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Title

Biomass and Macronutrient Accumulation and Losses of Switchgrass During and After the Growing Season

Investigators

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Two field studies were established at the University of Arkansas Agricultural Research and Extension Center in July, 2008. Switchgrass generally produces very little above-ground growth in Year 1 as it allocates a large amount of energy to its strong root systems. Harvestable biomass accumulates in Year 2, while maximum yields occur in Year 3 onward. Thus, data from these studies will be collected in Years 2 and 3 (May 2009 to February 2011). One study will describe growing-season biomass accumulation and NPK uptake curves for switchgrass grown for biomass and the other will determine nitrogen response curves for biomass yield for second- and third-year switchgrass stands. The first study will consist of 12 harvest dates, ranging from May to February. Trends in cumulative growth, moisture concentration, and nutrient concentration and removal will be fitted to regression models as a function of day of year and accumulated growing-degree days. Regressions will be tested on two phases of the year, in-season consisting of May to September, and post-season consisting of October to February. The second study will include treatments of urea applied on April 1 at the rates of 0, 35, 70, 105, and 140 kg/ha of N. One harvest per year will be taken in early October for moisture content and biomass yield. Plant biomass will be sampled to determine N concentration and to calculate N removal and apparent N recovery. Regression analysis will be used to calculate the response functions of biomass, N removal, and apparent N recovery to N application rate.

Objectives

1. Describe growing-season biomass accumulation and NPK uptake curves for switchgrass grown for biomass (Experiment 1).
2. Characterize post-growing-season losses in biomass and macronutrients in delayed-harvested stands of switchgrass for biomass (Experiment 1).
3. Determine nitrogen response curves for biomass yield for second- and third-year switchgrass stands (Experiment 2).

Expected Results

Switchgrass has a reputation for being difficult or slow to establish. This species generally produces very little above-ground growth in Year 1 as it allocates a large amount of energy to its strong root systems. Harvestable biomass accumulates in Year 2, while maximum yields occur in Year 3 onward. It is expected that switchgrass has a high efficiency in converting fertilizer nutrients to harvestable biomass with low removal rates, and therefore low concentrations, especially in the post-season. A single end-of-season (i.e. fall) harvest regime is generally considered the most energy-efficient and input-efficient system for harvesting switchgrass for biomass. We predict that nutrient accumulation will attain maximum during seed filling in late summer to early fall. Harvest can potentially be delayed until after maturity and harvested during the sub-sequent winter months to 1) stagger the work load and transport to a refinery, 2) provide out-of-season wildlife habitat, and 3) allow further moisture loss in the standing crop, which facilitates optimum moisture conditions. During late-season maturation and after frost, when the unharvested plant undergoes senescence and natural drying, switchgrass will likely lose significant amounts of macronutrients by retranslocation to below-ground organs and leaching of weathered foliage. Studies of biomass yield response to N fertilization generally show significant yield increases from 0 to 100 kg ha^{-1} and little or no response at higher N input levels. We expect a quadratic response in our trial, with diminishing slope at the highest increment of N fertilization, with maximum yield in Year 2 at the highest N rate of approximately 7 tons/acre and in Year 3 of 10 tons/acre.

Methods (reflecting changes since the 2008 proposal)

Location: Arkansas Agricultural Research and Extension Center, University of Arkansas Division of Agriculture, on Captina silt loam soils. In Experiment 1, the soil is actually a transition from Mountainburg variant (cobbly fine sandy loam) to Captina, with medium levels of soil-test P and K.

Experiment 1(Growth and nutrient curves): The entire field plot area was seeded with cv. Alamo on 3 July, 2008 (Year 1). Plots received no N fertilizer in 2008, but will receive 67 kg/ha of N as urea on 1 April 2009. The field trial consists of 6 replications arranged in blocks. Each block has 12, 1.8-m x 4.6-m plots consisting of 3 rows at 60-cm spacing, with each plot representing one sampling date.

