PERENNIAL WARM-SEASON GRASSES FOR BIOFUELS[1]

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ABSTRACT

Switchgrass (*Panicum virgatum*) is native to the eastern United States but is reported to have only traveled naturally as far west as AZ and NV. This warm-season perennial grass has been grown as a seed crop in the Pacific Northwest (PNW) for more than 20 years but monitoring for adaptability as forage or research into biomass for ethanol production had been lacking until about five years ago. This paper highlights some of our results and a few conclusions from hard-learned lessons and where switchgrass maybe successful for biofuel in the west.

INTRODUCTION AND GROWTH AND DEVELOPMENT OF SWITCHGRASS IN THE PNW

ESTABLISHMENT and EMERGENCE: Switchgrass seed is naked, very small with about 325,000 to nearly 400,000 easy to drill seeds per pound. When planting a clean and firm seedbed using covering chains or packing wheels ensures good soil-seed contact for rapid germination. We have successfully established stands with seeding rates ranging from 7 to 12 pounds PLS per acre with a drill on 6-inch centers. Seed germination for different varieties we have planted has ranged from < 30 to > 70% so it is important to check germination rate then calculate adjusted seeding rate based on PLS then adjust planting equipment appropriately. Weed control is a major issue during the first-year establishment period. Several herbicide trials at Paterson showed Prowl (pendimethalin) applied pre or post-emergence at 0.66 to 1 pound ai/a provided excellent control for many of our problem weeds at both locations. However, Prowl applied to sandy soils at Paterson nearly destroys establishing switchgrass stands. With a loamy soil at Prosser, Prowl used pre-emergence did stunt the switchgrass during the early seedling establishment stage but this lessened as seedling plants were developing. It does not provide season long control because of our irrigation methods that stimulates the weed seedbank. We have found injury differences among switchgrass varieties for post-emergence products. Callisto (mesotrione) damaged both Cave-In-Rock and Shawnee varieties more than Kanlow.

GROWTH and DEVELOPMENT: Switchgrass breaks dormancy from early to mid-April but has less than six inches of growth by May 1st. Early growth is dependent upon irrigation and temperature in our region. With adequate quantities growth will be 20-in or

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taller by late May. With increasing June summer temperatures and sunlight (photoperiod), growth increases significantly and regrowth should occur in 3 to 7 days. The earliest maturing switchgrass variety we've grown is Dacotah, which heads by mid-June and fully headed by July 1st, several weeks before other varieties. July growth and regrowth is rapid if soil moisture is maintained. Our first biofuel biomass harvest occurs within the first two weeks of July and grass will be about 4 to > 6 ft. tall. By leaving 4 - 6 inch stubble at harvest, regrowth will be observed within 3 - 10 days. Growth during August is slowed compared to July, we think not due to temperature or irrigation but due to photoperiod since August temperatures are about the same as July. By September, with cooling temperatures and shorter days, growth is much slower than in August. Initiation of switchgrass regrowth in September will range from 1 to 3 weeks. Final biofuel biomass harvest should be made in late September to mid October leaving suitable stubble for winter survival. We have not experienced winterkill, even though in December 2004 temperatures dipped to -19^{0}F, with any switchgrass varieties. We think this is due to the fall dormancy of the plants in late October to early November. Unlike cool-season grasses that develop a mature stand within 18 months of planting, switchgrass stands will take from 3 to 5 years to develop a mature stage stand. This is a key point to remember when growing switchgrass for forage or biofuel. During the grass maturation stages of growth, the root system continues to grow deeper into the soil without soil limiting factors. Switchgrass roots have the potential to penetrate to 10 ft., much deeper than our cool-season grasses, although we have not yet found this penetration depth in our plots.

