ESTABLISHMENT AND EVALUATION OF SWITCHGRASS ON RECLAIMED MINE SOIL[1]

David Lang[2], Brandon Shankle[2], Ernest Oswalt[2], Jeremy Duckworth[2], Judd Sanborn[3], Rebecca Buell[3], and Bill Roberson[4]

Abstract: Switchgrass (*Panicum virgatum* L.) is a native warm season perennial grass that has productive potential of up to 20 Mg ha^{-1} of biomass and it persists for decades when harvested once per year. Switchgrass provides excellent ground cover and soil stabilization once established and contributes to soil sequestration of new carbon. Slow establishment on newly reclaimed soil, however, provides for significant erosive opportunities thereby requiring initial soil stabilization with a cover crop. Several planting options were evaluated on two topsoil substitute soils. The planting options included: 1) an existing stand of bermudagrass (*Cynodon dactylon L.*) that was killed with glyphosate followed by disking in red oxidized topsoil substitute and prime farmland topsoil respread in 2007, 2) red oxidized topsoil substitute was seeded directly with switchgrass, 3) browntop millet (*Panicum ramosum*) was established with switchgrass, 4) or switchgrass was established in senescing browntop millet or wheat without tillage. Switchgrass was successfully established into a bermudagrass sod that had been killed with herbicides and disked as well as into a senescing stand of browntop millet or wheat. Significant soil erosion occurred on the disked area in 2008 leading to considerable repair work followed by planting wheat. Disked areas that did not erode had an excellent stand of switchgrass with 23.3 plants m^{-2} in November, 2008. Eroded areas replanted in April, 2009 into senescing wheat had 46 plants m^{-2} by July, 2009. The area planted directly into newly respread soil in May, 2009 was eroded severely by a 75 mm thunderstorm and was repaired, disked and replanted to switchgrass and browntop millet. Switchgrass seeded with browntop millet had a sparse switchgrass stand and was replanted to switchgrass in August, 2009. Rainfall volumes from August, 2009 to October, 2009 totaled 750 mm, but new erosion damage in areas successfully planted to switchgrass has been minimal.

Additional Key Words: Soil Erosion, Soil Stabilization, Native Species

---

[1] Paper was presented at the 2010 National Meeting of the American Society of Mining and Reclamation, Pittsburgh, PA ***Bridging Reclamation, Science and the Community*** June 5 - 11, 2010. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

[2] David. J. Lang, Associate Professor of Agronomy, Brandon Shankle, Ernest Oswalt and Jeremy Duckworth, Research Technicians, Dept. of Plant and Soil Sciences, Mississippi State University, Box 9555, Mississippi State, MS 39762, [3]Judd Sanborn, Environmental Specialist, [3]Rebecca Buell, Environmenal Manager email:, Red Hills Lignite Mine, Route 3, Box 98, Ackerman, MS 39735, [4]Bill Roberson, ProTurf, Grenada, MS 38901

Introduction

Switchgrass (*Panicum virgatum L.*) is a perennial warm season grass native to the Great Plains of North America (Moser and Vogel, 1995). It grows to a height of up to 2-3 m and spreads by short rhizomes and through seed. Individual plants contain numerous tillers that increase with age of the crown thereby increasing biomass and seed yield potential over time (Parrish and Fike, 2005). It takes up to three years for switchgrass plants to reach their full productive potential (Fike et al, 2006). Switchgrass can be utilized as forage, grazed by cattle and as a biomass bioenergy source. It has productive potential of up to 20 Mg ha $^{-1}$ (~10 tons Ac^{-1}) and it persists for decades when harvested once per year (McLaughlin et al, 1999). Switchgrass contains 8,400 kjoule kg^{-1} of biomass and is equivalent to lignite coal on a dry matter basis. Sulfur (0.03-0.05%) and ash (3-5%) levels are much lower than lignite, particularly when switchgrass is harvested late in the fall (Mclaughlin and Kszos, 2005). Switchgrass co-fired with coal is considered carbon neutral.

The root system of switchgrass is fibrous and extensive in that it reaches to 2-3 m depths within the soil, depending upon the presence of restrictive soil layers (Leibig et al, 2008). Once established switchgrass has great capacity to hold and stabilize soil and is often used to stabilize levees. Switchgrass established on reclaimed mine soils has the potential to sequester soil carbon and accelerate soil development. In agricultural soils in the Midwest USA, switchgrass was found to accrue 1.1 to 2.9 Mg C ha^{-1} yr^{-1} (Liebig et al, 2008) from 0-30 cm and 0-120 cm, respectively. Increases in soil organic carbon (SOC) significantly enhance soil quality by increasing water holding capacity, soil fertility and improving soil tilth.

