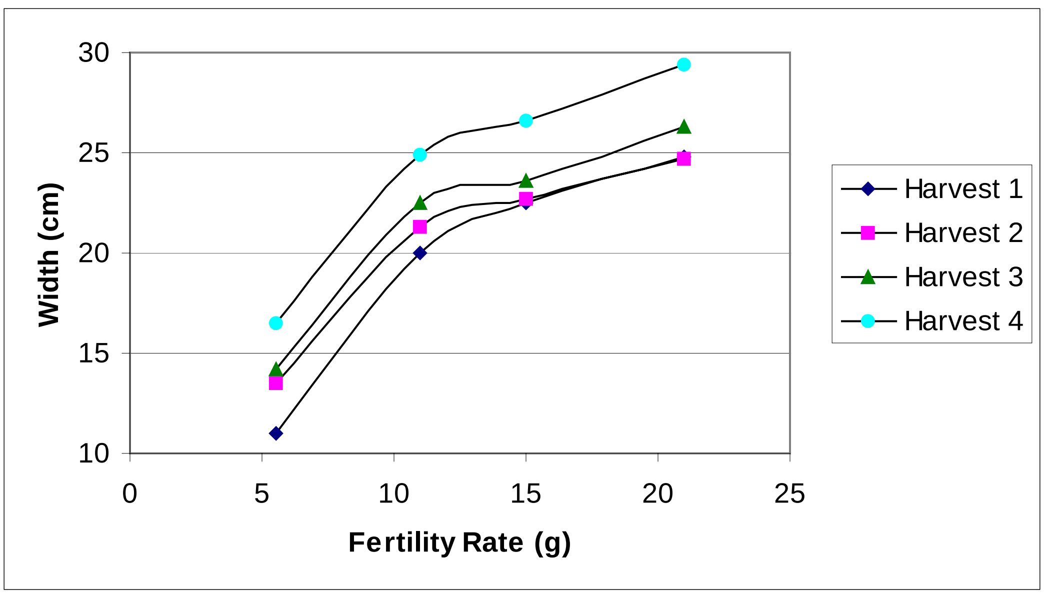

Figure 5. Plant width by fertility rate, and month of harvest for Experiment One. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

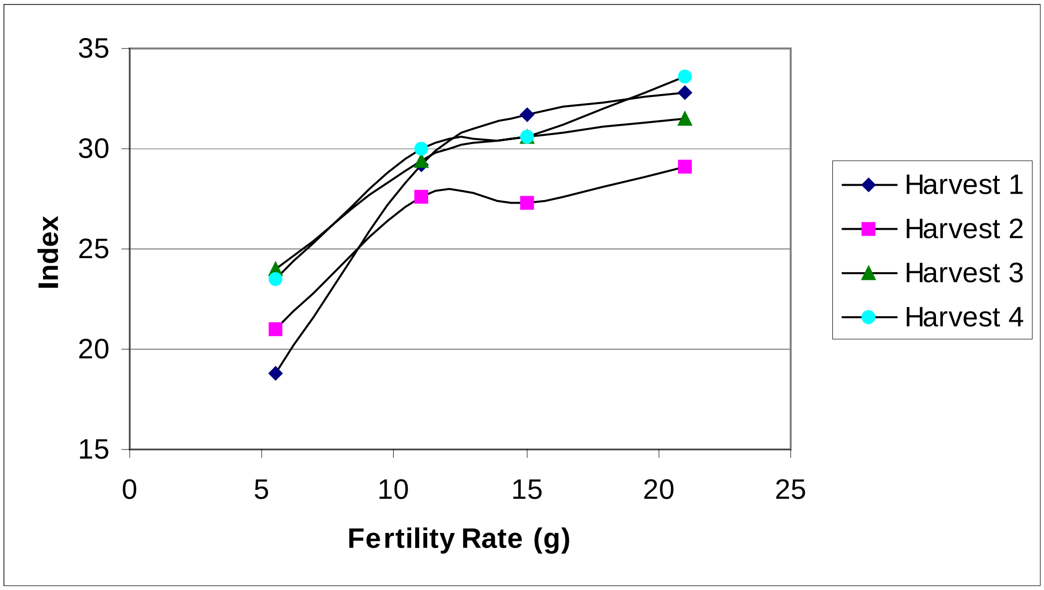

Figure 6. Plant growth index ((mean width + ht)/2) by fertility rate, and month of harvest for Experiment One. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

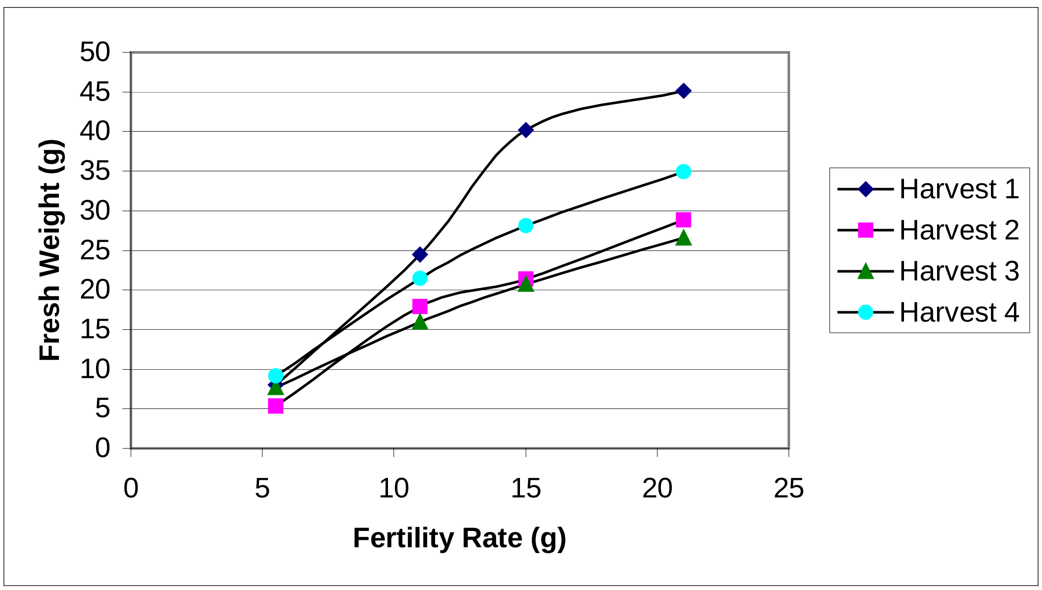

Figure 7. Total fresh weight cuttings by fertility rate and month of harvest for Experiment One. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

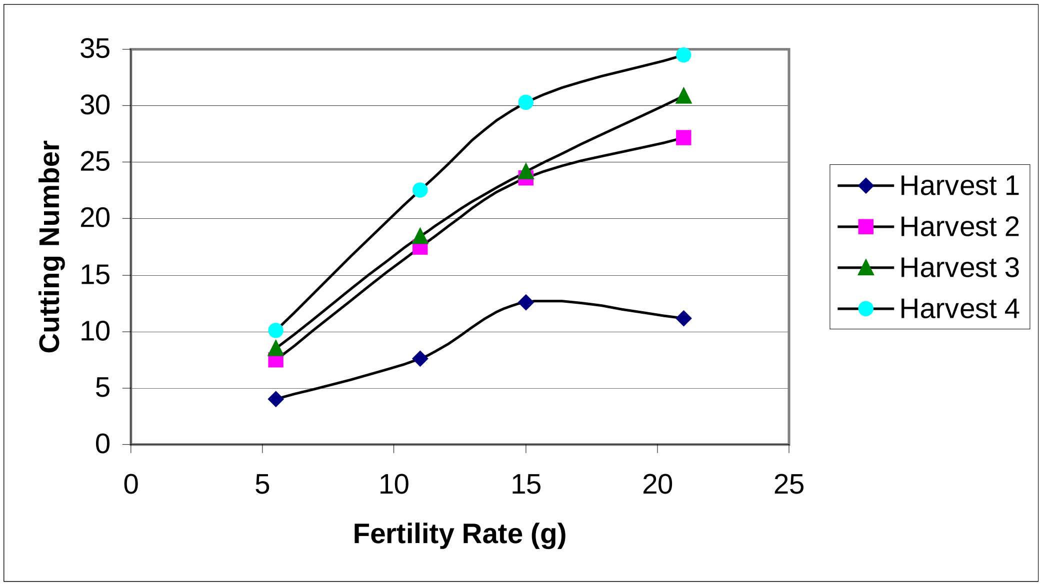

Figure 8. Cutting number produced by fertility rate and month of harvest for Experiment One. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

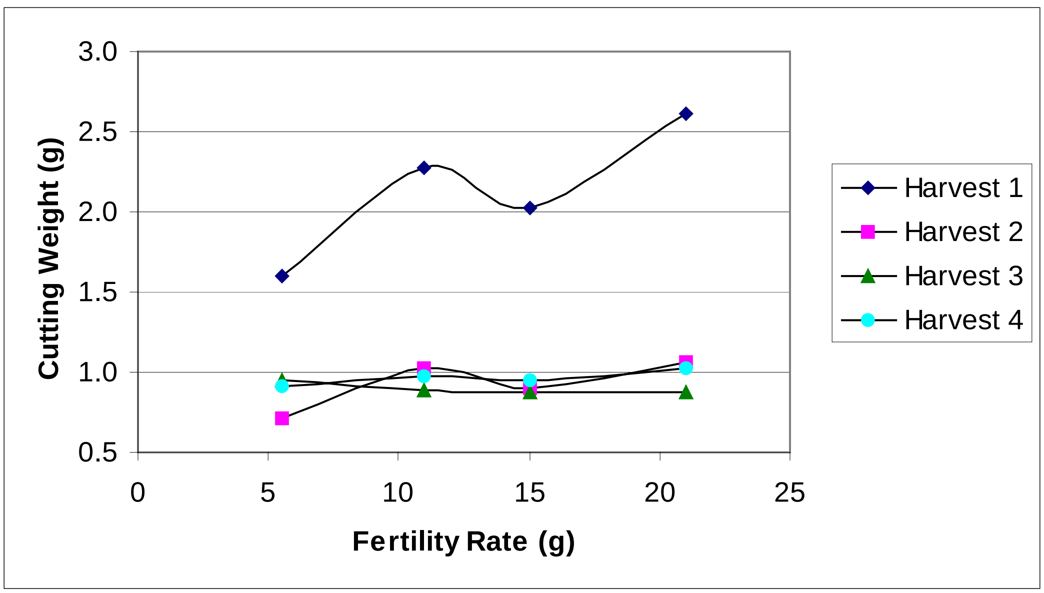

Figure 9. Cutting weight by fertility rate and month of harvest for Experiment One. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

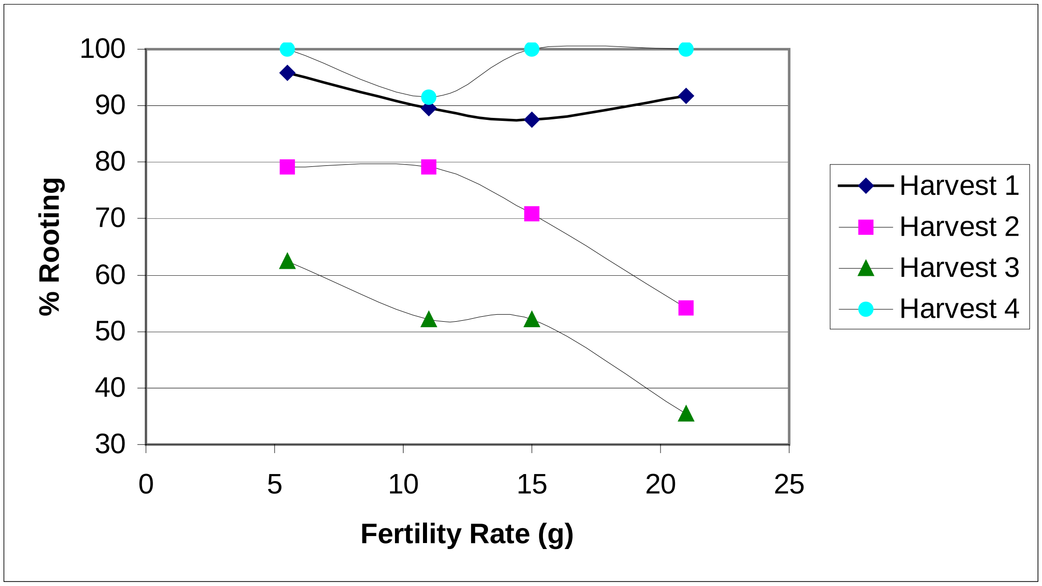

Figure 10. Percent rooting by fertility rate, and month of harvest for Experiment One. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