Our latest observations were taken on October 30, 2006 when crown and root samples were dug from Cave-in-Rock, Shawnee and Kanlow from 2 year-old stands. We expected all 3 varieties to be fully dormant and in early root shedding but this was not the case. Cave-in-Rock plots did show full root shedding (color of roots changed from white to tan to brown) while Shawnee still had about half white roots and half root shedding. Kanlow, the latest maturing variety of these 3, was the most surprising by showing no signs of root shedding at all at this time. This observation leads to some interesting speculation, i.e. are the higher yields we have measured with Kanlow due to greater crown (rhizome) bud development in the fall compared to the upland varieties of Cave-in-Rock and Shawnee? When does each variety start and stop root generation and root shedding? Then, should we be developing specified agronomic programs for each switchgrass variety if each responds differently to the same environmental stimuli? Finally, what set of agronomic practices results in highest ethanol and biofuel co-products yield, not simply total tons of biomass per acre?

PROCEDURES

During the past five years we have established irrigated field research studies at two locations differing widely in soil texture and nutrient composition. The results reported here are from our work at Paterson, WA, near the Columbia River, (Quincy sand with 0.4% OM; 92% sand, 5.6% silt and 2.7% clay) and Prosser, WA, in the Lower Yakima Valley, (Warden silt loam 1.5 to 2.5% OM; 2-5% slope). Table 1 reports differences in nutrient composition of these soils growing switchgrass biomass. Biomass yields are determined through harvesting various switchgrass cultivars twice per growing season and leaving 4 to 6 in. stubble. Samples are collected from each harvested plot, dried in forced air ovens then ground for analysis. Switchgrass must be irrigated in our region since our average precipitation is < 8 in. per year at either location. Irrigation water was applied though hand-lines and urea fertilizer was applied in the spring and again after first biofuel harvest. Biofuel harvests are taken in early to mid-July and late September to mid-October.

RESULTS AND DISCUSSION

Varieties: Switchgrass is separated into upland or lowland varieties, based on their natural area if evolution and adaptation. Switchgrass spreads by underground stems called rhizomes. Upland varieties have more active rhizome activity so spread more rapidly and fill in rows more quickly than lowland varieties. Morphologically lowland varieties have larger stems, leaves, ligules and panicle seedheads than upland. Additionally, lowlands (likely due from their natural environment) are more sensitive to moisture stress and droughty conditions than uplands. Most importantly, shoot growth from lowlands is only from buds on the rhizomes while uplands have growth from rhizomes buds plus basal culm buds (much like tillering in cool-season grasses). At this time we have only evaluated two varieties which are lowlands, Kanlow (late maturing) and Alamo (very late maturing) with all others being upland types. Last year we planted Alamo for the first time and to date stands are still very weak with an open canopy allowing for greater weed invasion than any other variety in our research. Kanlow has performed very well at both locations. Dacotah is the earliest maturing and may be too early for biofuel production under a 2 cut system in the lower Columbia Basin region. We believe Dacotah maybe best adapted to a higher elevation, shorter growing season where natural precipitation is adequate for this deeply rooted plant to survive. Other varieties evaluated include Cave-In-Rock, Trailblazer, Blackwell, Nebraska 28, Sunburst, Forestburg and Shawnee. Selected variety trial results are presented in tables 2 and 3. Stands of switchgrass are considered to be juvenile for the first 3 to 5 years. Thereafter they would be a mature stand. Table 3 shows the increase in biomass yield over a 2-year period but still within the juvenile stand establishment period. In the second yield of production the varieties seem to be separating compared to the first production year.

Response to Nitrogen Fertilizer: Western soils are less likely to have the high organic matter content compared to eastern soils. When expecting high biomass/biofuel yields we should expect to apply some level of fertilizer if the soils are lacking in adequate amounts of essential nutrients. We recommend soil samples and a complete soil test be conducted before planting a new stand of switchgrass. Nitrogen is a key element in growing any grass crop. Switchgrass responses to nitrogen fertilization is shown on tables 4 and 5. Cave-in-Rock and Shawnee did not respond to the 100 pound N application rate but Kanlow did, Table 4. Shawnee and Kanlow did produce more biomass at the 50 pound rate than Cave-in-Rock while Kanlow yielded more than the other varieties at 100 pounds N rate, Table 4. First harvest responses between the 2 nitrogen rates were not different within a year and 2006 biofuel yields increasing over the 2005 first harvest yields at both nitrogen rates, Table 5.

