Seedbed Preparation and Planting Depth Affect Switchgrass Establishment and Yield

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Abstract
Switchgrass (*Panicum virgatum* L.) is a native, long-lived, warm-season perennial grass that is well adapted, has potential for biofuel production, and can improve soil chemical and physical properties. It can be difficult to establish, but it can be productive in marginally productive or difficult to cultivate lands, and its root system can aid in soil conservation. The objectives of this 2-year field experiment were to determine the effects of seedbed preparation (burning, mowing, or tilling) and planting depth (0.25, 0.5, or 1.0 inches) on the establishment and yield of ‘EG 1101’ switchgrass. Planting between 0.25 and 0.5 inch generally resulted in more seedlings and greater stand percent and yield than 1.0-inch depth. Tilling generally resulted in more initial seedlings at 30 days after planting (DAP) than no-till with burning or mowing, but stand percent (150 DAP) and yield (postfrost) were not affected by seedbed preparation later in the growing season. However, all seedbed preparations and planting depths produced successful switchgrass stands of >1 seedling/ft² and ≥50% stands. Producers planting on land susceptible to erosion could consider no-till planting after burning or mowing in order to reduce soil erosion and promote better soil structure and fertility without any loss in switchgrass productivity.

As a long-lived warm-season perennial grass that is native to the United States east of the Rocky Mountains and south of 55°N latitude, switchgrass is well suited for renewable biofuel production due to its high biomass production under nutrient- or water-limited environments (Mitchell and Schmer, 2014). Conversion of conventional annual cropping systems to biofuel production with a perennial grass such as switchgrass can also improve soil chemical and physical properties. However, it is a small-seeded grass with seed dormancy issues (Sanderson et al., 1996; Eckberg et al., 2015) and can be difficult to establish, especially if seedbed preparation, planting depth, and weed control are not optimal.

As a perennial bioenergy crop, switchgrass, unlike corn (*Zea mays* L.), can be planted and be productive in marginally productive or difficult to cultivate lands that are susceptible to erosion (Vogel, 1996; Varvel et al., 2008), which necessitate no-till vs. conventional tillage. The benefits of no-till seeding compared with conventional tillage in conserving soil are well documented. Conventional tillage results in a loss of soil organic carbon (SOC) and subsequent release of C into the environment. Conversions: For unit conversions relevant to this article, see Table A.

Core Ideas
- Switchgrass has potential for renewable biofuel production.
- It is productive under nutrient- or water-limited environments.
- It can be no-till planted on lands that are susceptible to erosion.
atmosphere (atmospheric C source) (Kern and Johnson, 1993). Use of no-till methods could change conventionally tilled cropland soils from a source of atmospheric C to an atmospheric C sink (Kern and Johnson, 1993). By using no-till seeding methods into existing vegetation, well-formed soil microaggregates are promoted and more soil moisture, organic matter, and C can be retained and less soil can be lost due to wind or rain erosion compared with conventional tillage (Vaughan et al., 1989; Cambardella and Elliott, 1993). Dou et al. (2013) reported greater SOC, soil microbial biomass C, mineralizable C, and organic matter C with switchgrass production than with conventional cropping systems in Texas.

Erosion rates associated with conventional tillage average one to two orders of magnitude greater than rates of soil production, long-term geological erosion, and erosion under native vegetation, whereas no-till agriculture results in erosion rates closer to soil production rates (Montgomery, 2007). Climatological models suggest that as global temperatures and atmospheric CO₂ increase, total precipitation and the frequency of more intense rainfall events will also increase (IPCC, 2001). Most soil lost to erosion occurs with infrequent severe rainstorms, and projected climate changes could increase the risk of soil erosion (SWCS, 2003). Using models for three different temperature, precipitation, and CO₂ levels in central Oklahoma, simulated future soil loss under conventional, conservation, and no-till tillage was +33, +33, and −33%, respectively, compared with conventional tillage (30.3 and 0.7% stand frequency, respectively) in eastern Nebraska. Tiller density of ‘Cave-in-Rock’ switchgrass in Massachusetts was greater under no-till compared with conventional tillage (20 and 8 tillers/ft², respectively) (Sadeghpour et al., 2014). However, Harper et al. (2004) reported similar switchgrass stand counts between no-till and conventional tillage in Tennessee (0.7 and 0.6 plants/ft², respectively). Due to the limited information available on switchgrass tillage effects in the southern Great Plains, the objectives of this research were to determine the effects of sod destruction methods and planting depth on seedling density, stand, and biomass yield of ‘EG 1101’ lowland ecotype switchgrass in south-central Oklahoma.

