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THE EFFECTS OF PROPAGULE SOURCE, SOIL AMENDMENT, AND STOCK TYPE ON THE SURVIVAL AND GROWTH OF GIANT CANE (ARUNDINARIA GIGANTEA (WALT.) MUHL.) ESTABLISHED AS A LOW MAINTENANCE NURSERY

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By

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Submitted in partial Fulfillment of the Requirements
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Approved by:

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MAJOR PROFESSOR: Dr. James J. Zaczek

Giant cane [*Arundinaria gigantea* (Walter) Muhl.] is a native bamboo species that was once widely distributed within bottomland forests and as extensive monotypic stands (canebrakes) along waterways of the southeastern United States. Land conversion to agriculture greatly decreased the distribution of canebrakes. Limited to less than two percent of its historic range, canebrakes are now considered an endangered ecosystem. A 0.24 hectare low maintenance experimental nursery of giant cane was established at Southern Illinois University to examine the effect of planting stock type, soil amendments, and four collection sources on cane survival and growth (number of culms, height and diameter of the tallest culm, spread between furthest two culms) after two growing seasons. All treatments, plus interactions of source by soil, and source by stock, were significantly affected by survival. Collection source significantly affected all growth measurements. Stock type affected the number of culms, height, and spread. Soil amendments did not significantly influence any growth measurement but affected soil chemical properties. The interactions between source and stock affected the number of culms, height, and spread. The interaction between stock and soil significantly affected spread, but no other interactions significantly affected any growth measurements. Of all treatment combinations, the Cypress Creek

West source, when grown in containers, tended to have the greatest survival and overall growth after two years, regardless of soil amendments. This study highlights factors that are important in establishing a giant cane restoration nursery. This nursery will also generate growing stock for future canebrake restoration and rehabilitation projects.

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TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

FIGURE PAGE

CHAPTER 1

INTRODUCTION

Giant cane [*Arundinaria gigantea* (Walt.) Muhl.] is a species of bamboo or woody grass that is native to the southeastern United States. Native cane, documented throughout historical writings and songs, was once present in dense monotypic gregarious colonies, or canebrakes, along and within riparian and bottomland forest ecosystems (Platt and Brantley 1997). Giant cane was even described by Teddy Roosevelt in his journal on a trip across the United States (Roosevelt 1908). However, canebrakes have been depleted due to conversion to agricultural land, overgrazing, and an altered fire regime. Now canebrake ecosystems are limited to less than 2% of historical extents and are considered critically endangered (Noss et. al 1995). Local sources or genotypes are important to perseverance of viable populations (Frankel and Soulé 1981). Different genotypes allow for outcrossing of flowering giant cane. Choosing the appropriate genetic source has a significant impact on the success of a restoration project (Lesica and Allendorf 1999). Consequently, there is interest in developing a better understanding of giant cane ecology in order to conserve the species.

Although once considered the lone species of *Arundinaria* distributed in the U.S, (Figure 1) that included subspecies, recent treatments (Triplett et al. 2006, Clark et al. 2007) separated out two other species (*A. tecta* or river cane, and *A. appalachiana* or hill cane) with smaller distributions in the Coastal Plain, southern Appalachians, and upper Piedmont (Triplett and Clark 2009). Consequently, the following references may be referring to any or all of the species of cane when discussing giant cane (Ward

2009). The following thesis experimented on *Arundinaria gigantea*, which is also referred to as “giant cane” or “cane”.

Giant cane is associated with many different forest types, including longleaf-slash pine, loblolly-shortleaf pine, oak-pine, oak-hickory, oak-gum-cypress, elm-ash-cottonwood, and wet grasslands (Garrison et al. 1977, Marsh 1977). Giant Cane is associated with the southeastern United States and is considered a ‘Facultative Wetland’ type for the ‘Wetland Indicator Status’ by the United States Department of Agriculture. This indicates that this species is associated with wetlands approximately 75% of the time (77 Federal Register 27210).

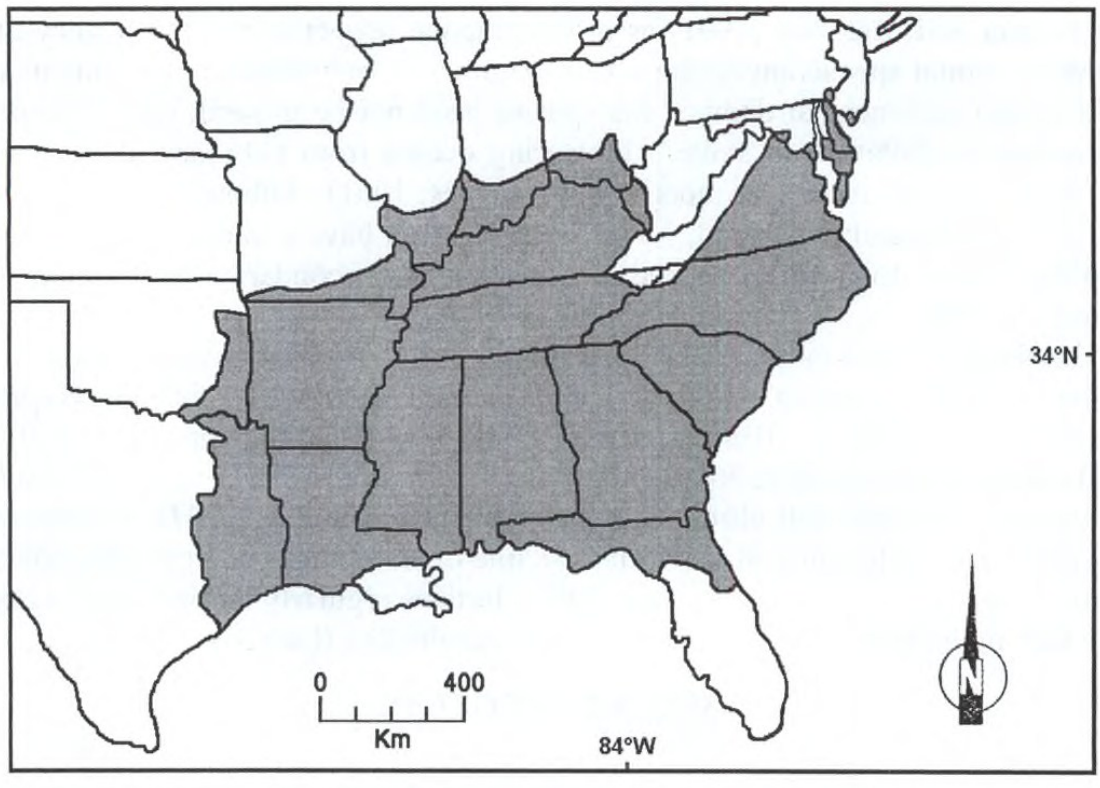

Figure 1. Distribution of giant cane (*Arundinaria gigantea*) in the southeastern United States modified from Marsh (1977) and Farrelly (1984) (Platt et al. 2001).

Giant cane grows best in mesic bottomlands that are well drained, where it can annually grow up to 6 m in lateral spread, and 8 m in height (McClure 1973). In general, above- and below-ground productivity of plants is largely determined by the availability of resources needed for growth, i.e., light, water, and nutrients. Furthermore, the availability of these resources can interact with management, such as burning (Blair 1997) or fertilization (Zaczek et al. 2009).

For giant cane to be vigorous, this species needs periodic disturbance and full sunlight. Disturbances include natural or prescribed fires, grazing, flooding, and wind from hurricanes or tornadoes. Using fire once every ten years as a disturbance tool helps to reduce competition, and return giant cane back to its original vigorous growth (Hughes 1951). After a fire has occurred, giant cane culm height and diameter declines the first year, but the following year the size increases (Zaczek et al. 2009). Grazing used as a disturbace should only occur during the late summer months after new culm growth is established (Hughes 1966). It has been suggested that Native Americans used fire as a management tool to help spread giant cane to create larger canebrakes for use in their culture (Platt and Brantley 1997, Platt et al. 2009).

Native Americans used giant cane for nearly every aspect of their daily lives and transformed it into many different items (Platt et al. 2009). Cane was used as food for Native Americans and boiled to produce teas and tonics for medicinal purposes (Platt et al. 2009). It is believed to have a cathartic effect, which helps stimulate the kidneys and renew strength. Cane was used as forage for domesticated animals of European settlers. Also, traps and snares were constructed by native Americans to help catch game animals. Cane was used to build the structure for houses, and also used for

thatching and creating waterproof walls. Jewelry, baskets, and armor were made from the intertwined fibers of the cane. The natives created blowguns, arrows, and knives from cane to create weaponry for defense against enemies and for hunting (Platt et al. 2009). To this day, people use cane shafts as poles for fishing and cover for duck blinds.

Giant cane also has high wildlife habitat values of cover for small mammals, and aquatic and terrestrial birds (Brantley and Platt 2001, Miller and Miller 2005). Giant cane provides critical habitat for threatened and endangered wildlife species, such as the canebrake rattlesnake (*Crotalus horridus atricaudatus*), Bachman's warbler (*Verivora bachmanii*) which is possibly extinct, and various insect species (Platt and Brantley 2003). Swainson's warbler (*Limnothylpis swainsonii*) inhabit a thick understory in bottomland hardwood forests for nesting. This includes floodplains with giant cane that produce a very dense litter layer. Restoration of cane along waterways will help to reestablish wildlife habitat (Brown et al. 2009).

While giant cane directly provides habitat, it also indirectly aids flora, fauna and humans by alleviating pollution in rivers and streams. Canebrakes on stream banks, or riparian zones, are influential in the reduction of water pollutants and sedimentation from agricultural runoff and stream bank erosion. Excess nitrogen (N) and other plant nutrients can result in algal blooms that reduce water quality and aquatic biodiversity of water bodies (Brooks et al. 2003). The dense root systems formed by rhizomes and culms of this species effectively takes up N and stabilizes stream bank soil to improve water quality. Giant cane can take up and sequester nutrients from both non-point and point-source pollution. Thus, giant cane helps to alleviate the harsh impact that

agricultural surface runoff imposes on waterways up to 90% (Blattell et al. 2009, Schoonover et al. 2005). It has been found that giant cane can sequester large amounts of N without affecting seedling growth or physiology (Cirtain et al. 2004).

Because giant cane is of great ecological and cultural importance, there has been a great deal of interest in restoring the species. There has been a growing body of restoration research with giant cane. This includes studies at Southern Illinois University (SIU) and other institutions primarily in southeastern United States. However, one of the main bottlenecks to the process of restoration is the availability of planting material to establish large-scale canebrakes.