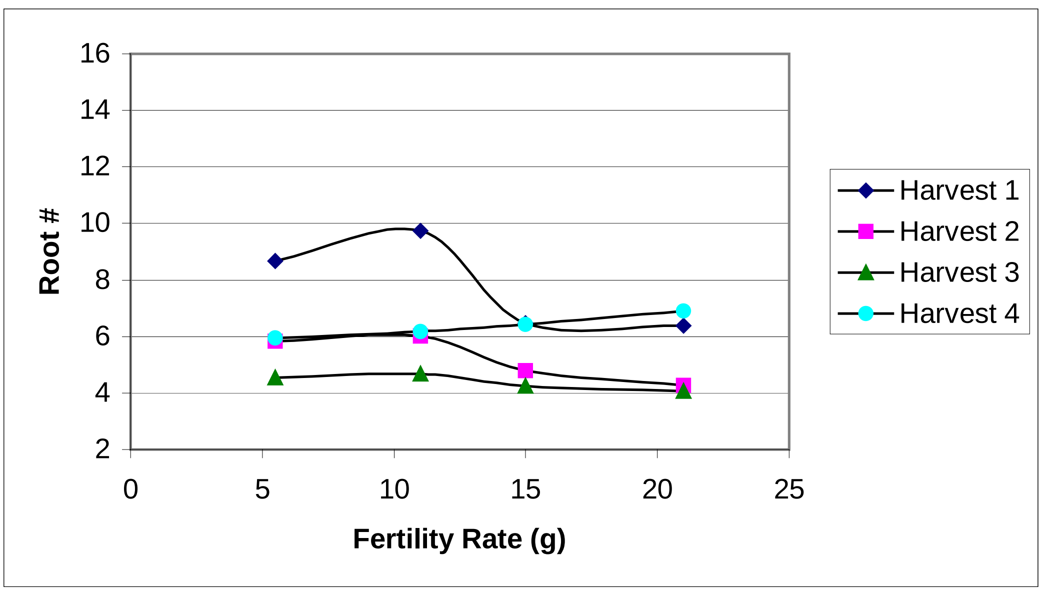

Figure 11. Root number by fertility rate, and month of harvest for Experiment One. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

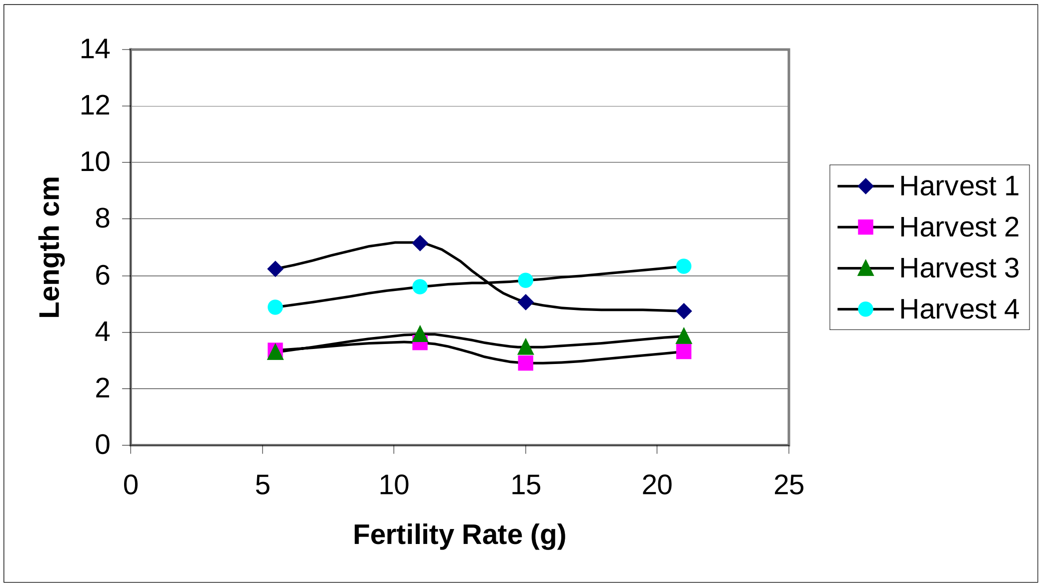

Figure 12. Root length by fertility rate, and month of harvest for Experiment One. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

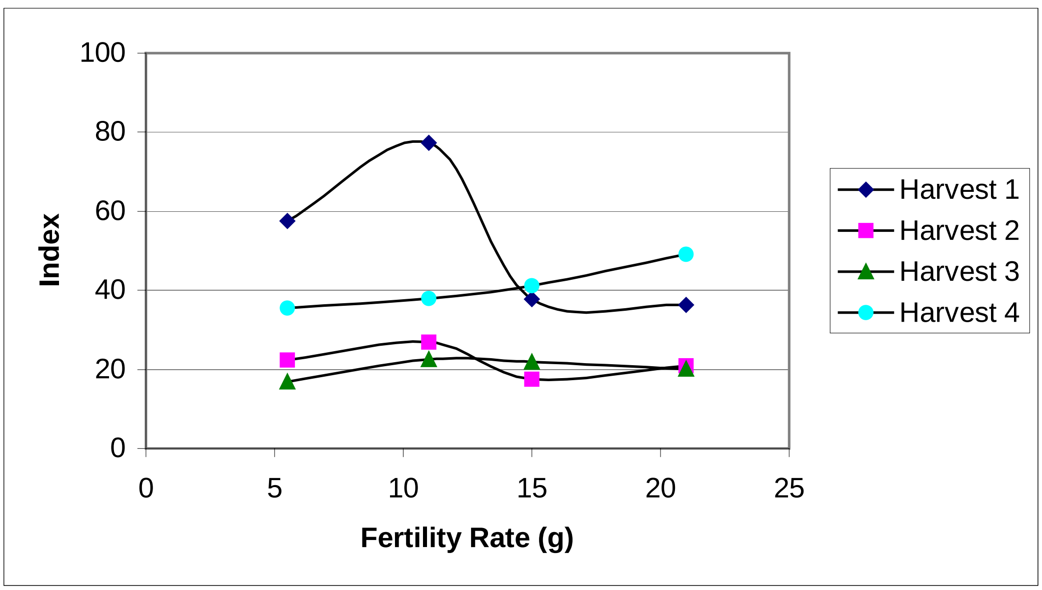

Figure 13. Root index by fertility rate, and month of harvest for Experiment One. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

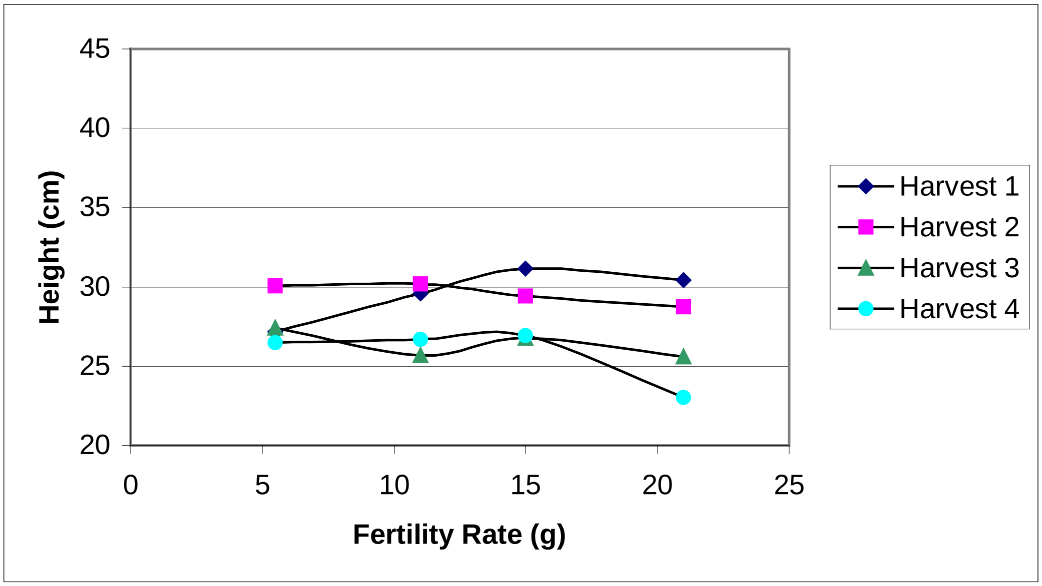

Figure 14. Plant height by fertility rate, and month of harvest for Experiment Two. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

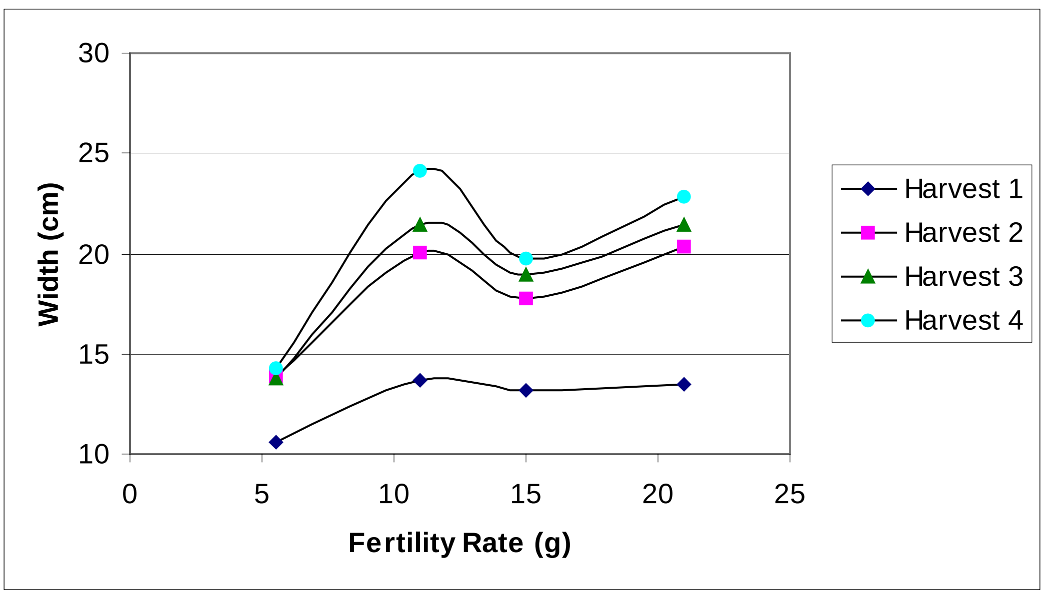

Figure 15. Plant width by fertility rate, and month of harvest for Experiment Two. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

