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# Giant Cane and Other Native Bamboos: Establishment and Use for Conservation of Natural Resources in the Southeast



Figure 1. Giant cane (*Arundinaria gigantea*).  
Photo credit Tim Oakes, 2011.

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# Acknowledgements

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# Preface

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The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Plant Materials Program has been involved in the evaluation of conservation plants and planting technology for more than 85 years. The native bamboos, particularly giant cane (*Arundinaria gigantea*) and switch cane (*A. tecta*) historically covered vast areas, called canebrakes, in at least 22 states. Both canes have many culturally significant uses for Native American Indian Tribes. The expansive canebrakes have significantly declined due to land use changes after European colonization. Renewed interest in giant cane has generated research into methods to propagate and re-establish it on the landscape. This document summarizes previous research on establishment of giant cane and makes recommendations for NRCS technical specialist and field office staff on how to use canes to meet specific conservation objectives.

For additional information on specific species of plants mentioned in this publication, please see the USDA PLANTS database at: (<http://plants.usda.gov/java/>) or contact the nearest Plant Materials Center or plant materials specialist (<http://plant-materials.nrcs.usda.gov/contact/>) and/or the Land Grant Universities that serve the State. For specific information on soils and soil health, please see USDA NRCS soils website at: (<http://www.nrcs.usda.gov/wps/portal/nrcs/site/soils/home/>). Also, see technical resources on the National Plant Materials Program Web site at: (<http://www.plant-materials.nrcs.usda.gov/>).



# Background

There are three species of bamboo or cane native to the United State (Triplett & Clark, 2009); all are monopodial or running bamboos that spread by rhizomes (Platt & Brantley, 1997).

*Arundinaria gigantea* (Walter) Muhl., now called giant cane, has also been called cane, rivercane, swampcane, switchcane, and wild bamboo (Anderson & Oakes, 2011). *Arundinaria tecta* (Walter) Muhl., now called switch cane, and *A. appalachiana* Triplett, Weakley and Clark, now called hill cane, were previously considered subspecies of giant cane and much of the historical information does not distinguish between them (Triplett & Clark, 2009). This tech note deals primarily with giant cane, although when adaptation differences between giant cane and switch cane are noted in the research cited, both species will be discussed.

Historically cane occurred across 22 states, ranging from New Jersey, south to central Florida, west to southern Missouri and south through eastern Oklahoma and Texas. Its limits correlated closely to those areas with a minimum of 180 frost-free growing days and at least a 40-inch annual precipitation (Marsh, 1977). Cane is found from sea level to an elevation of 2000 feet in the Appalachian Mountains. Giant cane grows in slightly acidic soils ranging from sands to loams, but grows best in loose, well-drained alluvial soils found in floodplains (Marsh, 1977; Farrelly, 1984; Platt & Brantley, 1997). Switch cane is restricted to non-alluvial swamps, moist pine barrens, and other communities of the Coastal Plain region of the southeastern U.S., but overlaps the range of giant cane in the western Coastal Plain region (Triplett & Clark, 2009)

Prior to European colonization, both giant cane and switch cane occurred in dense, massive stands, called canebrakes (Fig. 2; Brantley & Platt, 2001). These canebrakes covered many acres of the southeastern U.S., mainly in the floodplains of rivers and streams. Both species hold great historical significance to Native American tribes in the area of their occurrence. Their ancestors used the canes for a myriad of uses, including crafting weapons and tools, building structures, weaving mats and baskets, as well as a source of food (Anderson & Oakes, 2011).



Figure 2. Canebrake in Northeast Louisiana early 1900's (USDA Bureau of Plant Introduction Image 3208)

Due to conversion of these lands to agriculture, overgrazing by livestock, and changes in fire regimes, only a tiny fraction of this canebrake acreage still exists in the Southeast and most populations are small and isolated (Dattilo & Rhoades, 2005; Baldwin et al., 2009). Because of its ecological and ethnobotanical importance, there has been a great interest in reestablishing cane in the southeastern United States.