A major limitation to using switchgrass on reclaimed mine lands, however is that it is slow to establish. Switchgrass provides excellent ground cover and soil stabilization once established and contributes to soil sequestration of new carbon. Slow establishment on newly reclaimed soil, however, provides for significant erosive opportunities thereby requiring initial soil stabilization with a cover crop.

The objective of this paper was to evaluate the effect of establishing switchgrass into two reclaimed soils with various seeding methods on soil stabilization.

Methods

Planting I – 2008

The reclaimed land was planted to bermudagrass in 2007 and loblolly pine (*Pinus teada*) trees in January, 2008 at the Red Hills Lignite Mine north of Ackerman, MS. Two strips within the planted pines approximately 100 meters wide were killed with glyphosate at 4.7 L ha^{-1} on 15 July, 2008. A strip of pines and bermudagrass approximated 10 m wide was left between killed strips. Gullies discovered during herbicide application were disked and an additional 4.7 L ha^{-1} of glyphosate was applied on 25 July, 2008. The killed strips were disked on 6 August, limed at 4.5 Mg ha-1 and disked again on 7 August. 'Alamo' switchgrass was planted on 18 August, 2008 at 6 kg PLS ha^{-1} into a prepared seedbed with a Brillion cultipak planter on a total of 6 ha (Fig. 1). Soil samples were collected, prior to lime application, to a depth of 30 cm along three 200 m transects that ran south to north across disked strips. Extractable nutrients and other soil fertility parameters were analyzed according to the methods of Raspberry and Lancaster (1977) by the Mississippi State University soil laboratory. Soil varied from west to east with red oxidized subsoil as the approved topsoil substitute (Lang et al, 2005) in the western third and prime farmland topsoil in the eastern two thirds of the area. This variation is evident in Fig. 2.

Figure 1. Switchgrass was planted with Brillion (left) at 6 kg pure live seed (PLS) ha^{-1} on 18 August, 2008 into a prepared seedbed (right).

During August 2008 tropical storm Fay and other rainfall events (Table 1) totaling 286 mm reopened erosion gullies repaired in July (Fig. 3 and 4). These gullies were repaired with additional soil and planted to wheat (*Triticum aestivum L.*) on 1 October, 2008. The entire area was fertilized with 34-0-0 fertilizer at 112 kg ha^{-1} on 8 October, 2008. Switchgrass at 6 kg PLS ha^{-1} was planted into standing wheat on 15 April, 2009 with a Tye no-till drill (Fig. 5). No fertilizer was applied during 2009 due to wet conditions. Atrazine was applied at 4.7 L ha^{-1} with

2.3 L ha^{-1} crop oil on 23 March and repeated on 18 April, 2009 to suppress wheat, volunteer ryegrass (*Lolium multiflorum*) and various broadleaf rosettes.

Figure 2 . Switchgrass planted into two respread soils: Red oxidized subsoil to left of arrow and prime farmland topsoil to the right of arrow.

Switchgrass seedlings were counted within a 0.25 m^{-2} quadrats (Fig. 6). An initial random count was conducted on 6 November, 2008 and at 15 m intervals along each transect on 25 June and 5 November, 2009. Hand clipped samples within 0.25 m^{-2} quadrats were collected and dried at 55 ^{o}C on 25 June and 5 November, 2009. Two additional transects were installed prior to sampling in November, 2009.

Figure 3. Erosion gullies washed through switchgrass planted into a prepared seedbed with red oxidized soil with a 1-2 % slope (left) with overland flow from upslope following tropical storm Fay (right).

Figure 4. Erosion was minimal on level prime farmland topsoil (left) or where overland water flow was reduced (right) on 25 August, 2008.

Figure 5. Switchgrass was replanted with a Tye drill at 65 kg PLS ha^{-1} on 15 April, 2009 to redo planting in erosion repairs into standing wheat (left). Both repaired and non-eroded non-repaired areas were replanted.

Figure 6. Ground cover was estimated by counting intersecting points along a tape (left). Seedling counts and biomass were determined within 0.25 m-2 quadrats (right) on 25 June, 2009 in switchgrass established on 18 August, 2008. Smaller seedlings planted on 15 April, 2009 were not harvested on 25 June (right). Red oxidized soil.

Figure 7. Wheat strips and winter ground cover on 18 March, 2009.