In addition to changes in soil characteristics, tillage methods also affect tiller density and plant stand measurements, with no-till sometimes offering more benefits than conventional tillage. However, there is little literature available on the effects of tillage on switchgrass growth and development. Samson and Moser (1982) reported superior ‘Pathfinder’ switchgrass stand frequency in no-till planting with paraquat (1,1’dimethyl-4,4‘bipyridinium ion) + atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] broadcast at 0.3 and 2.0 lb/acre, respectively, compared with conventional tillage (30.3 and 0.7% stand frequency, respectively) in eastern Nebraska. Tiller density of ‘Cave-in-Rock’ switchgrass in Massachusetts was greater under no-till compared with conventional tillage (20 and 8 tillers/ft², respectively) (Sadeghpour et al., 2014). However, Harper et al. (2004) reported similar switchgrass stand counts between no-till and conventional tillage in Tennessee (0.7 and 0.6 plants/ft², respectively). Due to the limited information available on switchgrass tillage effects in the southern Great Plains, the objectives of this research were to determine the effects of sod destruction methods and planting depth on seedling density, stand, and biomass yield of ‘EG 1101’ lowland ecotype switchgrass in south-central Oklahoma.

### Sites, Establishment Treatments, and Data Collection and Analysis

This 2-year field switchgrass establishment experiment was conducted in Burneyville, OK (2011 and 2012), and Ardmore, OK (2012). Locations, site characteristics, and soil series are described in Table 1. The experiment was conducted during two establishment years, using a split-plot randomized complete block design with eight replicates at each of three locations under three seedbed preparation and three planting depth treatments.
Table 1. Locations and site characteristics of switchgrass seedbed preparation and planting depth establishment experiment in Oklahoma.

<table>
<thead>
<tr>
<th>Location</th>
<th>Site name</th>
<th>Planting date</th>
<th>Geographical coordinates</th>
<th>Soil series</th>
<th>Soil nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ardmore</td>
<td>Pasture Demonstration Farm</td>
<td>10 May 2012</td>
<td>34°13' N, 97°13' W; elevation 889 ft</td>
<td>Wilson silt loam (fine, smectitic, thermic Oxyaquic Vertic Haplustalf)</td>
<td>pH</td>
</tr>
<tr>
<td>Burneyville</td>
<td>North</td>
<td>17 May 2011</td>
<td>33°54’ N, 97°15’ W; elevation 738 ft</td>
<td>Eufaula loamy fine sand (siliceous, thermic Psammentic Paleustalf)</td>
<td>7.0</td>
</tr>
<tr>
<td>Burneyville</td>
<td>South</td>
<td>8 May 2012</td>
<td>33°54’ N, 97°16’ W; elevation 761 ft</td>
<td>Slaughterville fine sandy loam (coarse-loamy, mixed, superactive, thermic Udic Haplustoll)</td>
<td>7.0</td>
</tr>
</tbody>
</table>

† Organic matter.

Soils at all sites were fertilized with P and K according to soil tests; however, N fertilizer was not applied since it could potentially cause adverse competition from annual grasses.

Seedbed preparations (main plots, 15 by 20 ft) were burning, mowing (1- to 2-inch height), or clean-tillage (offset disk three times followed by culti-packer), and were applied within 1 week of planting (subplots, 5 by 20 ft) at 0.25-, 0.5-, or 1.0-inch planting depth into existing vegetation (native prairie grasses at all locations with no switchgrass present). Recommended planting depth for switchgrass generally depends on seed size and soil texture, with deeper depths recommended for sandy soils or arid environments (Newman and Moser, 1988; Aiken and Springer, 1995; Evers and Parson, 2003). Recommended planting depth in sandy soils in the southern Great Plains is 0.5 inch, and the 0.25- to 1.0-inch range was selected to try to determine optimum planting depth in this region. Lowland ecotype (EG 1101) switchgrass was planted at 4 lb pure live seed/acre (0.021 lb a.i./acre) of FirstRate [cloransulam-methyl: N-(2-carbomethoxy-6-chlorophenyl)-5-ethoxy-7-fluoro(1,2,4) triazolo-[1,5-c]pyrimidine-2-sulfonamide] and 2.0 qt/acre (2 lb a.i./acre) of glyphosate [(N-(phosphonomethyl) glycine] were applied to the plot area to control newly emerged weeds (primarily in the mowed and burned plots) as well as reduce weed competition. Glyphosate was added to the clean-tilled seedbed treatment to control the few weeds that had emerged, since tillage was 7 days prior to planting, and to keep the management across seedbed treatments the same, as to not confound the results. FirstRate had looked promising in suppressing annual grass weeds (Texas cupgrass [Eriochloa sericea (Scheele Munro ex Vasey] and broadleaf signalgrass [Urochloa platyphylla (Munro ex C. Wright) R.D. Webster]) as well as broadleaf weeds in herbicide screening trials in the region.

Seedling density (number of seedlings/ft²) was measured 30 DAP. Seedling density was the average of the number of seedlings in a 1-ft² quadrat placed on the ground over a drill row in two randomly selected locations per plot. Stand percent was the average of visual estimates of the entire plot by two observers in autumn at 150 DAP (physiological maturity with seed heads present). Stand percent was based on the assumption of a full, productive stand (“100% stand”) containing 1 to 2 plants/ft² (Lauchbaugh and Owensby, 1970). Postfrost biomass dry matter (DM) yield was measured once per year in December by mechanically clipping the whole plot with a Hege forage plot harvester (Colwich, KS) to a 3-inch stubble height and collecting the wet weight. Subsamples of each plot were taken, wet weights obtained, and dried in a forced-draft oven set at 120°F for more than 72 h to produce a constant weight and weighed. The percent DM of the subsamples was calculated and applied to the whole-plot wet weights to determine whole-plot biomass DM yield.

