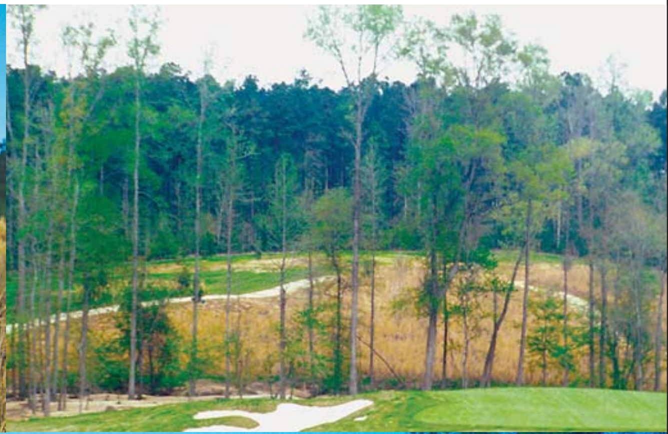
Bulletin 1132 June 2003

Evaluation of Native Grass Cultivars for Mississippi Golf Course Natural Areas Under Variable Management: Part I — Soil pH of 5.2



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Evaluation of Native Grass Cultivars for Mississippi Golf Course Natural Areas Under Variable Management: Part I — Soil pH of 5.2

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Introduction and Literature Review

In recent years, the use of native grasses on golf courses has increased dramatically. Native grasses have potential applications in secondary roughs and natural areas on golf courses for aesthetics, improved wildlife habitat, adaptability, and low maintenance. Only a few older golf courses now use native grasses. Currently, golf course architects tend to implement these concepts into their plans, and most new golf courses establish native grass natural areas.

Several major federal environmental statutes were enacted following the adoption of the National Environmental Policy Act (NEPA) in 1970. Since 1970, state and local legal involvement in environmental issues has increased (Powell, 1998). The Environmental Protection Agency was also created in 1970 (Powell, 1998). Several federal statutes have potential impacts on golf course developments. These include the Clean Air Act of 1970, the Clean Water Act of 1972, the Endangered Species Act of 1973, the Comprehensive Environmental Response, Compensation and Liability Act of 1980, the Oil Pollution Act of 1990, and the Resource Conservation and Recovery Act of 1976 (Powell, 1998). As a result, in certain areas of the country, planting and/or preservation of natural areas is encouraged, or mandated, by local and state governments. State environmental policies are generally required to mandate federal statutes, but they may have certain refinements specific to the state's environmental needs. In addition to state and federal requirements, local governments may use ordinances and rezoning conditions (Powell, 1998) to increase the amount of natural area on a development, such as a golf course. At present, planting of natural areas on golf courses in many areas of the country is still voluntary. However, in the future, government may have an increasing influence on the development of golf course natural areas. Reduced maintenance, reduced pesticide and fertility applications, enhanced wildlife and plant habitat, increased natural green space, and environmental buffering make natural areas a means for achieving the goals of many environmental statutes.

There were an estimated 13,951 golf courses in the United States in 1990 covering an estimated 1.3 million acres of maintained turfgrass (Balogh and Walker, 1992). These numbers indicate tremendous potential for additional utilization of native grasses on golf courses. The current planting increase has surpassed research on the adaptability of these grasses in a golfing environment.

The South and Middle Atlantic are among the states with the greatest density of golf course facilities (Balogh and Walker, 1992). There are more than 156 golf courses in Mississippi (Richard et al., 1996), but few currently utilize native grasses in natural areas. The focus of this study was on the adaptation and utilization of grass species that are native to Mississippi and may have potential for golf courses. However, this information may be useful in several other states, since many grasses are native over a large part of the Southeast. As with turf, development of cultural requirements for a new grass species generally requires several steps and independent studies. Information of this nature could be utilized by both superintendents and architects by providing some cultural guidelines for using native grasses on Mississippi golf courses.

Forage research has been conducted with some commercial native grass cultivars in Mississippi (Edwards et al., 1994), but forage qualities (like those associated with high productivity) may not be desirable in a golfing, or natural, environment.

Several native grass species are used as ornamentals (Greenlee, 1992; Grounds, 1998; King and Oudolf, 1998; Ottesen, 1989), but these are primarily vegetatively propagated cultivars. Vegetative planting of large areas, in most cases, would not be cost-effective. No research regarding golf course adaptability of native grass cultivars has been conducted in Mississippi.

A considerable amount of research has been conducted with regard to the species in these studies. Since this research is important and constitutes the efforts of numerous disciplines, a literature review has been included for the benefit of golf course superintendents unfamiliar with this information.