For cane propagation, sexual reproduction from seed is unreliable (Gagnon and Platt 2008). Although new seed production technique experiments are underway at Mississippi State, more yield is produced from asexual propagation of cane (Baldwin et al. 2009). Transplanting intact clumps of cane has produced surviving plants (Dattilo and Rhoades 2005), but is difficult and costly to do on a large scale (Cirtain et al. 2009, Platt et al. 2001). Transplanting bare rhizome pieces has resulted in surviving and expanding genets but results vary by date of collection, collection source, and rhizome morphology (Brendecke and Zaczek 2008, Hartleb and Zaczek 2007, Zaczek et al. 2009). However, collection of rhizome propagules is difficult and often impractical from wild canebrakes or cane patches.

Collection from existing cane stands shrinks patch size and sets back canebrake expansion. This justifies the development of cane nurseries where plant material could be grown and collected sustainably en masse for use in large-scale restorations. However, there are no reported giant cane nurseries or guidelines for their

establishment. Additionally, little is known about the cultural requirements for high survival and rapid growth when growing cane under such conditions.

The purpose of this project was to establish a relatively low maintenance prototype cane nursery at SIU and understand factors that influence survival, growth, and sustainability. Specifically, this project was conducted to determine if survival and growth of transplanted giant cane was influenced by collection source (four collection locations [putative genotypes]); stock type (bare rhizomes compared to containerized [greenhouse grown]); and soil amendment (added composted manure and leaves versus no amendment). This project also started a sustainable nursery at SIU to generate propagules for future restoration efforts.

The study builds on current research and methodology by providing new research on source, soil properties, and stock that influence growth and development techniques of giant cane rhizomes and the new culms that are generated. The long-term goals were to establish a giant cane nursery at SIU to create a supply of cane rhizomes or propagules for future plantings. Also, other goals were to determine factors affecting survival and growth, and to develop long-term low maintenance management techniques. The objectives were to test cultural practices of three factors: sources, stock, and soil for the survival and growth of planted giant cane. Specifically, this study tested the following hypotheses: 1) cane collection sources would not differ in growth and survival, 2) cane planted in amended soils will not differ in survival and growth compared to those planted in non-amended soils, 3) containerized stock of cane transplants will have similar survival and growth compared to planted bare rhizomes of cane.

CHAPTER 2

LITERATURE REVIEW

Giant cane is a native species to the southeastern United States. Cane spreads underground through rhizomes to create patches or canebrakes. Canebrakes uptake nutrients through sequestration to alleviate pollution and sedimentation. These monotypic stands create habitat for many different species of animals. Canebrake habitat is critically endangered, therefore restoration of this species is necessary. Overall, the literature presented demonstrates the need for restoration.

Marsh (1977) conducted a comprehensive work on the taxonomy and ecology of giant cane. Giant cane plants are composed of rhizomes that are underground horizontal shoots that give rise to new roots, more rhizomes and aboveground shoots or culms, from the nodes. The horizontal growth is referred to as diageotropic. The rhizome system is a running shoot system with lateral growth which is referred to leptomorphic. These rhizomes then spread within the first 15 cm of the soil surface (Marsh 1977, McClure 1966). Rhizomes can grow as much as 6.1 m in length in a single season (Marsh 1977). Roots grow relative to the amount of moisture available to the plant and can grow to the soil surface. Roots tend to be smaller if there is less moisture available to the giant cane (Marsh 1977). Rhizomes are the main source of vegetative reproduction, and they store food to produce new culms when disturbances occur to the giant cane (Hughes 1966).

Culms, also known as ramets, are the vertical aboveground growth arising from nodal buds on rhizomes (Marsh 1977). Culm sheaths are usually smaller than the internodes, and sheaths start to die out and wither with age (Marsh 1977). Branching

on culms is described as short and slender (McClure 1973), giant cane leaves are 6-25 cm long, and 0.8-3.0 cm wide while length, width, and pubescence of the plant vary upon site factors and ontogeny of the genet (patch). Giant cane culms can grow to heights of 10 m tall (Platt and Brantley 1997). McClure (1973) cited Takenouchi as observing that giant cane buds break after the internodal growth has completed, which is termed acropetal order. Culms usually live as long as five to ten years depending on site characteristics, and disturbance helps to form new culms when dieback is apparent (Platt and Brantley 1997), and culm dieback or death can be reduced with fertilization (Zaczek et al. 2009).

Giant cane, in conjunction with best management practices has been shown to sequester nutrient runoff from non-point source pollution and stabilize soil erosion from agricultural fields (Schoonover et al. 2005, Schoonover et al. 2006, Blattel et al. 2009). The dense mats of rhizomes or root system that giant cane forms help to stabilize the soil from erosion by increasing the soil porosity and infiltration. This same system also helps to alleviate excessive nutrient loads from the streams and rivers next to the giant cane waterway. Studies have shown that cane can reduce dissolved nitrate-N, dissolved ammonium-N, total ammonium-N and total orthophosphate masses by 100%. These reduced loads were similar to a forested buffer over relatively short distances (10m) (Schoonover et al. 2005). Giant cane can reduce sedimentation in the first 3.3 m of the buffer during the four different seasons of the year compared to a forested buffer, which only buffers sediment masses three seasons (Schoonover et al. 2006).

Sexual reproduction of giant cane through flowering and seeds is erratic and can take anywhere from 25 to 100 years to occur after initial establishment (Matthews et al.

2009, Marsh 1977). It is rare to see a flowering event of giant cane because it is so infrequent and seed production usually follows about a month after flowering, and the seed is not very viable (Hughes 1951). However, new observations have shown otherwise (Baldwin et al. 2009, Gagnon and Platt 2008). Early research concluded that canebrakes died back following flowering, also known as semelparity (Hughes 1951, Marsh 1977). Thus, reliance on sexual reproduction has not been very practical for use in restoration efforts.

Because seed production of giant cane in any one region is generally unpredictable and unreliable, there is a lack of available local planting stock to restore canebrakes. Thus, land managers wishing to restore canebrakes are faced with alternative approaches to do so. According to Gagnon (2006), there are three pathways to establish canebrakes in the field. The first is to reinvigorate already present cane stands. The second method is through vegetative propagation with transplanted rhizomes or with cane clumps or offsets (rhizomes with attached culms). Finally, the third pathway is to plant seeds collected elsewhere.

The first pathway to giant cane restoration is to restore cane that is already present in forest systems. Full sunlight is an ideal condition for giant cane to thrive. To allow for additional sunlight in the forest understory, a manager should thin a forest stand according to established silvicultural guidelines and requirements for the site's forest type. Uneven-aged silvicultural practices to develop multiple age groups of trees in some forest types may require repeated periodic thinning and appropriate use of periodic prescribed fires. This practice helps to increase cane plant vigor through increased light and other resources while maintaining some density of trees in the forest

(Gagnon 2006). As the forest stand develops, similar to a savanna, the canopy will close thus requiring additional periodic disturbances such as a fire to maintain vigorous cane within the understory.

The second pathway for cane restoration is to transplant clumps of rhizomes with attached culms (Platt and Brantley 1993), plants generated from bare rhizomes (Hartleb and Zaczek 2007, Sexton et al. 2003, Zaczek et al. 2009), or bare rhizomes alone (Gagnon 2006, Zaczek et al. 2009). In one of the earlier reported attempts of transplanting cane, Platt and Brantley (1993) found that culms with rhizomes had successful outcomes. These grew faster and earlier than the culm-only stock, which yielded no growth. The authors attributed this to the root system that was already established by the rhizomes. They also suggested planting the giant cane in full sunlight for future studies. High moisture was also recommended in determining the propagation success, since rhizomes are susceptible to desiccation (Platt and Brantley 1993).

In 2005, Dattilo and Rhoades recommended that clumps of rhizomes with attached culms should be transported as large root mats approximately 30-45 cm in length with as much intact soil as possible. However, digging, transporting, and transplanting large clumps of cane plants can be cumbersome (Hartleb and Zaczek 2007). If planted during the dry season, irrigation may be beneficial. In a Missouri study, root mats were transplanted in the soil. Rhizomes were planted with one to four culms, and it took two years for the giant cane to establish and spread. Accelerated growth was observed after flooding occurred, which may have been due to decreased competition from vines killed by the flooding waters. Despite an increasing interest in

the restoration of giant cane, little is known about the factors affecting the productivity and long-term establishment of this native grass species (Platt and Brantley 1997).

Storing clumps or large mats of rhizomes is an alternative approach to reintroducing this species, with positive results. Clumps were extracted from the soil and immediately placed into white plastic tubes with approximately 1L of water and sealed off on both ends. The tubes were then hung in shade for around six weeks and showed to avoid embolism in cane. The results proved to have greater than 96.3% success rate in rhizome transplantations (Baldwin et al. 2009). Baldwin also suggests to plant rhizomes in pot-in-pot horticulture techniques for easy removal of rhizomes from the soil when ready for transplants (Baldwin et al. 2009).

In an Illinois study that occurred over a 5 year span, individual rhizomes ranging from 20 to 30 cm were planted in a greenhouse and misted daily. After a period of one month the rhizomes were checked, and over three-quarters of the rhizomes exhibited new culm growth indicating that bare rhizomes alone without culms could be used to generate cane plants. Rhizomes with ten or more nodes had the most culm sprouts (Zaczek et al. 2004). From the prior research, potted rhizomes from two collection sources (putative clonal sources) were grown for 2 to 3 months in the greenhouse and subsequently transplanted into the field and measured over a 5 year period (Zaczek et al. 2009). There was 39% survival of the genets (the group of new culms and rhizomes arising from the originally planted stock plant) after 5 years. Growth increased each year so that by the fifth year each surviving original genet had a mean of 81 culms that averaged 100 cm tall and 212 cm in spread (the distance between the two most widely

separated culms of the genet). Collection source significantly influenced height but not the number of culms nor spread.

Zaczek et al. (2009) compared field-planted greenhouse-grown potted cane plants to bare rhizomes. Containerized plants showed some survival advantage over bare rhizomes after 3 years. Propagules with more buds and with taller culms exhibited greater survival. However, site preparation treatment with herbicide offered no advantage in survival and only little advantage in growth.

