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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.

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ABSTRACT

There is growing interest in using switchgrass (*Panicum virgatum* L.) as a biofuel crop and for its potential to sequester carbon. However, there are limited data on the establishment success of this species when grown as a forest intercrop in coastal plain settings of the U.S. Southeast. Therefore, we studied establishment success of switchgrass within experimental intercropped plots and in pure switchgrass plots in an intensively managed loblolly pine (*Pinus taeda*) plantation in eastern North Carolina. Pine trees were planted in the winter of 2008, and switchgrass was planted in the summer of 2009. Establishment success of switchgrass was measured over the growing season from May to October 2010, and quantified in terms of percent cover, height (cm), tiller density (number of tillers m^{-2}), leaf area index and biomass (Mg ha^{-1}). At the end of the growing season, pure switchgrass plots were taller than the intercropped treatments (114 ± 2 cm versus 98 ± 1 cm, respectively), but no significant treatment effects were evident in the other variables measured. Switchgrass biomass across all treatments increased from 2.65 ± 0.81 Mg ha^{-1} in 2009 to 4.14 ± 0.45 Mg ha^{-1} in 2010. There was no significant effect of distance from the pine row on any switchgrass growth parameters. However, we anticipate a shading effect over time that may limit switchgrass growth as the pines approach stand closure.

1. Introduction

Despite energy prices in the United States (U.S.) being among the cheapest worldwide, the economic, environmental and national security concerns associated with using fossil fuels have led to the search for renewable energy sources and development of the U.S. biofuel market. In 1985, the U.S. Department of Energy (DOE) began funding research on herbaceous species with the potential to serve as cellulosic biofuel feedstock [1]. Bioenergy and bio-based products have important environmental benefits including near-zero net emissions of greenhouse gases and improved soil and water quality [2]. Further, herbaceous energy crops can contribute to crop diversity and economic viability of growers [3]. Switchgrass (*Panicum virgatum* L.), a perennial warm-season grass, was chosen by the DOE as the model herbaceous species for

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development as a biomass energy feedstock [4,5]. This species is indigenous to the Central and North American tall-grass prairie, found in regions from the Atlantic coast to the eastern Rocky Mountains, and north into Canada [6].

Favorable characteristics of switchgrass for use as a candidate feedstock for energy production are well documented. These characteristics include its perennial nature, diverse geographic range [7] and high yield potential attained in screening trials compared with other herbaceous species [3,7–9]. In addition, switchgrass has a wide array of positive environmental attributes [1,3] which include a low nutrient demand [7], soil and water conservation benefits [7,9,10], ability to provide wildlife habitat [11], and increased belowground carbon (C) sequestration [4,11,12] compared to annual and other perennial species. Importantly, switchgrass can be harvested with conventional agricultural equipment [12].

Using native warm-season perennial grasses as herbaceous energy crops may offer producers an alternative cash source and an opportunity to diversify their land [4]. However, there is economic risk associated with growing a crop dedicated largely to the relatively new biofuel market [13]. An alternative approach is an intercropped forestry-biofuel management system where switchgrass could be grown in rows between the crop trees. The switchgrass and any tree components not traditionally used as forest products (e.g. residues remaining after a thinning or harvesting operation) could be used as feedstock for biofuel production. The product diversity offered by such a system has important potential environmental and economic benefits which include belowground C sequestration, potentially improved wildlife habitat for some species, lower economic risks associated with entering a new market, and increased yields with optimum use of available growing space [13].

Successful establishment of herbaceous biomass crops is essential for economically meeting land management objectives [14,15]. Failure to rapidly (within one year of seeding) establish a productive switchgrass stand reduces the economic viability of this species as a biomass feedstock [4]. Unfortunately, many warm-season perennial grasses like switchgrass can be difficult to establish [8,14,16,17]. Switchgrass stand failure may be attributed to a combination of factors which most often includes seed dormancy [6,18], incorrect seed placement [1], and competition from weeds [6,8,12]. Growth of switchgrass in the establishment year is determined by soil moisture and fertility, competition from other species [12], and soil pH, with seedling survival being significantly reduced by soil pH $\leq$ 4 or $>$8 [11,19]. Once established, well-managed switchgrass stands can successfully out-compete weeds, and require minimal maintenance [1,10]. Important elements of grass stand establishment include setting management objectives, site selection, plant material selection, site preparation, factors associated with planting (i.e. planting date and rate and depth of planting) management during establishment, and plant stand assessment, including growth and development [15].

Given the difficulty in establishing switchgrass stands, and the limited data on switchgrass establishment and growth in an intercropped system on a low pH forest soil, our objective was to determine the establishment success and quantify the growth rate of switchgrass during its second growing season when intercropped with loblolly pine (*Pinus taeda* L.), compared to pure switchgrass stands on the Lower Coastal Plain of North Carolina. Different levels of site preparation were employed in this study: the pine-switchgrass intercropped plots were V-sheared prior to planting, whereas the pure switchgrass plots were V-sheared and root raked, thereby creating a more uniform seed bed, but also a higher level of disturbance. Typically, there is a flush of soil available nitrogen (N) (Assart effect) following harvesting and site preparation, as these disturbances provide conditions suitable for rapid decomposition and nutrient release from the forest floor and harvest residue from the previous rotation [20–23]. These increases in available N are usually transitory, and only last for the first few years following harvesting [21,23]. Therefore, we hypothesized that the differences in site preparation between the pure and intercropped switchgrass stands would create a temporal gradient in soil N availability, resulting in productivity differences over the switchgrass growth rotation. Capturing the abundant mineralized soil N in switchgrass crop biomass and retaining it in root systems and subsequent soil organic C at the beginning of a rotation before the trees are large enough for significant uptake [24] could provide a mechanism for greater site N retention over the course of a tree rotation. Evidence of this has been demonstrated by Minick et al. [25], who showed that mineralized N was effectively used by switchgrass when grown as a pure stand, and when intercropped with pine.

2. Materials and methods

A long-term field study (Lenoir 1 Intercropping Sustainability Study) was established on the Lower Coastal Plain of North Carolina, U.S.A., to determine effects of intercropping and/or biomass management on site productivity and sustainability within the context of intensive forest management for production of solid wood products and biofuel feedstock. This study was established and is being maintained by Catchlight Energy, LLC (a Chevron|Weyerhaeuser Joint Venture) on forest land owned and managed by Weyerhaeuser Company. As this multifunctional intercropped production system has potential to be broadly applicable throughout the southeast U.S., we evaluated a range of potential operational treatments that could be used by forest landowners. However, it is important to note that our study is within an experimental and not an operational context.

2.1. *Site description and experimental design*

The field site was located in Lenoir County, on the Lower Coastal Plain of North Carolina, U.S.A. (35° N, 77° W). The soils were classified as Pantego (fine, loamy, siliceous, semiactive, thermic Umbric Paleaquults) and/or Rains (fine, loamy, siliceous, semiactive, thermic Typic Paleaquults) soil series which are deep, poorly drained, moderately permeable soils. The previous stand was a 109 ha loblolly pine plantation planted in 1974, with a site index of 21.3 m at age 25.

The study was installed as a randomized complete block design with four blocks. Treatment plots were 0.8 ha in size, with 0.4 ha measurement plots. Treatment plots had