Switchgrass Responds Well to Nitrogen in the Arkansas Delta Region, but Not to Phosphorus or Potassium

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A one-cut harvest system for switchgrass grown for biomass bioenergy places lower P and K demand compared to similar grasses used for forage.

High N responses can be expected, but the specific application rates are highly dependent on fertilizer cost and potential revenue from the sale of biomass.

Photos courtesy S. Green

Switchgrass fertility field trials located in Colt, Arkansas.

The southern United States has a humid climate. Agricultural soils in the region have provided food, feed, and fiber for many generations. More recently, fuel production has been added to the products that we demand from our agricultural enterprise. Many traditional summer annual crops, such as maize and soybean, have been used in bioenergy production. Biomass crops, such as switchgrass (*Panicum virgatum*), have received much attention for their potential use for cellulosic ethanol production. Biomass crops are not new to the agricultural enterprise nor to this region. However, biomass crops have traditionally been grown for animal feed.

Current fertilizer recommendations for switchgrass are based on native warm-season grasses used as forages, normally harvested as hay in early to mid-summer or grazed by livestock. Under these conditions and timing, N-P-K removal rates are typically much greater than when harvested in the fall after the crop senesces and dries down. Fall harvest of a perennial grass crop, as for biomass bioenergy, returns some of the macrontrients to the soil or to the roots and crowns for recycling back into subsequent year regrowth. This phenomenon could result in N, P and K recommendations that are lower than when the same grasses are utilized as forages.

A field study was conducted from 2011 to 2014 at the University of Arkansas Pine Tree Experiment Station located near Colt, AR. The study site consisted of Henry and Calloway silt loam soils (Fragiaqualfs and Fraglossudalfs) both with slopes less than 3%. Mean annual precipitation for the experimental study years was 1,120 mm. Switchgrass cultivar Alamo was established in 2009 by planting 11.2 kg/ha pure live seed with a grassland drill. Switchgrass was planted at 1 to 2 cm depth. No N was applied in 2009, but 56 kg P_2O_5/ha and 112 kg K_2O/ha were applied to the study site. In 2010, 73 kg N/ha was applied.

In 2011, three separate experiments were established at this site to evaluate the effect of N, P and K fertilizer rates on biomass yield. Each of the three experiments was arranged in a randomized complete block design with six replicates. Plots were 2.3 by 8.0 m in size. Four levels of N and five levels of P and K were applied to these experiments as indicated in **Table 1**. Prior to establishing the fertilizer treatments, soil test results indicated that the Mehlich III extractable P was very low to low (8 to 20 ppm) and extractable K was low to medium (50 to 100 ppm) for this soil. In each experiment, the other two primary macronutrients were applied in sufficient quantities such that they would not be limiting (i.e., N applied to P and K trials at 70 kg/ha; P applied to N and K trials at 60 kg P_2O_5/ha; K applied to N and P trials at 120 kg K_2O/ha).

Fertilizer was spread in late April or early May in each year. No other agronomic manage-

Table 1. Fertilizer N, P and K treatments applied from 2011 to 2014.

N	P_2O_5	K_2O
	kg/ha	
0	0	0
50	30	60
100	60	120
150	90	180
	120	240

Fertilizer was applied in the spring of each year, during the month of May.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; LSD = Least Significant Difference. IPNI Project USA-AR33

ment was provided during the growing season. Biomass yield samples were taken each fall in late October by harvesting a 1.4 m wide swath through the length of the 8.0 m plot.

Biomass Yield Response to Fertilizer

Switchgrass biomass yields were not influenced by P or K fertilizer application rates in any of the study years. Mean biomass yields in the P study were 10.8, 13.0, and 13.2 t/ha for 2012, 2013 and 2014, respectively (**Table 2**). Similarly, mean biomass yields in the K study were 10.9, 13.2 and 13.6 t/ha for 2012, 2013 and 2014 (**Table 3**).

Switchgrass biomass yields were significantly affected by N fertilizer rates in 2013 and 2014, but not in 2012. **Table 4** summarizes yields in the N study from 2012 to 2014. In both 2013 and 2014, N applications increased biomass yield above the 0 N control. In 2014, greater segregation of the treatments was observed with the 100 and 150 kg N/ha treatments providing greater yields than both the 0 and 50 kg N/ha treatments. This is comparable to results by Heggenstaller et al. (2009) who showed increasing yields with N application up to 140 kg N/ha. In their study in Iowa, optimum yields after two years was 13.5 t/ha at 140 kg N/ha N rate. The long growing season in Arkansas shows potential for substantial yields with adequate N application.

The final two years of the three-year study was described as a quadratic response in biomass yield due to N treatment (**Figure 1**). Though maximum yield occurred at the maximum N rate, the incremental biomass increase by increased N rate was only significant above the 50 kg/ha rate in year 2014. Economic returns based on price paid for switchgrass biomass will be the key to whether increased N rates are justified.