## Addressing NRCS Resource Concerns

Canebrakes served many ecological functions. For NRCS planners, use of cane in conjunction with specific conservation practices can address numerous resource concerns including:

### Soil

- sheet and rill erosion
- bank erosion from streams, shorelines, or water conveyance channels
- organic matter depletion
- aggregate instability

### Water

- nutrients transported to surface water
- pesticides transported to surface water
- pathogens and chemicals from manure, biosolids, or compost applications transported to surface water
- sediment transported to surface water

### Plants

- plant structure and composition

### Animal

- terrestrial habitat for wildlife and invertebrates
- aquatic habitat for fish and other organisms

Like many riparian species, giant cane stands stabilize the banks of rivers and streams and are thought to improve water quality by capturing sediments and nutrients. Actual studies that quantify the effectiveness of giant cane for improving water quality are relatively few, perhaps in part a reflection of the limited number of extant stands available for study.

Schoonover et al. (2006) reported that in southern Illinois a mature giant cane buffer ( $\approx 33$  stems/square yard) reduced sediment loss from an agricultural field cropped in a no-till soybean/corn rotation by 94% within about 10 ft of the buffer edge compared to only about 50% for a mature forest buffer ( $\approx 0.1$  stem/square yard). They attributed this to higher stem density for the giant cane, which better slowed and spread overland flow, and higher year-round litter inputs from the giant cane. They concluded that the performance of the giant cane buffer was like that of other herbaceous or forested buffer types with similar or much wider buffer distances.

In a preliminary study on the same buffer area, Schoonover and Williard (2003) reported a 90% reduction in ground water nitrate-N within the first 10 ft of a giant cane buffer compared to only 61% reduction in the adjacent forested buffer. Within about 30-ft buffer distance, both the giant cane and forest buffer reduced nitrate by 99% and 82%, respectively, because of denitrification and uptake for both systems. Better nitrate reduction for giant cane was attributed to greater rhizome and root network for the giant cane than the forest species. Subsequent studies at several other giant cane and forest buffer sites in southern Illinois confirmed that the giant cane had similar or better reductions in ground water nitrate- and ammonium-N and phosphate (Blattel et al., 2005; 2009; Schoonover et al., 2010) and all authors considered giant cane a good riparian buffer species.

Andrews et al. (2011) reported similar reductions in nitrate-N levels in stream water from either giant cane or a mixed hardwood planting in a restored riparian corridor in Kentucky compared to an upstream control of a channelized, cool season grass hay field. In the same study, soil carbon



was similar for giant cane and hardwood plantings and increased over the 2.5 year of the study by 2X the rate of the hay field control. This resulted in both plantings having improved soil health measures, particularly the giant cane planting which showed an improvement of 64% in >2 mm macroaggregate class vs 23% for the hardwood planting.

Although capable of forming dense, essentially mono-specific stands, cane can often function as an understory species in a variety of plant communities (Anderson & Oakes, 2011). Platt and Brantley (1997) stated that various authors had reported cane a component of such communities as the pocosins and Carolina bays, pine barrens, upland hardwood forests, swamp hardwood forests, mixed and western mesophytic forests, and southeastern evergreen forest types.

Canebrakes provided food and habitat for over 70 species of wildlife including invertebrates, reptiles, mammals, and birds (Platt et al., 2001; 2013). As habitat, canebrakes were and are still particularly important as nesting or overwintering sites for many bird species protected by the [Migratory Bird Treaty Act](#). Many mammals, even though not dependent on canebrake habitat, have used canebrakes as an important foraging resource due to nutritional value of the plant. Halvorsen et. al. (2011) reported leaves of giant cane averaged 14.8% crude protein, which was similar to other browse species consumed by goats (*Capra aegagrus hircus* L). Additionally, they reported total nonstructural carbohydrate to crude protein ratio of giant cane leaves was similar to other cool season grasses.