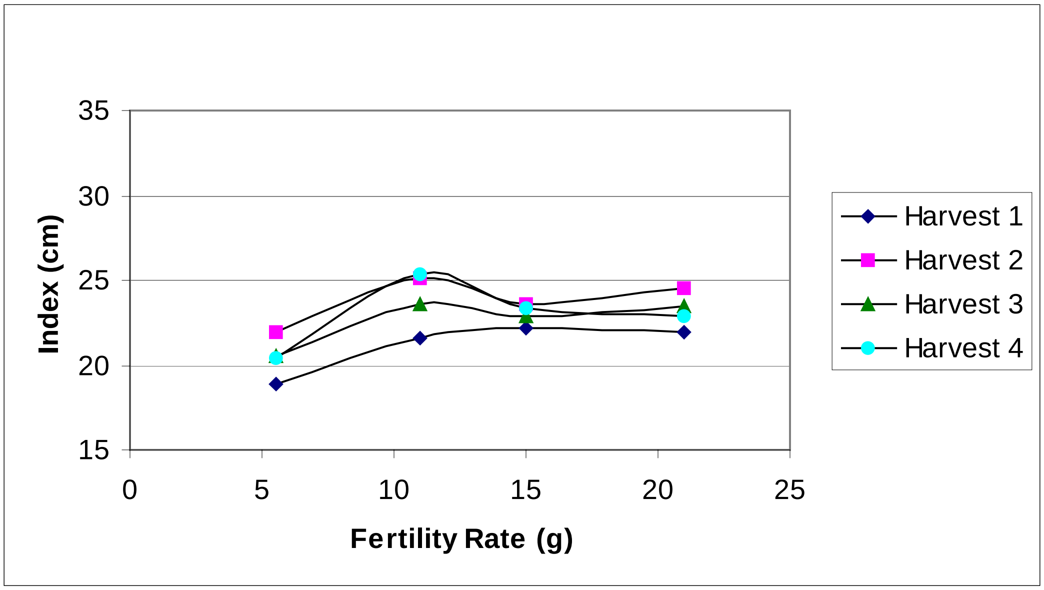

Figure 16. Plant growth index ((mean width + ht)/2) by fertility rate, and month of harvest for Experiment Two. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

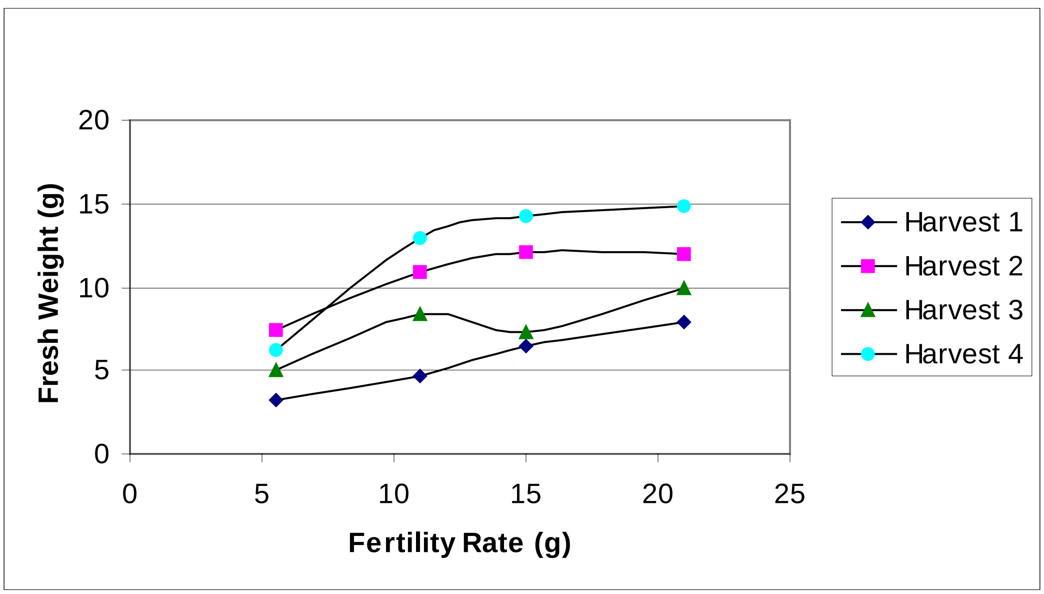

Figure 17. Total fresh weight cuttings by fertility rate and month of harvest for Experiment Two. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

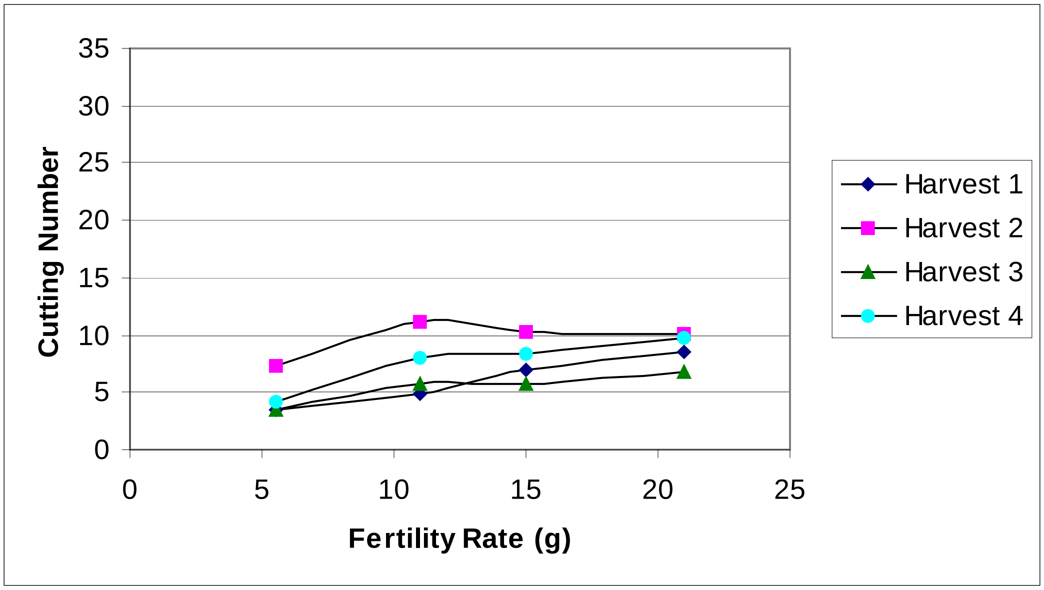

Figure 18. Cutting number produced by fertility rate and month of harvest for Experiment Two. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

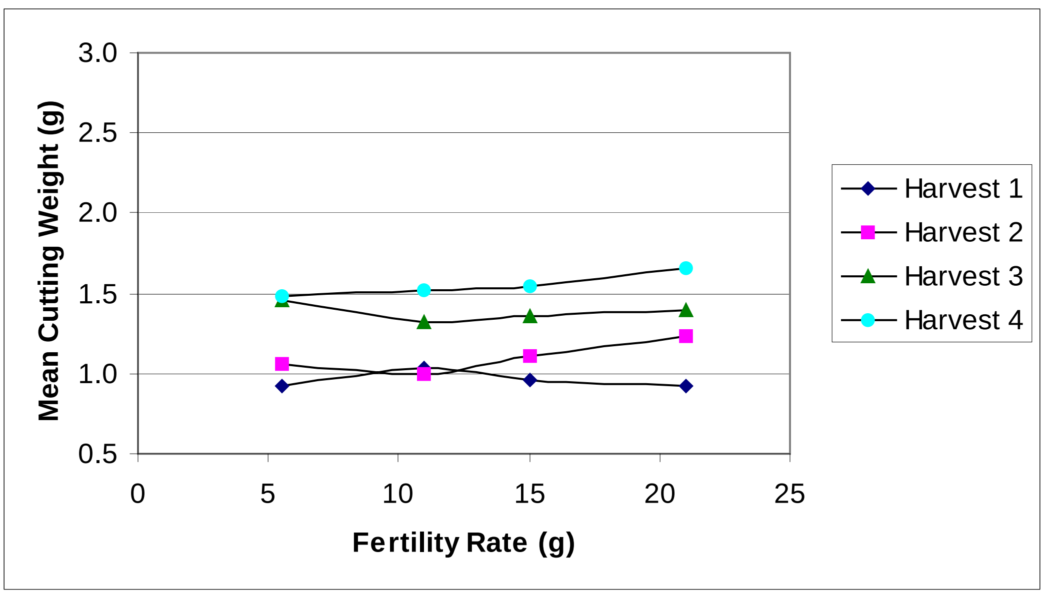

Figure 19. Cutting weight by fertility rate and month of harvest for Experiment Two. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

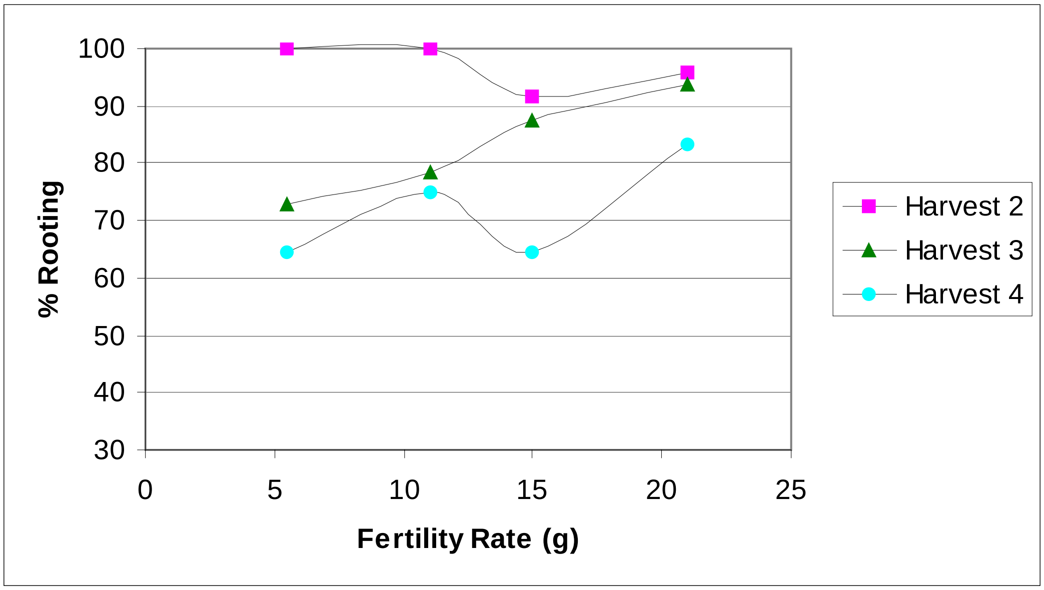

Figure 20. Percent rooting by fertility rate, and month of harvest for Experiment Two. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

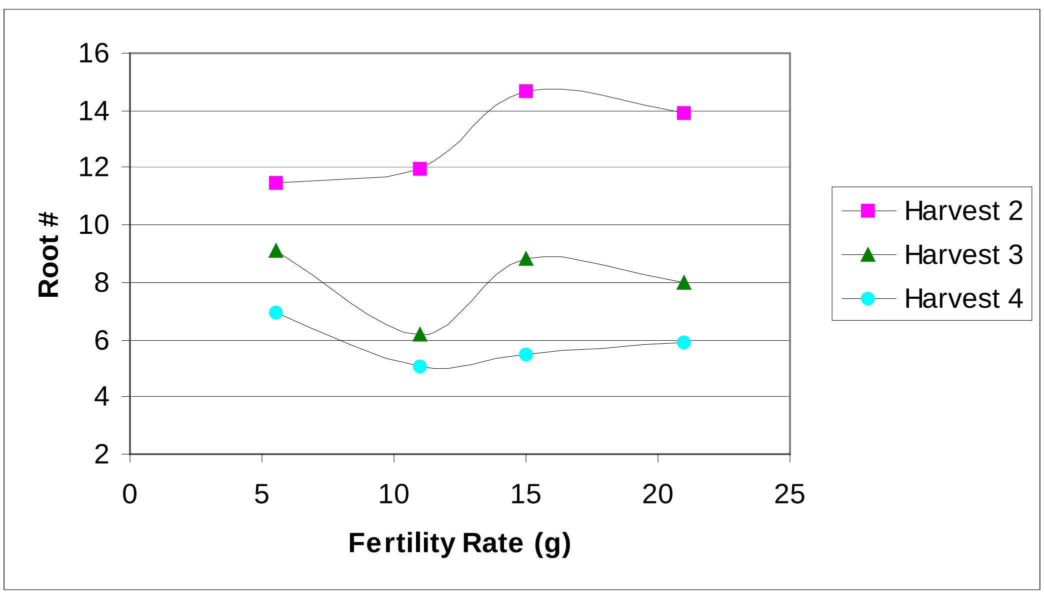

Figure 21. Root number by fertility rate, and month of harvest for Experiment Two. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

