ESTABLISHMENT AND MANAGEMENT OF SWITCHGRASS FOR FORAGE AND BIOFUEL UNDER IRRIGATION (OILSEED SERIES)

Summary

Switchgrass (*Panicum virgatum*) is a warm-season perennial grass that has been grown for seed for more than 30 years in the Columbia Basin. Switchgrass and other selected perennial warm-season grasses (WSG) can also be successfully grown in the hotter, irrigated regions of the Pacific Northwest (PNW) as feedstock for cellulosic biofuel or forage for livestock. Research studies were first established with switchgrass and other WSG at Washington State University Prosser in 2002. More than a decade later, this initial planting of switchgrass remained productive. After the establishment year, sprinkler-irrigated WSG fields were harvested twice per season for biofuel and as many as five times for pasture. By understanding and following the guidelines in this publication, we have maintained relatively dense, productive stands (specific to the species and variety) for years. We recognize switchgrass and many perennial WSG to be "sustainable" when properly managed. To accomplish the goal of long-term sustainable forage and feedstock production, the crop must be established properly, which is the focus of this publication.

Variety differences for number of seeds per pound, optimum planting time, weed control practices, growth and development above- and belowground, and establishment year yields of switchgrass under irrigation in the PNW are compared. This publication encapsulates many of our experiences, research results, and recommendations with pre- and post-seeding management and early switchgrass seedling development under irrigation. Guidelines are provided so growers and researchers may avoid critical errors when establishing switchgrass in the irrigated Inland PNW. The goal is to have each planted acre of switchgrass result in a successful stand that overwinters to produce high biomass yields for many years. The principles discussed apply to either forage or biofuel feedstock production when grown under irrigation.

Early Growth Comparisons of Switchgrass to Perennial Cool-Season Grasses

Switchgrass grows differently than traditional cool-season grasses (CSG) grown in the irrigated Inland PNW region. Growers who have easily established cool-season grasses like orchardgrass (*Dactylis glomerata*) or timothy (*Phleum pratensis*) will find establishing switchgrass to be different and certainly challenging.

Seeding year growth, development, and establishment is compared between switchgrass and traditionally grown CSG in Figures 1 and 2. Regional hay growers understand the fine details of successfully producing CSG. Throughout this publication, direct and contrasting comparisons will be made between switchgrass and traditional CSG. The first step in the process of establishing either cool or warm season grasses is an initial weed-free seedbed. Many CSGs germinate at soil temperatures around 45°F, while switchgrass seeds need soil temperatures above 65°F at two-inch soil depths for rapid germination. Those underlying soil temperature requirements occur from mid-March to mid-May for CSG but delay planting from late-May to late-June for switchgrass in the irrigated Columbia Basin and Yakima Valley (Figure 1). Cold, wet spring soils slow germination and early seedling growth of CSGs, which is the reason for a two-month window for optimum spring planting. With warming spring temperatures and longer day lengths, CSG growth increases rapidly resulting in two or three hay harvests during the year of establishment from a spring seeding (Figures 1 and 2).

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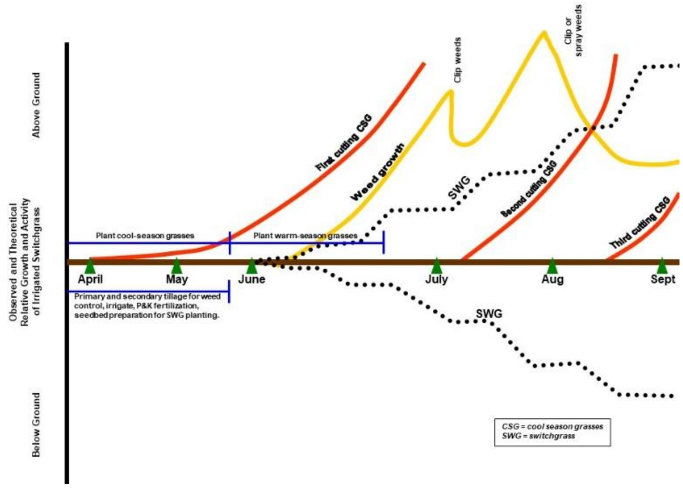

Figure 1. Pre and post seeding and early seedling development and key management of irrigated switchgrass in the Lower Yakima Valley and Columbia Basin.