Populations of several wildlife species have declined as canebrakes in the Southeast were lost (Dattilo & Rhoades, 2005; Schoonover et al., 2011). Regional declines in swamp rabbit (*Sylvilagus aquaticus* Bachman) populations in Indiana, Kentucky, and Missouri have been associated with loss of rivercane habitat (Platt et al., 2001). Giant cane seed had been identified as one of three primary mast food sources for passenger pigeons (*Ectopistes migratorius* L.) (Licenum, 1874, in Platt et al., 2001) and loss of mast sources has been identified as a major contributor to passenger pigeon extinction in the 19<sup>th</sup> century (Bucher, 1992). Other birds, such as Backman's warbler (*Vermivora bachmanii* Audubon) and Swainson's warbler (*Limnothlypis swainsonii* Audubon) are thought to have been dependent on these canebrake ecosystems. The loss of canebrakes has contributed to the possible extinction of Backman's warbler in the 20<sup>th</sup> century and species of concern status for Swainson's warbler (Remsen, 1986; USFWS, 2008). Giant cane also serves as an almost exclusive food source for the larvae of at least six species of butterflies which are now on species of concern lists due to habitat loss (Platt et al., 2001).

Where adapted and sources of planting material exist, giant cane may be an appropriate plant for the following USDA-NRCS conservation practice standards. Note: this species may need to be added to a state's approved plant lists:

- *Conservation Cover* (Code 327)
- *Riparian Forest Buffer* (Code 391)
- *Riparian Herbaceous Buffer* (Code 390)
- *Streambank and Shoreline Protection* (Code 580)
- *Forest Stand Improvement* (Code 666)
- *Wildlife Habitat Planting* (Code 420)
- *Restoration of Rare or Declining Natural Communities* (Code 643)

# Establishment and Management for Use in NRCS Conservation Practices

The following establishment and management guidelines for giant cane and switch cane were developed from a literature review (see page 9) and knowledge of NRCS conservation practices. Follow current state recommendations for other species planted in combination with cane as much as possible if they are compatible with cane management recommendations.

## Prior to Establishment Year

- Determine what resource concern(s) are being addressed and what ecological community type is desired to address concern(s). At this time, **giant cane is not recommended as the sole species to be used for practices that specify minimum effective planting widths** (e.g., *Riparian Forest Buffer* (Code 391) and *Riparian Herbaceous Cover* (Code 390), due to cost, inconsistent survival, and time required for stand to become effective at addressing resource concern.
- Determine availability of giant cane (or switch cane) planting material and any necessary companion species. Use companion species reasonably adapted to management requirements of giant cane, particularly *Prescribed Burning* (Code 338).
- Identify suitable restoration sites.
  - For giant cane, avoid sites that meet wetland classification or have preponderance of obligate wetland species or plant switch cane if native to area.
  - Flood plain sites or sites where flood plain hydrology is being restored that have loamy soils with moderate to moderately high  $K_{sat}$  in most restrictive layer are best for giant cane.
  - Depth to water table should not be in less than 12 inches for more than 2 weeks at a time for giant cane; sites with higher water tables or for more extended periods may be suitable for switch cane if native to area.
  - For restored flood plain sites, mechanical restoration of flood plain terraces or levees may be necessary to ensure adequate surface drainage.
  - Seek assistance of NRCS Soil Scientist to confirm flood plain landform, map unit boundaries, hydroperiod, etc.
- Determine appropriate planting date based on normal flooding regime or when Keetch-Byram drought index ([www.drought.gov](http://www.drought.gov)) is lowest for 3 to 4 month window in spring.

## Establishment Year

- Avoid sites with well-established rhizomatous grasses or implement *Herbaceous Weed Treatment* (Code 315) plan prior to planting cane.
- Install *Access Control* (Code 472) or *Fence* (Code 382) to control livestock; other actions to control feral hogs should be planned if population surveys warrant.
- Mechanical preparation should be minimal for type of planting material and method to be used. Mowing or broadcast, non-selective herbicide treatment to reduce herbaceous competition may be all that is necessary.
- If planting on site with existing forest overstory, do not thin overstory before planting.
- Do not apply lime or fertilizer at planting.
- Recommended planting rate is 1 clump (approx. 18-in. diameter), 2 well-rooted seedlings or sprouted and rooted rhizome pieces, or 4 freshly dug rhizomes per square yard.