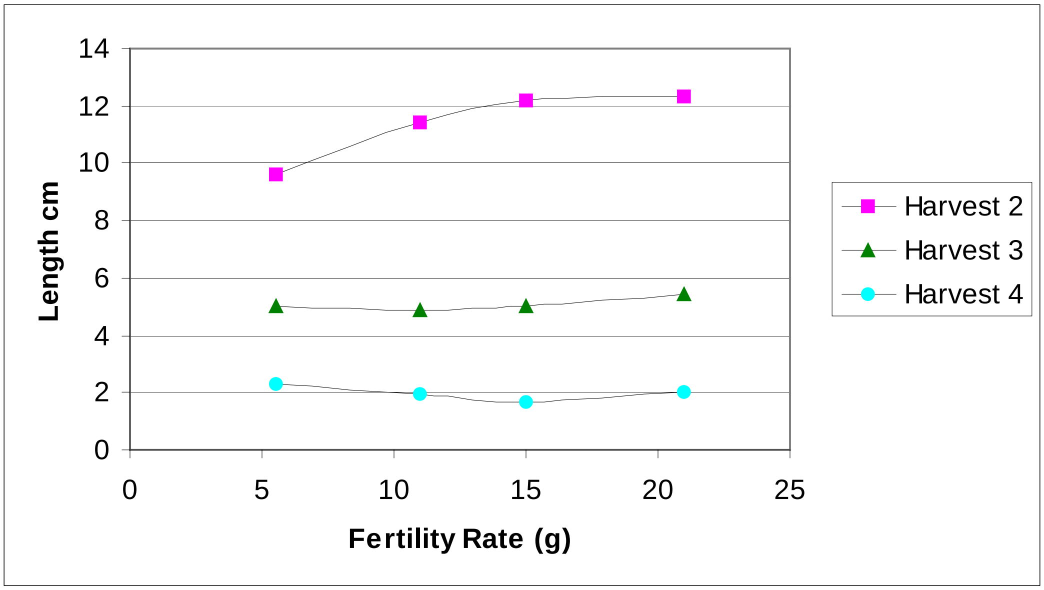

Figure 22. Root length by fertility rate, and month of harvest for Experiment Two. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

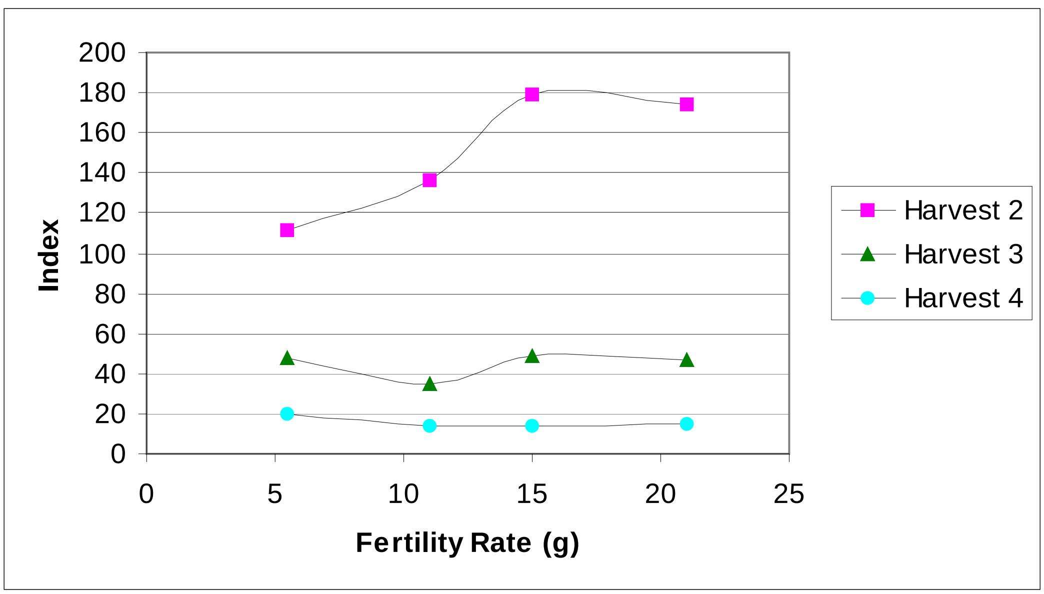

Figure 23. Root index by fertility rate, and month of harvest for Experiment Two. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month at 70ºF) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

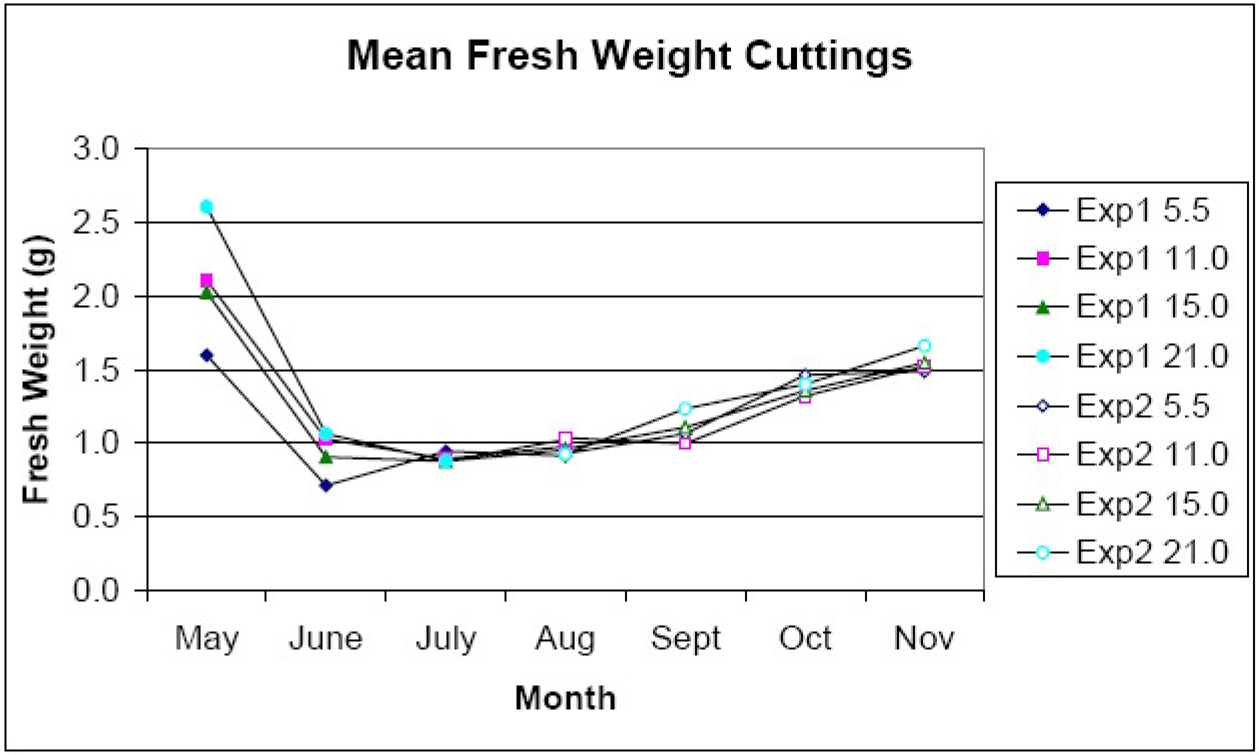

Figure 24. Mean fresh weight of cuttings by run, fertility rate, and month of harvest. Exp1 = Experiment 1, Exp2 = Experiment 2. Fertility rate in grams of Osmocote Plus (15-9-12, 8-9 month @ 70 F) per one-gallon pot, 5.5, 11.0, 15.0, and 21.0.

Table 2. Main effects by measured variable and experiment for total fresh weight cuttings, number of cuttings produced, and fresh weight of individual cuttings.

Response	Experiment	Source	DF	Anova SS	Mean Square	F Value	Pr > F
Total Fresh Weight Cuttings (g)	1	harvest	3	4235.52	1411.84	38.24	<.0001
Total Fresh Weight Cuttings (g)	1	trt	3	18438.91	6146.30	166.47	<.0001
Total Fresh Weight Cuttings (g)	1	harvest*trt	9	1763.46	195.94	5.31	<.0001
Total Fresh Weight Cuttings (g)	2	harvest	3	1221.18	407.06	23.75	<.0001
Total Fresh Weight Cuttings (g)	2	trt	3	849.31	283.10	16.52	<.0001
Total Fresh Weight Cuttings (g)	2	harvest*trt	9	151.78	16.86	0.98	0.4551
Cutting Number	1	harvest	3	2821.77	940.59	49.10	<.0001
Cutting Number	1	trt	3	10962.17	3654.06	190.75	<.0001
Cutting Number	1	harvest*trt	9	664.07	73.79	3.85	0.0002
Cutting Number	2	harvest	3	516.90	172.30	12.53	<.0001
Cutting Number	2	trt	3	474.19	158.06	11.49	<.0001
Cutting Number	2	harvest*trt	9	86.40	9.60	0.70	0.7103
Fresh Weight Individual Cutting (g)	1	harvest	3	48.15	16.05	165.21	<.0001
Fresh Weight Individual Cutting (g)	1	trt	3	3.03	1.01	10.41	<.0001
Fresh Weight Individual Cutting (g)	1	harvest*trt	9	4.17	0.46	4.77	<.0001
Fresh Weight Individual Cutting (g)	2	harvest	3	10.13	3.38	42.71	<.0001
Fresh Weight Individual Cutting (g)	2	trt	3	0.25	0.08	1.04	0.375
Fresh Weight Individual Cutting (g)	2	harvest*trt	9	0.53	0.06	0.74	0.669

Table 3. Main effects by measured variable and experiment for mean percent rooting, root number, root length, and root index (root number * root length).

Response	Experiment	Source	DF	Anova SS	Mean Square	F Value	Pr > F
Percent Rooting	1	harvest	3	261560.48	87186.83	63.34	<.0001
Percent Rooting	1	trt	3	18902.80	6300.93	4.58	0.0035
Percent Rooting	1	harvest*trt	9	23541.67	2615.74	1.90	0.0489
Percent Rooting	2	harvest	2	60216.11	30108.05	24.63	<.0001
Percent Rooting	2	trt	3	11313.90	3771.30	3.09	0.0269
Percent Rooting	2	harvest*trt	6	15035.23	2505.87	2.05	0.0574
Root Number	1	harvest	3	879.34	293.11	22.10	<.0001
Root Number	1	trt	3	137.98	45.99	3.47	0.016
Root Number	1	harvest*trt	9	316.61	35.18	2.65	0.0051
Root Number	2	harvest	2	4763.45	2381.72	125.71	<.0001
Root Number	2	trt	3	239.31	79.77	4.21	0.0059
Root Number	2	harvest*trt	6	352.25	58.71	3.10	0.0055
Root Length	1	harvest	3	754.28	251.43	34.89	<.0001
Root Length	1	trt	3	49.53	16.51	2.29	0.0772
Root Length	1	harvest*trt	9	180.15	20.02	2.78	0.0034
Root Length	2	harvest	2	7522.63	3761.31	564.25	<.0001
Root Length	2	trt	3	30.44	10.15	1.52	0.2079
Root Length	2	harvest*trt	6	204.14	34.02	5.10	<.0001
Root Index	1	harvest	3	100835.22	33611.74	29.57	<.0001
Root Index	1	trt	3	11970.67	3990.22	3.51	0.0151
Root Index	1	harvest*trt	9	43576.98	4841.89	4.26	<.0001
Root Index	2	harvest	2	1667607.44	833803.72	367.91	<.0001
Root Index	2	trt	3	38566.24	12855.41	5.67	0.0008
Root Index	2	harvest*trt	6	111787.20	18631.20	8.22	<.0001

CHAPTER 4
RESTORATION OF FOREDUNES WITH INTERMIXED COMPOSITE PLANTINGS

Introduction

Tropical cyclones can cause extensive damage to coastal ecosystems. Foredunes, the primary barrier to the damaging effects of storm surge on inland areas, absorb the brunt of these storms. Storm surge and attending waves often result in partial to complete destruction of foredunes creating a need for dune restoration.