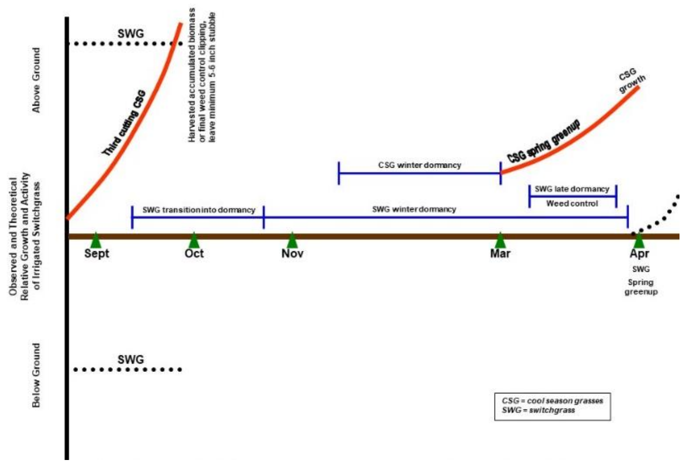

Figure 2. Late seedling development and winter dormancy management of irrigated switchgrass in the Lower Yakima Valley and Columbia Basin.

Switchgrass germination and early seedling growth will likely be difficult to monitor, because switchgrass germinates and emerges slowly (Figure 3), then proceeds through unique, alternating above- and belowground growth periods (Figure 1). This establishment period of growth requires a great deal of patience by the grower, because although the grass looks like it has stopped growing, it has only shifted growth location. Observing growth during July to mid-August will be frustrating, because most growers expect rapid production during this time, especially under irrigation. In seedling year stands of switchgrass, *this is not possible*. Seedling growth of switchgrass is much slower, resulting in less biomass yield than most CSG during the establishment year (Figure 4). Switchgrass develops a more massive root system during the establishment year compared to most CSG. Once CSGs have an adequate root system to support more aboveground vegetation, the plants shift from continued expansion of roots to harvestable forage.

Switchgrass uses the entire establishment year to set the rooting foundation at the expense of high hay yields. However, switchgrass hay production will be much larger than CSG once the crop is well established.

Figure 3. Emerging switchgrass seedlings about 21 days after planting. Photo taken in mid to late June at Paterson, WA.

Figure 4. Early establishing switchgrass seedlings about 30 days after planting. Photo taken in early to mid-July at Paterson, WA.

Switchgrass Seeds and Pure Live Seed (PLS)

Two ecotypes of switchgrass, classified as upland or lowland, have been identified. Upland ecotypes have relatively smaller stems and leaves; plants will be shorter with more aggressive rhizomes resulting in thicker stands over two growing seasons. Lowland ecotypes have much larger stems and leaves, are taller at harvest with less aggressive rhizomes, and require additional growing seasons for more fully developed stands. Native upland switchgrasses are more adapted in the northerly regions, while lowland ecotypes are typically grown in the southern regions of the US. Both ecotypes are adapted to the irrigated regions of the PNW, and growers should consult their local county Extension agent when selecting an ecotype or variety.

Based on seed counts conducted in our lab (four replications of 1,000 seeds each per variety), there was good agreement with the mean number of switchgrass seeds per pound (328,000) compared to published literature values (320,000 to 350,000 seeds per pound) (Table 1). There was more seed size variability within the upland ecotype varieties compared to the lowland ecotype varieties.

Table 1. Average seeds per pound for switchgrass varieties reported in this publication from laboratory testing.

Switchgrass Variety	Ecotype	Seeds per Pound
Alamo	Lowland	481,000
Blackwell	Upland	281,000
Cave-in-Rock	Upland	260,000
Forestburg	Upland	292,000
Kanlow	Lowland	483,000
Nebraska 28	Upland	313,000
Shawnee	Upland	297,000
Sunburst	Upland	283,000
Trailblazer	Upland	267,000
Overall Average		**328,000**
Upland Average	**Upland**	**285,000**
Lowland Average	**Lowland**	**482,500**

Surprisingly, lowland varieties have more seeds per pound than the upland varieties, as each seed is smaller. We observed lowland varieties are slower to develop for the first three to four months than upland varieties (Figure 1). Both ecotypes progress through the alternating above- and belowground growth habit. The lowland ecotypes are worth investing extra time during the seedling stage because they can be the top biomass producers after several years of production.

