SWITCHGRASS MANAGEMENT FOR A BIOMASS ENERGY FEEDSTOCK IN TEXAS

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ABSTRACT
Switchgrass (*Panicum virgatum* L.) is a warm-season perennial grass indigenous to North and Central America with excellent potential as a bioenergy crop. Our objective was to develop management practices for switchgrass as a bioenergy crop. We determined the adaptability of several switchgrass cultivars and germplasms at five locations, and examined the response of 'Alamo' switchgrass to defoliation frequency, nitrogen and phosphorus fertility, and row spacing at two locations during 1992 to 1996. Alamo switchgrass was the highest yielding entry at all locations with yields of 8 to 20 Mg of dry biomass ha^{-1}. Yield response of Alamo to N fertilizer was quadratic at Stephenville and linear at Beeville to the highest N rate used of 200 kg ha^{-1}. There was a small response to 20 kg ha^{-1} of P_2O_5 in 1992 at Stephenville, but no response in later years or at Beeville. Increased row spacing did not increase switchgrass yield. Total seasonal yields are decreased as harvest frequency increases.

KEYWORDS
Biofuel, warm-season grass, *Panicum virgatum*, bioenergy

INTRODUCTION
The Texas A&M University/Texas Agricultural Experiment Station was chosen by the U.S. Department of Energy as one of three Regional Cultivar and Management Testing Centers to focus on switchgrass as a bioenergy feedstock. This is part of a larger effort managed by the Biofuels Feedstock Development Program at Oak Ridge National Laboratory, which includes investigations into biomass production, economics, and environmental impacts at five primary locations in the southcentral and southeastern U.S. (McLaughlin, 1993).

Switchgrass was selected for development as a bioenergy feedstock because of its high yield potential, adaptation to marginal sites, and tolerance to water and nutrient limitations. Switchgrass has been researched extensively as a forage crop particularly in the midwestern and northeastern U.S.; however, little research has been done on switchgrass as a biomass or forage crop in Texas. Therefore, the objective of our research was to answer three applied questions: (1) what switchgrass cultivars or germplasm are adapted to Texas?, (2) what are the nitrogen and phosphorus fertilizer needs of switchgrass?, and (3) can switchgrass be managed both as a forage and biomass crop?

MATERIALS AND METHODS
Experiment 1: Multi-location Tests of Cultivars and Germplasm: Field plot trials comparing several cultivars and germplasms were established at Beeville, College Station, Dallas, Stephenville, and Temple in 1992. Eight switchgrasses (Table 1) were planted into 3- by 6-m plots in a randomized complete block design. Plots were harvested once per year in the fall or twice per year in June and October. Harvest systems (1-cut or 2-cut) were whole plots and switchgrass cultivars and germplasm were subplots. There were two replicates of each system-cultivar treatment combination. Plots were fertilized with 67 kg N ha^{-1} in 1993 and 134 kg N ha^{-1} in 1994, 1995, and 1996.

A second trial was established at Stephenville and College Station in 1993. Nine switchgrasses (Table 2) were planted into 1.5- by 6-m plots in a randomized complete block design with three replicates. Nitrogen was applied at 78 kg ha^{-1}. Plots were harvested once in the fall of 1994 and 1995. At each harvest in both trials, biomass was clipped to a 15-cm stubble height and fresh weights recorded. A 300-g subsample was dried at 55^{o}C for 48 hours to determine moisture percentage at harvest.

In October 1995, soil in plots of Alamo and Caddo (Trial 1) at each location was sampled to a 30-cm depth and analyzed for soil organic carbon. Ten cores were taken from four plots of each cultivar. In addition, an adjacent cultivated area was sampled and analyzed, as were soil samples taken in 1992 before the plots were established.

Experiment 2: Response to N and P Fertilizer and Row Spacing: Alamo switchgrass was established on a Windthorst fine sandy loam soil at Stephenville and on a Parrita sandy clay loam soil at Beeville in 1992. Fertilizer rates of 0, 50, 100, 150, and 200 kg N ha^{-1} and 0, 20, 40, 60, and 80 kg P_2O_5 ha^{-1} were applied each spring. Within fertilizer treatment whole plots, three row spacing treatment subplots were established. Row spacing treatments were 25, 50, and 100 cm at Beeville, and 18, 36, and 72 cm at Stephenville. Fertilizer treatments (N and P_2O_5 combinations) were arranged in an incomplete factorial with two replications. Plots were harvested in the fall to determine biomass yields during 1992 to 1996.

Experiment 3: Harvest Frequency: Field plots of Alamo switchgrass were established at Dallas and Stephenville in the spring of 1992. In 1993, treatments of four harvest frequency systems and three final fall harvest dates were imposed. System 1 was clipped three times (May, June, July), System 2 was clipped twice (May, June), and System 3 was clipped once (May), whereas System 4 was not harvested during the summer. In the autumn, one-third of each plot was harvested in either September, October, or November. Plots received 67 kg N ha^{-1} in 1993 and 167 kg N ha^{-1} in 1994, 1995, and 1996.

Biomass yield was measured at each harvest and plant and tiller densities were determined also. The experimental design was a randomized complete block with a split plot arrangement of treatments in three blocks. Harvest systems were whole plots and final fall harvest dates were subplots.