Dune restoration projects along the Southeast coast of the United States often plant monocultures of *Uniola paniculata* L. [Poaceae](Sea Oats) to restore foredunes. *Uniola paniculata* is the dominant grass naturally occurring on foredunes along the southeast coast of the United States (Dahl et al. 1977, Woodhouse 1978). This grass forms a dense latticework of rhizomes and tillers, which trap sand and stabilize forming dunes (Clewell 1986). *U. paniculata* is planted because it tolerates salt spray, sand accumulation, drought, and because of its dune stabilizing characteristics (Woodhouse et al. 1968, Clewell 1986). However, multiple species plantings or "intermixed composite plantings" may be beneficial because of potential positive interactions or facilitation among dune plants. Also, planting more than one species increases the diversity of plants available for wildlife.

Schizachyrium maritimum (Chapman) Nash [Poaceae]) (Gulf Bluestem), *Panicum amarum* Ell. *var*. *amarulum* (A.S. Hitchc. & Chase) P.G. Palmer (Bitter Panic Grass), and *Iva imbricata* Walter [Asteraceae] (Seacoast Marshelder) are three additional western

Gulf coast species commonly found on coastal dunes (Craig 1991), which are sometimes used in restoration projects.

Schizachyrium maritimum is considered the most important species of bluestem grass on the Gulf of Mexico and occurs primarily on dunes, beaches, and coastal swales (Craig 1991). It is a perennial, short, dense, stoloniferous grass (Johnson 1997). The plants prostrate growth habit makes it effective at trapping sand. *S. maritimum* is often dominant in coastal dunes (Clewell 1986) and naturally replaces *U. paniculata* as soon as a foredune ridge develops (Johnson 1997) making it a good candidate for beach projects requiring planting on the backside of a primary dune and all sides of secondary dunes.

Panicum amarum is a perennial, warm season grass that occurs on coastal dunes throughout the gulf coast. Although outcompeted by *U. paniculata, P. amarum* remains a part of the permanent vegetation cover along the southeastern coast (Seneca et al. 1976, Woodhouse 1978). *P. amarum* grows to heights of up to 213 cm and has large wide leaves. Plantings of *P. amarum* are less affective at accumulating sand when compared to *U. paniculata* and *Ammophila breviligulata* (Fernald) (American Beachgrass) or when planted in combination with those species. However, *P. amarum* provides more groundcover than *U. paniculata* or *A. breviligulata* during the same period of establishment, which suggests it's principal value may be in stabilizing sandy coastal areas and developing foredunes (Seneca et al. 1976).

Iva imbricata occurs on coastal dunes throughout the gulf coast and is used for dune restoration and stabilization projects (Craig 1991). The plant has sparse, woody, upright stems and fleshy, narrow leaves. It is prized for its ability to accumulate sand and produce low, rounded dunes. Both *I. imbricata* and *S. maritimum* have been identified as important beach mice foods (Moyers 1996).

Sand accumulation resulting from aeolian movement of dry sand on beaches is a major environmental factor effecting plant survival and growth. Burial is a strong selective force and can alter the composition of plant communities (Martinez and Psuty 2004). Plant species differ in how they respond to sand accumulation. Species tolerant of burial usually have an extensive system of both vertical stems and horizontal rhizomes (Ehrenfeld 1990). Plant response to burial changes from positive to negative at a species' threshold level of burial (Martinez and Psuty 2004). Foredunes species such as *U. paniculata* respond to sand accumulation below burial threshold by increasing photosynthetic rate (Yuan et al. 1993), which stimulates growth (Clewell 1986). This allows the plant to extend above the level of sand accumulation and survive. However, if sand accumulation exceeds a species' burial threshold then the plant is stressed, which can lead to death. Sand accumulation also can prevent seed germination and establishment if burial is too deep (Sykes and Wilson 1990). The stimulatory response is the most common response of dune species to burial (Maun and Baye 1989).

Plant-plant interactions can be competitive, neutral, or facilitative. Facilitation in plant communities occurs when a plant changes the conditions experienced by another plant resulting in benefit to one of the plants or benefit to both (mutualism) and causing harm to neither (Odum 1953). Facilitation may result when plants increase the nutrient content of the soil, increase soil moisture by shading the surface, reduce evaporation, block salt spray, increase soil stability and/or reduce herbivory or seed predation (Franks 2003b). Competition occurs when plants compete for resources to the benefit of one plant at the expense of another. The idea that positive as well as negative or neutral interactions may be fundamental processes in plant communities (Hunter and Aarssen 1988, Bertness and Callaway 1994, Callaway 1995) is gaining wide acceptance.

Succession refers to the changes observed in an ecological community following a disturbance that opens up a relatively large space (Connell and Slatyer 1977). Interspecific interactions between plants and the effect they have on local abiotic conditions are a major force driving succession in some ecosystems (Clements et al. 1916). Facilitation is likely more important than competition in the very early stages of succession (Bertness and Callaway 1994, Goldberg et al. 1999).

Reaction theory (Clements et al. 1916, Connell and Slayter 1977) suggests that the reaction of the environment to plants modifies the environment so that previously excluded plants can invade. Building on this early successional theory, the nucleated succession model suggests early colonizing plants establish in barren areas and alter the environment as they grow. These colonizers act as nurse plants (Niering et al. 1963) which facilitate the establishment of late successional species (Franks 2003b). As environmental conditions are altered and mid and late successional species become established, competition may replace facilitation as the dominant mechanism affecting species competition.

Successional endpoints however are not uniform and can change in response to xeric conditions, salt spray, periodic overwash and windblown sand (Snyder and Boss 2002) resulting in changes in species dominance at different locations. Knowledge about the stages of succession and what role facilitation plays in it could provide valuable information about succession of coastal ecosystems.

Experiments documenting facilitation have been conducted in many diverse ecological systems such as the Sonoran Desert, New England salt marsh, old Saskatchewan agriculture field sites, South African shrub lands, sub arctic coastal dunes, temperate coastal dunes, and tropical coastal dunes (Niering et al. 1963, Bertness 1991, Bertness and Hacker 1994, Li and Wilson 1998, De Villiers et al. 2001, Gagne and Houle 2001, Franks and Peterson 2003, Martinez 2003, Rudgers and Maron 2003). Facilitation among plants has been shown to increase in frequency as environmental stress increases (Callaway and Walker 1997, Maestre and Cortina 2004). Thus, facilitation may play an important role in the succession of coastal foredunes, as it is a highly stressful environment. Knowledge about how plant species interact with each other could prove to be valuable in dune restoration.

Interactions between plants may positively effect plant survival but negatively affect plant growth (Franks 2003a), suggesting that interactions may be even more complex with both facilitation and competition occurring at the same time through different mechanisms. In addition, the balance between competitive and facilitative interactions between plants can be affected by the life stage of the plant or as the environment they interact with is modified (Kellman and Kading 1992, Pugnaire et al. 1996, Callaway and Walker 1997). It has also been shown that facilitative and competitive mechanisms do not act independently of each other and can occur within the same community and even the same individual (Callaway and Walker 1997). With such complex interactions occurring a thorough understanding of the coastal dune systems ecology and the physiology of the plants found in it will be necessary before we can truly understand the different aspects of how plants are interacting.

Interactions among *I. imbricata*, *S. maritimum* and *P. amarum* are not well understood although *U. paniculata* seedling establishment has been found to increase when seeds germinate within the canopy of established *I. imbricata* plants (Franks 2003a). Facilitation among *Chamaecrista chameacristoides* (L.) and two late colonizing grasses, (*Schizachyrium scoparium* (Michx.) Nash and *Trachypogon plumosus* (Humb. & Bonpl. ex Willd.)) in tropical dune systems along the SE coast of the Gulf of Mexico has also been documented (Martinez 2003).

The objective of this experiment was to compare sand accumulation rates and survival of monocultures and composite plantings of *I. imbricata, P. amarum, and S. maritimum* at two plant densities. We asked the following questions. Does plant density affect the survival of individual species? Does planting combination affect survival of individual species? Does plant density affect sand accumulation rates for individual species? Does planting combination affect sand accumulation rates? Does sand accumulation have an effect on survival of individual species? Answering these questions will help to determine if facilitation or competition between species is occurring and what effect planting combinations have on sand accumulation and transplant survival. This information can be used to develop efficient methods for restoring dunes using plant combinations that provide for rapid sand accumulation and maximum survival of all three species.

Study Site

This study was conducted on Santa Rosa Island, Florida (30° 18’ N, 87° 16’ W), a Holocene barrier island consisting of almost 100% pure quartz sand (median diameter of 0.25 mm). Study sites were located on two nearly undeveloped sections of the island, which are part of Eglin Air Force Base (Figure 25). The island, part of the western panhandle of Florida, has historically been one of the most stable shorelines along the Gulf Coast (Otvos 1982, Morton et al. 2005, Otvos 2005). However, in 1995 two major hurricanes (Erin and Opal) impacted the Northwest Florida coast. These storms caused extensive beach erosion and leveled a majority of the established frontal dunes. Following a 9-year period of dune growth, Northwest Florida was hit by another major hurricane, (Ivan), in September 2004, which caused further erosion or loss of remaining established foredunes and flattened incipient foredunes.

The climate of Santa Rosa island is subtropical with 152 cm mean annual precipitation and rainfall peaks in summer and late winter/early spring. Northerly winds prevail from September-February with southerly winds the rest of the year. Highest monthly wind speeds occur during fall, winter, and spring (Miller et al. 2001).

Methods

Experimental Design

This experiment followed a randomized complete block design arranged as a split plot with sites as blocks, density allocated to main plots and planting combinations allocated to subplots. Six sites, each approximately 80 m from mean high tide line where overwash associated with hurricane Ivan's (16 September, 2004) 5 m (15 ft) storm surge removed perennial vegetation and frontal dune elevation, were randomly chosen from available overwash sites to serve as blocks and replicates. On Jan. 27-30 2005, *Schizachyrium maritimum*, *Panicum amarum*, and *Iva imbricata*, were planted in 0.6 x .9 m or 0.9 x 1.35 m subplots either 30 cm (12 in) or 44 cm (18 in) apart (density treatments) respectively in 8 planting combinations (combination treatments) for a total of 16 treatments. The total number of plants per combination treatment was held constant at 12 with a random placement of each plant within the 3 rows of 4 plants running parallel to the shoreline. Three of the combination treatments consisted of 12 plants of the same species (monoculture), three consisted of six plants each of two different species (biculture), one consisted of four plants each of three different species (triculture), and a control (no plants). Plants were beach planted with the top of the root ball placed approximately 5 cm below the surface without root scoring, supplemental watering, or fertilizer.

Data Collection

Base line and sand accumulation (change in height (cm)) at the center of each combination treatment was measured with a laser transit at 0, 33, and 117 days after planting (DAP), January 27, February 1, and May 24 respectively. Accumulation levels were calculated for three periods 0-33 DAP (period one), 33-117 DAP (period two), and Total sand accumulation.

Survival was recorded as the presence of any living shoot visible above the sand at 130 DAP. Total survival was determined for each subplot to determine plant density. To determine differences in survival of each species among treatments, a random subset of four plants per species from each treatment was used to standardize n.