Treatments will consist of 12 harvest dates, 7 before October 1 (in-season) and 5 from October 1 onward (post-season). The dates for the in-season phase will be May 1, May 22, June 12, July 3, July 31, August 28, and September 30 (expected date of maximum dry matter accumulation). Post-season harvest dates will occur every 28 days henceforth, ending on February 12. On February 12, the regrowth of all other plots will be cleared off the field.

Data will be collected in Years 2 and 3 (May 2009 to February 2011). Each sampling will consist of harvesting 4 m of row length of 2 rows/plot at 10-cm stubble height. After determining the fresh weight, a grab sample of at least 750 g will be weighed, dried at 60°C to constant weight, then reweighed to determine moisture content (fresh weight basis) and to correct the total harvest weight to dry biomass. This sample will be ground to pass a 1-mm screen before laboratory analysis of total ash (loss on ignition), N (LECO combustion), P and K (nitric acid-ICP) concentrations. Nitrogen, P, and K removal will be calculated as biomass yield x concentration.

Trends in cumulative growth (kg ha^{-1}), moisture concentration (g kg^{-1} FW), and nutrient concentration (g kg^{-1} DW) and removal (kg ha^{-1} DW) will be fitted to regression models as a function of day of year (Day 1 = 1 April) and accumulated growing-degree days (base temperature 12°C) using PROC NLIN in Statistical Analysis Systems. Regressions will be tested on two phases of the year, in-season consisting of 1 May to 30 September, and post-season consisting of 30 September to 17 February.

Experiment 2 (N response): Four replicate blocks were seeded with cv. Alamo in 2008 (Year 1), and data will be collected in Years 2 (2009) and 3 (2010). The soil has medium levels of soil-test P and K, and no N was applied in Year 1. In Years 2 and 3, there will be 5, 2.4-m x 8-m plots per replicate (20 plots total), each assigned a different N-rate treatment. Treatments will consist of urea applied on April 1 at the rates of 0, 35, 70, 105, and 140 kg/ha of N as urea. One harvest per year will be taken in early October for moisture content and biomass yield. Plant biomass will be sampled to determine N concentration and to calculate N removal and apparent N recovery. Regression analysis will be used to calculate the response functions of biomass, N removal, and apparent N recovery to N application rate.

Results

In 2008, Experiment 1 was established as planned according to the proposal of June 6, 2008. Seedlings emerged well with fairly low weed competition, although there are some gaps in the rows. These gaps will be filled with transplants from the greenhouse in early April 2009. By the end of the season, plants ranged from 40 - 60 cm tall, and were not harvested. These plots will be mowed on March 1, 2009. Soil will be composite sampled and analyzed for P and K to confirm desired level of medium soil test. This experiment is part of a more thesis comprehensive study by Amanda Ashworth. Additional measurements planned are soil water content monitoring at different depths, gross energy and fiber concentrations, and light interception by the developing canopy. She will also enter the soil, plant, light interception, and weather data into a crop simulation model (ALMANAC by USDA-ARS, Temple, TX) to verify its utility for predicting biomass accumulation and nutrient uptake. We will be working with the model developers to further calibrate and modify it to pertain to Arkansas conditions. This model will be useful in conducting future research on yield and nutrient-use predictions at other sites around Arkansas to verify its utility on diverse soils.

Experiment 2 was planned in the proposal to be established on a large soil site on a different part of the research station that had been in long-term permanent grass. Establishment of switchgrass failed at this site in 2008 owing to a heavy storm that washed soil and seed followed by extremely thick infestation by johnsongrass. Control of johnsongrass was attempted with a combination of mowing and herbicide spraying with no success in developing a usable stand of switchgrass. Fortunately, we established an extra plot area of switchgrass near the site of Experiment 1 that can to serve as Experiment 2 in 2009, but with fewer replications than originally planned (4 instead of the original 6). Therefore, we will proceed with Experiment 2 at the new site, and attempt to reestablish switchgrass at the originally planned site for future trials.

In summary, 2008 was a year of establishment and taking baseline measurements of soil conditions, plus developing our working knowledge of the ALMANAC model. Year 2, 2009, will mark the first of the intensive sampling and data collection years.

We request continuance of funding to support this research according to the budget below.