

**SCALE-UP AND COMMERCIALIZATION
OF
NEW SWITCHGRASS CULTIVARS**

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INTRODUCTION

A substantial research and development program was launched in 1992 by the ORNL-BFDP to develop herbaceous species as dedicated feedstock crops for bioenergy production. Switchgrass, *Panicum virgatum* (L.), was chosen as the model herbaceous species for initial R&D on the basis of its wide natural distribution in North America, high biomass production capability, and desirable environmental benefits (McLaughlin, 1992; McLaughlin et al., 1996). The R&D effort has focused on determining best establishment and production practices for switchgrass and on its breeding improvement. Technology advances in these areas are necessary to achieve the scale and economy of production necessary for successful deployment of bioenergy crops like switchgrass.

The switchgrass breeding effort is charged with supplying adapted commercial cultivars with enhanced performance capability for varied climatic and edaphic conditions. BFDP sponsored switchgrass breeding research is underway in Nebraska, Georgia and Oklahoma, with some additional effort in Tennessee and Wisconsin. New cultivar releases are expected from these programs in the near future and thereafter on a sustained basis as incremental improvements are attained through the breeding process. This document is intended to serve as a planning guide for the release of new switchgrass cultivars developed with the support of ORNL-BFDP.

TYPES OF SWITCHGRASS CULTIVARS.

Switchgrass is a long-lived perennial that reproduces by seed. The reproductive mode is sexual and outcrossing results from cross-pollination enforced by strong self-incompatibility. Switchgrass cultivars have traditionally been sexually propagated via seed and new cultivars emanating in the near future from current breeding programs will be the same. The new cultivars are expected to be either: 1) broad genetic base plant populations, 2) synthetics involving a few (~2-12) selected parent plants, or 3) F₁ hybrids. The distinction between 2-clone synthetic and F₁ hybrid varieties is somewhat gray, but the basic distinction would rest on whether generations beyond the F₁ are permitted. Also, Federal Seed Law dictates that seed sold as "F₁ hybrid" must comprise $\geq 95\%$ hybrid seed i.e. have no more than 5% seed from self-pollination.

The fidelity of cultivar types 1 and 2 is best maintained under a certified seed production system that limits seed increase to two or three generations beyond basic (breeder class) seed. Federal and state laws govern the production and sale of certified seed. The fidelity of cultivars under certification is ensured because certified seed fields have to be isolated by legally specified distance from other plants of the same kind insuring that only plants from the same cultivar pollinate each other. Pedigree seed classes are termed 'breeder', 'foundation', 'registered', and 'certified'. For cultivar types 1 and 2, breeder seed is usually the seed that is produced by intercrossing a selected set of parent plants. Intercrossing is normally accomplished by growing the selected parent plants in an isolated field "polycross" nursery. Seed beyond the 1st generation (Syn-1) may be classified as "breeder seed" at the discretion of the Breeder. Under this system, breeder

seed is used to establish plantings that will produce foundation seed, which in turn is used to produce registered seed, and so on.

No commercial F₁ hybrid switchgrass cultivar has been produced to date, but it is technically feasible to produce such **seed**. An F₁ hybrid cultivar could potentially be developed by mass clonal propagation of two highly self-incompatible parent plants and transplanting these in mixture (perhaps alternating rows) in seed production fields. Recent technology perfected by tissue/cell culture specialist Bob Conger through ORNL-BFDP supported research at the University of Tennessee enables the mass cloning of individual plants (Alexandrova et al., 1996a & 1996b).

CULTIVAR RELEASE PROCEDURES.

Specific release procedures of new switchgrass cultivars will be dictated by the policies of the institution owning the cultivar. In general, public institutions now release plant cultivars without restriction or with restrictions. Cultivars released without restriction are available to the general public without limitation on use or sale of propagating material except for those specifically specified in the release notice or required by seed certification laws. The initial increase of propagating stock is usually handled by a foundation seed service, but there is no requirement for producers of propagating stock to maintain the cultivar under certification.

Restrictions on how cultivars are produced or marketed, or both, are achieved through intellectual property protection or licensing, or both. Sexually reproduced cultivars may be protected against unauthorized use via the Plant Variety Protection Act (PVPA), or through the granting of a utility patent if developed by “non-obvious” means beyond manipulating “products of nature”. For most switchgrass varieties, the likely means of protection will be achieved through the PVPA. Protection was extended to F₁ hybrid cultivars by the 1994 PVPA Amendment Act. The certification option within the PVPA mandates that seed can be sold by cultivar name only as a class of certified seed. Private grass seed companies began releasing their cultivars under PVP as soon as the option became available. Until recently, many public forage breeding programs did not release their cultivars under PVPA because of the amount of work and associated expenses of obtaining the data to get PVP registration. Non-certified seed of unprotected cultivars can be sold under a cultivar name which can and has led to problems of cultivar identity which cultivars such as Alamo switchgrass and Hycrest crested wheatgrass. Consequently many public programs are starting to release their forage cultivars under PVPA.