Dattilo and Rhoades (2005) studied the effective difference between using hardwood mulch and nutrient rich manure mulch on the survival and growth of giant cane propagules. Root balls that were approximately 45 cm in diameter were removed from an existing canebrake and transplanted to another site approximately 500 meters away in a floodplain in central Kentucky. Manure was applied at similar weights as the hardwood mulch. During two growing seasons, there was 98% clump survival. The hardwood chip mulch had a significantly higher number of new culms, taller height, and larger clump area than unmulched. Manure also exhibited increased culm numbers than the mulched area. Both treatments enhanced above ground production of transplanted rhizomes.

Complementary data on resources (i.e., light, water, and nutrient availability) influencing the productivity of giant cane in response to burning and restoration in southern Illinois was gathered. Four treated plots (i.e. control, fertilized, burned, fertilized & burn) of cane was compared to a nearby early successional field. At the end of the growing season, the early successional field had higher soil moisture than the four treated cane plots. Percent soil N and Carbon (C) were lower ($P < 0.011$) in the

early successional field than the burned cane plots. Light and inorganic N were positively correlated with soil moisture ($P < 0.05$), and these relationships were driven by higher photosynthetically active radiation and inorganic N in the early successional field (D. Dalzotto, unpublished data).

The third pathway for giant cane restoration is to collect and plant seed from current cane patches and canebrakes (Gagnon 2006). Anecdotal evidence shows that information on the location of flowering giant cane patches that are producing seed is important. Giant cane can produce millions of seeds when flowering, but it flowers infrequently and seeds can often be non-viable (Hughes 1966). When flowering, the leaves look as though they are dying and the seeds resemble wheat. To collect seeds, it is important for a manager to be aware of these physical changes in the plants, so that when a patch does flower, the seeds can be collected as quickly as possible.

Growth from seed to plant has recently been documented due to flowering of giant cane in multiple states throughout the southeast including Mississippi, North Carolina, Alabama and Tennessee in 2006 and 2007 (Baldwin et al. 2009, Gagnon and Platt 2008). These seeding events have allowed for research on seed germination. At Mississippi State, germination studies were conducted and using a wet rolled towel with temperatures at 30 to 35°C during the day and 20 to 25°C during the night. Seedlings were produced, but seed propagation methods are still not viable compared to asexual propagation (Baldwin et al. 2009). Once seed is collected, it should be pressed into moist, well-drained soil in leaf litter with partial sun exposure. Since giant cane seeds are shade tolerant, planting a large number of seeds will help increase the survival rate of planted seeds. Out-crossing is necessary for successful seed set, and will help

create multiple genetically different individuals (Gagnon and Platt 2008). Additionally, using seed from non-local sources may result in genotypes or ecotypes that are not well adapted to local conditions.

Micropropagation research is also recently being performed to see if these are viable ways to propagate giant cane. Tissue culture was removed from new growth on culms and rhizomes and placed into a 1% agar with growth media. This experimental technique had potential for many new culms, but is limited because very little root formation was produced (Baldwin et al. 2009).

Due to the inconsistent nature of seed production and the difficulty of digging and transplanting stock from existing canebrakes, there is a need to develop methods to establish and grow giant cane nurseries from local sources that can sustainably produce stock for restoration. The goals of this study were to establish a giant cane nursery from local collection sources and determine the effect of cane propagule type (collection source and stock type [bare rhizomes and potted greenhouse plants]), and nursery cultural factors (soil amendments) on the survival and growth of planted giant cane.

CHAPTER 3

METHODOLOGY

Study site. In July of 2008, the study site for the giant cane nursery was created at the Tree Improvement Center (TIC) property on the SIU farms approximately two miles west of the SIU campus in Jackson County, IL (+37° 42' 34.74"N, -89° 16' 0.82"W). The planting site was on a small hill located between 3 ponds (Figure 2). The soil associated with the site is a Hosmer silt loam, which is a fine-silty, mixed, active, mesic, Oxyaquic Fragiudalf, with two to five percent slope (Figure 2).

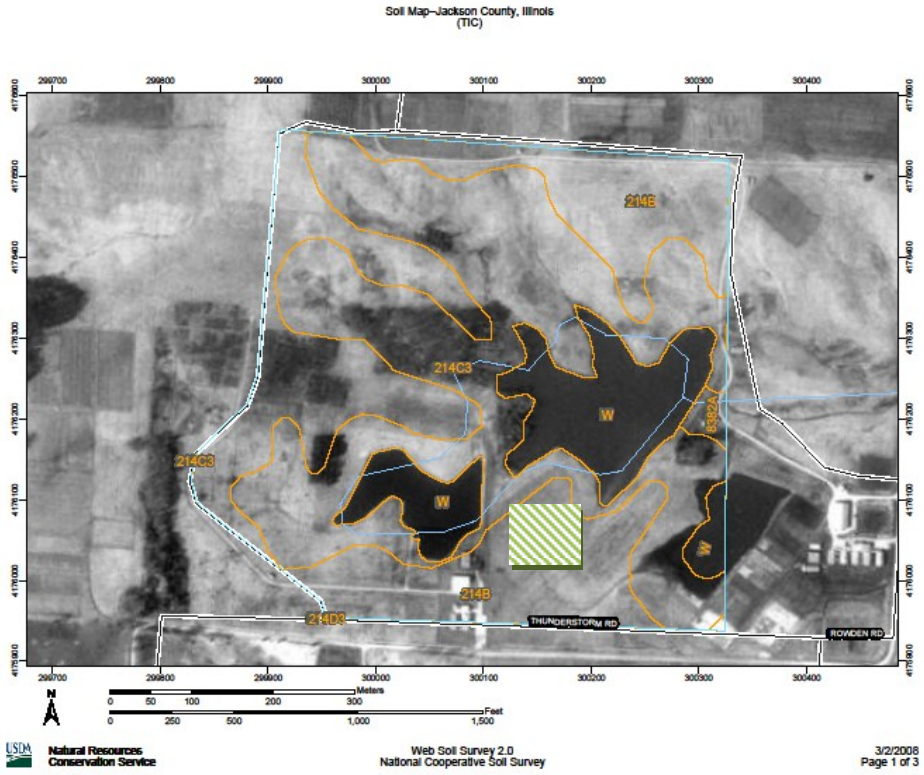

Figure 2. Soil series map and the location of the giant cane nursery in southern Illinois in green cross-hatching.

To prepare the site for nursery planting the existing vegetation at the site was sprayed with glyphosate in early May of 2008. Approximately 2 weeks later, after the vegetation yellowed, the site was tilled to a depth of approximately 20 cm. After tilling, the site was divided into 3 separate study areas: the nursery planting area, a cane germplasm propagation area, and a hydrology study area. This paper reports on only the nursery planting area which was 73.15 m long (north to south) x 32.92 m wide (east to west) or (240 ft x 108 ft), with an area of 0.24 hectares.

Nursery Design. The nursery consisted of three blocks 10.97 m x 73.15 m (36 ft x 240 ft) containing whole-plots 12.19 m x 32.92 m (40 ft x 108 ft) assigned to five different sources of giant cane according to a split-strip-split block design. I examined the effect of collection source (4 levels used,), soil amendment (2 levels), and type of planting stock (2 levels) on giant cane establishment (survival) and growth. Additionally, two levels of a clover (*Trifolium*) cover crop factor were initially used. However, this treatment factor was omitted from the analysis due to the cover crop encroaching onto control plots and not allowing for comparison.

The amendment and cover crop factors were assigned to each source block and soil amendment was randomly assigned and added to one of two 5.49 m x 73.15 m (18 ft x 240 ft) (east to west) strips in each block. Clover cover crop seed was randomly assigned and planted in one of two 6.09 m x 32.92 m (20 ft x 108 ft) (north to south) strips in each source resulting in subplots with a differing combination of soil amendments and cover crop treatments. Each of these combinations was split into assigned plantings of either containerized or bare rhizome stocks from each source. The Upper Cache River (UCR) source was only planted with containerized stock and

plants were approximately 6 months older than containerized stock of the other sources. Because of this, UCR was not included in the data analyses. A summary of the performance of UCR-sourced stock is presented in the appendix.

Amendment Treatment. The soil amendment treatment consisted of composted manure from the SIU farms and organic matter collected from the campus. The manure was composed mainly of cow waste, with a small amount of swine waste. The organic matter was mainly mixed hardwood leaves collected at SIU. A sample of the compost was collected in 2010 and tested for nutrients and other physical and chemical characteristics. Compost was analyzed at A & L Great Lakes Laboratories, Inc. (Fort Wayne, IN) using 'Test Methods for the Examination of Composting and Compost' (TMECC), which is the U.S. Composting Council standard for compost testing. The compost was applied to the soil surface July 10, 2008 to the assigned strips with a Kuhn 8140 side discharge spreader (Kuhn North America, Brodhead, Wisconsin) to a thickness of approximately 8 cm. The whole site was tilled again to incorporate the compost into the soil to a depth of 20 cm.

On July 16th, 2008, the day before the nursery was planted, the site was tilled again to remove any plants that had developed since the last tillage. Five 12.19 m x 32.92 m (40 ft x 108 ft) plots were established in a north to south orientation for each of the individual sources. A 3.05 m x 32.92 m (10 ft x 108 ft) buffer strip was located between each of the source plots to keep sources separate in later years as the planted cane grows and spreads.

Clover was seeded using a Brillion 1.68 m (66 inch) broadcast seeder (Brillion Farm Equipment, Brillion, Wisconsin) within 6.10 m x 32.92 m (20 ft x 108 ft) strips in a

north to south orientation. Four and a half kg of red clover (*Trifolium pretense*) and 2.3 kg of white clover (*Trifolium repens*) were mixed and applied at a rate of 4.4 kg/ha, but was not included in the final analysis as stated earlier and as discussed ahead.

Cane Source Collections. Giant cane rhizomes were collected from four existing canebrakes throughout southern Illinois in early May of 2008 (excluding UCR). Giant cane locations were located by contacting local resource managers, using information from previous SIU studies (Hartleb and Zaczek 2007, Sexton et al 2003), and by speaking with authorities on cane at conferences and symposia. Small canebrakes or patches of giant cane were located, and considered different sources because each may be of a different genotype or a composite of multiple genotypes. Two sources were collected from the Cypress Creek National Wildlife Refuge on U.S. Fish and Wildlife Service managed property near Perks, IL. One of these sources was collected near the entrance gate on the Frank Bellrose Waterfowl Reserve and is referred as Bellrose Gate. The second, Hickory Bottoms, was collected from a patch off the Hickory Bottoms Access Trail located off of Mount Olive Road near the north central portion of the refuge. Cypress Creek East and Cypress Creek West originated from two separate canebrakes located approximately 200 m apart on a private landowner's farm in Dongola, IL (Figure 3).

