AGRONOMICS OF SWITCHGRASS FOR BIOFUEL IN THE WEST

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ABSTRACT

Results from two bioenergy field studies evaluating switchgrass and other perennial warm-season grasses in the west suggest differences among grass species and varieties for high biomass yield potential. Switchgrass and Indiangrass seem to be adapted to the west when grown for biomass feedstock production under irrigation. Switchgrass requires several years to become well established with low biomass yields in the first couple years. By year production years three and four switchgrass can achieve high biomass yields equaling or exceeding corn silage. Switchgrass growth is influenced by temperature and daylength. The two biomass feedstock harvest schedule used at Washington State University reveal differences in biomass yield and crop height by species or varieties.

Key Words: switchgrass, corn, bioenergy, ethanol, biomass yield, cellulosic biomass

INTRODUCTION

The native forage crop, switchgrass (*Panicum virgatum*) was virtually unknown to most Americans until President George W. Bush announced in his 2006 State of the Union Address switchgrass could be part of the solution for U.S. energy self-sufficiency (citation). His announcement created great interest in the news media and others about the potential of switchgrass or any other perennial warm-season grass (WSG) to meet domestic energy goals. But to understand the significance of President Bush's address and the implications to U.S. energy policy we need to step back in time, over three decades ago.

The 1973 – 1974 OPEC oil embargo resulted in Americans experiencing long lines at gas pumps where shortages were common and traveling was difficult. The Department of Energy (DOE) launched new research considering switchgrass and many other woody and herbaceous plants for bioenergy in the late 1970's and during the 1980's. Unfortunately most of the western U.S. was left out of any consideration as a potential source of feedstocks for energy independence and essentially no biomass research for bioenergy was conducted in the west during this time. There were a couple innovative western university faculty members (NM and NV) who evaluated the potential of switchgrass and other WSG for forage. Their information and experiencing the oil embargo helped direct my research program for bioenergy in 2002.

This paper reports results from two studies conducted by Washington State University at Prosser, WA. The first is from the original study planted in June 2002, called WSG1. We learned a great deal from evaluating different species and varieties in this study. However, we wanted to

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compare feedstock potential of switchgrass directly with corn (*Zea mays*), which lead to WSG3. Western growers must recognize switchgrass and other perennial WSG require irrigation as the region lacks summer moisture received naturally in the mid-west and the southeastern states. These grasses are not native to the arid-west where our moisture largely comes from winter precipitation (snow) and summers are hot and very dry. Irrigation development has been an on going process for over the last 150 years in the arid-west resulting in a wide diversity of crops grown with high yields and exceptional quality farm products. Can switchgrass or other WSG compete economically and environmentally with these other crops in the west? To answer that question we need to determine if these grasses are adapted to the west under irrigation then what yield and bioenergy potential can they contribute to U.S. biofuel demands?

PROCEDURES

WSG 1 was planted on June 6, 2002 at Washington State University Irrigated Agricultural Research and Extension Center at Prosser, WA. This site is located in the lower Yakima Valley and just west of the greater Columbia Basin project. Two biomass harvests are conducted each growing season, the first in late June to mid-July (Summer) and the final in late September to mid-October (Fall). We had difficulty establishing little bluestem varieties that summer and these had to be reseeded for several more years before achieving adequate biofuel quality stands. Little bluestem varieties were: Aldous, Camper, and Cimarron. Big bluestem was easier to plant and get good biofuel stands, and varieties were: Kaw, Roundtree, and Pawnee. Side oats grama emerged quickly and produced excellent stands that have persisted well, with varieties: El Reno and Butte. Indiangrasses included: Cheyenne, Holt, Oto, and Osage. Switchgrass varieties were: Blackwell, Dacotah, Forestburg, and Trailblazer. Results in Table 1 are averaged over the 2005 through 2009 growing seasons by individual harvest.

WSG 3 was planted on June 3, 2005 and allowed to establish during that growing season. DeKalb DKC51-43 hybrid, a 101 day maturity corn was planted in 2006 and each year thereafter at either 37,400 seeds per acre for grain or 41,800 seed per acre for silage. Silage harvest was conducted when kernels reached the 50% milk line and grain at black layer. Switchgrasses were harvested in late June to mid-July (Summer) or early October (Fall). Grasses in both studies were harvested mechanically leaving 5 to 6 inch stubble at each biomass harvest. Corn was harvested by hand using the standard 1/1000 acre row.

Each year soil samples are collected across WSG 1 and WSG 3 both grass and corn plots. The goal is to maintain P and K levels in the medium to high range and applying 200 pounds of N on the grasses (split application; spring and after first biomass harvest) and 300 pounds of N to corn (planting and sidedress). We have learned to utilize both urea and ammonium sulfate as our N source or severe S deficiencies will likely occur.