Biomass Production Response in the PNW: We started growing switchgrass for biofuels only for the last 5 years. Thus we don't have a long history of results compared to other areas of the US, where these tall, warm-season grasses are native. However, we have experienced and identified several important results to consider before planting and growing any perennial warm-season grass in the western US. These include:

- Switchgrass is a long-lived grass and should be considered to have a 10 to 20 year life span. Be patient with this crop, it will take at least 1 year to establish and could take a second depending upon various factors you can or cannot control. The goal is to have a highly productive stand translating into biofuel production.
- Proper stubble heights at harvest is key for rapid second cutting regrowth and adequate stubble height for winter storage of carbohydrates and plant survival (this is as much if not more important than with cool-season grasses like timothy, orchardgrass or tall fescue).
- Stands thicken with age and time and stronger stands will yield more biomass. Lowland types have less aggressive rhizomes and rhizomes of upland types are very aggressive. They may need to be handled differently, we just don't know.
- Weeds will be a problem in the establishment year, know your soil texture as our experience has shown different soils will react to the same herbicide product differently. This can make or break your stand before anything else.
- Know your environment before you select a switchgrass variety. Our research was conducted in winter hardiness zone 6. If you live in a low number zone (more winter) then consider the earlier maturing varieties and vice versa for higher zones.
- Switchgrass does respond to nitrogen fertilizer but we do not know about other nutrients or the minimum rates for N in the PNW. Soil testing will be critical in the early years of stand establishment.
- Switchgrass must be irrigated in the west if: a) you receive less than 25 or more inches of precipitation per year, and; b) if much of that rain doesn't fall during the hot, summer growth period when it is most needed. We believe there are places in the west where switchgrass maybe grown dryland but for the vast majority of land it must be irrigated.
- Finally, results from our second year production stands (still very juvenile) yields were similar to those reported in the mid-west and southeast with six-year old stands. This is encouraging because under irrigation this highly productive crop could diversify the landscape, provide alternative feedstuffs to our livestock and provide a feedstock to meet our energy demands. The environment can be improved though nearly nil CO_2 emissions from switchgrass derived ethanol, we will add to naturally low soil organic matter western soils (carbon credits), we know how to grow perennial crops and make high quality hay – this will not be that much different, and costs of production should be low compared to growing annual crops.

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Table 1. 2006 Soil test for switchgrass research in the PNW.

Analysis	Prosser	Paterson
pH	8.1	6.6
Sol. Salts (mmhos)	0.14	0.10
P (ppm)	14.0	21.0
K (ppm)	121.0	196.0
NO_3 (lbs/A)	14.0	3.0
NH_4 (lbs/A)	21.0	75.0
Ca (meq)	31.4	4.0
Mg (meq)	2.1	1.5
S (ppm)	7.5	2.0
Series	Warden Silt Loam	Quincy Sand

Table 2. First biofuel harvest (TDMA) in 2006 from 2005 planting at Paterson.

Cultivar	Biomass Yield (TDMA)	Estimated Ethanol Yield (gal/A)
Alamo	2.0	183
Nebraska 28	2.4	220
Sunburst	2.9	266
Forestburg	3.0	274
Blackwell	3.2	293
Trailblazer	3.3	307
$LSD_{0.05}$	0.7	70

Table 3. First biofuel harvest (TDMA) in 2005 and 2006 by cultivars from 2004 planting.

Cultivar	2005	2006	$P < _{0.05}$
Cave-in-Rock	2.7	4.2	**
Shawnee	2.4	4.7	**
Kanlow	2.5	5.2	**
$P < _{0.05}$	ns	*	

Table 4. Total season biofuel yield (TDMA) in 2005 from 2004 planting.

Fertility	Cave-in-Rock	Shawnee	Kanlow	$P < _{0.05}$
50 N/A	5.7	7.3	7.5	**
100 N/A	5.9	6.5	9.3	**
$P < _{0.05}$	ns	ns	**	

Table 5. First biofuel yield (TDMA) in 2005 and 2006 from 2004 planting.

Fertility	2005	2006	$P < _{0.05}$
50 N/A	2.5	4.6	**
100 N/A	2.6	4.9	**
$P < _{0.05}$	ns	ns	