A backhoe was used to lift giant cane rhizomes out of the ground. This can cause more damage to the rhizomes than the use of a shovel, but use of a backhoe reduced labor and time in the field.

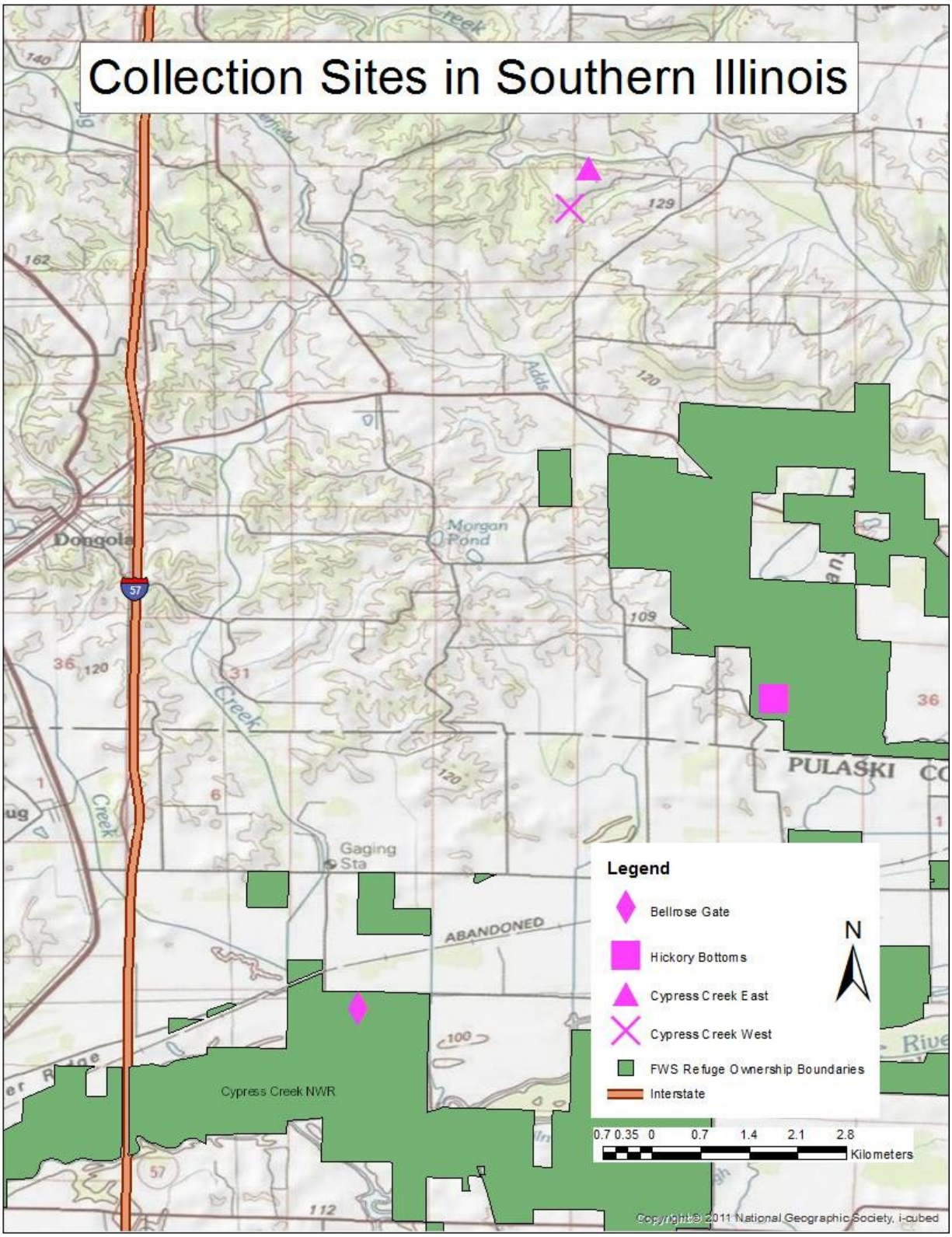

Figure 3. Map of four collection sites of giant cane in southern Illinois near Dongola.

Once the rhizomes were extracted from the ground, they were trimmed to approximately 30 cm long. Culms were trimmed from the attachment point and discarded. Approximately 300 rhizomes were collected from each site. Rhizomes were placed in white plastic bags and labeled with the site name and date collected. Plastic bags were placed in a cooler with ice packs for transportation from the field to the Horticulture Research Center (HRC) at SIU. At the HRC, moist peat moss was placed into the plastic bags with the rhizomes to limit desiccation. Labeled plastic bags with rhizomes were then placed in a cold storage room and maintained at 5^{o}C. Stock referred to as bare rhizomes were kept dormant for 2 months prior to planting directly in the nursery. Other rhizomes were stored only for about a week before they were planted in pots in the greenhouse to grow containerized stock for planting in the nursery.

Greenhouse Propagation of Containerized Stock. Approximately 120 rhizomes from the four different sources were planted in the greenhouse beginning on May 15 through May 17, 2008 into D40 Deepots and placed into D20C support trays (Stuewe and Sons, Inc. Corvallis, Oregon) using pre-moistened Fafard Canadian Growing Mix No. 2 (Conrad Fafard, Inc., Agawam, Massachusetts) with Micromax micronutrients (The Scotts Company, Marysville, Ohio). The D40 Deepot cells were 6.4 cm in diameter and 25.0 cm deep with a cell volume of 656 ml. The contents of the growing medium included Canadian sphagnum peat moss, perlite, vermiculite, starter nutrients, wetting agent, and dolomitic limestone. The medium was combined with Micromax micronutrients, which included Ca, Mg, S, B, Cu, Fe, Mn, Mo, and Zn at a rate of 0.96 L/m^3 of potting medium. Rhizomes were approximately 30 cm long and the distal 3 to 5

cm was left exposed above the potting media surface as recommended by previous SIU research (Sexton et al. 2003).

Once planted, the stock was immediately watered from above. Four greenhouse benches were lined with black plastic liners to hold water. Trays with D40 containers were placed on the plastic-lined benches and watered to a depth of approximately 2.5 cm, which kept the potting medium moist. Benches were watered as necessary throughout the week to keep the water at that level. The additional UCR greenhouse stock source generated from another study and was planted in the greenhouse previous to the nursery greenhouse plantings. All five sources were fertilized on a regular basis approximately every 7-10 days with Scotts Peters Professional water soluble fertilizer 10-10-20 peat-lite special (The Scotts Company, Marysville, Ohio) applied at a rate of 400 ppm N prior to planting in the nursery.

Nursery Planting. The five sources of cane propagules were randomly assigned to source blocks in the nursery and planted on July 17, 2008 at 0.91 m (north to south) x 1.52 m (east to west) spacing. Each factor, as well as a combination of these factors, was applied for three repetitions for each source of cane (Figure 4). Overall, approximately 900 giant cane propagules were planted in the nursery.

An irrigation system was installed the following day after planting on the nursery site to maintain moist soil conditions. Irrigation was primarily used because of the mid-summer planting date, and to minimize the potential for desiccation of the giant cane during hot, dry summer months. After the first growing season, the irrigation was removed, and the buffers between sources were mowed. The irrigation was reinstalled for the second growing season.

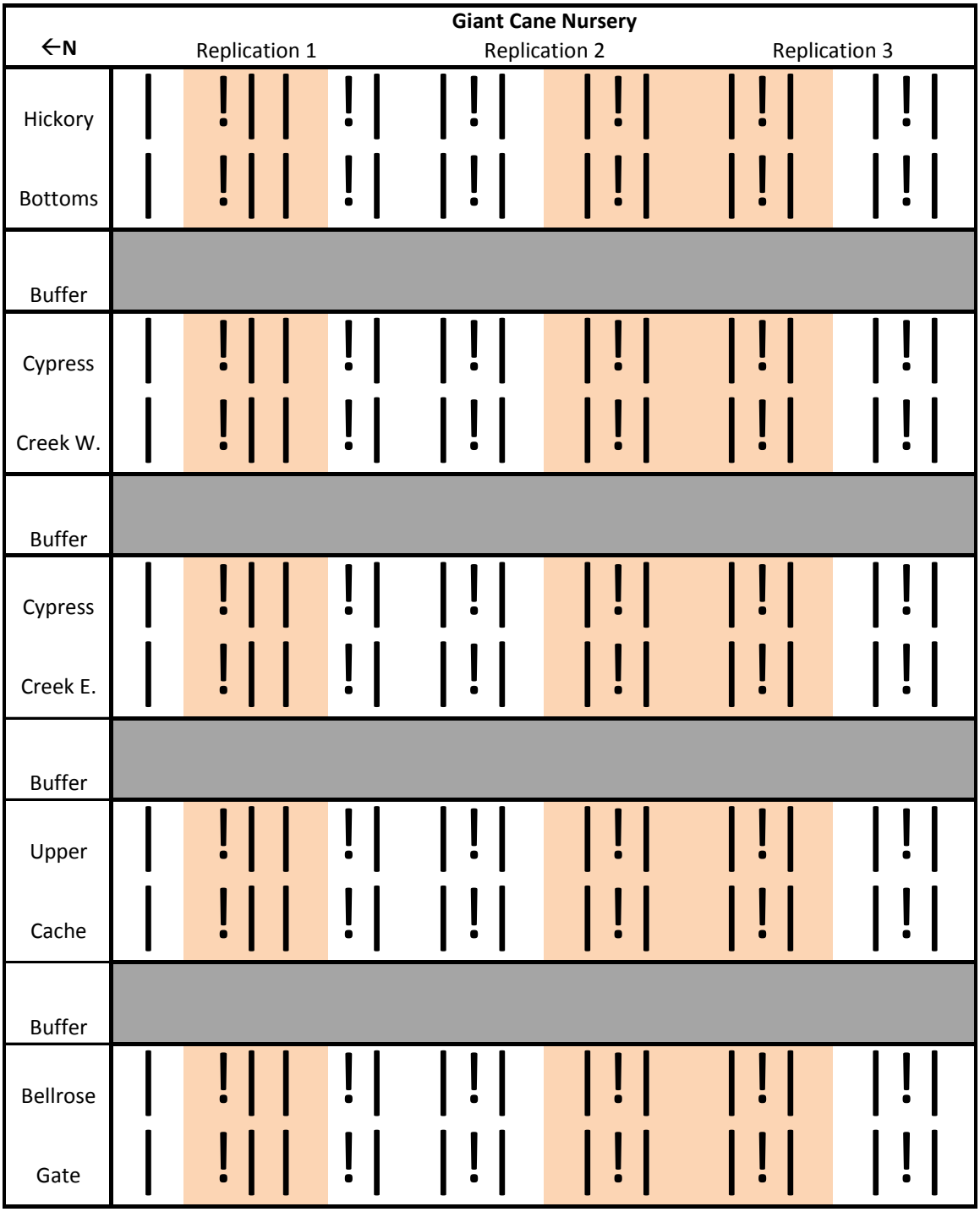

Figure 4. Layout of the giant cane nursery located at the SIU HRC farms.