Analysis

Data was subjected to Proc Mixed Procedure of SAS to perform a repeated measures analysis of variance (SAS Institute Inc. 2000-2004). Contrast statements were used to determine significant differences between planting combinations. Significance of main effects for survival was determined using the Proc Genmod procedure of SAS (SAS Institute Inc. 2000-2004).

Results

Sand Accumulation

Sand accumulated significantly more than bare sand controls in all planting combinations during the first 33 DAP (Table 4). All planting combinations except *S. maritimum* monocultures continued to gain significant amounts of sand for the remainder of the measurement period. Effects of planting combination and spacing on sand accumulation were significant. There was no significant interaction between spacing and planting combination.

Total mean sand accumulation for *P. amarum* planted in monoculture was significantly higher than when planted in combination with another species. Mean accumulation for *I. imbricata* planted in monoculture did not differ significantly from mean accumulation when planted in combination with another species for any accumulation period. *S. maritimum* planted in monoculture had significantly higher mean accumulation than when planted in combination with other species for the first 33 DAP but had significantly lower mean accumulation for period two and Total accumulation.

Mean sand accumulation was significantly higher (P = 0.0239) for 30 cm spacing compared to 44 cm spacing 33 DAP but did not differ significantly (P = 0.8109) between spacing treatments during period two. Total mean accumulation was significantly higher (P = 0.0038) at 30 cm compared to 44 cm spacing.

Monoculture plantings of *P. amarum* had a significantly higher mean sand accumulation than biculture plantings during all periods while monoculture plantings of *I. imbricata* did not have significantly different mean accumulation when compared to biculture plantings for all periods. Monoculture plantings of *S. maritimum* had significantly higher accumulation rates than biculture plantings 33 DPA. However, accumulation was significantly lower for period two and Total accumulation. Triculture plantings did not differ significantly from biculture plantings for any accumulation period.

Survival

Mean survival varied from 18 to 90% between the two grass species. Survival of *P. amarum* ranged form 75% to 100% for all spacing and planting combinations (Table 5). Differences among treatments were not detectable for *P. amarum* as all survival fell above 75%. Survival of *S. maritimum* ranged from 8 to 29% for all density and planting combinations. Survival was significantly higher (P = 0.0245) at 44 cm spacing where maximum plant foliage burial was 35% compared to 43% burial at 30 cm spacing. Planting combination did not have a significant effect on *S. maritimum* survival (P = 0.6607).

Survival of *I. imbricata* ranged from 54% to 92% for all spacing and planting combinations. Survival did not differ significantly for 44 cm compared to 30 cm spacing (P = 0.0879). Planting combination significantly affected survival (P = 0.0029). Survival of *I. imbricata* was lower (P = 0.0313) when planted in combination with *P. amarum* (Table 5).

Discussion

Higher density plantings accumulated more sand during winter months. However, the effect of plant density and plant species on sand accumulation changed during spring months. The decreased relative difference in percent ground coverage by aboveground plant parts among species and planting combination with active spring growth and low survival of *S. maritimum* may cause this change. Initially, the wider spaced plantings (lower plant density) corresponded to lower percent foliar and basal coverage. As a result, wider spaced plantings presented less resistance to sand movement and thus, lower accumulation occurred. As plants began to grow bare areas between plants were reduced resulting in relatively less difference in exposed area between plantings spaced differently and therefore, the ability of sand to move in and out freely was similar between plantings. Although differences in percent cover can be initially assumed due to difference in plant density and uniformity of transplants, growth data would have quantified the change in percent cover. However, growth data was not collected before the loss of the experiment by overwash during tropical storm Arlene (June 11, 2005).

The negative accumulation rate of monoculture plantings of *S. maritimum* during spring months (March – May) appeared to result from high plant mortality. After plant death, the subsequent deconstruction of the dead foliage during the months of March - May released the previously trapped sand. Lower accumulation rates for plantings of *P. amarum* in combination with other species may be a result of the replacement of *P. amarum* plants with *I. imbricata*, which was less effective than *P. amarum* at trapping sand. Death of a high percentage of *S. maritimum* also resulted in lower sand accumulation when planted with *P. amarum*.

In this study, I found no evidence of facilitation among *P. amarum*, *I. imbricata* and *S. maritimum* when planted in combination and at densities generally used in dune restoration. These results contradict those of (Franks and Peterson 2003) who suggested facilitation at higher densities positively effects plant survival and plant biomass in buried plots. Franks and Peterson also found that species richness had no effect on survival or biomass when plants were buried. However, there were differences between the two studies. Both density levels of my study fell between the high (50 cm) and low (20 cm) density levels of the Franks and Peterson study. In addition to *I. imbricata*, which was included in both studies, Franks and Peterson included different grasses, herbs, shrubs and vines, which were planted during the active growing season (July) and burial was applied as a one-time event.

Greater sand accumulation associated with increased planting density appears to have negatively impacted survival of *S. maritimum*. After 33 days, the crowns of *S. maritimum* transplants were as much as 12.7 cm below the soil surface and as much as 43% of the foliage was buried which may have exceeded the threshold level of burial (Martinez and Psuty 2004), subjecting the plants to stress and possibly causing death Similarly, Franks and Peterson (2003), found a 54% reduction in survival when several dune species were buried to approximately 50% of their height. *S. maritimum* as a secondary colonizing grass replaces *U. paniculata* behind foredune ridges (Johnson 1997). Because *S. maritimum* is often found on the leeward side of dunes where sand movement and salt deposition are reduced (Craig 1991), it may be less tolerant of sand burial although salt spray tolerance can also influence plant zonation (Oosting 1945). Two secondary colonizing grasses, *Schizachyrium scoparium* and *Trachypogon plumosis* have also been shown to be intolerant of high levels of sand burial and are restricted to areas where sand movement is decreased (Martinez et al. 2001).

However, my findings contradict an earlier study that found artificial burial with sand of 50 or 100% of foliar tissue increased plant dry weight of *Schizachyrium scoparium* above that of unburied controls Martinez and Moreno-Casasola (1996). Results for *S. scoparium* were recorded when plants were artificially buried while plants were actively growing (summer) as opposed to the results of my study where planting and natural sand burial occurred while plants were dormant (winter). Changes in environmental factors such as soil moisture and soil temperature in response to burial are the most important factors effecting plant growth and survival (Martinez et al. 2001). Burial during winter months may have decreased soil temperature and increased soil moisture to the detriment of plant survival.

Wind speeds, sand movement and accumulation are greatest during winter months on Santa Rosa Island and may represent the least advantageous time to plant *S. maritimum* (Miller et al. 2001). In this study, *S. maritimum* survival was $\leq$ 29% when planted in January in an overwash site on Santa Rosa Island. Yet, earlier studies on this island found 100% survival 2 1/2 yrs after planting when *S. maritimum* was planted during summer months behind a developing dune ridge (Thetford et al. 2005) and 100% survival (June until uprooted by hurricane Ivan (16 September, 2004)) when planted between condominiums less than 40 m from mean high tide line with no other dune structure landward of the planting (unpublished data). Conditions during winter months may limit the ability of *S. maritimum* to persist in foredunes with high sand accumulation rates. Future experiments are needed to determine what environmental factor or factors are responsible for the reduced survival of *S. maritimum* when planted in a foredune location during winter months.

Competition from *P. amarum* may be responsible for the lower survival rates of *I. imbricata*. Franks (2003a) found reduced biomass of *I. imbricata* when planted in combination with *U. paniculata*, however he found an increase in survival of *I. imbricata* suggesting the simultaneous occurrence of facilitation and competition. Further research is needed to determine the tolerance of *I. imbricata* to competition.

P. amarum is reported to be less tolerant of burial than *Uniola paniculata* and *Ammophila breviligulata*, especially during establishment (Woodhouse 1982); however, we found high survival rates during winter months when sand accumulation is highest for Santa Rosa Island (Miller et al. 2001). Survival rates ranging from 75% to 82% have been recorded for spring plantings of *P. amarum* (Seneca et al. 1976, Miller et al. 2001), which are similar to the survival rates found in this study. *P. amarum* spreads faster at sites receiving moderate amounts of sand accumulation compared to sites receiving little sand accumulation (Seneca et al. 1976). Moderate amounts of burial by sand have been shown to result in higher plant density, percent cover, and biomass per plant below a certain threshold level of burial (Maun 1998). My results suggest *P. amarum* is below its burial threshold when planted alone or in combination with plants and at densities used in this experiment in frontal dunes of Santa Rosa Island.

Greater tolerance of *P. amarum* and *I. imbricata* to sand burial compared to *S. maritimum* may result from differences in height and growth form among species. *S. maritimum's* low, prostrate growth may reduce its ability to tolerate burial resulting in the low survival rates seen in this experiment. However, *S. maritimum's* may also be less tolerant of salt spray and the increased wind speeds and sand movement during winter months may have increased salt exposure. The upright growth form of *I. imbricata* transplants may confer an ability to tolerate sand accumulation. This species tolerance to saltwater overwash, saltspray, and sandblasting may also contribute to its survival when transplanted on an overwash site (Woodhouse 1982).

Conclusions

Effects of intermixed composite plantings on survival of *P. amarum*, *I. imbricata*, and *S. maritimum* ranged from neutral to negative when compared to monoculture plantings. The effect of composite plantings on mean sand accumulation when compared to monoculture plantings was neutral or negative for all species when compared to monoculture plantings.

Survival rates of *I. imbricata* were reduced when planted in combination with other species, possibly as a result of interspecific competition, especially when planted in combination with *P. amarum*.

High plant density (30 cm spacing) compared to low plant density (44 cm spacing) increased sand accumulation. However, increased burial may have led to high mortality rates for *S. maritimum*. Threshold level of burial for individual species determines whether or not increasing the initial rate of sand accumulation with higher plant density will have a negative affect on transplant survival rates. The varying responses to burial suggest that some species have a higher threshold of burial and will be better suited to rapid dune formation and some species will have a lower threshold level of burial and should be planted in areas or orientations where they are less likely to accumulate sand as quickly. This will result in increased survival rates and increase the efficiency of restoration.

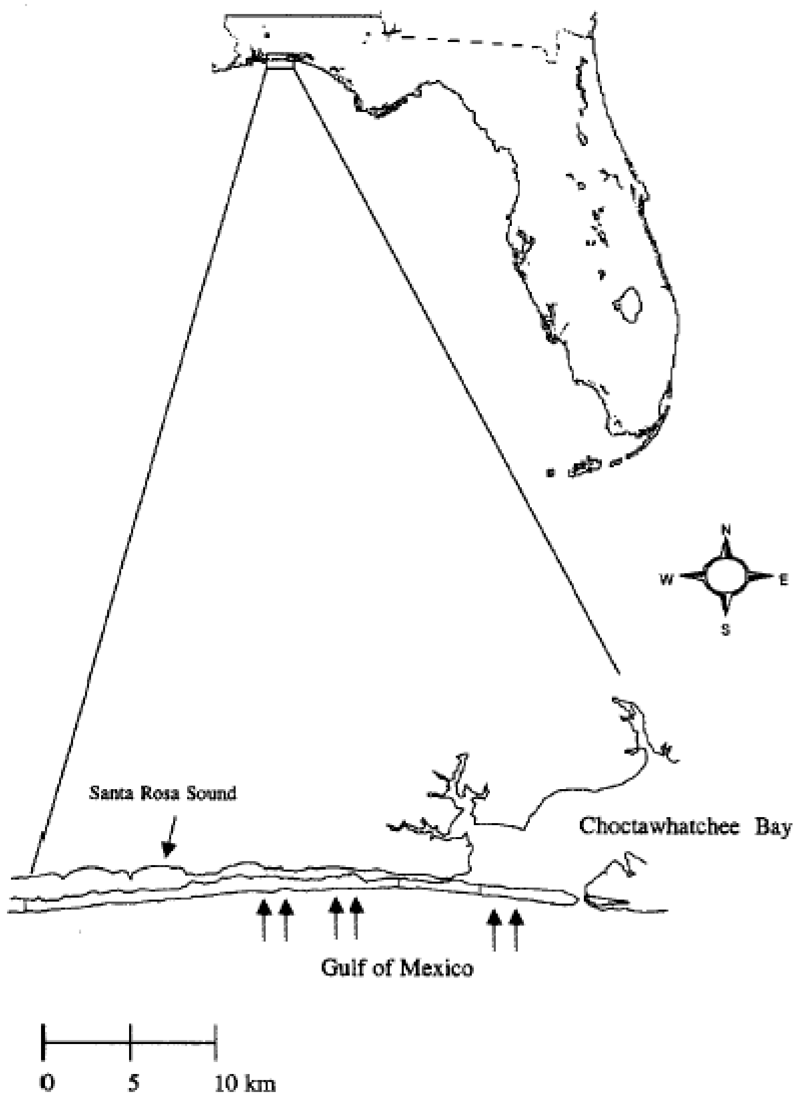

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Figure 25. Map of Florida with insert showing the location of Santa Rosa Island. Arrows indicate the location of the six study sites and Santa Rosa Sound.