- Plant in rows approximately 6 ft apart following contour or stream channel corridor; plant a minimum of 2 rows of cane if landform permits. If planting clumps, stagger clump placement in successive rows so they do not line up.
- Buffer plantings that include giant cane should follow width requirements specified in practice standard for the resource concern being addressed.
- Plant in the planting window previously determined and at a depth and orientation/placement recommended for cane planting material type; water immediately after planting.
- When planting companion species, follow state planting recommendations for *Rangeland Planting* (Code 550), *Conservation Cover* (Code 327), or *Tree/Shrub Establishment* (Code 612) for lowest density.
- Although not required, it is cheap insurance to mulch (Code 484) with hardwood chips, compost, or other suitable material immediately around the cane transplant and provide supplemental irrigation (Codes 441 and 449) for first year after planting.

### Post-Establishment Years (2-5)

- Monitor stand establishment. Rate stand as:
  - *Great* - >30% survival at start of second growing season
  - *Adequate* – 10-30% survival at start of second growing season
  - *Poor* - <10% survival at start of second growing season
- Stands rated as *Poor* should be carefully evaluated to determine probable cause of poor survival.
  - Partial list of causes:
    - Environmental – too dry, too wet, too shady, too sunny, just hit 100-year drought/flood, etc.
    - Planting material – source, handling prior to planting, planting process, etc.
    - Site management prior to and after planting – weed control, herbivory, etc.
  - Decide how easily cause(s) of poor stand can be mitigated.
  - Replant or augment existing giant cane planting if appropriate mitigating practices can be implemented.
  - If replanting does not seem reasonable, consider possibility of alternative site and start over. Monitor and manage companion species (if present) to ensure original resource concern(s) are addressed.
- Stands rated as *Adequate* or *Great* should be managed to enhance survival and spread.
  - Maintain fences if they were needed to protect planting site.
  - Continue to use irrigation if available for remainder of second growing season. Discontinue in year 3. If irrigation is needed after year 2, the planting site may not be suited for giant cane.
  - Monitor success of companion plantings, particularly if giant cane was planted as component of *Riparian Forest Buffer* (Code 391) or *Riparian Herbaceous Cover* (Code 390). Follow *Operation and Maintenance* requirements for companion species as outlined in the conservation practice used. If management recommendations for other species conflict with management recommendations for cane, cane management recommendations should, in most cases, take precedence unless they will lead to death of companion species.
  - Continue to monitor success of previous weed control measures (if applied) and consider the need for new or additional treatments (*Herbaceous Weed Treatment*



- (Code 315) or *Brush Management* (Code 314), particularly if warm season, rhizomatous grasses are present.
- Consider yearly minimum applications of 50 N lb/acre of complete fertilizer selectively for giant cane plants (years 2-5) unless there are known excess nutrients in ground or surface water issues at the site. Do not apply fertilizer immediately before seasonal flooding is expected.
  - If site has woody overstory left to provide shade, consider using *Forest Stand Improvement* (Code 666) to reduce shading to at least 60% full sun after year 2. Consult with NRCS Forester on how to implement this.
  - Apply *Prescribed Burning* (Code 338) sometime between year 3 to 5 for giant cane and year 2-3 for switch cane plantings if a prescribed burn is possible at the site. If fire not practical, consider mowing area once within the time frame given to stimulate stem production and reduce undesirable woody species competition.

### **Post-Establishment Years (>5 years)**

- Maintain fences if they were needed to protect planting site.
- Discontinue fertilization.
- If *Prescribed Burning* (Code 338) not already applied, do so in year 5 if site allows. Otherwise consider mowing.
- If *Prescribed Burning* (Code 338 or mowing) has been previously applied, start a burn (or mow) interval of 5-8 years for giant cane and 2-3 years for switch cane. Prior to and immediately after each burn (or mow), evaluate stem density in at least 2 or 3 permanently marked sites. If new cane stem numbers begin to decline in marked site, fire (or mowing) frequency may be too short for the site. Extend return fire (or mowing) interval of next burn.
- Around year 8-10 evaluate cane stand and decide if management is still needed to increase stand or if harvestable canes are the goal.
  - If vigorous expanding cane stand is the goal and stand counts show consistent positive trends and stand area is increasing, continue previous management. If not, reassess management practices, particularly burn interval and overstory density.
  - If stand is vigorous but artisanal canes are desired, evaluate current stand for cane quality characteristics. Selective thinning and/or extending the fire (or mowing) return interval may be necessary to generate desired cane type.
- Follow all other *Operation and Maintenance* requirements of the practice standard that cane was planted for.