Once grasses are established interplant competition generally eliminates weed issues. However, I routinely will apply glyophsate just before spring greenup to kill overwintering annual weeds or any perennial cool-season grass or weed that may have invaded. Spraying this product after grass greenup will certainly kill the WSG. Weeds in corn are controlled by hand pulling.

RESULTS

New growers to switchgrass will quickly realize they'll need a great deal of patience during the establishment year. We have discovered, under irrigation in our region, switchgrass will grow through a unique above and below growth cycle during the establishment year. The goal at the end of this first year is to achieve a productive biofuel stand, which can be challenging. In comparison to a spring planting of traditional cool-season perennial grasses, Figure 1 shows the different establishment growth habit of switchgrass. Expect every weed that ever set seed on your farm to germinate and grow with extra vigor that first year, because it will seem like this has occurred. But if you remember the goal, get a good stand and try to keep weed pressure to a minimum, then rewards of high tonnage will be found in subsequent growing seasons. If soil testing and fertility is maintained and cutting heights respected then switchgrass stands will continue to be productive for many years, irrigation is essential in the west.

Results from WSG 1 are combined by species rather than variety for the last five years for average crop DM at harvest and yield, table 1. Certainly switchgrass has been talked about and yields equally well to indiangrass in the first biomass harvest and better than big bluestem and other grasses. In the fall biomass harvest indiangrass excels in yield compared to other grasses. These data suggest atleast equal consideration should be given to indiangrass as well as switchgrass when considering these strictly for biofuel feedstock production. There are some regions in the west with varying soil or climatic issues where either switchgrass or indiangrass may not be well adapted. In these cases little bluestem, big bluestem or side oats grama or selecting a cool-season grass may be a better choice. Side oats grama is quick to mature, as shown by the higher DM at each harvest, table 1. We started making hay from the WSG in 2009 but as any grower knows, quickly removing moisture is the goal to make stable, dry hay for long-term storage. Initial crop DM is just one segment that must be considered during this process. If you are serious about growing high yielding biomass crops then a tedder is an essential piece of equipment to own.

We measure switchgrass height to the bottom of the seedheads (inflorescence) at each biomass harvest in WSG 3 study, table 2. This provides a measure of productive potential for biofuel rather than forage (which we also measure to the tip of the leaves but data not presented here). Stem tissue is important in bioenergy production and height to the bottom of seedheads gives both a quantitative and qualitative evaluation over time. The lowland varieties, Alamo and Kanlow are usually taller to the seedhead than the upland varieties of switchgrass, table 2. Biomass feedstock yields differ among the summer harvested switchgrasses with Shawnee, Sunburst and Trailblazer all producing more than 6 tons DM/acre. However, yields all decrease for the upland varieties while the lowland ecotypes remain productive in the fall harvest. This is averaged over 4 years (2006 – 2009) and provides some interesting findings and additional questions. For example, the hottest temperatures of summer occur during the fall growth period compared to the spring until about July 4th. So, the reduced fall yields are likely not due to temperature but to change in photoperiod of these grasses. By mid-August we have already lost about 2 hours of daylength and shorter days greatly influence switchgrass regrowth.

Table 3 compares corn silage or grain yields with switchgrasses as the perennial grasses develop into more adult-type plants with more massive root systems. Biomass feedstock yields from switchgrass are low the first two years, 2006 and 2007 compared to corn silage. However, in 2008 both Alamo and Kanlow out yield silage corn while upland switchgrass varieties were not comparable to corn silage production. We had the most unusual and unique spring in 2009. It was very cold and spring switchgrass emergence was delayed for about three weeks. Cold temperatures continued well into May and crop growth was simply reduced. Corn is planted in early May each year and 2009 was no exception. Corn emergence was delayed and early growth slowed with the colder than normal temperatures in May and June. The net result was both corn and switchgrass yields were lower in 2009 than the previous year. However, Kanlow, Shawnee and Trailblazer all yielded significantly more biomass feedstock than corn silage in 2009. I suspect the very cold spring further delayed Alamo's early spring growth that and it couldn't maintain daily typical May and June growth with Kanlow, so these separated. It was encouraging to find Blackwell and Forestburg both yielded over 10 tons DM/acre and Cave – in – Rock was close at 9.9 tons DM/acre in 2009. These results suggest the long-term investment of growing selected and well adapted perennial switchgrasses maybe potentially equal if not out yield corn under irrigation in the west.

