EARLY COMPETITIVE EFFECTS ON GROWTH OF LOBLOLLY PINE GROWN IN CO-CULTURE WITH SWITCHGRASS

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Abstract--This study: (1) examined competitive interactions between switchgrass and loblolly pine grown in co-culture, and (2) assessed early growth rates of loblolly pine as affected by differing switchgrass competition treatments. Co-cultures were established and monitored on two Upper Coastal Plain sites for 2 years. The Pontotoc site has a history of agricultural use with some likely residual fertility, while the Starr site has a history of forest use, although it has been maintained for several decades as a mowed field. Five treatments were employed at each site: (1) switchgrass only (SG); (2) pine only (Pine); (3) pine planted into switchgrass with a 1.2-m competition-free zone on either side of the row of trees (PS-4); (4) pine in switchgrass with a 0.6-m competition-free zone (PS-2); (5) and pine planted into switchgrass with no-competition free zone (PS-0). Switchgrass yields at Starr were roughly one quarter of those at Pontotoc, which led to differences in competitive intensities between species at the two sites. Loblolly pine heights at Pontotoc and Starr averaged 70 and 63 cm following year 1, and 161 and 176 cm following year 2, respectively. Planting pines directly into switchgrass significantly reduced tree heights, but seedlings in PS-4 treatments experienced growth ≥ Pine treatments. Switchgrass yields did not significantly differ by distance from tree row for any treatment. Our results suggest switchgrass dominates resource competition in early phases of this production system. However, these competitive pressures can be managed to effectively co-produce loblolly pine and switchgrass on southern lands.

INTRODUCTION

Emerging markets for biomass-based fuel sources present an opportunity for establishing and managing fast-growing and high-yielding bioenergy feedstocks on marginal or degraded lands. One common associate of North American grassland communities, switchgrass (*Panicum virgatum* L.), has been specifically identified by the U.S. Department of Energy as a model bioenergy feedstock. Characteristics making the species highly desirable include sustained high productivity across a wide spectrum of sites, relatively low demand for soil moisture and nutrients, and positive environmental benefits such as wildlife habitat and carbon sequestration (Keshwani and Cheng 2009, McLaughlin and others 1999, McLaughlin and Walsh 1998, Parrish and Fike 2005, Sanderson and others 2006).

In the southeastern United States, loblolly pine (*Pinus taeda* L.) is commonly planted on many of the marginal or degraded lands considered target areas for switchgrass production. Loblolly pine plantation yields can exceed 400 cubic feet per acre per year (Fox and others 2007), and the species dominates approximately 13.4 million acres of southern lands (Baker and Langdon 1990, Schultz 1999). While loblolly pine has customarily and still is primarily managed for pulpwood and high-value sawtimber production, expanding bioenergy markets have also raised interest in managing loblolly pine plantations for bioenergy production (Scott and Tiarks 2008).

Many landowners may lack confidence investing in relatively unfamiliar bioenergy feedstock production systems such as those involving switchgrass. One possible remedy may be to combine a well-known production system (loblolly pine) with an emerging system (switchgrass). Such a system (referred to here as co-culture) would ideally diversify investment risks and lead to greater net productivity per land area, relative to monocultures of either species. However, incorporating two high-yielding species on the same land area may spur intense interspecific competitive interactions, occurring both above and belowground, thereby hindering productivity. A better understanding of these competitive interactions is needed before loblolly pine-switchgrass co-culture management may be considered economically viable.

Specific objectives of this study were to: (1) examine competitive interactions between switchgrass and loblolly pine grown in co-culture, and (2) assess early growth rates of loblolly pine as affected by different switchgrass competition treatments.

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METHODS

Two study sites were established in northern Mississippi. The Pontotoc site was on a Mississippi State University (MSU) Agricultural Experiment Station site approximately 75 km north of Starkville, MS. The soil on the site is primarily an Atwood silt loam (NRCS 2013). The site has a history of agricultural production and likely possesses some residual fertility. The Starr site is on the MSU John Starr Memorial Forest located approximately 20 km south of Starkville, MS. The soil on the site is primarily an Ora fine sandy loam. The site has historically contained forest cover but has been maintained as a mowed pasture for the past several decades.

