TIME OF HARVEST ALTERS NUTRIENT MANAGEMENT OF SWITCHGRASS

Darryl Warncke, Kate Withers, and Kurt Thelen
Michigan State University, East Lansing, MI 48824

Abstract

Switchgrass is one of many cellulosic crops being considered as a biomass feedstock for the production of bioenergy, including ethanol. It is being promoted as a crop that can grow well on marginal lands with low nutrient inputs as well as on more fertile soils. Nutrient removal is important for long-term perennial crop production. A study, established to evaluate the effects of nitrogen rate and harvest management system, was used to evaluate the nutrient removal in switchgrass harvested at different times. Switchgrass was established by seeding in May, 2007. Nitrogen rates of 39, 78 and 157 kg ha^{-1} were applied in the spring of 2008 and 2009. Three harvest systems were used; 1) a two-cut system with the first cutting at early anthesis and the second cutting two weeks after the first killing frost, 2) one cutting taken in the fall two weeks after the first killing frost, 3) over-wintered switchgrass cut in March. Biomass tissue samples were collected for each N rate and harvest time each year. The tissue samples were analyzed for N, P, K Ca, Mg, S, Na, B, Cu, Mn, Zn, Fe and Al. Results were similar for the two site years. Removal of N, S, Mg and Cu was affected by N rate applied. Removal of the other nutrients was not affected by N rate. Potassium removal was most affected by harvest time. With the two cut system an average of 131 kg K ha^{-1} (124 in summer cut alone, sa) was removed annually compared with 44 for the one cut fall harvest and only 4.5 for the over wintered switchgrass harvested in March. Much of the K is remobilized into the root system and/or leached from the plant tissue when the switchgrass is not harvested until late fall or over-wintered. Similar numbers for N, across all N rates, were 95 (80 sa), 59 and 42 kg N ha^{-1}. Nitrogen removal increased with N rate. For P the numbers were 14 (1.9 sa), 6.4 and 3.6 kg P ha^{-1}, respectively. Removal of calcium was increased by delaying harvest until fall. In the fall one-cut harvest 34 kg ha^{-1} Ca was removed compared to 20 kg Ca ha^{-1} in the summer harvest with dry biomass yields of 9.5 and 10.3 Mg ha^{-1}, respectively. Switchgrass harvested when actively growing results in much more K and N being removed from the soil-plant system than when harvest is delayed until after the first killing frost.

Introduction

Switchgrass is one of many crops under consideration for cellulosic ethanol production. As a perennial crop, switchgrass, once established, requires less energy input than corn. The reduced annual cultural inputs minimize fossil fuel use in its production, and thereby improve the overall energy balance. The perennial nature of switchgrass provides benefits through its large deep root system that can cycle nutrients, reduce soil erosion, sequester carbon and enhance soil organic matter and quality. To maintain productivity of a perennial crop requires an understanding of the dynamics of its nutrient accumulation, cycling and removal. Forage crops are known to accumulate large amounts of some nutrients, especially nitrogen and potassium when actively growing. It is important to note that forage and biomass feedstocks, such as switchgrass, grown for bioenergy have different nutrient management objectives that for forages produced for animal consumption. For bioenergy we want to minimize N, K and other nutrients in the biomass for bioenergy quality as well as minimizing nutrient removal reasons. When forage crops, such as switchgrass, begin to senesce, some of these nutrients are mobilized and transported into the root system. The timing of switchgrass harvest, therefore, may greatly affect the amounts of certain nutrients that are removed from the soil-plant system. The objectives of this study were to determine the amounts of essential nutrients removed in harvested switchgrass biomass and to develop an understanding of how harvest management affects this nutrient removal.

