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Genetic variation among switchgrasses for agronomic, forage quality, and biofuel traits

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GENETIC VARIATION AMONG SWITCHGRASSES FOR AGRONOMIC, FORAGE QUALITY, AND BIOFUEL TRAITS.

by

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DISSERTATION TITLE

Genetic Variation Among Switchgrasses for Agronomic, Forage Quality, and Biofuel Traits

BY

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GRADUATE COLLEGE
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GENETIC VARIATION AMONG SWITCHGRASSES FOR AGRONOMIC, FORAGE QUALITY, AND BIOFUEL TRAITS.

Andrew Arnold Hopkins, Ph.D.
University of Nebraska, 1993

Advisor: Kenneth P. Vogel

Objectives of this research were to (1) determine genetic differences among 'elite' switchgrass populations for agronomic, forage quality, and biofuel traits; (2) determine the magnitude of genotypic by environmental (G x E) interaction for these traits among elite switchgrass populations; (3) determine genetic variation among switchgrass accessions for agronomic, forage quality, and biofuel traits; and (4) determine the magnitude of G x E interaction for these traits among switchgrass accessions. Elite populations were planted in sward trials at Mead, NE, Ames, IA, and West Lafayette, IN, in 1990 and evaluated in 1991 and 1992. The 23 accessions, collected from remnant midwestern prairies, and five elite check strains were evaluated in space planted nurseries at the same locations in the same years. Forage was sampled at a vegetative growth stage and at heading. Forage yield was determined at heading, for both experiments; regrowth was sampled and harvested for the sward trial. Some populations in the sward trial consistently ranked high for forage yield despite large G x E interactions. Two such populations, Cave-in-Rock and Cave-in-Rock High Yield-DMD C1,

also ranked high for holocellulose yield, a potential biofuel trait. The population Ey x FF High IVDMD Cycle 3 WS had consistently high forage quality at the vegetative growth stage and at heading, despite large G x E interactions at the latter growth stage. Regrowth forage yield and quality was low. Among accessions, G x E interactions were important for agronomic and forage quality traits, although forage yields of some accessions, namely IA34 and IL62, were comparable to forage yields of check strains. Also, some accessions should provide useful genetic variation for forage quality traits. Developing switchgrass populations for broad areas of the midwest for forage and/or biomass feedstock production will require evaluating advanced populations in sward trials at multiple locations in multiple years. Remnant prairies will provide useful genetic variation for agronomic, forage quality, and biomass traits, although G x E interactions will need to be considered when evaluating such germplasm.

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INTRODUCTION

Switchgrass (*Panicum virgatum* L.) is a perennial warm season grass native to the tallgrass prairie that is commonly used for forage production and conservation purposes. Switchgrass is a C_4 species (Waller and Lewis, 1979) and can complement cool season grasses in grazing programs by supplying forage during the summer months. This species has a wide range of adaptation, with native populations being reported from Mexico to Ontario, and from Arizona to Massachusetts (Hitchcock, 1950).

Wide variation in chromosome number of switchgrass has been reported. Nielsen (1944) found chromosome numbers of 18, 36, 54, 72, 90, and 108 in accessions collected from central North America, primarily the Great Plains, and concluded that the genomic chromosome number of switchgrass was x=9. Switchgrass cultivars examined by Riley and Vogel (1982) were found to be either tetraploid or hexaploid. They concluded that switchgrass behaves meiotically as a diploid during microsporogenesis and that breeding methods developed for cross-pollinated diploids such as maize (*Zea mays* L.) would be applicable to switchgrass.

Genetic variation for several traits has been reported in switchgrass, which is nearly a 100% outcrossed species (Talbert et al., 1983). Within the cultivar 'Pathfinder', which originated from Kansas and Nebraska germplasm, genotypes

were found with cold tolerance sufficient for adaptation to Ottawa, Ontario (Hope and McElroy, 1990). Newell and Eberhart (1961) found significant variation for rust reaction, presumably incited by *Puccinia graminis*, in switchgrass populations. They also reported heritability estimates of 0.16 - 0.62 for visually rated forage quality. In a divergent selection experiment, Vogel et al. (1981) obtained realized heritabilities of 0.59 for high *in vitro* dry matter digestibility (IVDMD) and 0.55 for low IVDMD. Heritability estimates for digestibility have generally been higher than those observed for forage yield. Godshalk et al. (1986) reported heritability estimates on a within half-sib family basis of 0.60 for IVDMD and 0.20 for forage yield in a switchgrass population. Hopkins et al. (1993) used parent-progeny regression to calculate a heritability estimate of 0.40 for IVDMD in a population similar in origin to the one Newell and Eberhart (1961) used to derive a heritability estimate of 0.05 for forage yield. Genetic variation has also been reported in switchgrass for nitrogen concentration in initial growth and IVDMD of regrowth (Godshalk et al., 1986).