Alamo switchgrass was seeded at each site in spring of 2010. At Pontotoc, site preparation and seeding consisted of disking, drill seeding, and cultipacking. The site was seeded three times in 2010 to ensure full establishment. At Starr, site preparation and seeding consisted of prescribed burning, liming, and drill seeding. Containerized loblolly pine varietal seedlings were planted at both sites in March 2011. Pine seedlings were planted into subsoiled rows, spaced 9.0 m apart with 1.5 m within row tree spacing. Measurement plots were 15 m (i.e., 10 trees) by 9 m (i.e., 4.5 m on either side of the tree row).

The study consisted of five treatments: (1) switchgrass only (SG); (2) pine only (Pine); (3) pine planted in switchgrass with a 1.2-m competition-free zone on either side of the row of trees (PS-4); (4) pine in switchgrass with a 0.6-m competition-free zone (PS-2); and (5) pine planted into switchgrass with no-competition free zone (PS-0). Applications of 2 percent glyphosate were applied as needed to exclude unwanted vegetation from competition free zones. Treatments were replicated eight times at each site.

At Pontotoc, the 2011 growing season switchgrass was harvested between January 31 and February 9, 2012, and the 2012 growing season switchgrass was harvested on November 15 and November 20, 2012. At Starr, the 2011 switchgrass growing season harvest was initiated on January 6, 2012 but was not completed until March 14, 2012 due to complications with harvesting equipment. The 2012 switchgrass harvest occurred on November 1, 2012. At each site, switchgrass was harvested and yields were determined in four 1-m strips on either side of the tree rows. At both sites, subsamples were collected for each 1-m strip, weighed fresh, dried and reweighed, and total yields were converted to a dry weight basis. Per ha dry weight yields of switchgrass were evaluated relative to proximity to the tree row (0-1, 1-2, 2-3, and 3-4 m), and for the total plot. Year 1 pine seedling heights were measured in early February 2012 at both sites, and year 2 pine seedling heights were measured in January 2013.

Differences among treatments were evaluated using analysis of variance (ANOVA). If ANOVA revealed significant main effects or significant interactions, Tukey multiple comparison tests were used for post-hoc comparisons. Statistical significance was set at a critical value of α = 0.05, and all statistical analyses were performed using Statistical Analyses Software (SAS) version 9.3 (SAS, Cary, NC).

RESULTS

Switchgrass yields differed substantially between sites in both 2011 and 2012 (table 1). In 2011, Pontotoc per ha dry weight yields for all treatments other than Pine averaged nearly 7.1 Mg ha^{-1} and ranged as high as 12.7 Mg ha^{-1}. Switchgrass yields at Starr in 2011, for treatments other than Pine, averaged only 1.6 Mg ha^{-1}, and much of the yield consisted of herbaceous plant material other than switchgrass. Pontotoc switchgrass yields in 2012 averaged 9.74 Mg ha^{-1} and ranged as high as 13.6 Mg ha^{-1}. Starr switchgrass yields averaged 2.18 Mg ha^{-1} and were still largely a scattered mixture of herbaceous grasses in 2012. At both sites and for both years, yields per m^2 of established switchgrass did not differ by treatment or distance from tree row. However, plot averages of total switchgrass yields did differ by treatment, reflecting the exclusion of switchgrass within the competition-free zones.

Tree heights at Pontotoc after the first growing season (2011) were greatest in the Pine and PS-4 treatments, averaging 84 cm (fig. 1). Heights in the PS-0 and PS-2 treatments were significantly less, averaging 46 cm and 66 cm, respectively. The seedlings at Pontotoc put on

Table 1—Switchgrass harvest yields at Pontotoc and Starr, MS

Location	Treatment	---------Yield---------- 2011	2012
		------*Mg ha^{-1}*------	
Pontotoc	SG	7.9	10.7
	PS-0	8.1	10.3
	PS-2	6.4	9.5
	PS-4	5.9	8.4
	Pine	2.3	---
Starr	SG	1.8	2.4
	PS-0	1.7	1.6
	PS-2	1.7	2.7
	PS-4	1.3	2.1
	Pine	1.1	---

considerable growth the following growing season (2012), and the Pine and PS-4 treatments averaged 207 cm at the end of the growing season. Tree heights for PS-2 and PS-0 treatments at Pontotoc were 137 and 91 cm following the 2012 growing season, respectively. Starr tree heights following the initial growing season (2011) averaged 63 cm and ranged from 59 to 68 cm (fig. 2). Tree heights in year 2 averaged 176 cm and were greatest in the PS-4 treatment and smallest in the PS-0 treatment. Year 2 trees at Starr were larger in the PS-4 treatment than in the Pine treatment.