Table 4. Incremental and Total sand accumulation (cm) of height gained for 30 cm and 44 cm spacings of *Iva imbricata*, *Panicum amarum, and Schizachyrium maritimum* planted in different combinations of 12 plants including a control (no plants). Combinations consisting of two species have six plants of each species planted and combinations consisting of three species have four plants of each species planted. Iva = *Iva imbricata*, Pan = *Panicum amarum*, Sch = *Schizachyrium maritimum*. Analysis of variance for main effects and contrasts, significance at $P \leq 0.05$.

		Period of Accumulation (days)					
		0-33		33-117		0-117	
		Spacing (cm)					
Planting Combination		**30**	**44**	**30**	**44**	**30**	**44**
Control		3.43	-1.14	-1.45	-0.91	1.98	-2.06
Iva		6.78	0.76	2.21	4.42	8.99	5.18
Pan		8.23	2.82	4.80	5.41	13.03	8.23
Sch		7.85	3.66	-0.50	-1.37	3.35	2.29
Iva+Pan		3.43	1.98	4.65	3.28	8.08	5.26
Iva+Sch		1.68	1.98	1.52	0.23	3.20	2.21
Pan+Sch		4.34	3.66	2.67	1.75	7.01	5.41
Iva+Pan+Sch		3.96	3.05	3.35	2.13	7.32	5.18
Analysis of Variance	**df**						
Main effects		**p-value**		**p-value**		**p-value**	
Rep	3	0.3548		0.4559		0.0232	
Spacing	1	0.0592		0.8109		0.0038	
Planting Combination	7	0.0542		<.0001		<.0001	
Spacing*Planting Combination	7	0.3040		0.4116		0.9291	
Contrasts							
Control versus Iva	1	0.0975		0.0005		0.0002	
Control versus Pan	1	0.0072		<.0001		<.0001	
Control versus Sch	1	0.0049		0.1483		0.1072	
Iva versus Iva+Pan, Iva+Sch	1	0.2689		0.3899		0.1179	
Pan versus Pan+Iva, Pan+Sch	1	0.1134		0.0567		0.0078	
Sch versus Sch+Iva, Sch+Pan	1	0.0588		0.0013		0.0002	
Iva+Pan, Iva+Sch, Pan+Sch versus Iva+Pan+Sch	1	0.6048		0.6874		0.4616	

Table 5. Mean survival (percent) for 30 cm and 44 cm spacings of *Iva imbricata*, *Panicum amarum*, and *Schizachyrium maritimum* planted in different combinations of 12 plants. Combinations consisting of one species have 12 plants of the same species planted and combinations consisting of two species have six plants of each species planted. Combinations consisting of three species have four plants of each species planted. Iva = *Iva imbricata*, Pan = *Panicum amarum*, Sch = *Schizachyrium maritimum*.

	Survival%					
	Iva		Pan		Sch	
	Spacing (cm)					
Planting Combination	**30**	**44**	**30**	**44**	**30**	**44**
Iva	88	92	*	*	*	*
Pan	*	*	96	92	*	*
Sch	*	*	*	*	17	29
Iva+Pan	63	54	88	75	*	*
Iva+Sch	58	92	*	*	8	29
Pan+Sch	*	*	83	96	8	21
Iva+Pan+Sch	71	83	100	88	17	17

Analysis of Variance	**df**	**p-value**	**p-value**	**p-value**
Main effects				
Rep	5	0.0909	*	<.0001
Spacing	1	0.0879	*	0.0245
Rep*Spacing	5	0.9619	*	0.3595
Planting Combination	3	0.0029	*	0.6607
Contrasts				
Iva versus Iva+Pan	1	0.0313	*	*
Iva versus Iva+Sch	1	0.3844	*	*

APPENDIX
MEANS AND STANDARD ERRORS FOR *IVA IMBRICATA* PROPAGATION STUDY

Table 6. *Iva imbricata* stock-plants mean height (cm) and standard deviation of by harvest and fertility rate using repeated measures of proc mixed (SAS Institute Inc. 2000-2004). Fertilizer rate (fert) = fertility rates in (g) Osmocote/1 gallon container. Experiment 1, harvests 1-4 = 114, 146, 175, and 206 days after potting. Experiment 2, harvests 1-4 = 49, 79, 108, and 136 days after potting.

Experiment 1					**Experiment 2**				
harvest	**fert**	**N**	**Mean**	**Std dev**	**harvest**	**fert**	**N**	**Mean**	**Std dev**
1	5.5	12	26.6	6.26	1	5.5	12	27.2	4.86
1	11	12	38.4	5.74	1	11	12	29.6	7.50
1	15	12	40.8	5.36	1	15	12	31.2	5.02
1	21	12	40.8	6.81	1	21	12	30.4	5.33
2	5.5	12	28.5	4.64	2	5.5	12	30.1	3.55
2	11	12	34.0	4.65	2	11	12	30.2	3.30
2	15	12	31.9	3.80	2	15	12	29.4	4.23
2	21	12	33.6	4.48	2	21	12	28.8	3.31
3	5.5	12	33.8	2.78	3	5.5	12	27.4	2.02
3	11	12	36.3	4.17	3	11	12	25.7	3.60
3	15	12	37.6	5.44	3	15	12	26.7	2.80
3	21	12	36.7	3.38	3	21	12	25.6	2.71
4	5.5	12	30.6	4.93	4	5.5	12	26.5	3.23
4	11	12	35.1	4.44	4	11	12	26.7	4.08
4	15	11	34.6	3.83	4	15	12	26.9	3.06
4	21	12	37.9	4.36	4	21	12	23.0	4.97

Table 7. *Iva imbricata* stock-plants mean width (cm) and standard deviation of by harvest and fertility rate using repeated measures of proc mixed (SAS Institute Inc. 2000-2004). Fertilizer rate (fert) = fertility rates in (g) Osmocote/1 gallon container. Experiment 1, harvests 1-4 = 114, 146, 175, and 206 days after potting. Experiment 2, harvests 1-4 = 49, 79, 108, and 136 days after potting.

Experiment 1					**Experiment 2**				
harvest	**fert**	**N**	**Mean**	**Std dev**	**harvest**	**fert**	**N**	**Mean**	**Std dev**
1	5.5	12	11.0	2.79	1	5.5	12	10.6	1.88
1	11	12	20.0	3.53	1	11	12	13.7	3.46
1	15	12	22.5	3.10	1	15	12	13.2	2.80
1	21	12	24.8	4.39	1	21	12	13.5	1.79
2	5.5	12	13.5	2.60	2	5.5	12	13.9	3.12
2	11	12	21.3	2.41	2	11	12	20.1	2.42
2	15	12	22.7	1.98	2	15	12	17.8	5.14
2	21	12	24.7	2.53	2	21	12	20.3	2.55
3	5.5	12	14.2	2.19	3	5.5	12	13.8	3.91
3	11	12	22.5	2.28	3	11	12	21.4	3.95
3	15	12	23.6	2.25	3	15	12	19.0	3.92
3	21	12	26.3	3.32	3	21	12	21.4	3.06
4	5.5	12	16.5	2.37	4	5.5	12	14.3	3.68
4	11	12	24.9	3.57	4	11	12	24.1	4.54
4	15	11	26.6	2.74	4	15	12	19.8	5.47
4	21	12	29.4	3.52	4	21	12	22.9	4.27

Table 8. *Iva imbricata* stock-plants mean index (cm^3) and standard deviation of by harvest and fertility rate using repeated measures of proc mixed (SAS Institute Inc. 2000-2004). Fertilizer rate (fert) = fertility rates in (g) Osmocote/1 gallon container. Experiment 1, harvests 1-4 = 114, 146, 175, and 206 days after potting. Experiment 2, harvests 1-4 = 49, 79, 108, and 136 days after potting.

Experiment 1					**Experiment 2**				
harvest	**fert**	**N**	**Mean**	**Std dev**	**harvest**	**fert**	**N**	**Mean**	**Std dev**
1	5.5	12	18.8	4.42	1	5.5	12	18.9	2.86
1	11	12	29.2	4.03	1	11	12	21.7	4.15
1	15	12	31.7	3.46	1	15	12	22.2	3.32
1	21	12	32.8	4.60	1	21	12	21.9	2.59
2	5.5	12	21.0	3.21	2	5.5	12	22.0	2.93
2	11	12	27.7	2.77	2	11	12	25.1	1.99
2	15	12	27.3	2.36	2	15	12	23.6	4.31
2	21	12	29.1	3.05	2	21	12	24.5	2.36
3	5.5	12	24.0	1.76	3	5.5	12	20.6	2.64
3	11	12	29.4	2.23	3	11	12	23.5	2.39
3	15	12	30.6	2.41	3	15	12	22.9	2.71
3	21	12	31.5	2.57	3	21	12	23.5	1.93
4	5.5	12	23.5	3.21	4	5.5	12	20.4	3.12
4	11	12	30.0	3.36	4	11	12	25.4	3.25
4	15	11	30.6	2.20	4	15	12	23.4	3.83
4	21	12	33.7	2.81	4	21	12	22.9	3.39

Table 9. *Iva imbricata* stock-plants mean total fresh weight (g) and standard deviation of by harvest and fertility rate using repeated measures of proc mixed (SAS Institute Inc. 2000-2004). Fertilizer rate (fert) = fertility rates in (g) Osmocote/1 gallon container. Experiment 1, harvests 1-4 = 114, 146, 175, and 206 days after potting. Experiment 2, harvests 1-4 = 49, 79, 108, and 136 days after potting.

Experiment 1					**Experiment 2**				
harvest	**fert**	**N**	**Mean**	**Std dev**	**harvest**	**fert**	**N**	**Mean**	**Std dev**
1	5.5	12	8.0	4.45	1	5.5	12	3.2	2.05
1	11	12	24.5	8.26	1	11	12	4.7	2.56
1	15	12	40.2	7.82	1	15	12	6.4	3.00
1	21	12	45.1	15.45	1	21	12	7.9	2.31
2	5.5	12	5.3	1.67	2	5.5	12	7.4	1.68
2	11	12	17.9	5.38	2	11	12	10.9	2.93
2	15	12	21.4	4.07	2	15	11	12.2	3.17
2	21	12	28.9	7.05	2	21	12	11.9	3.50
3	5.5	12	7.7	1.47	3	5.5	12	5.1	3.04
3	11	12	16.0	2.11	3	11	10	8.4	3.07
3	15	12	20.8	2.47	3	15	12	7.3	3.16
3	21	12	26.6	4.02	3	21	12	9.9	4.82
4	5.5	12	9.2	2.80	4	5.5	11	6.3	3.34
4	11	12	21.5	4.67	4	11	11	13.0	4.98
4	15	11	28.1	4.22	4	15	11	14.3	7.63
4	21	12	34.9	5.18	4	21	12	14.9	8.44

Table 10. Mean number and standard deviation of cuttings harvested from of *Iva imbricata* stock-plants by harvest and fertility rate using repeated measures of proc mixed (SAS Institute Inc. 2000-2004). Fertility rate (fert) in (g) Osmocote/1 gallon container. Experiment 1, harvests 1-4 = 114, 146, 175, and 206 days after potting. Experiment 2, harvests 1-4 = 49, 79, 108, and 136 days after potting.