Research Approach

A field study, established to evaluate the effects of nitrogen rate and harvest management system, was used to evaluate nutrient removal in switchgrass harvested at different times. The soil at the selected site at the Michigan State University Agronomy Farm was a mixture of Aubbeenaubee-Capac sandy loams (fine-loamy, mixed, active, mesic Aeric Epiaqualfs) and Colwood-Brookston loams (fine-loamy, mixed, active mesic Typic Endoaquolls and Typic Haplaquolls). The upland switchgrass cultivar "Cave-in-Rock" was seeded at 9 kg ha^{-1}, ~1.25 cm deep, with a Brillion double roller seeder on May 24, 2007. The eastern two thirds of the field had a mean pH of 6.4 while the sandier, western third of the field had a mean pH of 5.6. The P and K levels were fairly consistent and slightly below optimum levels. At green up in the spring of 2008 and 2009 nitrogen (urea) was broadcast at rates of 0, 39, 78 and 157 kg N ha^{-1}. Weeds were controlled with S-metolachlor and atrazine. Three harvest systems were used both years. 1) A two-cut system with the first cutting taken during the summer at early anthesis plus a second cutting taken two weeks after the first killing frost (Nov. 5, Oct. 26), 2) One cutting taken two weeks after the first killing frost, 3) switchgrass was over-wintered and cut in March (22, 19). Switchgrass was cut at 18 cm with a commercial forage harvester (model 7650 Hesston) outfitted with a weigh bin. Total biomass was measured for each plot. Subsamples were dried at 100^{o} C for 72 hours or until a constant weight was achieved. Dry biomass yields were calculated. The subsamples were ground and analyzed for N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Zn and Al content.

Results and Discussion

The focus of this paper is the effect of harvest system on nutrient accumulation and removal in the harvested switchgrass biomass. Comments on the N rate effects will be limited. Yields across all N rates and harvest systems ranged from 4.0 to 10.25 Mg ha^{-1} in 2008 and from 9.0 to 12.25 Mg ha^{-1} in 2009. The higher yields in 2009 may have been related to more rain and/or to a more vigorous stand. The yield in judged to be about two-thirds of full potential and in 2009 yield was close to full potential. For the one-cut fall harvest in 2009 biomass yield with 157 kg N ha^{-1} applied was 12.80 Mg ha^{-1} compared to 12.36 with 78 kg N ha^{-1}. For 2008 and for the other harvest systems in 2009 yields with 78 and 157 kg N ha^{-1} were not different.

Across all nitrogen rates biomass yield was slightly lower with the one-cut fall harvest compared with the two-cut system (Table 1). Some harvestable biomass was probably lost due to lodging. Harvestable biomass was much lower when the switchgrass was overwintered. Loss in 2008/2009 was greater due to more snowfall than in 2009/2010. There was significant loss due to lodging, loss of leaves, panicles/peduncles being blown away and probably some loss due to decomposition. When harvested during the summer at early anthesis (just that one cutting), nutrient removal was much higher for N, P, K and slightly higher for Mg and S than with the fall one-cut (Table 1). When the two cuttings of the two-cut system are combined the N, P and K removals are 37.5, 59.5 and 66.3 % greater than in the fall one-cut biomass. This indicates that a large amount of these three elements were being remobilized into the root system as the crop senesced in the fall. When overwintered, even more of the N, P and K was moved below the harvest level (18 cm) due to lodging of plant material and leaching out of the plant tissue into the ground. Leaching of potassium from the plant tissue was especially great as the K concentration changed from 0.40% in the fall senesced plant tissue to only 0.05% in the overwintered tissue. Calcium concentration in the plant tissue actually increased (0.20 to 0.31%) as the switchgrass matured, summer harvest vs. fall harvest. Hence, Ca removal was 40.8% higher in the fall one-cut harvest compared with the summer harvest and 21.9% higher than the sum of the two-cut system.

Table 1. Biomass yield and nutrient accumulations by harvest time. (Two year average).

