SWITCHGRASS GROWTH AT VARIOUS PLANT DENSITIES

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ABSTRACT

Switchgrass (*Panicum virgatum* L.) is a C_4 perennial indigenous to North and Central America with potential as a bioenergy crop. Our objective was to determine the relationship between plant density, N and water stress in switchgrass. We measured aboveground plant and tiller mass, tiller number, and stage of development during 1993 and 1994. There were responses to all factors studied, but the responses were dependent on year. Nitrogen tended to increase tiller mass and number and increased stage of development in 1994. Water stress reduced tiller mass and maturity at harvest in the seeding year (1993). Managers can exert influence over these factors in managed swards to manipulate development and production.

KEYWORDS

warm-season grass, *Panicum virgatum*, stand density

INTRODUCTION

Switchgrass is a native warm-season perennial grass adapted to much of North America. Switchgrass plant density may have effects on phytomass yields. In Alabama, 'Alamo' switchgrass (a lowland, tetraploid ecotype) increased in biomass yield as spacing between rows was increased (Sladden *et al*., 1995). However, Sanderson *et al*. (1996) found no response, or a negative response of Alamo switchgrass yield to increased row spacing at two locations in Texas. The reasons for the different results at the different environments may be related to rainfall amount.

The objectives of our research were to determine how plant density, N level, and water availability affected Alamo switchgrass growth and development.

MATERIALS AND METHODS

Alamo switchgrass was planted in 1.8 m diameter by 0.6 m deep nonweighing lysimeters on 4 May 1993 at the Texas A&M University Agricultural Research and Extension Center at Stephenville. The planting arrangement in each lysimeter was a wagon-wheel layout with eight spokes and four plants per spoke. Plant spacings within each spoke were 10, 20, and 30 cm. Nitrogen was applied at 22 or 112 kg ha^{-1} in June 1993 and May 1994 as NH_4NO_3 dissolved in 20 l of water to ensure uniform application. Two soil moisture levels were maintained by an automatic watering system controlled by tensiometers (Irrometer Co., Riverside, CA) placed 30 cm deep in each lysimeter. The tensiometers had a magnetic switch which triggered a solenoid valve on a water supply line when soil water tension fell below a preset level. A timing device was programmed to query the solenoid valves at 8 a.m., noon, and 5 p.m. each day. If the solenoid was switched on, the lysimeter watered for one hour. Water was distributed within the lysimeter via a drip irrigation system with ten 8 l hr^{-1} emitters at 28 cm intervals. The experimental design was a completely randomized design with a 2 x 2 factorial arrangement of N and water levels in four replications. The plant spacing arrangement was based on a systematic design for plant spacing experiments (Nelder, 1962).

The soil in each lysimeter was a Bunyan (fine-loamy, mixed, nonacid, thermic, Typic Udifluvents) with a pH of 8.2. Nutrients other than N were present in amounts adequate for plant growth and no fertilizer other than N was applied in each year.

Plant height, tiller number per plant, and stage of morphological development (according to Sanderson, 1992) were measured weekly beginning 28 June 1993 and 15 April 1994. Water was withheld from the low water treatment for two 15-day periods in 1993 and for three 18- to 20-day periods in 1994. After the stress periods, all lysimeters were returned to high water levels.

On 10 September 1993 and 15 August 1994, plants in each lysimeter were hand-clipped to a 15 cm stubble height. The number of tillers per plant, developmental stage of the five most mature tillers per plant, number of internodes, height of the two largest tillers, and leaf area were measured. Biomass yields were determined for individual plants from both rows and leaf blade dry weight determined by drying at 55^oC for 48 h in a forced-air oven.