Switchgrass can be planted at seeding rates ranging from 6 to 12 pounds per acre. Planting about 10 pounds per acre pure live seed (PLS) in the irrigated region is sufficient. The goal is to successfully develop a switchgrass stand by the end of the establishment year. With the difficulties and potential problems in establishing switchgrass stands, it does not make economic sense to skimp on quality seed or planting rate. More critical is planting seed on a PLS basis. Figure 5 is an example of information found on a switchgrass seed tag. Seed tags will not display PLS. One must determine that from the information on the tag. Simply multiply the actual germination by the purity to calculate PLS. Total germination is a combination of dormant seed plus actual rapid seed germination. Do not use total germination percentage as it will underestimate the number of seed needed to obtain a good switchgrass stand. Once PLS is determined for the seed lot to be planted then simply divide the planned seeding rate by the PLS value to give the true number of seed needed to be planted to achieve the target PLS seeding rate. Multiply that value by the number of acres to be planted for the total amount of seed to purchase. Switchgrass seed is expensive, and there is no evidence that higher planting rates will enhance seedling growth during establishment.

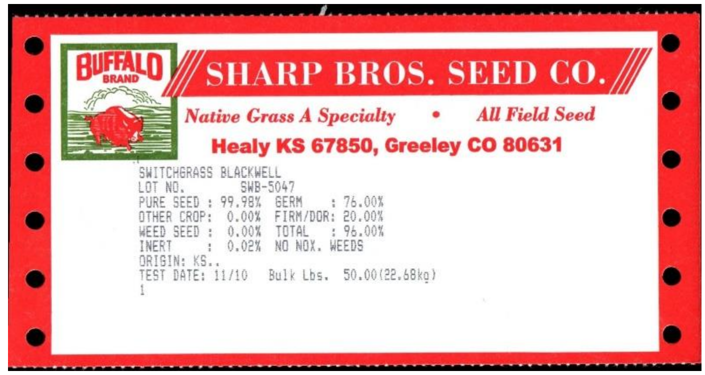

Figure 5. Representative switchgrass seed tag. Note both actual germination and total germination values are reported on tag. Courtesy of Sharp Bros. Seed Co. (2011).

Seedbed Preparation and Planting

Soil testing is important when establishing switchgrass or CSG. Collect representative soil samples, and use soil testing guidelines to apply phosphorus, potassium, and micronutrients before or during seedbed preparation. Avoid applying nitrogen during the establishment year. The growth of switchgrass is very slow for the first six weeks after emergence (Figures 1 and 3), so these small seedlings do not require much nitrogen. Nitrogen encourages weed growth, placing the newly emerged switchgrass seedlings at a distinct competitive disadvantage, so applying it during the establishment year is not recommended. Nitrogen will be a key input once the crop is established.

Primary and secondary tillage is used to prepare the seedbed, incorporate nutrients, and kill germinating weeds. The window of opportunity for spring tillage is longer for switchgrass than for CSGs. Use this long window of spring tillage to control germinating annual weeds, because they will be an ongoing problem after planting and during switchgrass seedling emergence. Switchgrass should be planted about ¼ to ½ inch in a well-packed, cleanly worked seedbed. Test the firmness of a potential new seedbed by walking across it prior to planting. If your footprints are more than ¼ inch deep, then the seedbed is not adequately firm for planting WSGs. Due to the limited time required for establishing a good stand, we do not recommend no-till seeding switchgrass at this time in Washington; however, no-till seeding is recommended in other parts of the United States. Seed can be broadcast or drilled (incorporation and firming) using a Brillion seeder or a grassland drill equipped with depth bands and press wheels. Stand failures may be more common for switchgrass than CSGs in part because of the small seed size, the open planting window is short and only one establishment period per growing season, Figure 1. A nurse or companion crop is never recommended when establishing switchgrass, as young switchgrass plants are poor competitors.