Forage quality of switchgrass can limit productivity of ruminant animals. Although anti-quality factors are thought to occur in switchgrass (Puoli et al., 1992), low digestibility is an overriding concern. Anderson and Matches (1983) found that switchgrass should be initially grazed prior

to the boot stage, the R_0 growth stage in the system of Moore et al. (1991), to exceed maintenance requirements for most classes of livestock.

Improved switchgrass digestibility has become a major breeding goal due to the importance of forage quality. Godshalk et al. (1988) used a selection index to achieve a significant increase in regrowth IVDMD for switchgrass germplasm originating from the southeastern USA. Vogel et al. (1981) reported a significant shift in IVDMD after one cycle of divergent recurrent, restricted phenotypic selection (RRPS) for IVDMD in Ey x FF Cycle 0, a base population of switchgrass. Anderson et al. (1988) showed that the population selected for increased digestibility led to substantially increased animal gains per hectare compared to Pathfinder, which is similar in origin and breeding to Ey x FF Cycle 0. The high IVDMD selection was released as the cultivar 'Trailblazer' (Vogel et al., 1991). Three total cycles of RRPS in the Ey x FF germplasm have resulted in further gains in IVDMD, without a significant decline in forage yield (Hopkins et al., 1993).

Changes in cell wall composition have occurred as a result of selection for increased IVDMD in switchgrass. Gabrielsen et al. (1990) found no consistent differences in detergent fiber components between the high IVDMD, low IVDMD, and unselected strains developed by Vogel et al. (1981).

However, lignin composition changed with selection for IVDMD. Concentration of para-coumaric acid (PCA) was higher for both the low IVDMD and unselected strain compared to the high IVDMD strain. Para-coumaric acid is a phenolic compound associated with reduced cell wall digestibility, perhaps due to cross linkages between lignin and hemicellulose (Morrison, 1974). Gains in IVDMD obtained with further cycles of selection in the Ey x FF germplasm were found to be associated with increased cell wall digestibility (Hopkins et al., 1991). In turn, increased cell wall digestibility was associated with lignin composition changes.

Improved forage yield is often an objective in switchgrass breeding. Using index selection for forage yield in switchgrass, Godshalk et al. (1988) improved forage yield over a base population without decreasing IVDMD. In contrast, two cycles of RRPS for forage yield has been unsuccessful in other switchgrass populations (Hopkins et al., 1993).

In the future, breeding switchgrass for traits related to biomass fuel production may be important. In such a system, fuel ethanol would be produced from cellulosic biomass (Lynd et al., 1991). Switchgrass has been suggested as a useful source of biomass because of its productivity (Cherney et al., 1990). Whether biomass fuel production becomes a reality hinges on production economics and environmental factors.

Information on genotypic by environmental (G x E) interactions is important to breeders developing broadly adapted cultivars, and switchgrass producers. However, research examining genotype by location interactions in switchgrass has not been reported to date. The lack of information is somewhat surprising since switchgrass is grown throughout the central USA.

This dissertation reports on research conducted using two sets of switchgrass germplasm. One set consists of 20 'elite' switchgrass populations, including seven cultivars and 13 experimental breeding populations. These elite populations include almost all switchgrass cultivars which are or may be available during the next decade for forage production, and perhaps biomass production, in the midwest. Genetic variation for economically important traits will be needed for breeding gains to be made in switchgrass. Remnant prairie sites may be a source for useful genetic variation in switchgrass. The second set of switchgrass populations evaluated in this research consisted of accessions collected from remnant prairie sites.

Research objectives of this dissertation were to (1) determine genetic differences among 'elite' breeding populations of switchgrass for agronomic, forage quality, and biomass fuel feedstock production traits; (2) determine the magnitude of genotypic by environmental (G x E) interactions