Switchgrass Biomass Yield and Fertilizer Requirements by Month of Harvest: Economic Consequences of Nutrient Translocation and Remobilization

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Abstract:

If switchgrass harvest is delayed until after senescence, some nutrients will translocate to the plant's crown and roots. Biomass yield and fertilizer requirements depend on harvest date. The objective is to determine switchgrass biomass yield, nutrient concentration in biomass, fertilizer requirements, and expected production cost by month of harvest.

Key words: biomass, cost, feedstock, harvest month, nutrient remobilization, switchgrass, translocate

Switchgrass Yield and Fertilizer Requirements by Month of Harvest: Economic Consequences of Nutrient Translocation and Remobilization

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INTRODUCTION

The U.S. Department of Energy's (2011) 21 Billion-Ton Update reported that 40 to 60 million acres of U.S. cropland and pasture could be converted to produce dedicated energy crops. Early studies on switchgrass production as feedstock for a biorefinery have reported yield decrease associated with delaying harvest past senescence. In most prior studies switchgrass is assumed to be harvested during a narrow time frame after maturity when maximum dry matter yield can be achieved. In the southern plains of the United States the switchgrass harvest window could extend over many months. With an extended harvest window, switchgrass biomass could be delivered just in time to reduce harvest and storage cost. However, with an extended harvest window expected harvestable yield and expected fertilization requirement may differ depending on the month of harvest.

OBJECTIVE

The objective of this research is to determine switchgrass biomass yield and fertilizer requirements by month of harvest and to determine the expected cost of providing a flow of biomass to a biorefinery from an extended harvest period relative to a narrow harvest window.

DATA

Data were produced in a split plot randomized complete block field experiment with six replications over three production seasons from 2007 to 2010. The experiment was conducted at the Oklahoma State University experiment station in Stillwater, OK (36°7.98' N, 97°6.26' W). Treatments on the established stand of lowland switchgrass consisted of harvest month (Nov, Dec, Jan, Feb, Mar). The experiment produced biomass yield and biomass nutrients (nitrogen, phosphorus, and potassium) concentration by month. Statistical methods were used to determine the biomass yield and nutrients content of the biomass as a function of harvest date. Point estimates from these regressions were used to prepare standard enterprise budgets for each harvest month to determine the economic consequences of an extended harvest window on feedstock production cost.

METHODS

- A biomass yield response to harvest date function was estimated.

$$y_{itk} = \alpha_0 + \alpha_1 * date_t + \alpha_2 * date_t^2 + \alpha_3 * date_t^3 + \theta_t + \gamma_k + \varepsilon_{itk} \qquad (1)$$

where y is the yield, date is the harvest date with July 1 = 1, θt and γk are random effects of year and replication, respectively.

- Levels of P and K in the harvested material was also estimated

$$P = f\,(harvest\ date) \qquad (2)$$

$$K = f\,(harvest\ date) \qquad (3)$$

- Points estimates from equations (1) to (3) were used to prepare enterprise budgets for each harvest month following Turhollow and Epplin (2012) and Griffith et al. (2010).
- Budgeted fertilizer costs were based on estimates of nutrients removed in harvested material.

RESULTS

Table 1. Switchgrass Yield Response to Harvest Date ($Mg\ ha^{-1}$)

Effect	Estimate	Standard Error	Pr > |t|
Intercept	-56.0761	27.9452	0.1826
Date	0.8990	0.4134	0.0327
Date2	-0.0042	0.0019	0.0386
Date3	6.32E-06	3.14E-06	0.0471

- The linear, quadratic and cubic polynomial terms were all significant in the yield equation
- Switchgrass biomass harvestable yield differs across harvest month
- Harvestable yield declines from early to late winter (Figure 1)
- Significant yield difference across years
- Figure 1 presents expected yield and expected levels of P and K removal in biomass across harvest month
- Delaying harvest results in a decline in nutrient concentration in biomass confirming nutrient translocation from above ground biomass to the plants crowns and rhizomes.

Table 2. Nutrients in Harvested Biomass by Harvest Month

Month	P_2O_5 ($Kg.ha^{-1}$)	K_2O ($Kg.ha^{-1}$)
November	27	43
December	28	37
January	22	26
February	16	16
March	14	12

- Because nutrients translocate after senescence, fertilization requirements differ depending on previous year harvest date.

Table 3. Cost to Deliver Switchgrass by Harvest Month ($ Mg^{-1})

Month	High cost	Low cost
November	93	53
December	83	48
January	83	48
February	95	55
March	97	56
Average	90	52

Note: High and low cost scenarios are based on different assumptions on establishment, transportation and land lease costs

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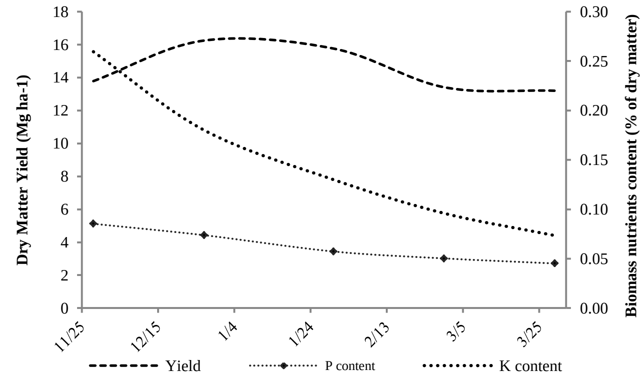
Figure 1. Predicted Switchgrass Yield and Biomass P and K Content by Harvest Date



- Significant yield decrease from the beginning to the end of winter.
- K content declines as harvest is delayed.
- P content also declines as harvest is delayed.
- As harvest is delayed, P and K translocated from the above ground biomass to the below ground root system of the plant from which they can be remobilized in subsequent years.

CONCLUSIONS

- Switchgrass growth continues through December for some years
- Yield declines as harvest is delayed for late winter
- Nutrient translocation continues throughout the winter

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