# Review of Literature

## Factors that Effect Establishment of Giant Cane.

Selection of a suitable site is perhaps the most important factor in successful establishment of giant cane, more so than planting material. Studies (Shoemaker, 2018) have shown that site factors that affect moisture regime (e.g., soil type, flooding frequency, inundation period, overstory species, etc.) and light availability (e.g., disturbance, overstory species, invasive species, etc.) are most important.

Considered an adaptable species, giant cane has been reported growing in a variety of soil conditions (Baskin et al., 1997; Cirtain, et al., 2004; Platt, 1999; Platt & Brantley, 1997). Unfortunately, this adaptability has not translated into easy restoration. Numerous establishment studies have produced highly variable survival rates (0 – 98%; Conley, 2015; Dattilo & Rhodes, 2005; Eade et al., 2018; Gagnon & Platt, 2008; Zaczek et. al., 2009) regardless of propagule type (e.g., seedlings, rhizome divisions, excavated clumps). For NRCS field office planning purposes, reasonable expectation of survival, even if only at predictably low rates, is necessary. A better understanding of soils where giant cane is currently growing, other than simple map unit name, is key to site specific management recommendations for successful planting.

Relatively few detailed assessments of soils, where giant cane is present, have been conducted. Table 1 summarizes soil information for giant cane stands in southern Illinois and western North Carolina based on Web Soil Survey information and/or separate field determinations. Commonalities of the two locations include soils that are relatively flat and associated with flood plain landforms, have loamy texture,  $K_{sat}$  of the most restrictive layer moderately high to high, flooding is frequent, and soil pH is acid to slightly acid. All of these are consistent with historical reports of river floodplain occurrence of giant cane. Some differences between sites or between current and previously reported site characteristics that impact site selection recommendations were found.

**Table 1. Physical and chemical characterization of soils supporting natural giant cane (*Arundinaria gigantea*) stands at different locations in US.**

Soil Characteristic	Illinois	North Carolina
Slope, %	≤3	0-3
pH	5.3-6.7	5-6.5
Soil Texture	silt loam to silty clay loam	sandy loam to loam
Landform	flood plain	flood plain and associated levees, depressions, and terraces
Drainage Class	poorly to very poorly	poorly to very well
Hydric	yes	no (88% map units)
Flooding Frequency	frequent	none to frequent
Ponding Frequency	frequent	none to occasional
Depth to Water Table, in.	0-12	18-70
$K_{sat}$ Most Restrictive Layer	moderately high	moderately high to high

<sup>†</sup>Adapted from Nelson et al. (2014) with additions from Web Soil Survey, Pulaski County, IL

<sup>‡</sup>Adapted from Griffith et al. (2009) and Tanner et al. (2011) with additions from Web Soil Survey, Jackson and Macon Counties, NC.

Drainage class for the soils at the Illinois site, poorly to very poorly drained, was more consistent than for the soils in North Carolina which ranged from poorly to well-drained. Giant cane is listed as a facultative wetland species (FACW; <http://wetland-plants.usace.army.mil>), meaning it usually occurs in wetlands. The drainage class and hydric designation for the most common map units reported in the Illinois study (Bonnie and Petrolia) at least partially support this. Tanner et al. (2011) disagree with FACW classification because most of the soils where giant cane stands occurred in the North Carolina study were not hydric and did not occur in sites that meet jurisdictional wetland status. But even the poorly drained soils in both states had moderate to moderately high  $K_{sat}$  values for their most restrictive layer and enough depth to water table such that the rhizome/root zone of the giant cane did not remain saturated for long periods. Tanner et al. (2011) suggested that these may be key characteristics of giant cane planting site selection. In contrast, the well-drained soils in North Carolina that were never saturated (flooded) occurred in drainageway locations on steep slopes that received enough moisture from upslope areas to sustain giant cane stands. This shows that giant cane can be grown on non-riverine sites when natural moisture or irrigation is adequate.