An additional source of cane from the Upper Cache River (UCR) was planted in the nursery but only as potted material (containerized stock) from previous greenhouse research at SIU HRC. Because UCR was not collected and grown in the manner described previously, it will not be included in the analysis reported on in the results section of this research paper.

Nursery Measurements. Number of culms, height of the tallest culm (HTC) to the nearest 0.5 cm, diameter of the tallest culm (DTC) to the nearest 0.1 mm and spread to the nearest 0.5 cm were sampled three different times over a two year period. Spread was defined as the distance (cm) between the two most widely separated culms originating at each planting spot. The first sampling was a month following planting. The second sampling followed the first hard freeze in December of 2008, and the final sampling was following the end of the second growing season. The data presented in this paper is from the third set of measurements taken in January of 2010. All data analyses were performed using the final measurements described.

Giant Cane Replanting. Spots where planted rhizomes did not survive were replanted on March 16, 2010 with remaining potted material that had been maintained in the greenhouse. Giant cane propagules were replanted to increase the number of culms for future restoration stock. Replanted propagules were not used in the data analysis described below.

Data Analysis. Observations during final measurements showed that clover had spread from cover crop plots to control plots. Percent cover of clover was measured for each planting site and this was analyzed by source, according to a strip-split block design using the mixed model procedure in SAS (SAS Institute Inc., Cary, North

Carolina). These analyses demonstrated that percentage cover of clover was similar in clover-sown and non-sown treatments. Thus, the cover crop factor was ignored in subsequent data analysis.

Cane survival, growth, HTC, DTC, and spread were analyzed by source according to a split-strip-split-block design, with source as the whole plot factor, and type of stock (bare and containerized) as the split plot factor, and soil as the split plot factor (amended and non-amended) (Figure 4). All statistical tests were performed using SAS (SAS Institute, Cary, NC) software and tested at $\alpha = 0.05$. Means and standard deviations were calculated for the treatments for each variable. A normality test was performed for height, diameter, number of culms, and spread. Height and diameter both had normal distributions. Number of culms and spread had skewed distributions and the data were log transformed. Percentage survival was calculated for the planted propagules for each stock type, by soil amendment, and by block for each source. A three-way factorial ANOVA was performed to determine if there were significant effects of treatments (source, stock, and soil) or their interactions on survival. The procedure univariate was run in SAS (SAS Institute, Cary, NC) and the data did not violate normality assumptions therefore no transformations were necessary. Student's t-tests were used to determine if the variables differed between treatment levels with a 95% confidence interval.

Nutrient Testing. Test methods for the examination of composting and compost (TMECC) analysis was collected from the compost pile March 29, 2010. A one-way ANOVA was performed in SAS (SAS Institute, Cary, NC) to determine significance of the soil composition and micronutrients.

Fifteen randomly selected soil samples were extracted March 29, 2010 from the amended soil strips and non-amended soil strips, and these samples were analyzed April 1, 2010 at KSI Laboratories (Shelbyville, IL) for micro- and macronutrients. Amended and non-amended soils were statistically analyzed using an ANOVA to determine if they differed in soil nutrient and chemical properties.

CHAPTER 4

RESULTS

*Survival***.** After the second growing season, mean survival percentage of the planted propagules across all treatments was 48.1%. Survival of individual treatment combinations ranged from 23.8% (n=21) (containerized stock of Bellrose Gate in amended soils) to 83.3% (n=30) (for each of two containerized stock of Cypress Creek West grown in either amended or non-amended soils) (Table 1). There were approximately 60 containerized propagules and 120 bare rhizome propagules planted for each source.

A three-way factorial ANOVA revealed significant main effects of source ($p<0.0001$), stock ($p<0.0001$) and soil ($p=0.0130$), and interactions of source x stock ($p<0.0001$) and source x soil ($p=0.0216$) on survival (Table 2). Examining the source stock interaction, compared to bare rhizomes containerized stock had; higher survival for sources from Cypress Creek West and Cypress Creek East; similar survival for the Hickory Bottoms source; and lower survival for the Bellrose Gate source. Overall, cane planted in amended soils tended to have lower survival (42.2%) compared to those planted in non-amended soils (54.4%), but the effect varied by source (Table 1).

*Measurements of Growth***.** There were significant main effects of source and stock as well as a source x stock interaction on the number of culms and HTC (Table 2). Soil amendment did not significantly affect the number of culms, HTC, or DTC when tested as a main effect or as an interaction with other treatments. However, there was a main effect of soil and a stock x soil interaction on the spread of the genets.

Table 1. Percent survival of planted giant cane propagules by collection source, stock type [containerized (CONT) or bare rhizomes (BARE)], and soils [non-amended (NA) or amended soils (AM)] two growing seasons after planting.

Source	Stock	Soil	n	Source x Stock x Soil Survival %	Source x Stock Mean Survival %	Source mean Survival %
Cypress Creek West	CONT	NA	30	83.3		
Cypress Creek West	CONT	AM	30	83.3	83.3	
Cypress Creek West	BARE	NA	60	56.7		
Cypress Creek West	BARE	AM	60	48.3	52.5	62.8
Bellrose Gate	CONT	NA	25	48.0		
Bellrose Gate	CONT	AM	21	23.8	40.0	
Bellrose Gate	BARE	NA	55	61.8		
Bellrose Gate	BARE	AM	57	38.6	50.0	46.2
Cypress Creek East	CONT	NA	30	70.0		
Cypress Creek East	CONT	AM	30	70.0	70.0	
Cypress Creek East	BARE	NA	60	25.0		
Cypress Creek East	BARE	AM	60	33.3	29.2	42.8
Hickory Bottoms	CONT	NA	30	50.0		
Hickory Bottoms	CONT	AM	30	30.0	40.0	
Hickory Bottoms	BARE	NA	60	40.0		
Hickory Bottoms	BARE	AM	60	41.7	40.8	40.6

Table 2. Significance levels from a three-way factorial ANOVA of giant cane sources, stock types, and soils on survival, number of culms, height (cm) and diameter (mm) of the tallest culm, and spread (cm) of genets growing from planted cane propagules two growing seasons after planting. Treatment combinations with an (*) are not significantly different (α = 0.05).

	P-Values				
Treatments/Interactions	Survival	# Culms	Height	Diameter	Spread
Source	<0.0001*	0.0056*	0.0080*	0.0002*	<0.0001*
Stock	<0.0001*	<0.0001*	0.0002*	0.0559	<0.0001*
Soil	0.0130*	0.5597	0.1520	0.6714	0.0742
Source x Stock	<0.0001*	0.0042*	0.0077*	0.0621	<0.0001*
Source x Soil	0.0216*	0.8504	0.8056	0.7304	0.5897
Stock x Soil	0.2811	0.3952	0.9918	0.9550	0.0293*
Source x Stock x Soil	0.3966	0.3868	0.7532	0.5835	0.8493

Table 3. Field measurements collected after second growing season for mean number of culms, mean height (cm), and mean diameter (mm) of giant cane genets by source and stock.

Source	Stock	# of culms	Height (cm)	Diameter (mm)	Spread (cm)
Cypress Creek West	CONT	5.2	90.08	5.16	46.81
Cypress Creek West	BARE	2.3	53.69	4.02	7.92
Bellrose Gate	CONT	4.9	59.06	3.06	13.82
Bellrose Gate	BARE	3.0	44.04	2.54	5.85
Cypress Creek East	CONT	3.4	58.51	3.42	17.27
Cypress Creek East	BARE	2.6	50.78	3.54	5.85
Hickory Bottoms	CONT	2.9	62.57	3.75	12.70
Hickory Bottoms	BARE	1.9	52.49	3.65	5.12

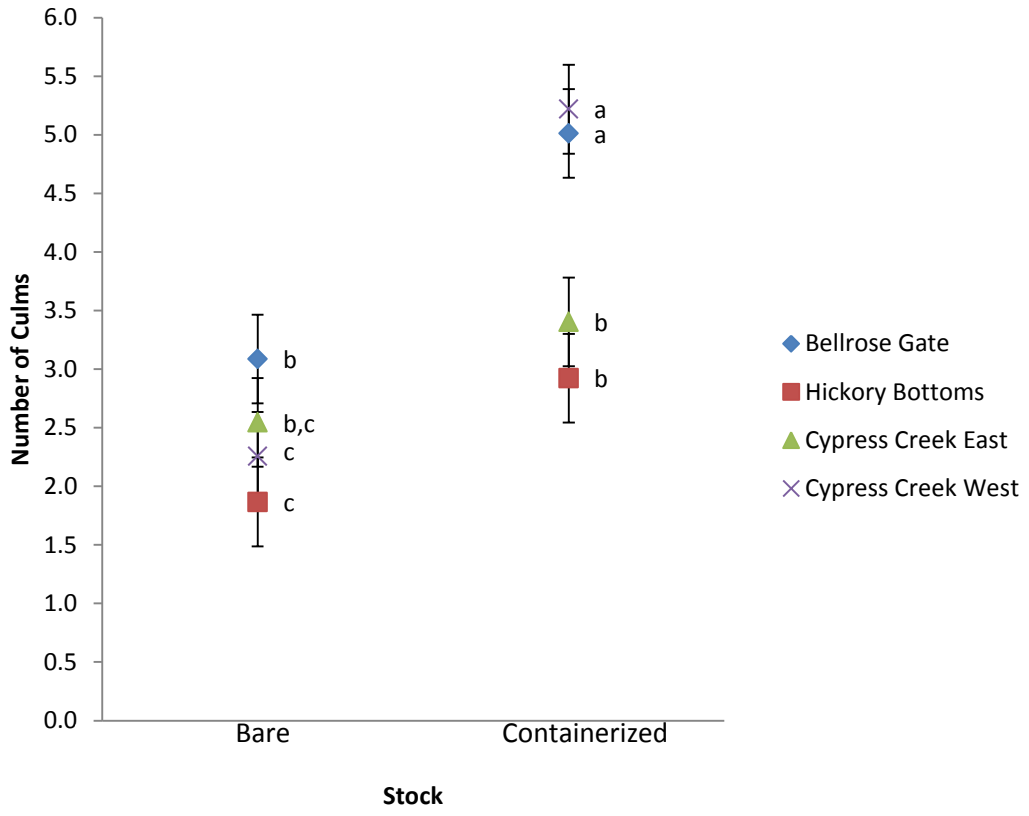

Figure 5. Estimated number of culms illustrating the source x stock interactions. Treatment combinations with the same letter are not significantly different (α = 0.05).