Management of Irrigation Water When Establishing Switchgrass

Since switchgrass seeds are small (Table 1) and planted at a shallow depth, irrigate frequently, almost daily, using light applications, like establishing a lawn for the first ten weeks after planting. It is recommended that growers maintain a moist soil surface but do not allow the soil surface to overly dry or become saturated with ponded water during this critical period. For the first three weeks, apply about 0.05″ of water daily or 0.10″ every other day. Once seedlings emerge, irrigation is critical for another three to five weeks when temperatures are near their summer peak. A missed irrigation event is the difference between stand success and failure. As the new stand reaches about six inches in height, the grass has a deeper root system, then the frequency may be reduced but increase the amounts of applied water. As the grass continues to develop above- and belowground (Figures 1 and 2), transition to a twice weekly irrigation schedule.

Windows for Planting Switchgrass

The recommended window for planting switchgrass is shorter (about May 20th until June 25th) than CSG (about March 15th until May 20th, and again August 15th until September 25th) (Figure 1). Different planting windows for switchgrass were investigated at Othello, Washington. For this study, results from planting dates in 2008 (May 1st, June 16th, and July 22nd) and 2009 (May 15th, June 12th, July 17th, and August 14th) are reported in Tables 2 and 3, respectively. Plots were seeded with a Carter planter using the same seed lot for each planting date each year. Unfortunately, missed critical irrigations during emergence of the May 15, 2008, and June 12, 2009, planting dates resulted in lost results and complete seedling death. Stand determinations were made the next spring after establishment to determine true stand survival following winter.

The 2008 results (Figure 1) support the recommended planting window for switchgrass from May 20 to June 25 for the mid-Columbia Basin. Alamo, a lowland ecotype switchgrass developed and released by the Texas Agriculture Experiment Station, established better stands with a July 22nd planting compared to June 16th (Table 2). Kanlow, another lowland ecotype developed in Kansas and Oklahoma, did not produce a stand when planted in July but did develop adequate stands when planted in June (Table 2).

Table 2. Percent of stand potential of switchgrass plants by variety on May 7, 2009, from two planting dates in 2008 at Othello, Washington.

Switchgrass Variety	June 2008	July 2008
	Percent	
Alamo	5.6	42.6
Blackwell	89.8	54.6
Cave-in-Rock	90.8	80.5
Forestburg	94.4	63.0
Kanlow	57.4	0
Nebraska 28	96.3	51.9
Pathfinder	89.8	43.5
Shawnee	94.4	65.7
Trailblazer	90.7	39.8
Grass Mean	78.8	49.1
$LSD_{0.05}$	5.4	6.7

In the second year (2009), switchgrass varieties were evaluated for successful stands for four planting dates (Table 3). As noted, one or two missed irrigation applications after the June planting negatively affected results. Switchgrass establishment does not require excessive water during establishment, but the soil surface must remain moist during this time.

Table 3. Percent of stand potential of switchgrass plants by variety on June 11, 2010, from three planting dates in 2009 at Othello, Washington.

Grass Variety	May 15, 2009	July 17, 2009	August 14, 2009	Avg over Dates
	Percent			
Alamo	19.1	0	0	6.4
Blackwell	33.9	74.7	53.7	54.1
Cave-in-Rock	56.8	52.5	35.8	48.4
Forestburg	25.3	69.8	48.8	47.9
Nebraska 28	23.5	76.6	58.6	53.9
Kanlow	38.5	0	0	13.2
Shawnee	39.5	79.6	48.8	56.0
Grass Mean	26.9	36.6	24.6	29.4
$LSD_{0.05}$	17.4	24.8	12.4	6.8

Similar trends for specific grasses were found for the two years. For example, Kanlow produced stands when planted in May (2009) or June (2008) but not in July or August of either year. Blackwell, Cave-in-Rock, Nebraska 28, Forestburg, and Shawnee produced stands at every planting date. Pathfinder and Trailblazer were included in 2008 and produced good stands at both dates. Alamo produced its best stands in July 2008 but did not develop a sustainable stand when planted in either July or August 2009. Othello is at 46.8°N latitude, and Alamo switchgrass is likely not as well adapted to the north Basin area. In summary, acceptable stands of upland ecotypes are possible when planted in either May or July, but June is still the preferred month, as shown in Figure 1. Kanlow should be planted in June.