Tanner et al. (2011) concluded that giant cane is more FAC (facultative; occurs in wetlands and non-wetlands) or FACU (facultative upland; usually occurs in non-wetlands but may occur in wetlands) species. Historical reports of giant cane occurring on flood plain ridges that rapidly drain and current inundation studies that show giant cane growth rate is affected by inundation in as little as 2 – 14 days support this change in designation to FAC or FACU (Cirtain et al., 2004; Mills et al., 2011). The study by Mills et al. (2011) showed switch cane was also affected by as little as 14 days inundation but recovered faster than giant cane after inundation stopped. That study supports the FACW designation for switch cane which occurs on poorly drained histosols in the coastal plain (Grey et al., 2016). For this reason, Mills et al. (2011) recommend that switch cane be used instead of giant cane on sites where flooding or ponding events exceed about 2 weeks at a time. Sites that normally experience flooding or ponding for longer than 6 weeks at a time, may not be suitable for either species (Mills et al., 2011).

Although not tolerant of long-term saturated soil conditions, giant cane is known to be very sensitive to even short-term moisture deficit at planting (Baldwin et al., 2009; Cirtain et al., 2004), particularly when the rhizome system has been cut during transplanting (Campbell, 2011). Date of planting studies with switch cane showed similar sensitivity to moisture deficit (Klaus & Klaus, 2011).

Consequently, management strategies at planting have been directed toward minimizing short-term moisture stress. Selecting the planting date with most consistent soil moisture is one method. Klaus and Klaus (2011) found switch cane transplant survival was highest when Keetch-Byram drought index ([www.drought.gov](http://www.drought.gov)), which estimates current moisture conditions based on previous rainfall and temperature, was lowest at planting. They recommend using this index for establishing planting dates. They also felt irrigation, preferably for the first growing season, should also be used, if available.

Another option is to minimize moisture requirements or losses associated with the planting site. Dattilo and Rhoades (2004) reported mulch (hardwood or manure) did not improve giant cane survival during establishment year but did increase stem (culm) size and number by year 2. They attributed this to the ability of mulch to reduce periods of moisture stress during the 2-year study.

Selecting a site with shade from existing over story species or providing shade by planting companion plants will also minimize moisture requirements. Russell (2012) found when moisture was limiting, shading (30 to 85% full sun) did not affect giant cane seedling transplant survival but did affect plant growth index ( $\text{cm}^3$ ). Plant growth index essentially did not change the first 6 months for the full sun and up to 50% shade treatments, but essentially doubled and quadrupled for the 60 and 85% shade treatment, respectively, during that period. Across a 23-month period, plant growth index of full sun controls did not change after planting compared to positive increases for all shade treatments with a maximum of  $\approx 36X$  increase for the 60% shade treatments. Biomass and stem number changes followed similar trends. Based on this work, Russell (2012) recommended a minimum of 60% shade for restoration plantings regardless of soil moisture. These studies on mulch and shade mirrored the results of Gagnon and Platt (2008) with direct seeding, who found better seed germination (30-50%) on sites with natural litter layer (mulch) and partial shade compared to sites with only bare mineral soil (<20% germination) and better survival of germinated seedling in partial shade than full sun.

Neighboring plants provide shade benefits but can be a biotic stress when they compete too much for moisture and light. Various studies have evaluated first year survival of giant cane transplants of all types (Osland et al., 2009; Schoonover et al., 2011; Zacaek et al., 2009). These studies generally have found no effect of surrounding understory vegetation on giant cane establishment survival in forested sites or early successional, cool season species. But Campbell (2011) reported establishment of giant cane planted into non-native, rhizomatous grasses was poorer than when interplanted into native bunch grasses or forbs in Mississippi and Kentucky. This indicates sites with introduced rhizomatous species will need some form of weed control prior to planting.