Figure 8. Switchgrass on 25 June 2009, established 18 August, 2009 into red oxidized subsoil as a topsoil substitute as approved in the permit as topsoil substitute for upland reconstruction (left). Transect from north to south for ground cover and stand evaluation (right).

Figure 9.Transect downslope for initial harvest of switchgrass on 25 June, 2009 (left). Upper strip of switchgrass planted 18 August, 2008 on 25 June 2009 east to west (right) in red oxidized soil.

Figure 10. Lower strip east end looking west into transition from prime farmland (PFL) topsoil to red oxidized topsoil substitute (lighter green switchgrass in background) on 25 June 2009 (left) and Switchgrass in PFL soil on 25 June 2009

Figure 11. Switchgrass planted 18 August, 2008 on 2 November, 2009 in red oxidized soil (left) and repair strip upslope west end on 2 November, 2009 (right)

Figure 12. Switchgrass growth in brown silt loam prime farmland soil on 2 November, 2009.

Planting II – 2009

An ash road just to the south of the 2008 switchgrass planting was reclaimed with red oxidized topsoil substitute during the winter and spring of 2009. Soil to east was red oxidized topsoil substitute; soil to the west was a mixture of red oxidized topsoil substitute with gray unoxidized materials. Lime was applied at 4.5 Mg ha^{-1} and disked to prepare a seedbed. This area was initially planted on 20 May, 2009 with ‘Alamo’ switchgrass at 6 kg PLS ha^{-1} mixed with 10 kg ha^{-1} browntop millet (*Panicum ramosum*) with a Brillion cultipak planter (Fig. 13). Rainfall (Table 1) was heavy during May, 2009 (342 mm) following planting causing multiple erosion gullies where slope was greater than 1-2% (Fig. 14 and 15). The lower area to the north was disked and replanted with ‘Alamo’ switchgrass mixed with 20 kg ha^{-1} browntop millet on 2 June, 2009. The seeding rate of browntop millet was increased to help provide more ground cover quickly in order to stabilize soil as is normally planted during reclamation at the Red Hills Mine (Fig. 16 and 17). An evaluation of switchgrass emergence in July indicated that seedling density was less than 5 plants m^{-2}. An additional planting of switchgrass 6 kg PLS ha^{-1} with a Tye no-till drill was made on 6 August, 2009 into browntop millet stubble (Fig. 18). Five transects, 100 m long were established that ran south to north across the area from west to east for evaluation of seedling density and ground cover with 0.25 m^{-2} quadrats on 6 November, 2009 (Fig. 19). Switchgrass planted on 2 August, 2009 had 20 to 25 plants m^{-2} on 6 November, 2009.


Figure 13. New Switchgrass Area on May 26 2009 (left) . Initial planting on 20 May, 2009 10 kg PLS ha-1 with Brillion planter along with 10 kg browntop millet seed per ha. Numerous erosion gullies required disking and switchgrass was replanted on 2 June 2009 along with 20 kg ha^{-1} of browntop millet to provide sufficient ground cover (right).

Figure 14.Green growth to the left was planted 20 May, 2009 and replanted after erosion repairs on 2 June, 2009 (left). Green growth to right is browntop millet planted with switchgrass on 20 May, on 9 June, 2009 (right).

Figure 15. New erosion gully as of 9 June 2009 following planting on 2 June and application of 2.4 Mg ha^{-1} mulch (left). Erosion gullies following the 2 June planting were isolated and not repaired. Green to the left was planted earlier in May, 2009 had few erosion gullies (right).

Figure 16. Terrace was planted to browntop millet and bermudagrass on 2 June 2009 (left). Ground cover of browntop millet and bermudagrass on 25 June, 2009 (right).

Figure 17. Browntop millet fertilized with was too competitive for switchgrass seedlings. It was clipped in July and formed a suppressive mat that provided good erosion control (left). Erosion gully in newly planted switchgrass and browntop millet on 24 July 2009 (right) same gully as in Fig. 13 left.

Figure 18. Switchgrass was replanted on 6 August 2009 into senescing browntop millet (left) and provided sparse ground cover by 6 November, 2009 (right).

Figure 19.Switchgrass planted into senesced browntop millet on 6 August, 2009 was evaluated for seeding density within a 0.25 m-2 frame (left) and for ground cover at intersecting points along a tape (right) on 6 November, 2009.

Figure 20. Switchgrass planted on 6 August 2009 on 6 November, 2009 (left). Same erosion gully as in Fig. 13 left and 17 left on 6 November, 2009 (right).