	Summer	Fall	Fall	Spring
Nutrient	- - - 2 cut - - -		1 cut	1 cut
Biomass, ***Mg ha^{-1}***	**10.3**	**1.2**	**9.5**	**6.3**
N, kg ha^{-1}	80.3 [a]	14.4 [d]	59.2 [b]	42.4 [c]
P, kg ha^{-1}	13.9 [a]	1.9 [d]	6.4 [b]	3.6 [c]
K, kg ha^{-1}	124.1 [a]	6.7 [c]	44.1 [b]	4.5 [c]
Ca, kg ha^{-1}	20.0 [c]	6.4 [d]	33.8 [a]	27.0 [b]
Mg, kg ha^{-1}	18.0 [a]	2.8 [c]	15.6 [a]	7.8 [b]
S, kg ha^{-1}	7.6 [a]	1.6 [d]	5.9 [b]	4.5 [c]

*Data across all nitrogen rates.

**Number in a row followed by different letters are significantly different at p>0.05.

The timing of switchgrass harvest has serious implications for long-term management of N, P and K, especially K. Harvesting switchgrass in the summer will result in a quicker drawdown of available soil K levels. Maintenance applications of potash will be essential. The deep root system may also result in the depletion of K in the subsoil as well in the surface soil. On marginal soils K deficiency could quickly become a limiting factor for yield, longevity of stands and multiple year productivity. On marginal soils it would be recommended to only harvest switchgrass after it has gone dormant. Waiting until Spring to harvest resulted in very little K being lost from the system, but there was a large reduction in harvestable biomass. Harvesting closer to the ground may improve biomass recovery and some increase in K removal.

Harvesting actively growing switchgrass results in more N and P removal from the field. When harvested in the fall 20 or so kg N ha-1 is moved into the root system. Presumably this sequestered N will become available for the next year's crop by cycling through the soil system or by remobilization in the root system. The modest amount of extra P removed when switchgrass is harvested at early anthesis may eventually affect the need for supplemental P.

Removal of boron, iron and manganese is greater in switchgrass harvested in the fall after being allowed to grow for the entire growing season compared to switchgrass harvested in the summer at early anthesis, even though biomass yields are similar (Table 2). Loss of the micronutrients is less when the switchgrass is overwintered compared to the major nutrients. Management of the micronutrients in relation to harvest time is less critical than for N, P and K.

Table 2. Micronutrient accumulations in harvested biomass by harvest time. (Two year average).

	Summer	Fall	Fall	Spring
Nutrient	- - - 2 cut - - -		1 cut	1 cut
B, g ha^{-1}	19.1 [b]	5.0 [c]	26.0 [a]	16.1 [c]
CU, g ha^{-1}	42.1 [a]	8.5 [d]	31.6 [b]	21.4 [c]
Fe, g ha^{-1}	541.4 [b]	119. 2 [c]	867.4 [a]	715.1 [a]
Mn, g ha^{-1}	353.2 [b]	87.4 [d]	469.2 [a]	194.9 [c]
Zn, g ha^{-1}	130.5 [a]	38.9 [c]	116.3 [a]	77.9 [b]

*Data across all nitrogen rates.

**Number in a row followed by different letters are significantly different at $p>0.05$.

Summary

Harvesting switchgrass during the summer at early anthesis resulted in removal of about 7.8 kg N, 3.1 kg P_2O_5, and 14.4 kg K_2O in each Mg of dry biomass harvest. Not harvesting the switchgrass until it has gone dormant in late fall resulted in less nutrient removal; about 6.2 kg N, 1.5 kg P_2O_5, and 5.6 kg K_2O in each Mg (megagram) of dry biomass. More N, P and K inputs will be needed for switchgrass harvested when actively growing, at early anthesis, compared to being harvested after it is has gone dormant.

PROCEEDINGS OF THE

40^{th}

NORTH CENTRAL
EXTENSION-INDUSTRY
SOIL FERTILITY CONFERENCE

Volume 26

November 17-18, 2010
Holiday Inn Airport
Des Moines, IA

Program Chair:
Richard Ferguson
University of Nebraska - Lincoln
Lincoln, NE 68583
(402) 472-1144
rferguson@unl.edu

Published by:
International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
Web page: www.IPNI.net