Data on seedling density, stand percent, and biomass yield were subjected to analysis of variance using PROC MIXED (SAS Institute, 2002). Stand data were subjected to arcsine transformation before statistical analysis and back-transformed for data presentation. Seedbed preparation, planting depth, and their interaction were considered fixed effects, while planting year, location, and replicate were considered random effects to make inferences across years and locations with different environmental and edaphic conditions. Significance was determined at P ≤ 0.05. The PDIFF function of the LSMEANS procedure was used to compare means.
Rainfall (measured at Ardmore and Burneyville Mesonet sites) was below the 30-year average for most of the growing season in 2011 at Burneyville, while rainfall amounts were generally more typical of the 30-year average early and late in the growing season at both locations in 2012 (Table 2). Both sites received critical rainfall in the spring, which favored switchgrass establishment.

Switchgrass seedling density was affected by seedbed preparation × planting depth interaction (P = 0.001). There were generally fewer seedlings when planted at 1.0 inch than at the other depths (Table 3). Tilling generally resulted in more seedlings than mowing or burning (Table 3). When averaged over untilled, disked, and dead oat (Avena sativa L.) cover seedbed preparations in two establishment years in Nebraska, King et al. (1989) reported an average of 7.9 ‘Trailblazer’ switchgrass seedlings/ft² at approximately 45 DAP, which was similar to the average of 7.7 seedlings/ft² observed in the tilled seedbed treatment in the current study. While some differences were detected, all seedbed preparation × planting depth combinations in the current study produced successful switchgrass stands of >1 seedling/ft² (Launchbaugh, 1966; Vogel, 1987).

There was no effect of seedbed preparation on switchgrass stand (P = 0.617) or DM yield (P = 0.949). Conversely, Sadeghpour et al. (2014) reported greater ‘Cave-in-Rock’ switchgrass yield with no-till compared with conventional tillage (1240 and 420 lb DM/acre, respectively) in Massachusetts. Marietta and Britton (1989) reported an average yield of 320 lb DM/acre for establishment year ‘Blackwell’ switchgrass in the southern High Plains of Texas under conventional tillage, which was 35% less than our average of 900 lb DM/acre. All seedbed preparations resulted in >50% stand (Table 4), and could be considered successful (>50%) according to the criteria established by Launchbaugh and Owensby (1970), Vogel and Masters (2001), and Schmer et al. (2006).

Across locations and years, planting depth affected switchgrass stand percent (P = 0.002) and DM yield (P = 0.001), and these parameters were greatest in the 0.25- and 0.5-inch planting depths as compared with the 1.0-inch depth (Table 5). These results support similar ideal planting depths as reported by Parrish et al. (2008) and Propheter et al. (2010). Switchgrass establishment year stand of 60% and DM yield of 900 lb DM/acre were comparable to 67% stand and 840 lb DM/acre reported by Interrante et al. (2015) in similar soils and environments in Ardmore and Burneyville, OK. It is likely that DM yield will increase after the establishment year as stands become fully established and N fertilizer application increases (Propheter et al., 2010).
Table 5. Switchgrass stand at 150 days after planting and dry matter (DM) yield at the end of the growing season as affected by planting depth in Ardmore, OK, and Burneyville, OK. Stand and yield data are means across three seedbed preparation methods, three locations, two years, and eight replicates (n = 144).

<table>
<thead>
<tr>
<th>Planting depth</th>
<th>Stand</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>inches</td>
<td>%</td>
<td>lb DM/acre</td>
</tr>
<tr>
<td>0.25</td>
<td>64 a†</td>
<td>1020 a</td>
</tr>
<tr>
<td>0.5</td>
<td>66 a†</td>
<td>940 a</td>
</tr>
<tr>
<td>1.0</td>
<td>50 b</td>
<td>750 b</td>
</tr>
<tr>
<td>P value</td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>SE</td>
<td>0.5</td>
<td>87.5</td>
</tr>
</tbody>
</table>

† Means followed by the same letter within column do not differ by the LSMEANS test (P > 0.05).

All seedbed preparation methods and planting depths resulted in ≥50% stands and could be considered successful by the standards defined by Launchbaugh and Owensby (1970), Vogel and Masters (2001), and Schmer et al. (2006); however, 0.25- and 0.5-inch planting depths are generally recommended and dependent on soil texture.

Implications for Producers

Successful switchgrass stands (>1 seedling/ft² and ≥50% stand) can be established on drained sandy soils in the southern Great Plains by planting between 0.25- and 0.5-inch depth with either conventional tillage or no-till drilling that is preceded by either burning or mowing to remove excess vegetation. However, environmental strategies for soil conservation, improving soil fertility and structure, and reducing SOC lost to atmosphere via conventional tillage can be partially achieved through the use of no-till planting methods with no negative effects on establishment year stands or DM yield.

Acknowledgments

The authors would like to thank Ceres, Inc. for partially funding this research.

References