Alamo should be planted no earlier than June or July. These results suggest an additional planting window in July for some switchgrass varieties (Tables 2 and 3), recognizing these stands will be less strongly developed entering fall and winter (Table 5). This provides small grain growers with an opportunity to harvest the small grain crop, prepare and irrigate the soil, and plant switchgrass by mid-July. Irrigation management during the hot summer period will be critical, as complete stand losses will result with missed water applications, as we have experienced.

Weed Management in Establishing Switchgrass

Weed control is important to obtain stands and maximum growth of switchgrass. Growers should begin managing weeds the year prior to planting switchgrass, especially in fields containing difficult-to-control weeds such as perennial grasses. The seedbed can be prepared and packed four to eight weeks prior to planting switchgrass to promote weed emergence. The first one or two flushes of weeds can then be eliminated with non-residual herbicides (glyphosate or paraquat), flaming, or shallow tillage before planting switchgrass. The yellow line in Figure 1 depicts uncontrolled cool- and warm-season annual grass and annual broadleaf weed competition often encountered by emerging switchgrass seedlings. Weeds need to be controlled with herbicides or frequent and ever-increasing heights of mowing, chopping, and removal of weeds so they do not get taller than switchgrass. Moderate weed competition is expected. The better weed management is practiced during the establishment year, the less weed issues there will be in subsequent production years.

The Washington State Department of Agriculture has ruled that switchgrass is considered a forage, fodder, and hay crop (crop group 17), and any pesticide labeled for commercial use on switchgrass grown for forage, fodder, or hay can be legally applied to switchgrass grown for biofuel. Table 4 lists several herbicides that can be utilized during switchgrass establishment. Glyphosate can be applied prior to emergence of switchgrass. We have successfully used preemergent herbicide on newly seeded switchgrass on both sandy and silt loam soils to control a broad spectrum of annual broadleaf weeds. Consult the herbicide label for soil types and percent organic matter requirements for using preemergent herbicides. For postemergence control of broadleaf and grass weeds, several other herbicides are available (Table 4), and all require waiting until the switchgrass has five to six leaves before applying to avoid injury to the young switchgrass seedlings. Annual grass weed escapes can often be controlled with quinclorac. Minor crop injury may result but is normally less harmful than that which occurs if weeds are left uncontrolled. Read and follow labels carefully to avoid crop injury, and do not use herbicides that do not specifically list switchgrass on the label.

Mowing is another option to suppress broadleaf weeds and to reduce the potential weed seed bank. Mow one to three times at a height sufficient to remove no more than the tips of switchgrass seedlings to avoid injury.

Variety Response during Early Seedling Development

Growth differences can be observed between ecotypes during early seedling growth stages. Upland varieties develop more rapidly during seedling growth, probably due to the larger seed size (Table 1). Lowland varieties with smaller seeds develop more slowly, requiring more days to progress through early seedling development. At the end of the establishment season, we consistently observe, at our latitudes, upland switchgrass varieties advance into fall and winter dormancy more rapidly than the lowland ecotypes. There is no visible rhizome activity from either upland or lowland switchgrass seedlings during early growth stages under irrigation.

In October, we measured grass height to the leaf tip when planted in June or July at Othello (Table 5). We found differences among the grasses planted by mid-June, inside the window of opportunity for establishment success (Figure 1), but none in July. End of the season heights of switchgrass varieties planted in July ranged from 37 to 46% of those planted in June (Table 5).

Table 4. Useful herbicides for establishing switchgrass stands for biofuel production.

Herbicide (active ingredient)	Trade Name(s)	Weeds Controlled	Stage of Switchgrass for Herbicide Application
Glyphosate	Many trade names	Broadleaf, grasses	PRE to crop emergence
Quinclorac	Quinstar, Facet	Broadleaf, annual grasses	PRE or POST 3–4 leaf
Dicamba	Clarity, Banvel, others	Broadleaf	POST 3–4 leaf
2,4-D	Many trade names	Broadleaf	POST 5–6 leaf
Sulfosulfuron	Certainty, Outrider	Broadleaf, sedges, quackgrass	POST 3–4 leaf

Note: Products are labeled for use in establishing native grasses in specific situations. Consult labels for additional information. Some products have shown significant injury that on occasion has resulted in some switchgrass mortality at specific locations. Follow all label precautions.