I am often asked why we've chosen two biomass feedstock harvests per growing season and what advantage this may or may not have in the west. Grasses grow from the "bottom-up" while legumes grow from the "top-up", which is known by most forage growers in the west. This being understood, and monitoring both temperature and daylength of these short-day grasses grown under well maintained irrigation scheduling, it was clear when observing WSG 1 growth and how quickly early and intermediate varieties when to boot or heading. Thus, we must harvest long before the fall or winter as is normal in the mid-west or southeastern U.S. Otherwise, grass growth essentially ceases as it advances in maturity to heading. More likely, yields will decline as leaves dry and shatter and stems lodge above or at ground level. With later maturing varieties of switchgrass the tendency is to allow them to grow weeks beyond July 4th but this is not my recommendation. The reason comes back to daylength and photoperiod sensitivity of the grass. So, the summer or first biomass feedstock yield maybe increased slightly but at great expense to the fall or second harvest. As shown by tables 1 and 2, there is greater need to increase the fall harvest than summer yields. There maybe locations in the west where three biomass feedstock harvests are possible. In this case I would suspect the first biomass harvest would be earlier than ours allowing a second to occur in early August when adequate temperature, daylength and irrigation water permitted rapid regrowth providing an adequate fall biomass crop. Because our agronomic approach is different than the mid-west or southeastern U.S., irrigated western switchgrass growers will need to more carefully monitor soil nutrients, cutting heights and daylength. A single season biomass feedstock harvest is unlikely for western switchgrasses. One additional point, quality of switchgrass biomass is dynamic and changes by harvests. For example, biomass protein will be highest in the summer while biomass sugar concentrations will be highest in the fall harvest. Digestible NDF fiber will vary by switchgrass variety, by harvest and by year. Although our samples have not returned from the lab for ethanol or BTU determinations, the hypothesis is western grown switchgrass biofuel potential will be equal if not greater than that reported in the literature. Thus, our hypothesis is by maintaining actively growing switchgrass plants throughout the growing season the result in higher total feedstock yields with higher quality fiber of greater energy value.

CONCLUSION

We are living in a very exciting time in agriculture. In 2005 DOE projected 1.4 billion tons of biomass was needed annually to meet the projected bioenergy needs. Of this, 1 billon tons came from agriculture, mostly wastes like wheat straw or corn stover. They also included some from CRP and switchgrass from the mid-west and southeast, nothing of any substance from the west. Our research at WSU since 2002 has focused on perennial warm-season grasses for bioenergy. This work continues forward and results shared in this paper and others still ongoing suggest it is possible the west can become a major contributor to DOE's 1 billon tons of annual biomass. What we urgently need is a market, i.e. we need one (or more) cellulosic biorefinery in the west that is using locally grown feedstock biomass as its source of fuel. I sense the interest is throughout the agricultural industry but growers are not willing to take the risk of establishing these grasses and living through several lower production years if the only market is competing against the traditional grass hay or forage market. To maintain economic profitability with the cellulosic biomass grasses such as switchgrass, transportation cost will likely need to be kept to a minimum. As shown by these results the future could be very bright and profitable for both the western biorefinery industry and the western irrigated biomass feedstock grower.

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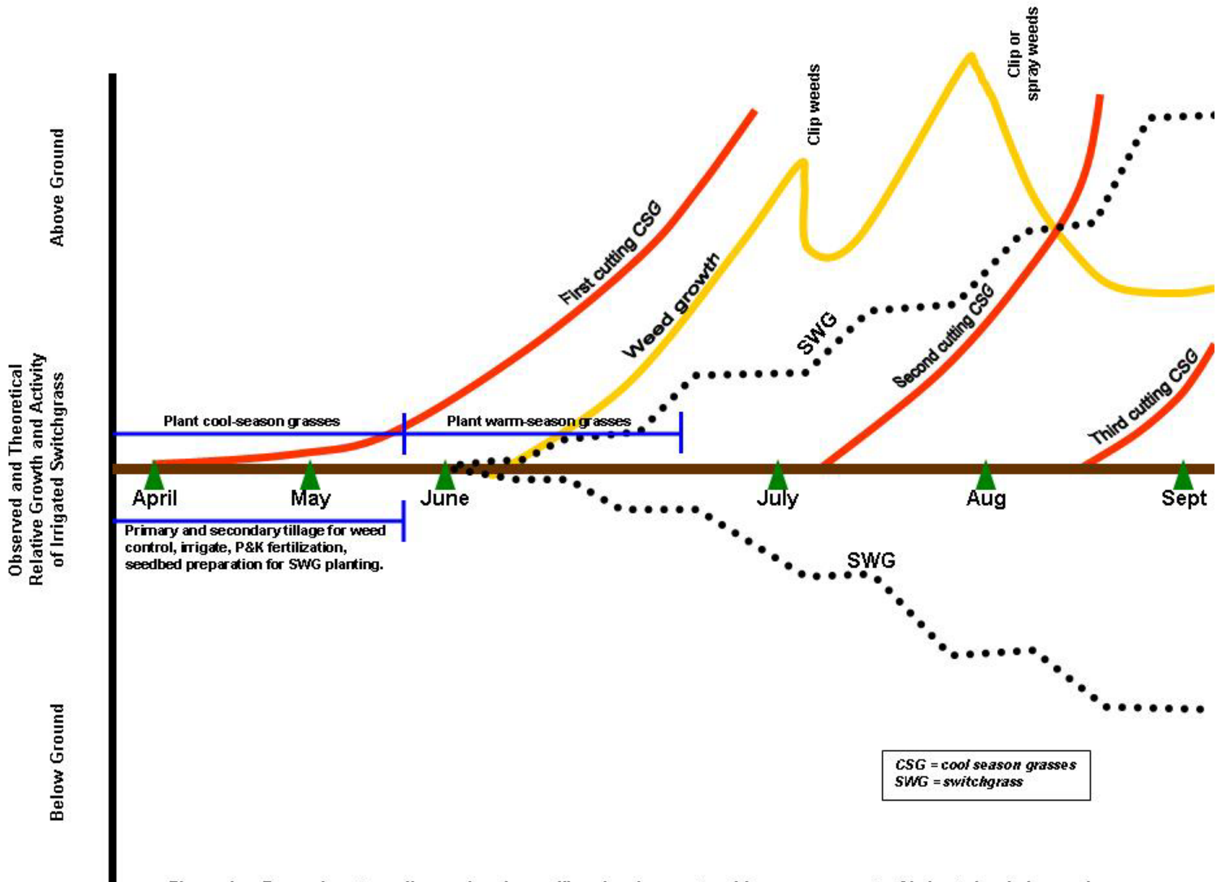