Several planting options were evaluated on two topsoil substitute soils which consisted of red oxidized topsoil substitute and prime farmland topsoil. The planting options included 1) an existing stand of bermudagrass that was killed with glyphosate followed by disking in red oxidized topsoil substitute and prime farmland topsoil respread in 2007 2) red oxidized topsoil substitute respread in 2009 was seeded directly with switchgrass, 3) browntop millet was established with switchgrass, or 4) switchgrass was established in senescing browntop millet or wheat without tillage. These were large, unreplicated areas that provided anecdotal opportunities for observation as illustrated pictorially above. Soil response was the main factor quantified across transects.

Results

Planting I - 2008

Switchgrass was successfully established into killed and disked bermudagrass as well as into senescing browntop millet or wheat. An initial random count conducted on 6 November, 2008 indicated that there 24 to 36 switchgrass plants m^{-2}. Significant soil erosion occurred following heavy rains in August, 2008 (Table 1) on the disked area in 2008 leading to considerable repair work followed by planting wheat (Fig. 3). Disked areas that did not erode (Fig. 4) had an excellent stand of switchgrass with 23 plants m^{-2} in November, 2008. According to Vogel and Masters (2001) and Schmer et al (2005) a successful and productive stand of switchgrass has 10-20 plants m^{-2}. Eroded areas replanted in April, 2009 into senescing wheat (Fig. 5, 6 and 7) had 46 plants m^{-2} by July, 2009 (data not shown).

Table1. Monthly Rainfall Volumes for 2008 and 2009

Month	2008	2009
	------------------ mm --------------------	
January	130	158
February	124	100
March	108	195
April	135	44
May	135	342
June	35	72
July	102	239
August	286	53
September	106	364
October	77	292
November	73	37
December	280	125
Total	1592	2019

Table 2. Soil fertility of two soils prior to lime and fertilizer application, July 2008.

Soil	O.M.	pH	P	K	Ca	Mg	Zn	Na	CEC
	%	s.u.	-------------------- mg kg^{-1} -------------------------						$cmole^{+}$ kg^{-1}
Red	0.75	5.0	15	70	762	413	1.6	152	11.7
PFL	0.88	5.4	17	86	1183	505	2.2	45	15.5
LSD (0.05)	0.27	0.4	5	17	404	195	1.2	24	3.0

Two distinct respread soils were present in the area planted to switchgrass in August, 2008 (Fig. 1). Red soil to the west was more acidic and had less extractable Ca than prime farmland topsoil (Table 2). It also had significantly less cation exchange capacity (CEC) and slightly less organic matter (not significant) than prime farmland topsoil (PFL). These differences in soil fertility were reflected in the initial growth of switchgrass (Table 3). Switchgrass growing in red soil exhibited nearly half the growth of switchgrass growing in PFL soil. It should be noted that no fertilizer was applied in 2009. Fertilizer was deliberately omitted during establishment as is generally recommended to reduce competition from weeds (Douglas et al, 2009). Nitrogen as 34-0-0 at 112 kg ha^{-1} was added in October, 2008 to stimulate wheat growth. Fertilizer was scheduled to be applied in June, 2009, however wet conditions and availability of equipment and personnel delayed application until August so a decision was made to not apply fertilizer in 2009. This provided an opportunity to assess the natural soil fertility and productivity of unamended red oxidized substitute soil and prime farmland topsoil. These growth differences are illustrated in Fig. 8, 9, 10, 11, and 12.

Table 3. Yield and height of switchgrass established after one year on two reclaimed mine soils, harvests on 25 June and 5 November 2009

	Plant density	June Yield?	November Yield	Final Height
Soil	Plants m^{-2}	kg ha^{-1}	kg ha^{-1}	cm
Red	45	746	3027	97
PFL	47	1314	5458	136
LSD (0.05)	21	542	1458	23

Planting II -2009

The area planted directly into new respread in May, 2009 was eroded severely by a 75 mm thunderstorm (Fig. 13) and was repaired with new respread, disked and replanted to switchgrass and browntop millet (Fig. 14, 15 and 16). The area where switchgrass was seeded into browntop millet had a sparse switchgrass stand of less than 5 plants m^{-2} and was replanted to switchgrass in August, 2009 (Fig. 17 and 18). An acceptable stand of switchgrass with 23 plants m^{-2} was established by November, 2009 (Fig. 19). Rainfall (Table 1) from August, 2009 to October, 2009 totaled 750 mm (30"), but new erosion damage in areas successfully planted to switchgrass has been minimal (Fig. 20).