Experiment 1					**Experiment 2**				
harvest	**fert**	**N**	**Mean**	**Std dev**	**harvest**	**fert**	**N**	**Mean**	**Std dev**
1	5.5	12	4.0	0.74	1	5.5	12	3.5	1.93
1	11	12	7.6	2.23	1	11	12	4.9	3.15
1	15	12	12.6	3.75	1	15	12	7.0	3.84
1	21	12	11.2	3.13	1	21	12	8.6	2.31
2	5.5	12	7.5	2.35	2	5.5	12	7.3	2.27
2	11	12	17.5	5.45	2	11	12	11.1	2.68
2	15	12	23.6	4.42	2	15	12	10.3	4.52
2	21	12	27.2	6.56	2	21	12	10.1	3.63
3	5.5	12	8.5	2.39	3	5.5	12	3.5	2.02
3	11	12	18.4	4.12	3	11	12	5.7	3.80
3	15	12	24.2	4.30	3	15	12	5.8	2.63
3	21	12	30.8	5.22	3	21	12	6.8	3.49
4	5.5	12	10.1	3.00	4	5.5	12	4.2	2.98
4	11	12	22.5	5.65	4	11	12	8.1	4.66
4	15	11	30.3	5.18	4	15	12	8.4	5.09
4	21	12	34.5	5.90	4	21	12	9.7	6.87

Table 11. Mean cutting weight (g) and standard deviation of cuttings harvested from of *Iva imbricata* stock-plants by harvest and fertility rate using repeated measures of proc mixed (SAS Institute Inc. 2000-2004). Fertility rate (fert) in (g) Osmocote/1 gallon container. Experiment 1, harvests 1-4 = 114, 146, 175, and 206 days after potting. Experiment 2, harvests 1-4 = 49, 79, 108, and 136 days after potting.

Experiment 1					**Experiment 2**				
harvest	**fert**	**N**	**Mean**	**Std dev**	**harvest**	**fert**	**N**	**Mean**	**Std dev**
1	5.5	12	1.6	0.66	1	5.5	12	0.9	0.28
1	11	12	2.3	1.06	1	11	12	1.0	0.42
1	15	12	2.0	0.46	1	15	12	1.0	0.20
1	21	12	2.6	0.65	1	21	12	0.9	0.14
2	5.5	12	0.7	0.01	2	5.5	12	1.1	0.27
2	11	12	1.0	0.02	2	11	12	1.0	0.18
2	15	12	0.9	0.01	2	15	11	1.1	0.25
2	21	12	1.1	0.01	2	21	12	1.2	0.21
3	5.5	12	0.9	0.18	3	5.5	12	1.5	0.32
3	11	12	0.9	0.16	3	11	10	1.3	0.35
3	15	12	0.9	0.13	3	15	12	1.4	0.31
3	21	12	0.9	0.12	3	21	12	1.4	0.18
4	5.5	12	0.9	0.10	4	5.5	11	1.5	0.40
4	11	12	1.0	0.19	4	11	11	1.5	0.26
4	15	11	1.0	0.22	4	15	11	1.6	0.29
4	21	12	1.0	0.14	4	21	12	1.7	0.32

Table 12. Mean root length (cm) and standard deviation of cuttings harvested from of *Iva imbricata* stock-plants by harvest and fertility rate using repeated measures of proc mixed (SAS Institute Inc. 2000-2004). Fertility rate (fert) in (g) Osmocote/1 gallon container. Experiment 1, harvests 1-4 = 114, 146, 175, and 206 days after potting. Experiment 2, harvests 2-4 = 79, 108, and 136 days after potting.

Experiment 1					**Experiment 2**				
harvest	**fert**	**N**	**Mean**	**Std dev**	**harvest**	**fert**	**N**	**Mean**	**Std dev**
1	5.5	46	6.2	3.01	*	*	*	*	*
1	11	43	7.1	3.71	*	*	*	*	*
1	15	42	5.1	2.81	*	*	*	*	*
1	21	44	4.7	2.57	*	*	*	*	*
2	5.5	38	3.4	1.55	2	5.5	48	9.6	3.15
2	11	38	3.6	1.94	2	11	48	11.4	3.24
2	15	34	2.9	1.87	2	15	44	12.2	3.16
2	21	26	3.3	2.61	2	21	46	12.3	3.23
3	5.5	30	3.3	1.66	3	5.5	35	5.0	2.20
3	11	25	3.9	2.38	3	11	38	4.9	2.86
3	15	25	3.5	2.33	3	15	42	5.0	2.34
3	21	17	3.9	2.12	3	21	45	5.4	2.33
4	5.5	48	4.9	2.93	4	5.5	31	2.3	1.33
4	11	44	5.6	2.74	4	11	36	1.9	1.70
4	15	48	5.8	2.96	4	15	31	1.7	1.33
4	21	48	6.3	3.31	4	21	40	2.0	1.97

Table 13. Mean root number and standard deviation of cuttings harvested from of *Iva imbricata* stock-plants by harvest and fertility rate using repeated measures of proc mixed (SAS Institute Inc. 2000-2004). Fertility rate (fert) in (g) Osmocote/1 gallon container. Experiment 1, harvests 1-4 = 114, 146, 175, and 206 days after potting. Experiment 2, harvests 2-4 = 79, 108, and 136 days after potting.

Experiment 1					**Experiment 2**				
harvest	**fert**	**N**	**Mean**	**Std dev**	**harvest**	**fert**	**N**	**Mean**	**Std dev**
1	5.5	46	8.7	4.03	*	*	*	*	*
1	11	43	9.7	4.55	*	*	*	*	*
1	15	42	6.5	4.70	*	*	*	*	*
1	21	44	6.4	4.09	*	*	*	*	*
2	5.5	38	5.8	2.93	2	5.5	48	11.5	5.04
2	11	38	6.0	3.71	2	11	48	12.0	5.23
2	15	34	4.8	3.34	2	15	44	14.7	4.85
2	21	26	4.3	3.26	2	21	46	13.9	5.04
3	5.5	29	4.6	2.80	3	5.5	35	9.1	3.85
3	11	25	4.7	3.06	3	11	38	6.2	3.40
3	15	25	4.2	4.36	3	15	42	8.9	3.90
3	21	17	4.1	3.93	3	21	45	8.0	3.13
4	5.5	48	6.0	3.36	4	5.5	35	6.9	4.20
4	11	44	6.2	2.90	4	11	44	5.1	3.77
4	15	48	6.4	2.86	4	15	42	5.5	4.78
4	21	48	6.9	3.48	4	21	46	5.9	4.01

Table 14. Mean root index (cm) and standard deviation of cuttings harvested from of *Iva imbricata* stock-plants by harvest and fertility rate using repeated measures of proc mixed (SAS Institute Inc. 2000-2004). Fertility rate (fert) in (g) Osmocote/1 gallon container. Experiment 1, harvests 1-4 = 114, 146, 175, and 206 days after potting. Experiment 2, harvests 2-4 = 79, 108, and 136 days after potting.

Experiment 1					**Experiment 2**				
harvest	**fert**	**N**	**Mean**	**Std dev**	**harvest**	**fert**	**N**	**Mean**	**Std dev**
1	5.5	46	57.5	41.0	*	*	*	*	*
1	11	43	77.3	62.1	*	*	*	*	*
1	15	42	37.8	37.0	*	*	*	*	*
1	21	44	36.3	36.4	*	*	*	*	*
2	5.5	38	22.3	15.3	2	5.5	48	111.4	58.9
2	11	38	27.0	24.3	2	11	48	136.3	66.4
2	15	34	17.5	18.3	2	15	44	179.2	68.2
2	21	26	21.0	33.8	2	21	46	174.3	85.5
3	5.5	29	16.9	15.3	3	5.5	35	47.7	27.1
3	11	25	22.5	19.9	3	11	38	35.3	27.2
3	15	25	21.9	31.1	3	15	42	48.4	36.1
3	21	17	20.2	26.8	3	21	45	47.0	27.4
4	5.5	48	35.5	34.7	4	5.5	31	19.6	14.3
4	11	44	37.9	26.7	4	11	36	13.4	15.3
4	15	48	41.2	29.9	4	15	31	14.0	14.9
4	21	48	49.1	35.0	4	21	40	14.7	16.6

Table 15. Mean rooting percentage and standard deviation of cuttings harvested from of *Iva imbricata* stock-plants by harvest and fertility rate using repeated measures of proc mixed (SAS Institute Inc. 2000-2004). Fertility rate (fert) in (g) Osmocote/1 gallon container. Experiment 1, harvests 1-4 = 114, 146, 175, and 206 days after potting. Experiment 2, harvests 2-4 = 79, 108, and 136 days after potting.

Experiment 1					**Experiment 2**				
harvest	**fert**	**N**	**Mean %**	**Std dev**	**harvest**	**fert**	**N**	**Mean %**	**Std dev**
1	5.5	48	95.8	20.19	*	*	*	*	*
1	11	48	89.6	30.87	*	*	*	*	*
1	15	48	87.5	33.42	*	*	*	*	*
1	21	48	91.7	27.93	*	*	*	*	*
2	5.5	48	79.2	41.04	2	5.5	48	100.0	0.00
2	11	48	79.2	41.04	2	11	48	100.0	0.00
2	15	48	70.8	45.93	2	15	48	91.7	27.93
2	21	48	54.2	50.35	2	21	48	95.8	20.19
3	5.5	48	62.5	48.92	3	5.5	48	72.9	44.91
3	11	48	52.1	50.49	3	11	46	78.3	41.70
3	15	48	52.1	50.49	3	15	48	87.5	33.42
3	21	48	35.4	48.33	3	21	47	93.6	24.71
4	5.5	46	100.0	0.00	4	5.5	48	64.6	48.33
4	11	47	91.5	28.21	4	11	48	75.0	43.76
4	15	47	100.0	0.00	4	15	48	64.6	48.33
4	21	47	100.0	0.00	4	21	48	83.3	37.66

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BIOGRAPHICAL SKETCH

Josiah graduated from Pensacola High School in 1992. He took many college prep courses during high school but did not begin college until 1997. Josiah worked various jobs that ranged from cooking in a seafood restaurant to working as an automobile mechanic. The skills that he learned during that time are still valuable lessons in his life today. He began his college career by attending Pensacola Junior College from January 1997 to December 1999. After graduating with honors with an A.A. degree in environmental horticulture, he was accepted by the University of Florida to continue his college education. He began classes in the University of Florida's Environmental Horticulture program located at the West Florida Research and Educational Center in Milton, Florida, where he attended classes from January 2001 to May 2002. Josiah graduated as a University Scholar with highest honors. While at the West Florida Research and Educational Center he completed an undergraduate research project observing the genetic diversity of 'Red Baron' Cogongrass. He presented his research at the southern Nurseryman Association conference and was awarded first place in the undergraduate research competition. Josiah worked as a Sr. Laboratory Technician under Dr. Mack Thetford during the final semester of his undergraduate degree. He continued to manage his lab group until December 2003 when he left to attend Graduate School at the University of Florida in Gainesville. Josiah entered the master's program in interdisciplinary ecology in the School of Natural Resources and Conservation. In Gainesville, he began to study coastal restoration, specifically looking at plant interactions during dune restoration. Hurricanes and tropical storms repeatedly destroyed his research, but he was able to gather enough information to complete his thesis. Josiah currently works with the Department of Environmental Protection in Pensacola, Florida. He does not see himself continuing his education in a university setting.

When asked to look back at his college career, Josiah states that there are two important factors that stand out in his mind. First, the time he took off between high school and college taught him many things that helped him become better student. The second is financial aid, without which, he would not have been able to afford to go to college.