Figure 1. Pre and post seeding and early seedling development and key management of irrigated switchgrass in the Lower Yakima Valley and Columbia Basin.

Table 1. Five-year average for perennial warm-season grass species averaged over varieties for crop DM and biomass yield from 2005-2009 at Prosser, WA

Grass species	Summer Harvest DM -%-	Summer Harvest Yield -TMDA-	Fall Harvest Dm -%-	Fall Harvest Yield -TMDA-
Big Bluestem	30.5	4.9	33.9	2.2
Little Bluestem	33.0	3.2	37.3	2.5
Indiangrass	31.8	5.6	38.6	3.6
Side Oats Grama	41.3	3.0	45.7	1.7
Switchgrass	35.1	5.6	37.6	2.3
$LSD_{.005}$	1.9	0.5	2.4	0.7

Table 2. Four-year average of bioenergy crops by seasonal harvest for height to bottom of seedheads, standing crop DM and biomass yield from 2006-2009 at Prosser, WA.

Crop	Summer Harvest			Fall Harvest		
	Height to bottom seedhead -cm-	DM -%-	Yield -TDMA-	Height to bottom seedhead -cm-	DM -%-	Yield -TDMA-
Corn silage	--	--	--	--	29.1	11.8
Corn grain	--	--	--	--	100	6.5
SWG:						
Alamo	127.6	26.5	5.0	127.6	32.2	6.1
Kanlow	146.2	32.3	5.8	150.9	31.6	5.5
Blackwell	100.4	30.9	5.8	94.8	34.0	2.9
C-in-Rock	105.4	32.6	5.9	98.6	33.7	2.6
Dacotah	81.5	30.1	2.9	79.9	36.6	1.4
Forestburg	100.1	31.0	5.4	97.9	41.5	2.2
Nebraska 28	88.3	28.7	4.0	85.9	40.3	2.0
Shawnee	106.5	33.6	6.3	90.6	31.8	2.5
Sunburst	112.3	34.3	6.0	111.4	41.3	2.4
Trailblazer	100.4	31.1	6.2	88.0	33.7	2.4
$LSD_{0.05}$	6.1	1.5	0.5	8.7	1.1	0.8

Table 3. Total season biomass yields (tons DM/acre) for corn and switchgrass grown for biofuel 2006-2009 at Prosser, WA.

Crop	2006	2007	2008	2009	4-year mean
Corn silage	12.6	12.6	12.3	9.7	11.8
Corn grain	8.1	6.6	6.9	4.4	6.5
SWG:					
Alamo	3.8	8.6	13.8	9.5	8.9
Kanlow	5.0	7.9	14.6	11.6	9.8
Blackwell	6.4	8.7	9.4	10.5	8.7
C-in-Rock	5.8	9.3	9.4	9.9	8.6
Dacotah	4.6	7.9	6.3	4.9	4.7
Forestburg	5.0	7.6	7.7	10.0	7.6
Nebraska 28	4.4	6.3	6.0	7.4	6.0
Shawnee	5.9	5.2	10.6	10.9	8.8
Sunburst	5.4	9.5	9.2	9.6	8.4
Trailblazer	5.6	8.6	9.2	10.8	8.6
$LSD_{0.05}$	1.1	1.2	1.3	1.1	1.5