Table 4. Soil fertility of two soils prior to planting switchgrass over reclaimed ash road, April 2009.

Location	O.M.	pH	P	K	Ca	Mg	Zn	Na	CEC
	%	s.u.	-------------------- mg kg^{-1} -------------------------						$cmole^{+}$ kg^{-1}
East	0.30	5.4	20	69	1723	915	1.9	131	20.0
West	0.47	6.4	13	51	2117	866	1.3	164	19.7
LSD (0.05)	0.16	0.8	6	18	697	199	0.7	26	3.7

Baseline soil samples collected in April, 2009 to a depth of 30 cm indicated that soil organic matter is low, ranging from 0.3 to 0.5% (Table 4). Soil to the east is red oxidized topsoil substitute and soil to the west is a mixture of red oxidized topsoil substitute with gray unoxidized materials. These organic matter concentrations will be monitored over time as switchgrass becomes established in 2010. Additional soil samples from this site will be collected over the next few years to study organic carbon accumulation and soil development.

Conclusions

Heavy rains during and after switchgrass was planted illustrated a potential weakness of utilizing switchgrass on newly reclaimed land at the Red Hills Mine in Mississippi. The soil needs to be stabilized with quick growing ground covers such as browntop millet. No-tillage drills can successfully establish switchgrass into browntop millet and likely also into bermudagrass that has been killed with appropriate herbicides. The switchgrass planting in 2010 will be into a killed bermudagrass sod. Soil productivity differences between prime farmland topsoil stockpiled from bottomland soil collected to a depth of 30 cm and red oxidized subsoil as a topsoil substitute were significant. Switchgrass grown for biomass as a clean, weed free mulch source on red oxidized soil will aid in its soil development and future productivity by building organic matter and sequestering carbon.

References

Douglas, J., J.Lemunyon, R.Wynia and P. Salon. 2009. Planting and Managing Switchgrass as a Biomass Energy Crop USDA NRCS Plant Materials Program Technical Note No. 3 http://plant-materials.nrcs.usda.gov/intranet/Publications/npmptn3-13079.pdf

Fike, J.H., D.J. Parrish, D.D. Wolfe, J.A. Balasko, J.T. Green, Jr., M. Rasnake, and J.H. Reynolds. 2006. Long-term yield potential of switchgrass for biofuel systems. Biomass and Bioenergy 30:198–206.

Lang, D.J., G. Hawkey and B. Chow. Productivity of Reclaimed Soil at The Red Hills Lignite Mine in Ackerman, MS. 2005. pp. 667-677. *IN:* R.L. Barnhisel (ed.). Proceedings of the 22nd Annual Meetings of the American Society of Mining and Reclamation. Breckenridge, CO, 19-23 June, 2005. American Society of Mining and Reclamation, Lexington, KY.

Liebig, M.A., M.R. Schmer, K.P. Vogel, and R.B. Mitchell. 2008. Soil carbon storage by switchgrass grown for bioenergy. Bioenerg. Res. (1):215–222.

McLaughlin, S., J. Bouton, D. Bransby, B. Conger, W. Ocumpaugh, D. Parrish, C. Taliaferro, K. Vogel, and S. Wullschleger. 1999. *IN*: Perspectives on new crops and new uses. J. Janick (ed.), ASHS Press, Alexandria, VA. pp. 282-299.

McLaughlin, S.B. and L.A. Kszos. 2005. Development of switchgrass (*Panicum virgatum*) as a bioenergy feedstock in the United States. Biomass and Bioenergy 28:515–535.

Moser, L.E. and K.P. Vogel. 1995. Switchgrass, Big Bluestem and Indiangrass. *IN*:Forages Vol. I: An Introduction to Grassland Agriculture. Barnes, R.F, D.A. Miller, and C.J. Nelsons (eds). pp. 409-420.

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

Raspberry, F.P.and J.D. Lancaster. 1977. A comparative evaluation of the Mississippi soil test method for determining manganese, magnesium, and calcium. Comm. Soil Sci. Plant Anal. 8:327-339.

Schmer, M.R., K.P Vogel, R.B. Mitchell, L.E. Moser, K.M. Eskridge, and R.K. Perrin. 2005. Establishment stand thresholds for switchgrass grown as a bioenergy crop. Crop Sci. 46:157–161.

Vogel, K.P. and R.A. Masters. 2001. Frequency grid—A simple tool for measuring grassland establishment. J. Range Manage. 54:653–655.