Table 5. October 2008 switchgrass crop height to tallest leaf tip from June and July planting dates at Othello, Washington.

Grass Variety	June Leaf Tip	July Leaf Tip	Ratio in June/July Ht.
	Inches		Percent
Alamo	43.0	16.3	37.9
Blackwell	45.1	15.7	34.8
Cave-in-Rock	41.7	18.5	44.4
Forestburg	29.6	13.8	46.6
Kanlow	43.1	17.5	41.6
Nebraska 28	41.9	18.1	43.2
Pathfinder	43.3	16.2	37.4
Shawnee	40.0	16.9	42.2
Trailblazer	42.6	16.8	39.4
LSD $_{0.05}$	4.2	NS	----

Note: NS = Not significantly different.

Transitioning into Fall Dormancy

As switchgrass seedlings transition into fall dormancy, it is important they have moist but not saturated soils. Although we have not experienced frost heaving of irrigated seedling switchgrass during the dormant period of the establishment year, this does occur in the Midwest and Northeast. Frost heaving occurs on more poorly drained sites where soil temperatures are cooler and with higher soil moisture and alternating periods of freezing and thawing. This action forces the seedling crowns and roots out of the soil. Seeding during the proper window for planting will provide adequate time for deep root development in the PNW.

Switchgrass growth rate decreases with shortening day lengths in the fall as plants enter winter dormancy. Upland switchgrasses will transition into dormancy earlier than lowland varieties. Earlier maturing switchgrasses will transition before later maturing varieties. Figure 6 compares the color difference in a three-year-old stand of upland switchgrass (brown to tan color) compared to a lowland (bright green color) ecotype at Paterson, Washington, in October. The color transitions indicate these grasses are preparing for winter dormancy as leaves progress from green to yellow to tan (Figure 7).

Leaf density in late-seeded stands is very open due to limited time for tillering in early fall (Figure 8), allowing an abundance of sunlight to reach the soil surface. However, within the switchgrass canopy, the lower, older leaves will transition first, even though shading is not a factor. As fall dormancy continues, middle and upper leaves in the canopy transition to lighter colors, like leaves exhibiting nitrogen deficiency symptoms. But this does not appear to be the case. Switchgrass is simply transitioning into winter dormancy and will continue to do so as mature plants (Figure 2). Application of nitrogen or sulfur is not recommended during this transition into dormancy. By mid-November, switchgrass is normally in winter dormancy and if biomass had been harvested earlier, only brown stubble would exist (Figure 9). Stubble height should be above five or six inches (as shown in Figure 9), as carbohydrates stored in the stubble tissue are essential for winter survival.

Figure 6. Fall transition of lowland switchgrass (green) compared to upland switchgrass (yellow) in mid-October prior to final biomass harvest in the establishment year.

Figure 7. Late seedling development of upland switchgrass in mid-October of the establishment year, just prior to fall biomass harvest.

Figure 8. Close-up of late seedling development of upland switchgrass in the seedling year taken in October. Notice leaf discoloration lower in the switchgrass canopy and progression of colors to the upper canopy.

Figure 9. Same late seedling stand as Figures 7 and 8 in the establishment year but after biomass harvest. Switchgrass is now in winter dormancy. Photo taken in mid-November. Notice the critical six-inch remaining stubble, which is essential for winter survival and spring growth. Tall fescue in the foreground was still actively growing when the photo was taken.

CSGs will transition into winter dormancy much later than switchgrass (Figure 1). Even when CSGs are dormant, they will often remain green during the winter dormancy period, a stark contrast to the brown and dead appearance of switchgrass. CSGs break winter dormancy much earlier, often one month to six weeks before switchgrass.