The three-year mean response to N rate is shown in **Figure 2**. The fitted linear regression indicates that biomass yield increased by approximately 60 kg for each kg increase in N applied above the control up to the max 150 kg/ha N rate. The yields achieved in this study in Arkansas are somewhat greater than those of Heggenstaller et al. (2009), which was in the 12 to 15 t/ha range. The yields obtained, however, were on the greater end of average yields across a 17 state study where mean biomass yield was 12.9 t/ha for lowland switchgrass

Table 2. Switchgrass biomass yields from P fertilizer applications over three years at Colt, AR.

kg P_2O_5/ha	2012	2013	2014
		t/ha	
0	11.2	12.3	12.2
30	10.6	13.1	12.8
60	10.4	13.3	14.6
90	11.4	13.1	13.2
120	10.3	13.0	13.0
Mean	10.8	13.0	13.2
LSD (0.05)	NS†	NS	NS

†NS indicates no significant differences at $p = 0.05$.

Table 3. Switchgrass biomass yields from K fertilizer applications over three years at Colt, AR.

kg K_2O/ha	2012	2013	2014
		t/ha	
0	10.4	12.9	13.1
60	11.2	13.6	13.3
120	10.8	12.9	13.7
180	10.8	13.3	13.8
240	11.3	13.3	14.1
Mean	10.9	13.2	13.6
LSD (0.05)	NS†	NS	NS

†NS indicates no significant differences at $p = 0.05$.

Table 4. Switchgrass biomass yields from N fertilizer applications over three years at Colt, AR.

kg N/ha	2012	2013	2014
		t/ha	
0	10.6	9.3 b	6.7 c
50	13.5	15.1 a	12.8 b
100	11.9	17.5 a	17.9 a
150	15.3	19.4 a	19.6 a
LSD (0.05)	NS†	5.6	3.4

†NS indicates no significant differences at $p = 0.05$. Different letters within the same column indicate differences among treatments.

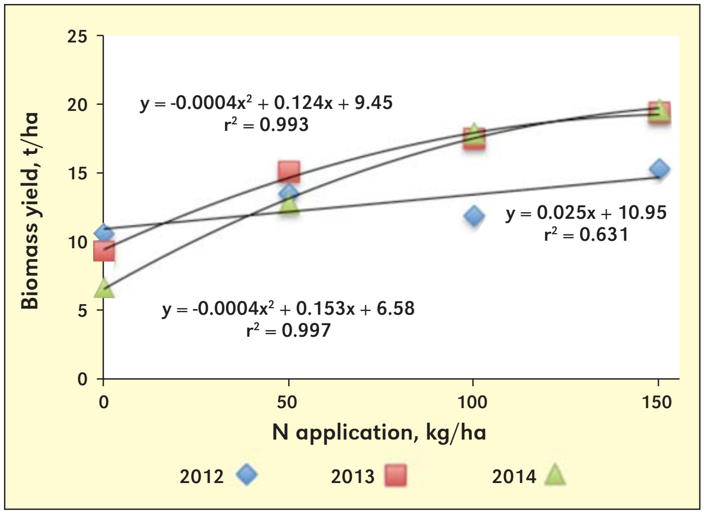

Figure 1. Biomass yield response to N rate. Regression fits for 2012 is linear while regression lines for 2013 and 2014 are quadratic.

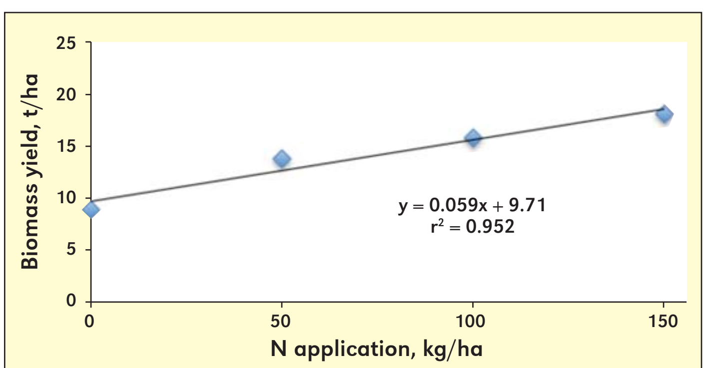

Figure 2. Linear regression fit for the means of biomass yields through the three-year study in response to N rate.

varieties such as Alamo (Wullschleger et al., 2010). Our 17 to 20 t/ha yields are in line with N-fertilized switchgrass grown in west Tennessee, which has a similar climate and growing season as our study site in Arkansas (Boyer et al., 2012).