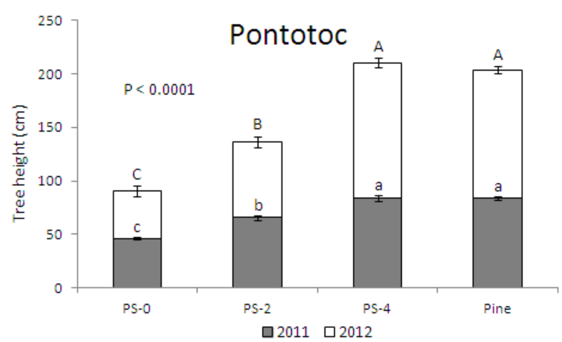

Figure 1--Tree heights at Pontotoc following the 2011 and 2012 growing seasons. Within years, differing letters indicate significant differences among treatments.

DISCUSSION

Switchgrass yields varied greatly between the two sites in northern Mississippi. At Pontotoc, switchgrass yields approached the 15 Mg ha^{-1} sustainable average reported by Parrish and Fike (2005), but Starr yields fell well below this mark. Yield discrepancies between sites were likely driven by differences in cultural techniques. Pontotoc received multiple herbicide applications in the years prior to seeding and had a previous agricultural history, which minimized weed pressure from residual seedbanks, allowing the switchgrass to rapidly establish a canopy and shade out emerging competitors. Fewer efforts to control weed pressures at Starr, combined with a well-established weed seedbank from years of pasture usage, hindered switchgrass establishment and its ability to form a dense canopy. The current lack of selective herbicides for controlling herbaceous competition without negatively impacting switchgrass presents an obstacle to the conversion of previous pasturelands to herbaceous bioenergy feedstocks (Buhler and others 1998).

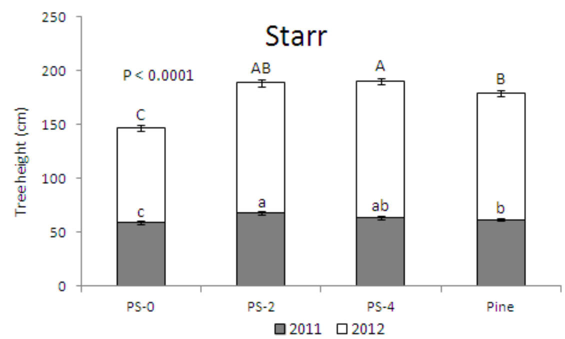

Figure 2--Tree heights at Starr following the 2011 and 2012 growing seasons. Within years, differing letters indicate significant differences among treatments.

It is well established that loblolly pine responds favorably to early competition control with increased growth (Cain 1991, Miller and others 1991, Morris and others 1993, Nilsson and Allen 2003, Zutter and Miller 1998). However, few studies have specifically examined competition dynamics within loblolly pine-switchgrass systems (Albaugh and others 2012, Blazier and others 2012). In our study, loblolly pine second year heights within the PS-4 and Pine treatments were over twice that of the PS-0 treatment and significantly greater than the PS-2 treatment at the highly competitive Pontotoc site. Competitive relationships were less drastic at Starr due to lower switchgrass yields. Interestingly, 2012 tree heights in the PS-4 treatment at Starr exceeded those of the Pine treatment, suggesting on some sites a moderate level of herbaceous competition may promote tall, slender crop trees as opposed to the undesirable lateral-branching characteristics often found when trees are open grown.

Our switchgrass biomass yields are in agreement with those of Albaugh and others (2012), who found no significant differences in switchgrass growth parameters when examined in relation to distance from loblolly pine tree rows, early in stand rotation. However, switchgrass biomass yields were significantly reduced beneath loblolly pine canopies by mid-rotation in Louisiana (Blazier and others 2012). As pine trees mature at our sites, we expect to observe significant switchgrass yield reductions in relation to distance from tree rows.