The release of new cultivars by public research agencies under exclusive or semi-exclusive licensing arrangements has become increasingly common over the past two decades. This usually places a new cultivar with one to a few companies (grower groups in some cases) who have the exclusive production and marketing rights. The owner is typically remunerated through an agreed upon fee structure usually based on seed sales.

There are arguments for and against exclusive releases by public research agencies, but such releases have generally worked well. This is particularly true for crops like perennial grasses that require specialized seed production and seed processing technology and for which planting seed demand is relatively low compared to major annual food and feed crop species. Exclusive release can be effected in a manner that provides incentive to the licensee(s) to help assure market success of a cultivar by promotion (e.g. advertising) and quality assurance (e.g. maintain the cultivar under certification and sell only high quality seed). New switchgrass cultivars being developed with ORNL-BDP support can likely be most effectively and efficiently delivered to the public through the mechanisms of exclusive release and PVP. There have been some problems with exclusive release of forage cultivars to single companies because of later mergers or mismanagement.

NRCS lists of seed companies specializing in grass seed production and marketing are included in the appendix. Additional listings and information is available from the American Seed Trade Association website at www.amseed.com and the Southern Seedsmen's Association website at www.seedsmen.com.

PREPARING FOR RELEASE

Testing and Characterization of Candidate Cultivars.

The release of a new plant cultivar by a public research agency (or agencies) is contingent on sound scientific data demonstrating that the cultivar is superior to existing commercial standard cultivars in one or more important performance traits, or combination of performance traits. It is incumbent on the breeder to document the performance of breeding materials by adequate testing through space and time. Multi-environment performance testing of switchgrass breeding materials from ORNL-BFDP supported programs is facilitated by the network of scientists and sites available to assist in evaluations. New switchgrass cultivars are expected to conform to the generally recognized criteria of a "variety" i.e. to be identifiable and reproducible within defined levels of variation. The development of descriptive information sufficient to distinguish the new cultivar from existing cultivars is the responsibility of the breeder.

Seed Scale-Up.

Seed scale-up usually begins when experimental breeding lines reach the final stages of evaluation. Such scale-up is necessary to support the generally greater number and larger size of plantings in the final testing. For synthetic cultivars, it is also desirable to have some performance data on generations beyond the Syn-1. The desired amounts of seed may vary from a few kilograms to a few hundred kilograms, depending on the number and size of the final test plantings.

When the Breeder decides to release a new cultivar for commercial production, it is important to have an adequate quantity of breeder class seed to establish the desired amount of foundation class production. Foundation class pedigree seed is generally produced under the auspices of state Foundation Seed Organizations. Functionally, the

Breeder and the Foundation Seed Organization usually work together closely to achieve the desired foundation seed increases. The foundation seed is used to establish plantings to produce either registered or certified seed. The registered class **PLS 6991** omitted for **all recent** switchgrass cultivars because it is not needed to produce adequate quantities of seed.

Switchgrass Seed Production.

Switchgrass seed in commercial channels comes either from “wild” harvests of natural stands or drilled swards, or from dedicated seed production enterprise. This section focuses primarily on the latter. Dedicated switchgrass seed production is currently confined mainly to the Great Plains and Corn Belt states, with the former being the historical region of highest production. Substantial switchgrass seed production occurs in the Great Plains states of Texas, Oklahoma, Kansas, Nebraska, and South Dakota. Switchgrass seed is also produced in Missouri and Iowa.

Moser and Vogel (1995) note that scientific data on switchgrass seed production is sparse. Much of the available information comes from producer experience. Switchgrass seed yields vary greatly depending on cultivar and growing conditions, but typical yields range from 150 to 500 lbs. pure seed per acre (PSA). Under optimal conditions PSA yields of 1000 lbs. or more are attained. In west Texas and southwestern Oklahoma, ‘Alamo’ seed yields from irrigated production have averaged around 150 pure live seed (PLS) lbs. acre⁻¹, corresponding to about 200-250 lbs. PSA (Turner, 1999). Stock Seed Company, Murdock, NE, obtains PLS yields in the neighborhood of 150-200 lbs. acre⁻¹ from upland switchgrass cultivars (e.g. Cave-in-Rock, Pathfinder, Blackwell, NE 28) grown in rows without irrigation (Fritz, 1999).