Herbivory is also a potential biotic stressor. Historical information has shown the detrimental impact of unrestricted grazing by domestic livestock (Platt & Brantley, 1997). Unrestricted herbivory by native mammals can also be a problem with restoration plantings due to relatively small area of most new plantings. Campbell (2011) reported that rabbits (*Sylvilagus* spp.) impacted giant cane growth for as long as 7 years after planting. Although domesticated hogs (*Sus scrofa domesticus* Erxelben) were a component of the European settlement livestock that contributed to the declines in canebrakes, increasing populations of their feral descendants are considered a more significant threat to cane re-establishment than domesticated livestock at this time (Shoemaker, 2018). Fencing, to ensure access by domestic livestock is controlled, is a minimal requirement of cane plantings. If feral hogs are present, adequate fencing may be cost prohibitive and more targeted types of control may be necessary.

### **Factors that Affect Persistence of Giant Cane Plantings**

Repeated establishment studies have shown giant cane, in most cases, grows relatively little during the establishment year (Dattilo & Rhoades, 2004; Osland et al., 2009; Schoonover et al., 2011; Zacaek et al., 2009;). This is thought to be due to its extreme sensitivity to transplant stress, taking up to a year to resume rapid growth (Campbell, 2011). This explains why benefits from site manipulations, other than those that affect immediate moisture availability, have been limited in the first (establishment) growing season. Many of these studies have found that first season treatments do produce benefits in later years.

Two separate herbicide treatment studies (Osland et al., 2009; Klaus & Klaus, 2011), where herbicide (glyphosate) was applied prior to planting, found no benefit of herbicide on stand

establishment, but better growth (e.g., new stems, rhizome spread, etc.) for cane in herbicide treated plantings in year 2 and 3. Klaus and Klaus (2011) also evaluated post-planting herbicide applications on switch cane transplants and found switch cane was tolerant to two common forestry herbicides, trichlopyr and hexazinone. Further testing with giant cane is warranted to determine if their use can be recommended within existing labelling. Until that time, preplant broadcast herbicide with non-selective chemical, such as glyphosate, should be used if associated vegetation is not necessary to mitigate soil moisture stress or competing species include dense stands of non-native rhizomatous grasses.

In contrast to shade benefits in the establishment year, many studies clearly show the benefit to reduced shade in subsequent years. Certain et al. (2009) reduced overstory density for natural giant cane stand by 60% by girdling and herbicide treatment. Photosynthetic active radiation readings went from 32 mmol/m<sup>2</sup>/s in the control site to 781 mmol/m<sup>2</sup>/s in the thinned site. Overstory thinning caused an increase in new shoot development compared to un-thinned control plots. Gagnon and Platt (2008) found prescribed fire in natural canopy blowdown sites (due to tornado) improved stem density 1 year after burning but not in full canopy stands. But in a more long-term study at the same locations, Gagnon et al. (2013) found a positive response due to fire by 5-year post-burn in both blowdown and full canopy sites, with stem density almost doubled compared to respective undisturbed sites. They attributed much of this response to increased light levels due to reduced tree competition due to burning.

Fertilization has also shown limited affect during application year, but positive effect in subsequent years. Dattilo and Rhoades (2005) applied >150 lb N/acre as commercial fertilizer or composted cow manure on mature clump division during transplant year only and saw no response in stem number, height, or area in the transplant year to either type of nutrient addition. They did see an increase in stem numbers for both types of nutrient addition in year 2. Certain (2009) working with transplanted clumps found a cumulative response for shoot production 2 years after treatment with a complete, slow release fertilizer. Working with a 5-year-old stand of giant cane, Zacaek et al. (2009) found no effect of an initial annual fertilizer application of 50 lb N/acre of 12-12-12, but after the second application in year 2, fertilization increased stem density, height, and diameter. They speculated the lack of response the first year was due to insufficient nutrients provided by the fertilization rate or a lag time in aboveground response. They did report fewer stems died in fertilized plots compared to unfertilized plots in year 1, suggesting the “lag” may be a result of required positive below ground response to fertilization initially before observing aboveground differences.