Early September or March is an excellent time to collect soil samples for analysis. March is also an excellent time to consider applying glyphosate herbicide to control winter annual weeds such as cheatgrass (*Bromus tectorum*) that germinated the previous fall. Many winter annual weeds are actively growing in the Lower Yakima Valley and Columbia Basin in March. Additionally in March, switchgrass is in winter dormancy but invading perennial grassy weeds, such as quackgrass (*Elymus repens*) or Kentucky bluegrass (*Poa pratensis*), are actively growing at this time. Glyphosate applied in March will greatly reduce their competitive presence and will not cause harm to switchgrass before it breaks winter dormancy and initiates new spring growth.

Increasing both soil temperature and day length is required to stimulate switchgrass to mobilize sugars from stored tissues to the apical meristems (growing points). Spring green-up of switchgrass ranges from early until mid-April (Figure 2). Growth during April is typically slow because of cool soil temperatures. Fertilizers should be applied at this time based on early September- or March-collected soil samples. Winter annual weeds that escaped glyphosate treatment or newly emerged broadleaf weeds can be controlled with 2,4-D or dicamba at this time. Irrigation should be resumed on these grasses as soils have dried over the winter and the root systems are active again. By comparison, CSGs will initiate spring growth four to six weeks earlier; thus, soil samples and fertilizer application must be completed before active spring growth occurs. Total harvestable tonnage for the growing season in year two will be equal to or greater for the switchgrass than CSGs with fewer harvesting events. Interplant competition from switchgrass is high during the summer months, and few weeds will survive during the major biomass production period. In the Lower Yakima Valley and the Columbia Basin, using good agronomic management of irrigated switchgrass, stands for biomass should be productive for 20 or more years. Many CSG hay stands are typically replanted within 5 years. This should not be the case with well-managed switchgrass.

Establishment Year Yield

A single biomass harvest from switchgrass may be possible in September or October of the establishment year, but yields will likely be variable and will depend on variety chosen (Table 1) and success of stand establishment (Figure 1). On the other hand, CSG will produce two seasonal hay harvests or multiple grazing rotations during the establishment year, plus the possibility of one smaller cutting of hay in October. This is in contrast to WSG where one harvest may be expected during the establishment year. When switchgrass biomass is harvested in the fall, a six-inch stubble height *must* be retained to ensure winter survival and adequate carbohydrate storage for regrowth the following spring.

Planting within the optimum window, late May to late June (Tables 2 and 3; Figure 1), results in grass leaf tip heights exceeding three feet for some switchgrass varieties by October (Table 5). For biofuel, traditional height of grass is not as important as height of the crop from the top of the stem or bottom of the seedhead (Table 6). At biofuel harvest, switchgrass should have a higher stem to leaf ratio. Stem tissue yields more ethanol than leaf tissue. Stem cells have a greater proportion of desirable characteristics for bioenergy rather than for livestock feedstuffs. Varieties differ in both dry matter

(% moisture) and yield in October (Tables 6 and 7). Early maturing switchgrasses will have a higher dry matter (DM) percentage at the single biomass harvest than late maturing types. Establishment year yields will vary among the varieties, as shown in the Othello and Paterson experiments (Tables 6 and 7). These 2 to 4 ton/acre yields are comparable to other studies we have conducted in the establishment year. However, establishment year yields do not reflect yield potential of a particular variety when the grass crop is three to five years old. We expect first year total yields of CSG to exceed those reported in Tables 6 and 7. However, "the rest of the switchgrass story" is high biomass yields in following years.

Animal Health Issues from Switchgrass Forage

Many forage plants form compounds termed "secondary metabolites." These compounds differ from primary metabolites in that they are not essential for specific metabolic pathways or plant functions. Often these secondary metabolites are toxic to animals, people, fungi, and lower tiers of biological life. Some secondary metabolites have been commercialized for drugs and medicines for targeted end uses. For example, saponins, based on the Latin word *sapo* for soap, are found more in legumes than grasses. Oats (*Avena sativa*) have several families of saponins which possess strong antifungal properties. Alfalfa (*Medicago sativa*) produces different chemical saponins compared to oats, but they are similar to other saponins, as they form stable, soap-like foam in water. Oat grain or oat hay and alfalfa hay can be fed safely to horses, sheep, goats, and cattle without fear of saponin toxicity.