Number of Culms. The number of culms of surviving genets tended to be greater for containerized stock but varied by source. This ranged from 1.9 culms per genet for bare rhizome stock from Hickory Bottoms to 5.2 culms per genet for containerized stock from Cypress Creek West (Table 3 and Figure 5).

Height of the Tallest Culm. The HTC was greater for surviving genets arising from stock that was containerized compared to their bare rhizome counterparts for all sources (Table 3 and Figure 6). In particular, for containerized stock, the Cypress Creek West source was taller at over 90 cm in height than the other three sources which were about one-third smaller and did not significantly differ from each other.

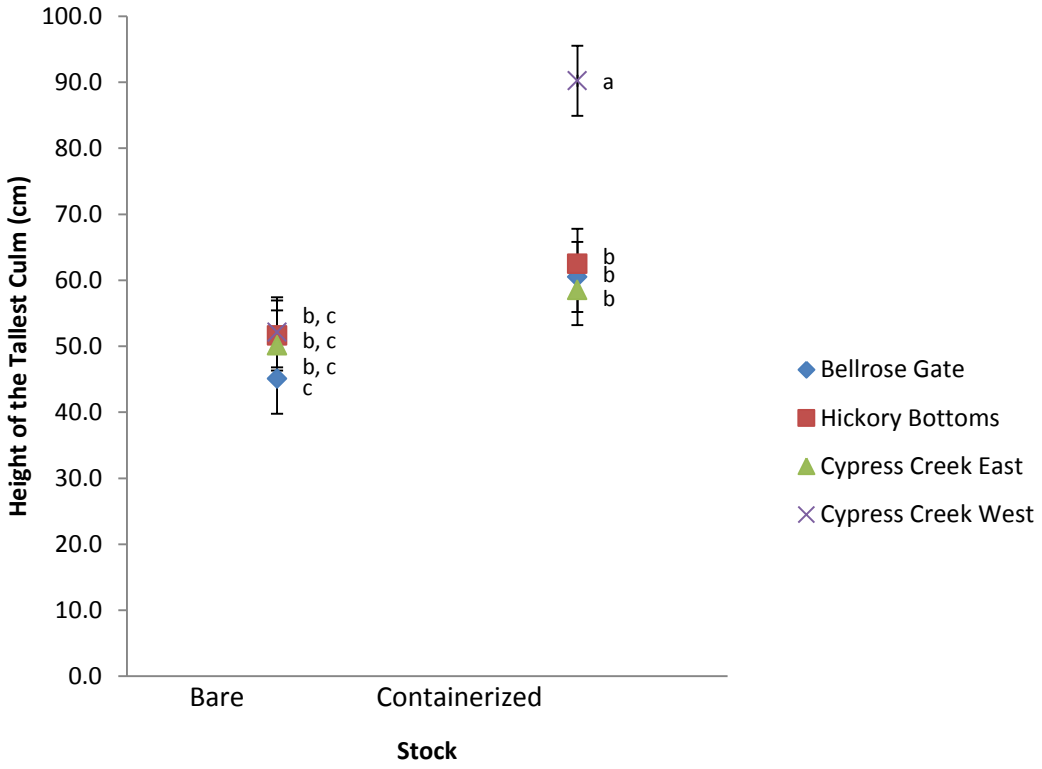

Figure 6. Height of the tallest culm illustrating the source x stock interaction. Treatment combinations with the same letter are not significantly different (α = 0.05).

Diameter of Tallest Culm. There was an effect of source (p=0.0002) on DTC of surviving genets ranging from a mean high of 4.59 mm for Cypress Creek West to a low of 2.80 mm for Bellrose Gate. However, DTC was not influenced by stock (p=0.0559), amended soils (p=0.6714), source x stock (p=0.0621), source x amended soils (p=0.7304), or amended soils x stock (p=0.9550), nor was there a three-way interaction of source x amendment x stock (p=0.5835) (Tables 2 and 3).

Spread of propagules with two or more culms. Mean spread of the furthest culms for genets arising from bare rhizome stock was 10.70 cm in amended soils and 10.16 cm in non-amended soils. The mean spread for containerized stock was 20.83 cm in amended soil and 29.69 cm in non-amended soil.

When investigating the spread of furthest culms of a genet, there were effects of source ($p<0.0001$), stock ($p<0.0001$), source x stock ($p<0.0001$), and a soils x stock interaction ($p=0.0293$); Cypress Creek West was the only significantly different source. However, spread was not influenced by amended soils ($p=0.0742$), source x amendment ($p=0.5897$), nor was there a three-way interaction of source x amended soils x stock ($p=0.8493$) (Figures 7 and 8).

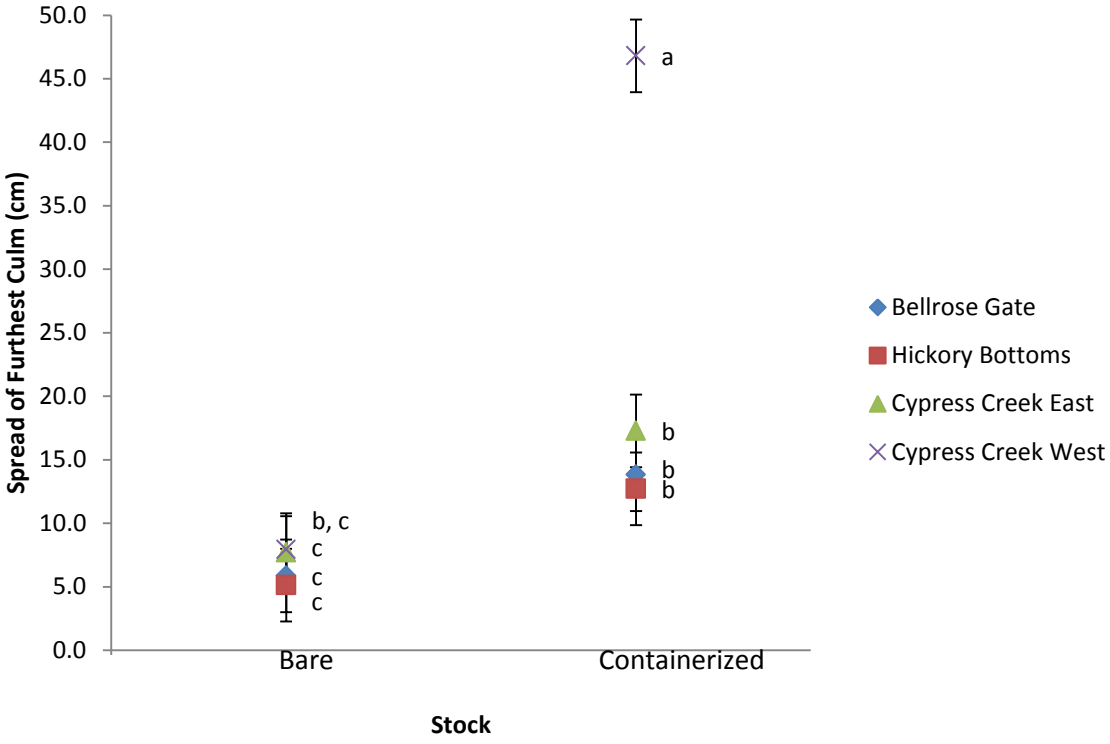

Figure 7. Spread of furthest culms illustrating a source x stock interaction. Treatment combinations with the same letter are not significantly different ($\alpha = 0.05$).

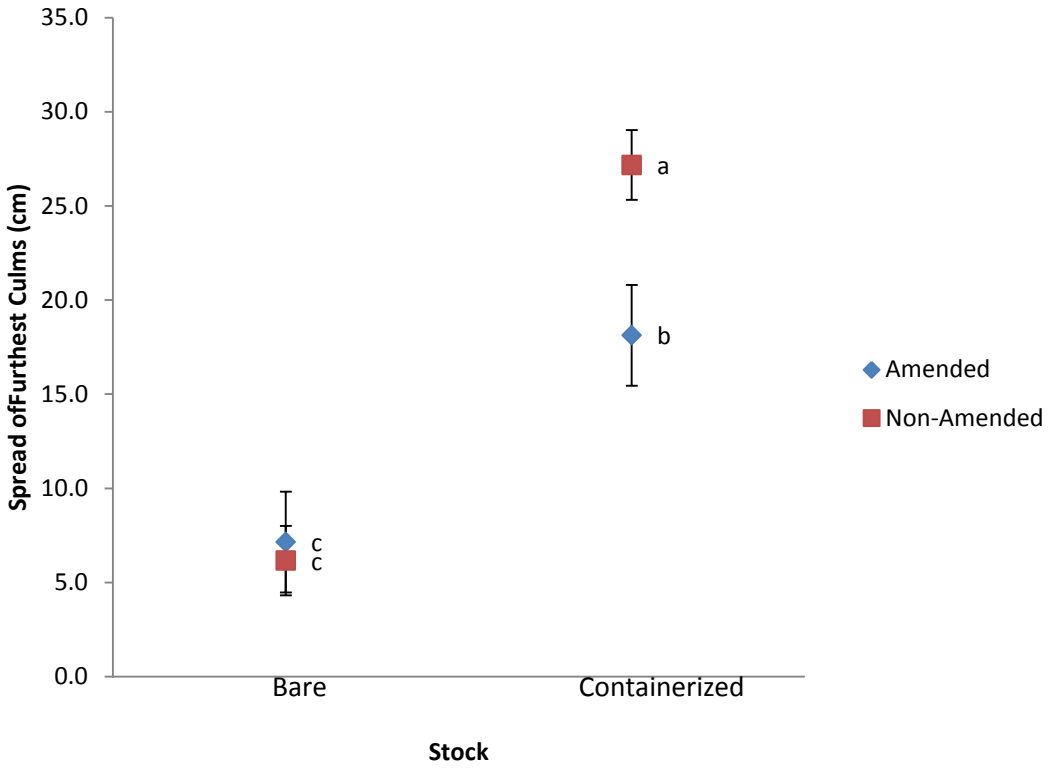

Figure 8. Spread of furthest culms for stock x soil. Treatments with the same letter are not significantly different at α = 0.05.