Establishing and managing seed production fields. Smith et al. (Undated) provide much practical information on switchgrass seed production in their publication “Native Grass Seed Production Manual”. Copies of the two pages of information on switchgrass in this manual are appended. Establishment and production practices across regions will deviate in minor ways from those outlined in this manual, but the information is generally applicable across the current switchgrass seed production area. Seed production fields are usually planted in rows 3 to 3.5 feet apart at seeding rates of 1.5 to 2 PLS lbs. acre⁻¹.

The key factors affecting stand establishment are soil moisture and weed competition. Typical management practices for established stands include annual fertilization in the spring with 50 to 100 lbs. N acre⁻¹ plus the addition of P and K if soil test results indicate low levels. In southern production areas, additional N at rates of 20 to 40 lbs. acre⁻¹ may be applied through the irrigation system in mid-summer and again in late summer. Seed production fields are often burned in the late winter or early spring prior to fertilization. Fields planted in rows are often cultivated in spring after burning and prior to fertilization.

Seed is either direct combined or swathed and dried prior to combining. The shorter upland switchgrasses are amenable to direct combining while the much taller and more

robust lowland types are not. The indeterminate flowering habit of switchgrass causes seed to mature over a period of 2-4 weeks. Harvest occurs when the majority of the inflorescences have seed in the hard dough stage. Some seed will have shattered by this time.

Time requirement. Seed scale-up of a traditional switchgrass cultivar with breeder, foundation, and certified classes usually requires 3 to 5 years to attain the levels needed for its establishment in commerce. The seed scale-up scenario in Table 1 assumes a planting rate of 2 lbs. PLS acre⁻¹ and PLS seed yields of 50 and 100 lbs. acre⁻¹ for establishment year and subsequent years, respectively. The scenario in Table 2 assumes the same planting rate, but PLS seed yields of 50 and 150 lbs. acre⁻¹ for establishment year and subsequent years, respectively. Scenarios 1 and 2 would respectively result in 531,250 and 1,125,000 PLS lbs. of certified seed in the fifth production year which would permit the seeding of 100,000 to 200,000 acres of biomass production fields per year. These scenarios assume good production practices and the ability to minimize the effects of drought. If the demand is high, seed producers will move production to irrigated fields with high yield potential of 500 to 1000lbs per acre. This occurred during the Conservation Reserve Program.

Table 1. Time line for seed scale-up of a cultivar with breeder, foundation, and certified seed classes. Assumptions include a seeding rate of 2 pure live seed (PLS) lbs. acre⁻¹ and PLS seed yields of 50 and 100 lbs. acre⁻¹.

Class	Years									
	1		2		3		4		5	
	------(Cumulative acres) Total PLS lbs.-----									
Breeder†	(1)	50	(1)	100	(1)	100	(1)	100	(1)	100
Foundation			(25)	1250	(75)	5,000	(100)	8,750	(125)	11,250
Certified					(625)	31,250	(3,125)	187,500	(7,500)	531,250

†One polycross nursery established with equal numbers of clonal plants of each parent plant in a design to promote random intercrossing. Plants could be spaced about 3 feet apart. Foundation and certified production fields established by seeding in rows.

Table 2. Time line for seed scale-up of a cultivar with breeder, foundation, and certified seed classes. Assumptions include a seeding rate of 2 pure live seed (PLS) lbs. acre⁻¹ and PLS seed yields of 50 and 150 lbs. acre⁻¹.

Class	Years									
	1		2		3		4		5	
	------(Cumulative acres) Total PLS lbs.-----									
Breeder†	(1)	50	(1)	150	(1)	150	(1)	150	(1)	150
Foundation			(25)	1250	(100)	7,500	(175)	18,750	(250)	30,000
Certified					(625)	31,250	(4,375)	281,250	(13,750)	1,125,000

†One polycross nursery established with equal numbers of clonal plants of each parent plant in a design to promote random intercrossing. Plants could be spaced about 3 feet apart. Foundation and certified production fields established by seeding in rows.

The time line for scaling up production of F₁ hybrid cultivars would depend on the capability of mass cloning the two parent plants. Plants equally spaced 3.5 feet (rows and plants in rows spaced 42 inches) would require 3,556 plants acre⁻¹ (1778 clonal plants of

each parent). A 100-acre field would then require 355,600 plants, or 177,800 plants of each parent. Assuming PLS yields of 50 and 150 lbs. acre⁻¹ in the 1st and subsequent years, respectively, the yields from the 100 acre field would then be 5,000 lbs. in year 1 and 15,000 lbs. in subsequent years.

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