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Improvement of Switchgrass as a Bioenergy Crop

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11.1 Introduction

Switchgrass (*Panicum virgatum* L.) is a widely adapted, perennial C_4 grass native to the prairies of North America. Switchgrass was identified by the United States Department of Energy (DOE) as its main herbaceous, dedicated energy crop because of its potential for high fuel yields, environmental enhancement characteristics, and ability to grow well on marginal cropland without heavy fertilizing or intensive management. Methods for establishing and managing the crop are well documented and no more difficult than other perennial warm-season grasses. Switchgrass is grown currently for hay, pasture, and conservation uses, but for bioenergy production it will be used mainly as a feedstock for ethanol. Although named cultivars are available, when compared to other high value forages, the species is barely removed from the wild from a crop improvement standpoint. Therefore, potential exists to improve the grass as a biofuel feedstock through breeding, biotechnology, and management research.

Switchgrass is a highly self-incompatible, out-crossing species, therefore, conventional breeding methodologies currently include population improvement with the eventual development of synthetic cultivars, and the possible production of F_1 hybrid cultivars. The main traits of interest for switchgrass improvement are yield, improved seedling establishment, and increased feedstock quality. The use of genomic and transgenic technologies is new, and still in the initial stages for the grass. Microsatellite markers are being developed, and an initial framework map and mapping population are publicly available. Effective modes of tissue culture regeneration are documented, and transformation was successfully achieved using both microprojectile bombardment and *Agrobacterium* protocols. Recent grant awards should continue to advance genomics and transgenic information available to solidify its role as the major dedicated herbaceous energy crop in the USA.

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11.2 Rationale for Using Switchgrass as a Bioenergy Crop

The Bioenergy Feedstock Development Program (BFDP) was begun at the DOE's Oak Ridge National Laboratory in 1978 (McLaughlin and Kszos 2005). For over 25 years, this program sought to select the most promising plant species for use as bioenergy feedstocks. As a result of this process, switchgrass was chosen as the main herbaceous crop for future research due to its high yield, perennial nature, its soil and wildlife enhancing ability, ability to be established from seed, its status as a native grass, and its adaptability to poor soils and marginal cropland.

The BFDP-sponsored switchgrass research projects resulted in a reduction of its projected production costs by 25% mainly from documenting the highest yielding, currently available cultivars on a regional basis, from management research that optimized harvest methods and timing, and from fertility studies that minimized nitrogen fertilization (McLaughlin and Kszos 2005). The BFDP-sponsored breeding research developed improved switchgrass cultivars with higher yields. Other research on high carbon sequestration in the crop's below ground biomass also demonstrated other indirect but positive benefits for growing the grass.

A recent, and extremely important report, was an on-farm evaluation of switchgrass as cellulosic ethanol crop as grown in North and South Dakota and Nebraska (Schmer et al. 2008). Switchgrass was managed as a biomass crop on marginal cropland on 10 farms in the region. There was great variation in both precipitation and temperature, resulting in yield variation of 5.2–11.1 Mg ha^{-1}. However, switchgrass produced 540% more renewable energy than consumed, produced 93% more biomass yield and equivalent net energy when compared to human-made prairies, and its estimated greenhouse gas emissions were 94% lower than that of gasoline. Since this study was initiated in 2000, and genetics and management techniques have been improved since that time, the authors concluded that the energy sustainability and biofuel yield of switchgrass would be further enhanced if this same study was conducted today.

Finally, due to the high price of oil and tightening supplies of gasoline, the economic value of switchgrass has increased substantively (Bouton 2007). This situation has opened the door for increased investment into the genetic improvement of the crop as a basic feedstock for the still developing biofuel industry.

11.3 Botanical Description of Switchgrass

Switchgrass is an erect C_4 perennial grass that can reach up to 3.0 m in height (Moser and Vogel 1995; Vogel 2004). Most switchgrass genotypes are caespitose (i.e. they grow in small dense clumps) and possess short rhizomes that allow it to form a loose sod over time. It is native and widely adapted to North America, being found growing in the continent from 20° north latitude to almost 60° north latitude (Moser and Vogel 1995) and east of 100° west longitude (Vogel 2004). It is a predominant component of the North American prairies, and along with indiangrass (*Sorghastrum nutans* (L.) Nash), and big bluestem (*Andropogon gerardii* Vitman), compose the "big three" grasses due to their composing the greatest percentage of the species