Soil and Compost Analysis. Compared to non-amended soils (control), amended soils had greater pH ($p<0.0001$), phosphorus (P) ($p<0.0001$), potassium (K) ($p<0.0001$), percent organic matter (OM%) ($p=0.0002$), and sulfur (S) ($p<0.0001$), but reduced amounts of iron (Fe) ($p<0.0001$) and manganese (Mn) ($p<0.0001$). However, zinc (Zn) ($p=0.0719$), copper (Cu) ($p=0.3787$), and boron (B) ($p=0.3787$) did not differ between amended soils and non-amended soils (control). Non-amended soils were approximately 100 times more acidic (average 5.4) than pH for amended soils, which were neutral (average 7.2). OM% of amended and non-amended soils was 2.3% and 2.0% respectively.

For micronutrients, S levels were higher in amended soils compared to non-amended soils. Interestingly, Fe and Mn levels were lower in amended soils. Otherwise, all other micronutrients were similar in abundance in both soils.

Table 4. Analysis of compost applied to the giant cane nursery.

Compost Analysis				
Parameter	Unit	Analysis Result	Dry Basis Result	Analysis Method
Moisture @ 70 C	%	54.28	-	TMECC 03.09-A
Dry Matter	%	45.72	-	TMECC 03.09-A
Total Nitrogen (N)	%	0.47	1.03	TMECC 04.02-D
Phosphorus (P)	%	0.13	0.29	TMECC 04.03-A
Phosphate (P205)	%	0.3	0.67	TMECC 04.03-A
Potassium (K)	%	0.33	0.72	TMECC 04.04-A
Potash (K20)	%	0.4	0.86	TMECC 04.04-A
Sulfur (S)	%	0.24	0.52	TMECC 04.05-S
Magnesium (Mg)	%	0.59	1.28	TMECC 04.05-MG
Calcium (Ca)	%	7.39	16.17	TMECC 04.05-CA
Sodium (Na)	%	0.04	0.09	TMECC 04.05-NA
Iron (Fe)	%	0.23	0.51	TMECC 04.05-FE
Aluminum (Al)	%	0.17	0.38	TMECC 04.05-AL
Copper (Cu)	mg/kg	11	24	TMECC 04.05-CU
Manganese (Mn)	mg/kg	189	413	TMECC 04.05-MN
Zinc (Zn)	mg/kg	65	142	TMECC 04.05-ZN
pH	-	7.2	-	TMECC 04.11-A
Soluble Salts	dS/m	4.74	-	TMECC 04.10-A
Ash @ 550 C	%	25.26	55.25	TMECC 03.02-B
Organic Matter by LOI @ 550C	%	20.46	44.75	TMECC 05.07-A
Organic Carbon by LOI @ 550C	%	10.23	22.38	Estimated
Carbon:Nitrogen Ratio (C:N)	-	21.7:1	21.7:1	TMECC 05.02-A

Table 5. Soil analysis of amended soil approximately 19 months after nursery establishment.

					Micro Nutrient Test Results (kg/ha)					
Amended Soil Samples	Soil pH	P kg/ha	K kg/ha	Organic Matter %	S	Zn	Fe	Mn	Cu	B
1	7.2	90	238	2.4	41	2	27	40	2	2
2	7.3	100	242	2.4	29	2	25	58	2	3
3	7.3	149	412	2.4	38	3	21	16	3	2
4	7.3	179	421	2.2	33	3	20	15	3	2
5	7.2	90	336	2.0	44	3	25	12	2	2
6	7.1	59	215	2.2	25	2	21	58	2	2
7	7.2	54	323	2.0	25	3	21	36	2	2
8	7.3	87	323	2.2	36	2	20	21	2	3
9	7.3	82	296	2.2	25	2	16	16	2	3
10	7.2	72	323	2.4	37	2	20	12	2	3
11	7.1	59	188	2.3	24	2	20	45	2	2
12	7.3	82	359	2.4	25	2	16	33	2	2
13	7.1	68	354	2.0	21	3	15	22	2	2
14	7.3	94	256	2.7	22	2	22	12	2	2
15	7.2	55	309	2.4	29	3	19	12	2	2
Average	7.2	88	306.4	2.3	30.2	2.3	20.5	27.3	2.3	2.3

Table 6. Soil analysis of non-amended soil approximately 19 months after nursery establishment.

					Micro Nutrient Test Results (kg/ha)					
Non-Amended Samples	Soil pH	P kg/ha	K kg/ha	Organic Matter %	S	Zn	Fe	Mn	Cu	B
1	5.5	22	139	2.3	21	1	27	104	2	2
2	5.4	22	175	2.0	19	2	29	68	3	2
3	5.4	20	175	1.8	22	2	27	68	3	2
4	5.4	21	157	1.8	24	2	35	103	2	2
5	5.4	15	202	1.7	17	2	27	43	2	2
6	5.5	22	135	2.0	13	2	24	132	2	2
7	5.4	19	157	1.8	17	1	29	137	2	2
8	5.4	16	157	2.0	20	2	25	93	2	2
9	5.4	18	161	2.2	24	2	33	90	2	2
10	5.4	18	229	2.0	17	2	35	35	2	3
11	5.4	26	170	2.0	19	1	27	127	3	3
12	5.4	15	157	2.0	19	2	25	147	2	2
13	5.4	17	170	1.7	17	3	24	90	2	2
14	5.4	19	179	2.0	20	3	31	58	2	2
15	5.5	20	238	2.3	22	3	24	20	3	2
Average	5.4	19.4	173.4	2.0	19.4	2	27.9	87.7	2.3	2.2

CHAPTER 5

DISCUSSION

Survival of giant cane was significantly different among sources in this study as had been reported in past studies at SIU (Brendecke and Zaczek 2008, Hartleb and Zaczek 2007, Zaczek et al. 2009). Two cane sources utilized in the current study, Bellrose Gate and Hickory Bottoms, were also used in other SIU studies. The second year survival of containerized stock from the Hickory Bottoms source at irrigated planting sites was 40% in the current study which was comparable to 45% survival reported by Zaczek et al. (2009). Containerized stock from Bellrose Gate in the current study exhibited 40% survival after two years. In previous studies, containerized stock collected from Bellrose Gate had somewhat similar survival of 52% and 48% after one and three years, respectively, when planted at the Big Creek site but first- and third-year survival of only 18% when planted at the Perks site (Schoonover et al. 2011, Zaczek et al. 2009). Plantings at the Big Creek and Perks sites were not irrigated which may have influenced the variability in survival between planting areas. This also illustrates that site conditions, such as moisture, fertility, and soils may affect the survival and growth of cane.

Overall survival tended to be greater among cane planted in non-amended soils compared to amended soils but that was dependent on source (Tables 1 and 2). It is speculated that this reduced survival in some cases could be due to an abundance of vigorous weeds that impacted competition in the areas where manure-based compost was added as an amendment. Cane is reported to be vulnerable to competition (Feeback and Luken 1992, Platt and Brantley 1992) but is also reported to be a fierce

competitor or be tolerant of competition (Schoonover et al. 2011). Although not specifically quantified, distinct rows of vigorous weeds (mainly morning glory and pokeweed) were observed within amended soils strips whereas unamended areas had fewer weeds that were less vigorous (D. Dalzotto, personal observation). When amending soils with animal manure, the presence of viable weed seeds that have passed through animals can be a concern although the viability of weed seeds can be reduced during composting by reaching 60^{o}C temperatures or by maintaining moist conditions during most of the composting period (Eghball and Lesoing 2000). The compost used in this study appeared to have not been treated adequately to reduce weed seed viability. Thus, weeds that germinated in amended areas grew under conditions of more available nutrients (except for Fe and Mn), which likely resulted in their more vigorous growth compared to non-amended soils. Cane grown in amended soils did not exhibit increased number of culms, height, diameter, or spread compared to untreated soils suggesting that the weed cover may have competitively sequestered the additional nutrients making them unavailable at levels needed for cane growth and development. Since the levels of most nutrients (P, K, S) and other soils factors (pH and percent organic matter) in the amended soils were greater than in the non-amended soils more than 19 months after planting, it is also possible that cane was not growth-limited at the levels seen in the non-amended soils nor growth-responsive to the increased levels in the amended soils. Weeds generally have lower nutrient use efficiency, so they would be more competitive in higher nutrient conditions.

Source of the cane propagules tended to affect survival and growth in most comparisons either as a main effect or as an interaction with stock. Collection source

has been shown in other studies to affect survival and growth of cane (Brendecke 2008, Hartleb 2007, Zaczek et al. 2009). Sources from private land, in particular, Cypress Creek West, and to some extent, Cypress Creek East tended to be the most vigorous especially as containerized stock. These sources (potentially individual clones) may be genetically well-suited to propagation and growth or it may be related to condition of the source at the time of rhizome collection. These cane sources came from canebrakes which were existing in riparian zone buffers adjacent to row-crop agricultural lands. These canebrakes received fertilization for many years compared to the other two sources which came from canebrakes along the edge of forest stands on the Cypress Creek Refuge that did not border agricultural lands.

Although weed competition for nutrients may reduce cane growth, dense cover from competing vegetation may enhance survival and protect cane from low winter temperatures (Schoonover et al. 2011), which has been reported to damage the species particularly near the species northern extent of its range as in Carbondale, Illinois (Zaczek et al. 2009). The presence of other vegetation may also serve as an alternate food source or a physical barrier for herbivores that may damage cane (Schoonover et al. 2011). Thus, additional weeds in compost-amended areas may have positive and negative impacts on the developing cane.