RESULTS
Experiment 1: In both trials, Alamo switchgrass was the highest yielding cultivar (Tables 1 and 2). Alamo is a lowland ecotype and was developed by the USDA Natural Resources Conservation Service (NRCS) from plant material originally collected in south Texas (Alderson and Sharp, 1994). Caddo and Blackwell are upland ecotypes developed from plant material collected in Oklahoma (Alderson and Sharp, 1994) and Cave-in-Rock was released by the NRCS and developed from germplasm collected in southern Illinois. Caddo and Cave-in-Rock matured in June, whereas the other switchgrasses matured in August and September. PMT-279 and PMT-785 were collected by the NRCS but were not released. NCSU-1 and NCSU-2 are unreleased breeding lines from North Carolina.

Shelter and Summer did not establish well at Stephenville and College Station in Trial 2, which probably contributed to their low yields. Shelter was developed from ecotypes collected in the northeastern U.S., and Summer was selected in South Dakota from plant material collected in Nebraska (Alderson and Sharp, 1994).

At the start of the experiment in 1992, soil organic carbon levels in the surface 30 cm averaged 10.1 g kg^{-1} for the five locations. In October 1995, soil organic carbon levels averaged 12.3 g kg^{-1} in plots of Alamo and Caddo (average of five locations), an increase of 22%.

Experiment 2: Biomass yield of Alamo switchgrass increased with increasing N rate at each location in each year (Fig. 2). Biomass yields were lower in the initial years at Stephenville (1992) and Beeville (1993), probably because the stand had not yet fully established. Yield responses in subsequent years were greater than in the initial years.

There was a small response to 20 kg of P_2O_5 ha^{-1} at Stephenville in 1992, but there was no response to P fertilizer at Stephenville or Beeville in later years. Soils at both locations were low in P (less than 10 kg ha^{-1} of available P in the surface 30 cm of soil according to soil test). The lack of response of switchgrass to P fertilizer indicates that switchgrass is a very efficient user of P, which may be a result of colonization of switchgrass roots by vesicular-arbuscular mycorhizae (Brejda et al., 1993).

There was no yield response to row spacing at Stephenville. At Beeville, there was a N by row spacing interaction in 1993. There was a greater response to N fertilizer at narrow than wide row spacing. Yield decreased as row spacing increased at Beeville. Sladden et al. (1995) reported a an interaction of row spacing and N rate in Alamo switchgrass in Alabama. They reported that the increase in biomass yield due to an increase in row spacing was greater at higher N levels.

Experiment 3: At both Dallas and Stephenville, increasing harvest frequency reduced total season biomass yields of Alamo switchgrass (Fig. 3). The highest yields at both locations were obtained with a single harvest in September. Delaying the final fall harvest until October or November reduced yields; however, biomass yields in May harvests the following year were higher in plots harvested in November than those of September of the previous year. Similar decreases in biomass yields of switchgrass were reported by Parrish and Wolf (1993) in Virginia. They suggested that switchgrass remobilized and translocated compounds to the below ground portion of the plant during the fall, partially accounting for the yield loss. Harvesting in September may have caused regrowth to come from basal buds and reduced the number of active meristems in the spring of the following year as suggested by Hafercamp and Copeland (1984).

In the multiple harvest systems, about 40% of the yield was obtained at the first harvest in May. Thus, an early harvest of switchgrass to provide forage for livestock on a diversified farm probably will limit biomass yields from regrowth. An alternative may be to delay harvest of switchgrass for biomass until June, and then use the limited regrowth for grazing or hay production in late summer and fall.

Table 1
Biomass yields of eight switchgrasses in Texas. Data are averages of five locations in each year.

	1993		1994		1995	
Entry	1-cut	2-cut	1-cut	2-cut	1-cut	2-cut
	kg dry biomass ha^{-1}					
Alamo	12257	10653	17746	14539	14052	9472
Kanlow	9957	8788	14182	10849	12749	7828
PMT-279	9066	7927	14963	11328	12345	7685
PMT-785	9016	10148	14972	12524	12069	9401
NCSU-1	9577	8281	12478	10592	12315	8518
NCSU-2	8457	8017	12409	10882	12036	8382
Caddo	6637	6695	7428	8612	5703	6932
Cave-in-Rock	3731	5701	7372	7389	5101	6040
L.S.D. (0.05)	1978		1814		1501	

L.S.D. = least significant difference at the 0.05 probability level.

Table 2
Biomass yields of nine switchgrasses at two locations in Texas.

	College Station		Stephenville	
Entry	1993	1994	1993	1994
	kg dry biomass ha^{-1}			
Alamo	8897	14082	14448	20729
Kanlow	6835	6792	10394	15784
PMT-279	6264	5974	10416	16177
Blackwell	3952	4044	5915	7972
Caddo	4030	4210	8236	7860
Cave-in-Rock	4837	5919	5071	5350
Shelter	3069	2828	3003	2827
Summer			1753	1442
Late Synthetic	3957	3294	7531	7270
L.S.D. (0.05)	1054	2375	2137	3196

L.S.D. = least significant difference at the 0.05 probability level.

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Figure 1a
Response of switchgrass to nitrogen at two locations duing several years. 1b. Switchgrass yield response to harvest frequency. Data are averages of 3 yr and two locations.