RESULTS AND DISCUSSION

Biomass yield of switchgrass was reduced by low water levels by 25 and 10% at 0.83 and 2.0 m^2 $plant^{-1}$ in 1993 (Fig 1A). In 1994, biomass yield of switchgrass at the highest area $plant^{-1}$ (lowest plant density) was greater at low water than at the high water level. Switchgrass plant mass in Kansas decreased by 85% in response to a 7-fold increase in plant density (Hartnett, 1989). Decreases in plant mass for this study were similar (35% in 1993 and 80% in 1994). Nitrogen did not increase biomass yield of switchgrass in 1993 (Fig. 1B). In 1994, N increased biomass yield of switchgrass by 3-fold at the highest plant density and 2-fold at the other plant densities.

Number of tillers per switchgrass plant was not affected by water levels in either year and were numerically greatest at low plant densities (Fig. 1C). However, N increased the number of tillers in 1994 by 20 to 50%, but not in 1993 (Fig 1D). These results are similar to those reported by Hartnett (1989) in which number of tillers per plant declined by 65% as plant density increased. In 1993, tiller mass was increased by 35% at high water and 15% at 112 kg N (data not shown). In 1994, tiller mass increased by 75% at the high N level and was unaffected by water level. George and Reigh (1987) reported both an increase in tiller density (as compared to tillers per plant in this study) and tiller mass (13%) for upland ecotypes of switchgrass in Iowa. Number of tillers of Alamo switchgrass have doubled when fertilized with as little as 45 kg N (Haferkamp and Copeland, 1984).

In 1993, the low water level delayed developmental stage at all plant densities, whereas in 1994, limited water had no effect on maturity of the switchgrass (Table 1). Nitrogen had no effect on developmental stage in 1993; however, in 1994, a significant N by plant density interaction occurred (Table 2). Developmental stage of switchgrass was decreased at 22 kg N at all plant densities, but the decrease was greater for plants with less available area.

Water and N limitations in switchgrass delay maturity, inhibit tiller recruitment, and limit biomass production and are modified by plant density. Nitrogen rate, plant density and to a lesser extent water can all be manipulated in managed swards.

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Table 1
Developmental stage of switchgrass grown in nonweighing lysimeters as affected by soil water level and plant density. Data are averages of 32 plants in each year.

		1993		1994	
Water Level	Area Plant^{-1}	Stage†	SE	Stage	SE
	m^2 plant^{-1}				
Low	0.09	21.1	0.82	22.6	1.10
Low	0.50	23.0	0.94	25.2	0.98
Low	0.83	25.6	0.81	27.9	0.78
Low	2.00	27.5	0.69	29.3	0.54
High	0.09	24.3	0.99	22.7	1.23
High	0.50	27.3	0.75	25.8	1.11
High	0.83	30.1	0.54	29.0	0.69
High	2.00	31.2	0.19	30.1	0.22

† According to the scale of Sanderson (1992). Stages 21 to 29 represent percentage of inflorescence emergence; stage 30=inflorescence completely emerged; 31=beginning anthesis.

Table 2
Developmental stage of switchgrass grown in nonweighing lysimeters as affected by nitrogen and plant density. Data are averages of 32 plants in each year.

		1993		1994	
Nitrogen Level	Area Plant^{-1}	Stage†	SE	Stage	SE
kg N ha^{-1}	m^2 plant^{-1}				
22	0.09	22.6	1.00	18.9	1.09
22	0.50	24.8	0.92	22.5	1.11
22	0.83	28.2	0.81	27.4	0.89
22	2.00	29.9	0.66	28.9	0.54
112	0.09	22.9	0.91	26.3	0.81
112	0.50	25.4	0.95	28.4	0.65
112	0.83	27.6	0.78	29.4	0.48
112	2.00	28.8	0.52	30.4	0.14

† According to the scale of Sanderson (1992). Stages 21 to 29 represent percentage of inflorescence emergence; stage 30=inflorescence completely emerged.

Figure 1
Biomass yield response of switchgrass to plant density at two water levels (A) and two N levels (B) and tiller response of switchgrass to plant density at two water levels (C) and two N levels (D).