Compost can be beneficial if added to a site because it can act as a buffering agent, which helps keep pH of the soil at the same level as prior to planting and change the plant availability of nutrients (Brady and Weil 2001). Amended soils in the nursery had an average pH of 7.2, whereas non-amended soils averaged a pH of 5.4. There was lower survival on amended soils compared to the non-amended soils. However,

there was a significant difference between the control (pH 7.1) and a restored canebrake (pH 7.5), and this was due to soil weathering (Andrews et al. 2011). A study at SIU also showed no effect on growth of giant cane by soil pH (unpublished data, Goble 2012). Adding compost can also increase the moisture holding capacity of a soil (Mays et al. 1973), which may aid in the survival and growth of plants. Since the planting was irrigated, the potential effect of compost improving moisture conditions would not have been realized compared to an unirrigated planting. Overall measures, results suggest that the compost amendment that was utilized in this study tended to have a somewhat negative or neutral effect on the survival and growth of giant cane over the first two years of establishment.

Compost increased the pH of the amended soils, and levels of Fe and Mn were greater in the non amended soils. These micronutrients are usually added with compost (Brady and Weil 2001), but Fe and Mn levels in the amended soils were lower in my study. This may be due to the competition of weeds. Metals can be more available/soluble in soils that are more acidic as pH affects solubility of metals (Eghball et al. 2000). Plant available nutrients in manure can be available of organic N from 18-55%, P up to 70%, K up to 100%. For micronutrients, Ca and Mg are available at greater than 55%. Zn, Fe, Mn, Cu, S, and B were less than 40% plant-available (Eghball et al. 2002). Organic matter percentage among amended and non-amended soils was 2.3% and 2.0%, respectively, which is expected after compost has been tilled into the soil. Microbes in the soil could break down compost quickly because it was exposed to sunlight and water (Brady and Weil 2001).

Management Implications. For managers working to restore *Arundinaria gigantea*, with very limited resources, I would suggest using bare rhizomes from field collections planted directly into the field soils using a machine such as a tree planter. The results of my work suggest that planting rhizomes in a greenhouse prior to the field is not critically needed for successful survival and growth. However, if ample resources are available for restoration, planting rhizomes in containers in a greenhouse offers some survival and growth advantages for some sources. If using a tree planter to plant the containerized stock, there would be an advantage of the D40 pots because the relatively narrow width and moderate depth of the pot allows it to be placed into the tree planter.

The private landowner's source (CCE and CCW) of giant cane had the best overall results; this may be due to fertilization runoff from the adjacent farmland and nutrient uptake by the cane. If resources are available, it might be beneficial to fertilize cane the prior year to cane collection. This may help to yield results similar to CCE and CCW. However, cane should be collected from multiple sources for use in restoration plantings in part due to ensure genetic outcrossing of the restored genets to help ensure viable seed production in the rare event that flowering does occur.

Also, it is suggested to not plant a clover cover crop; we planted clover to add additional N to the soil. Planted clover spread rapidly and was a strong competitor to other adjacent plants including giant cane, and this may have caused some cane mortality and stunted its growth. Amendment of the soil with improperly prepared compost is also discouraged because it increased weeds to the point that it overtopped the giant cane. However, if a manure fertilizer is added, managers should be sure that

no viable seed stock exists in the manure. Utilizing an appropriate herbicide could potentially reduce some of the weeds that encroach on a restoration site. If adding N is warranted because of nutrient poor soils, adding inorganic fertilizer would be an alternative to compost which would not introduce weed seeds and thus limit the need for herbicides.

Irrigation was added to site because of the late, hot, and dry summer planting date. The following two days, temperatures reached over 37°C, and irrigation helped to limit death of the propagules. I would suggest to plant cane in late winter or early spring using bare rhizomes and after the local freeze/frost date if using in-leaf containerized plants. Some areas of the nursery were oversaturated with water after heavy precipitation events. We even found a couple rhizomes that were washed away from original planting location.

We observed various damage from small animals and insects (most often encountered was the Colorado potato beetle; [Coleoptera: Chrysomelidae]) and took note of which plants were affected, but this only occurred on very few of the approximately 900 giant cane rhizomes planted. Even after these attacks, there were multiple new culms showing signs of new growth and, therefore, we do not anticipate this to be an issue with managers.

CHAPTER 6

CONCLUSIONS

A growing interest in giant cane restoration has developed in the last several years, but very limited literature and past research is available. Giant cane populations have seen a dramatic decline since European settlers arrived in America. A giant cane source was needed to help with future restoration efforts in the southeastern United States. This nursery was developed for the eventual sustainable harvesting of giant cane propagules, and to help understand cultural treatments to enhance the survival and growth of giant cane.

For managers creating a nursery, we suggest extracting rhizomes from the ground from multiple sources and storing them in a refrigerator or cold-storage until plots of land are ready to be planted. Land should be tilled a few days before the project is ready to be started. If a greenhouse is available, it could be beneficial for the survival and growth of some sources to grow containerized stock prior to transplanting to the restoration site.

Future research projects could look at the effects of disturbance (i.e. fire) on giant cane planted after a five year or 10 year period. Also, it would be important to compare cane growth in amended soils versus non-amended soils over a five year period. Longer-term comparisons of bare rhizomes versus containerized stock are also needed. This project will help future restoration efforts with methods to establish and grow new giant cane nurseries.

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APPENDIX

Appendix A. The mean performance of the Upper Cache River (UCR) source planted as containerized stock (CONT) only for each soil amendment treatment (AM=soil amended with compost, NA=soil not amended) for percentage survival, number of culms per genet and the height and diameter of the tallest culm from each surviving genet after the first growing season.

Source	Stock	Soil	n	% Survival	# of culms	Height (cm)	Diameter (mm)
UCR	CONT	AM	90	13.30	12	76.85	1.35
	CONT	NA	90	20.00	18	79.00	1.45

Vita

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Education

M.S. Forestry – Southern Illinois University Carbondale, Restoration Ecology, May 2013, GPA: 3.674

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Professional Experience

Technical Assistant I – University of Arkansas Fayetteville, Forest Entomology, Dr. Fred M. Stephen, April 2011 to Present

Field work includes setting up wet and dry insect traps for graduate research as well as weekly travels to different sites in the Ozark and Ouachita National Forests for trap collections. Lab work includes sorting and identifying wet and dry insect samples. Built rearing houses for emergence of *Sirex* woodwasps*, Monochamus* long-horned beetles*,* and *Ips* bark beetles. Used destructive sampling of pine logs to examine presence of *siricid* larvae. Created and maintained lab website for Dr. Stephen.

Graduate Assistant – Southern Illinois University Carbondale, Forestry, Dr. James J. Zaczek, Spring 2008 through Spring 2010

Created and established a giant cane (*Arundinaria gigantea*) nursery and germplasm collection. A bare rhizome stock was planted in greenhouses located at Southern Illinois University Carbondale farms. The effects of varied cultural methods including cover cropping and organic soil amendments were determined for the survival and growth of planted giant cane. Nursery plantings were used to produce a sustainable supply of rhizome propagules for habitat restoration.

Restoration and Assessment Assistant – Southern Illinois University Carbondale, Plant Biology, Dr. Sara G. Baer, Fall 2005, Spring 2006, Fall 2006, and Spring 2007

Field work included seed collection, planting, plant survey and soil cores from restoration plots at Konza Prairie Research Natural Area in Manhattan, Kansas. Lab experience included analyzing biomass, carbon and nutrient content from field samples with necessary equipment. Created and maintained lab website for Dr. Baer.

Field Assistant – Southern Illinois University Carbondale, Forestry, Dr. James J. Zaczek, Spring 2005 and Spring 2006

Field work included measurements of giant cane for percent cover, density, average height and diameter of culms. Greenhouse experience included propagating giant cane rhizomes and characterizing their morphological features including length, diameter, number of nodes and buds per rhizome.

Forestry Technician (Timber pre-sale) – USDA Forest Service – Sulfur Ranger District, Grand Lake, CO, Kevin McLaughlin, May through August 2005

Duties included timber cruising, which consists of obtaining sampling information of timber for a tract of land. Sample measurements included height and diameter of trees. Duties also consisted of marking boundaries within tracts of land for sale.

Lab Assistant – Southern Illinois University Carbondale, Zoology, Dr. Matt Whiles, Spring 2005
Entomology lab experience included sorting invertebrates from substrate under a dissecting microscope.

Archeological Assistant – University of Illinois, Illinois Transportation Archeological Research Project, August through November 2003
Cleaned and labeled Native American artifacts collected from the Cahokia Mounds area.

Teaching Experience

Teaching Assistant, Southern Illinois University Carbondale, Forestry 202 – Tree Identification Laboratory, Fall 2008 and Fall 2009

Publications

Zaczek, James J., Sara G. Baer, and **David J. Dalzotto**. 2010. Fire and Fertilization Effects on the Growth and Spread of Rhizome-Transplanted Giant Cane (*Arundinaria gigantea*). *Restoration Ecology* 18:462-468.

Presentations/Posters

Giant Cane Day, Cypress Creek National Wildlife Refuge, IL, 2009 (Presentation)
Association of Southeastern Biologists, *Arundinaria* symposium, MS, 2008 (Presentation)
St. Louis Area Undergraduate Symposium, MO, 2007 (Poster)
Southern Illinois University Carbondale Undergraduate Research Forum, IL, 2007 (Poster)

Awards

St. Louis Area Undergraduate Symposium, 2nd place poster competition, 2007, $250
Research-Enriched Academic Challenge, Southern Illinois University Carbondale, 2006, $1445
Forestry Alumni Scholarship, Southern Illinois University Carbondale, Fall 2005 and Spring 2006, $1000
Undergraduate Assistantship Award, Southern Illinois University Carbondale, Plant Biology, 2005 through 2007
Honors Program, Southern Illinois University Carbondale, 2005

Professional Training

Conservation Leaders for Tomorrow, South Central – Student Workshop, Wildlife Farms, Casscoe, AR, 2010
Illinois Ethics and Compliance Training, 2008, 2009, 2010
Cane Restoration Workshop, Cypress Creek Refuge, Mingo National Wildlife Refuge, MO, 2008
Wildland Firefighter Red Card Certification, USDA Forest Service, 2005
Volunteer Grounds Crew Maintenance, Giant City State Park, IL, August through October 2004

Professional Organizations and Appointments

Xi Sigma Pi (National Forestry Honor Society), 2005 through 2010
Saluki Heritage Interpreters, Southern Illinois University Carbondale, Vice-President, 2009 through 2010

Restoration Club, Southern Illinois University Carbondale, 2009 through 2010
Future Farmers of America, High School Regional Exam Administrator, 2006 through 2010
American Waters Resource Association, Southern Illinois University Carbondale Chapter,
New Student Recruiter, 2006