Established stands of giant cane have been reported to decline or “stagnate” at around 10 years of age (Hughes, 1966). Research detailing stem production and growth suggest stand productivity may decline at earlier ages. Zacaek et al. (2010) reported stagnate growth (no changes in stem numbers) in control plots between years 5 and 7, although stem diameter did increase. Fairly largescale disturbance, such as canopy removal by wind or fire, is now recognized as a requirement for long-term growth and survival of giant cane stands (Shoemaker, 2018). Gagnon et al. (2007) found stem production of natural stands in tornado blowdown was twice that of undisturbed forest setting. They attributed this response to better light conditions. When fire was imposed, there was an interaction with light. After fire, stem density declined in forest settings the first year but increased in the blowdown setting where light was not limiting (Gagnon et al., 2008). Similarly, Zacaek et al. (2010) found stem density of a 6-year-old planted giant cane stand, that had no significant tree canopy, increased after burning. They suggested



that time-controlled burn may be a good management tool for new giant cane stands. Long-term effects of fire support this recommendation regardless of vegetation type. Gagnon et al. (2013) followed up on the effect of burning for 4 years after a single burn and found stem growth increased over time even in undisturbed forest settings and more than compensated for initial stem losses from burning. Grey et al. (2016) reported similar results with switch cane where fire stimulated increases in stand area, but the rate of stand increase for switch cane started to decline by 2 years post burn.

This work supports the observation of Hughes (1966) that giant cane stands start to senesce around 7-year post fire disturbance and follow-up disturbance at that time rejuvenates the stand. Disease has been postulated as the reason for reduced growth as stands age (Gagnon et al. 2013), but work with cultivated perennial grasses in pasture situations has shown that growth slowdown is often associated with normal pattern for N cycling in soils (Floate, 1987; Myers & Robbins, 1991; Peake et al., 1990). Declines in unfertilized perennial pasture grass productivity occur when N becomes limiting due to progressive N immobilization as the stand matures (Myers & Robbins, 1991). Zacaek et al. (2009) observation that fewer stems died after fertilization supports this as an explanation of giant cane stand decline over time, as does the historical dominance of giant cane in riverine areas. Cirtain et al. (2009) observed that riverine areas are subject to periodic nutrient additions in water and sediments from flooding. Burning, in addition to removing competition, rapidly releases nutrients for recycling which immediately benefits cane rhizomes that have escaped the fire. More rapid rate of growth decline in switch cane (2 year) vs. giant cane (5-7 year) could be explained by more rapidly limiting nutrients in switch cane isolated wetland sites compared to annually “fertilized” riverine sites of giant cane. The efficacy and practicality of N application to maintain vigor of older giant cane or switch cane stands is untested, and until studied, controlled burning is a practical way of releasing nutrients and stimulating growth. In areas where controlled burning (or taming a tornado) is not practical, simply mowing or selective harvesting of canes from existing stands or even high-intensity, low frequency prescribed grazing may be acceptable methods to control hardwood invasion and reset stand vigor.

Even though fire or other type of disturbance is beneficial for giant cane stand persistence, such disturbances at too frequent or too long an interval leads to stand decline. Classic example of too frequent is the effect of unrestricted grazing in the historical record (Platt & Bradley, 1997). But previous disturbance interval recommendation for NRCS planners of every 10 years (Anderson & Oakes, 2011) may be too long. Recent studies indicate disturbance frequency <10 years will result in more rapidly spreading stands, particularly if the disturbance includes reducing overstory competition. Gagnon et al. (2013) suggest a burn interval of 3 to 8 years for giant cane. Grey et al. (2016) suggest an even more frequent fire return interval of 2 years for switch cane stands. These are more frequent than the 7 to 10 years reported as historical management by Native Americans (Platt & Bradley, 1997). Historically longer fire return intervals may be based on empirical understanding by Native Americans of the effect of fire on cane quality. Hoffman (2010) looked at the effect of stem age and density from natural stands in North Carolina and found interior stems most often met the desired characteristics for Cherokee artisans (e.g., >6 ft branch-free height with a diameter >0.5 in) possibly due to larger rhizome size in older portions of the stand. Hoffman (2010) suggested for artisanal purposes, allow stands to reach about 18 stems/square yard before selective thinning of smaller stem, not blanket thinning as would occur with a burn or mowing.

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