This study demonstrates that interspecific competition is a legitimate concern for those considering intercropping switchgrass between rows of loblolly pine. Early in the stand rotation, switchgrass appears to be the dominant competitive species and exerts considerable competitive pressures on loblolly pine seedlings. However, we expect loblolly pines will develop extensive root systems and dense canopies as stands mature which will increase their competitive importance. Overall, our data suggests the establishment of a competition-free zone around pine seedlings can improve resource availabilities for pines and increase tree growth to levels comparable to a pine-only system.

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LITERATURE CITED

Albaugh, J.M.; Sucre, E.B.; Leggett, Z.H. [and others]. 2012. Evaluation of intercropped switchgrass establishment under a range of experimental site preparation treatments in a forested setting on the lower coastal plain of North Carolina, U.S.A. Biomass and Bioenergy. 46: 673-682.

Baker, J.B.; Langdon O.G. 1990. *Pinus taeda* L. Loblolly pine. In: Burns, R.M; Honkala, B.H., tech. coords. Silvics of North America. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture: 497-512. Vol. 1.

Blazier, M.A.; Clason, T.R.; Vance, E.D. [and others]. 2012. Loblolly pine age and density affects switchgrass growth and soil carbon in an agroforestry system. Forest Science. 58(5): 485-496.

Buhler, D.D.; Netzer, D.A.; Riemenschneider, D.E.; Hartzler, R.G. 1998. Weed management in short rotation poplar and herbaceous perennial crops grown for biofuel production. Biomass and Bioenergy. 14(4): 385-394.

Cain 1991. The influence of woody and herbaceous competition on early growth of naturally regenerated loblolly and shortleaf pines. Southern Journal of Applied Forestry. 15: 179-184.

Fox, T.R.; Jokela, E.J.; Allen, H.L. 2007. The development of pine plantation silviculture in the southern United States. Journal of Forestry. 105: 337-347.

Keshwani, D.R.; Cheng, J.J. 2009. Switchgrass for bioethanol and other value-added applications: a review. Bioresource Technology. 100: 1515-1523.

McLaughlin, S.; Bouton, J.; Bransby, D. [and others]. 1999. Developing switchgrass as a bioenergy crop. In: Janick, J.J., ed. Proceedings of the 4th national new crops symposium. Alexandria, VA: ASHS Press: 282-299.

McLaughlin, S.B.; Walsh, M.E. 1998. Evaluating environmental consequences of producing herbaceous crops for bioenergy. Biomass and Bioenergy. 14(4): 317-324.

Miller, J.H.; Zutter, B.R.; Zedaker, S.M. [and others]. 1991. A regional study on the influence of woody and herbaceous competition on early loblolly pine growth. Southern Journal of Applied Forestry. 15: 169-179.

Morris, L.A.; Morris, S.A.; Garbett, W.S. 1993. Competitive interference between selected herbaceous and woody plants and *Pinus taeda* L. during two growing seasons following planting. Forest Science. 39: 166-187.

Nilsson, U.; Allen, H.L. 2003. Short- and long-term effects of site preparation, fertilization, and vegetation control on growth and stand development of planted loblolly pine. Forest Ecology and Management. 17: 367-377.

NRCS [Natural Resources Conservation Service]. 2013. Soil climate analysis network site 2089. Portland, OR: U.S. Department of Agriculture Natural Resources Conservation Service, National Water and Climate Center. http://www.wcc.nrcs.usda.gov/. [Date accessed: June 20, 2013].

Parrish, D.J.; Fike, J.H. 2005. The biology and agronomy of switchgrass for biofuels. Critical Reviews in Plant Sciences. 24: 423-459.

Sanderson, M.A.; Adler, P.R.; Boateng, A.A. [and others]. 2006. Switchgrass as a biofuels feedstock in the USA. Canadian Journal of Plant Science. 86: 1315-1325.

Scott, D.A.; Tiarks, A. 2008. Dual-cropping loblolly pine for biomass energy and conventional wood products. Southern Journal of Applied Forestry. 32: 33-37.

Shultz, R.P. 1999. Loblolly - the pine for the twenty-first century. New Forest. 17: 71-88.

Zutter, B.; Miller, J.H. 1998. Eleventh-year response of loblolly pine and competing vegetation to woody and herbaceous plant control on a Georgia flatwoods site. Southern Journal of Applied Forestry. 22(2): 88-95.