Switchgrass produces a family of saponins termed "diosgenin" that is different from either alfalfa or oat saponins. *The saponins in switchgrass are documented to be toxic to horses and sheep. More recently, we have experienced a suspected switchgrass saponin toxicity in goats*. Apparently, all classes of beef and dairy cattle have the ability to detoxify switchgrass saponins and excrete them without harm to the animal. Horses, sheep, and goats must lack this detoxification mechanism, so *forage from switchgrass should not be fed to horses, sheep, or goats*. Damage from switchgrass saponins to these animals appears to be concentrated in the liver. From the early research, it appears both upland and lowland switchgrass varieties possess the same diosgenin saponins with lowland ecotypes possibly having higher concentrations. Leaves have three to four times higher concentrations of saponins than switchgrass stems. Saponins are not an issue as a biomass feedstock.

Table 6. Establishment year switchgrass height from soil surface to bottom of seedheads, percent dry matter, and DM yield from June planting and October harvest in 2008 at Othello, Washington.

Grass Variety	Grass Height to Bottom Seedheads	Crop Dry Matter	Biomass Yield
	Inches	Percent	Tons DM/acre
Alamo	NA	28.3	3.0
Blackwell	31.8	33.5	3.8
Cave-in-Rock	31.8	33.8	3.4
Forestburg	25.1	36.6	2.1
Kanlow	NA	28.6	2.5
Nebraska 28	29.1	38.6	3.0
Pathfinder	NA	31.5	3.5
Shawnee	28.1	31.8	3.0
Trailblazer	29.5	32.9	3.1
$LSD_{0.05}$	3.8	2.6	0.6

Note: NA = Not available; no seedheads produced in the seedling year.

Table 7. Establishment year dry matter and dry matter yield from June planting and October harvest at Paterson, Washington.

Grass Variety	Crop Dry Matter	Biomass Yield
	Percent	Tons DM/Acre
Alamo	36.8	1.8
Blackwell	43.0	4.4
Cave-in-Rock	38.4	3.0
Forestburg	36.8	1.6
Kanlow	33.9	3.3
Nebraska 28	39.8	1.8
Shawnee	36.3	2.9
Sunburst	41.6	2.0
Trailblazer	38.2	2.9
Average	38.3	2.6
$LSD_{0.05}$	ND	0.7

Note: ND = Not determined.

Summary

Switchgrass is a long-lived, warm-season grass, long thought to not be adapted to the irrigated regions of the PNW. Intensive research studies at four locations in the Yakima Valley and Columbia Basin since 2002 have found that switchgrass is well adapted to the region. A major challenge with switchgrass occurs during the year of establishment. The grass requires higher soil temperatures for germination than traditionally grown, cool-season grasses. Seedling growth and development of switchgrass results in a single, low-yielding cutting in the fall. The goal during this establishment year is to develop a dense plant stand and allow the grass to transition into winter dormancy. The fall production can be harvested using traditional haymaking equipment, but five to six inches of switchgrass stubble must remain after harvest to maintain carbohydrate reserves for growth the next spring. This fall-harvested biomass can be used for biofuel or fed to cattle, but never to horses, sheep, or goats. With good agronomic management, switchgrass stands will be highly productive for many years. The future for cellulosic biofuel from switchgrass looks bright, but it all starts the first year by achieving a well-developed stand.

Acknowledgments

We would like to thank the 2007–09 and 2009–2011 WA Legislature for the WSDA-WSU Joint Near-Term Research and Development Bioproducts and Biofuels for funding WSU Project 10A-3319-8008 and 10A-3319-8009. We appreciate the excellent review of this publication by Drs. Bill Johnston (deceased), John Kugler (retired), and Mark Stannard (retired) from Washington State University. Thanks to Dr. Glenn Shewmaker (retired) at the University of Idaho, Mylen Bohle (retired) from Oregon State University, and Dr. Tom Griggs (retired) from West Virginia University for suggestions and review. We also appreciate the helpful review from Dr. Rich Wynia (deceased) from USDA-NRCS Plant Materials Center, Manhattan, KS.

Further Reading

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By
Steve Fransen, Forage and State Extension Agronomist, Emeritus, Irrigated Agriculture Research and Extension Center, Washington State University
Hal Collins, Soil Scientist, retired, USDA-Agricultural Research Service
Rick Boydston, Weed Scientist, retired, USDA-Agricultural Research Service

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