The lack of yield response to P and K fertilizer is not surprising. There is an abundance of evidence that native warm season grasses do not respond to P and K fertilizer, even on low P and K soils (Brejda, 2000; Muir et al., 2001). There is evidence that native warm-season grasses such as switchgrass are able to meet some of their P requirements as a result of symbiotic relationship with arbuscular mycorrhizal fungi (Hetrick et al., 1991). Additionally, native warm-season grasses have low K requirements and are generally able to meet their K requirements without K fertilization, even on low K soils (Taylor and Allinson, 1982).

Even though yield did not respond significantly to P and K fertilizer, the impact on nutrient removal does need to be taken into account. Increasing P fertilizer rates had no impact on N or K removal, but had a slight impact on P removal in 2013 (**Table 5**). Increasing K fertilizer rates had no impact on N and P removal, but had a significant impact on K removal (**Table 6**). Increasing N fertilizer rates had an impact on N, P and K removal (**Table 7**). Since N fertilizer rates impact yield, N will need to be managed in switchgrass production systems. However, this does not mean that P and K fertilizers can be ignored. With N fertilizer rates of 50 to 100 kg N/ha, switchgrass harvest had removal rates of 65 to 86 kg N/ha, 25 to 31 kg P_2O_5/ha, and 81 to 99 kg K_2O/ha. Management of N fertilizer will necessitate P and K fertilizer applications in order to return P and K removed from switchgrass harvest (Kering et al., 2013). These results are from late season harvest after beginning of senescence of the plant and earlier harvests will likely require even more fertilizer additions than those suggested here.

Summary

Switchgrass grown for biomass energy in a one-cut system responds to fertilizer N, but not to fertilizer P or K, even on low P and K soils. Nitrogen application rates will need to be determined based on fertilizer cost and potential revenue from sale of biomass with an understanding that higher rates of N have the potential to provide substantial increases in biomass. Over the three-year study, average biomass response to N fertilizer was 60 kg biomass/kg N applied. In addition to N management, P and K fertilizer inputs will need to be managed due to P and K removal with harvested switchgrass biomass in order to sustainably produce switchgrass on an on-going basis. BC

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Table 5. Switchgrass N, P and K removal from single fall harvest for biomass at Colt, AR as affected by P fertilizer rate.

	2013			2014		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
kg P_2O_5/ha	-------- kg/ha --------			-------- kg/ha --------		
0	50.7	23.1 c	58.7	50.8	22.0	67.3
30	47.9	26.1 b	63.7	66.6	22.2	71.1
60	49.5	26.4 ab	59.3	66.2	26.6	73.8
90	55.7	28.2 ab	60.0	54.4	26.1	72.2
120	42.9	28.6 a	59.6	55.8	26.1	74.2
Mean (all)	49.3	26.6	60.2	58.8	24.5	71.7
Mean (fertilized)	49.0	27.3	60.7	60.8	25.2	72.9
LSD (0.05)	NS†	2.3	NS	NS	NS	NS

†NS indicates no significant differences at $p = 0.05$.

Table 6. Switchgrass N, P and K removal from single fall harvest for biomass at Colt, AR as affected by K fertilizer rate.

	2013			2014		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
kg K_2O/ha	-------- kg/ha --------			-------- kg/ha --------		
0	54.0	22.5	61.3 d	55.6	24.7	61.9 c
60	54.8	23.4	79.0 c	52.4	22.7	73.0 bc
120	51.3	23.8	84.9 bc	60.9	23.1	88.2 ab
180	55.7	23.8	94.4 ab	51.4	24.1	103.1 a
240	57.0	23.6	97.1 a	59.6	24.3	101.3 a
Mean (all)	54.6	23.4	83.4	56.0	23.8	85.5
Mean (fertilized)	54.7	23.6	88.9	56.1	23.6	91.4
LSD (0.05)	NS†	NS	11.1	NS	NS	15.7

†NS indicates no significant differences at $p = 0.05$.

Table 7. Switchgrass N, P and K removal from single fall harvest for biomass at Colt, AR as affected by N fertilizer rate.

	2013			2014		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
kg N/ha	-------- kg/ha --------			-------- kg/ha --------		
0	49.9	24.3	62.5 b	43.0 c	15.1 c	43.2 b
50	65.5	31.2	98.1 a	67.3 b	25.0 b	81.0 a
100	75.3	31.4	99.0 a	85.9 b	29.6 a	91.3 a
150	97.9	29.8	99.5 a	114.3 a	31.4 a	89.1 a
Mean (all)	72.1	29.1	89.8	77.6	25.2	76.1
Mean (fertilized)	79.6	30.7	98.9	89.2	28.6	87.1
LSD (0.05)	NS†	NS	29.8	20.5	4.1	16.6

†NS indicates no significant differences at $p = 0.05$.

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