Geographic Distribution and Ecology

Native grasses are members of the Poaceae family that originated in a given environment and are therefore adapted to it. As a result, grasses native to the western Great Plains, such as buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.], may not be adapted to the Southeast. Big bluestem (*Andropogon gerardii* Vitm.) was the dominant species of tallgrass prairie vegetation of the Great Plains (80%) (Weaver, 1968). It is also a component of many Southeastern grasslands, but to a lesser extent. In addition to variation in species distribution, varieties and ecotypes may also vary from state to state, or among environments within a state. As early as 1940, ecotypes of big bluestem were observed by Law and Anderson (1940). Many commercial native grass cultivars are actually selections of naturally occurring ecotypes. It has been demonstrated that performance problems can result from moving southern ecotypes of switchgrass north or moving northern switchgrass ecotypes south (Vogel, 2000).

Chromosome numbers have been counted for most commercial cultivars of big bluestem, indiangrass [*Sorghastrum nutans* (L.) Nash], and switchgrass (*Panicum virgatum* L.) (Riley and Vogel, 1982; Vogel 2000). Ploidy variability within a site has been discovered in switchgrass (Hultquist et al., 1997) and big bluestem (Keeler, 1992). Polyploidy in big bluestem was also studied across the tallgrass prairie region by Keeler (1990). Norrmann et al. (1997) indicate that there are 90-chromosome cytotypes of big bluestem, although most of the commercial cultivars are 60-chromosome cytotypes (Vogel, 2000). Despite these differences, there have been no commercial forage cultivars of big bluestem, indiangrass, little bluestem [*Schizachrium scoparium* (Michx.) Nash (Syn. *Andropogon scoparius* Michx.)], or switchgrass selected from Mississippi or the Southeast.

In the Southeast, many of the native grasses are relatively tall (Hitchcock, 1971). In Mississippi, many of these grasses can be found in small prairies, like the Jackson and Blackland Prairies. In these physiographic regions, big bluestem, broomsedge (*Andropogon virginicus* L.), indiangrass, little bluestem, side-oats grama [*Bouteloua curtipendula* (Michx.) Torr.], and switchgrass make up the majority of the native grasses in open areas. These grasses also occur in many other areas of the state and Southeast, especially broomsedge, which tends to frequent low pH soils (Pierre and Robinson, 1937; Staley and Wright, 1991).

In order of taxonomical standing, there are species, botanical varieties, ecotypes, and cultivars. Furthermore, some grass species have botanical varieties and some do not. The author considers the term “variety” to be synonymous with botanical variety. Cultivars have been considered “cultivated varieties,” and in publications the term “variety” has been used synonymous with cultivar (Alderson and Sharp, 1994). However, botanical varieties are not cultivars. Cultivars (derived from “cultivated varieties”) are generally selected ecotypes of species, or their botanical varieties. Therefore, to avoid confusion, the term “cultivar” will be used throughout the text, even though other authorities may refer to them as varieties.

Seed Characteristics and Seeding

Most native grass areas on golf courses are planted by seed. Despite a fair amount of research on native grass seed characteristics and establishment, failures are common (Moser, 2000). Big bluestem, indiangrass, and little bluestem seed have appendages and pubescence that make planting with conventional planters difficult. A process has been developed to remove these from seed, thereby reducing bulk and seed density and improving flowability (Vogel et al., 1998). Despite this process, most natural areas are still planted by hydroseeders with or without mulch. Neither method overcomes the fact that there is variation in seed characteristics both within and among cultivars of a species (Bortnem and Boe, 1993), and especially among different species. For example, scarification of neoteric switchgrass seed was shown to increase germination by 73% (Jensen and Boe, 1991), but hull removal from indiangrass seed has resulted in lower field establishment (Geng and Barnett, 1969).

Seed size has been associated with early seedling vigor in grasses (Haynes et al., 1997; Smart and Moser, 1999). However, in switchgrass, seed size apparently has minimal long-term effects upon growth and development of seedlings (Smart and Moser, 1999). Despite their findings, Aiken and Springer (1995) stated that seed size and soil texture had a greater effect on emergence than did planting to a depth of 20 mm. Aiken and Springer also noted that the presence of light had no effect on switchgrass germination. However, the Association of Official Seed Analysts (1991) uses light as part of their protocol for switchgrass, as well as big bluestem, little bluestem, and indiangrass seed germination.

Seed dormancy has long been an issue when planting native grasses (Coukos, 1944; Emal and Conard, 1973; Geng and Barnett, 1969; Knapp, 2000; Rafii and Barnett, 1970). Knapp (2000) provides an excellent overview of seed dormancy in native warm-season grasses. In the mid-1940s, Coukos (1944) noticed that stored big bluestem, little bluestem, and indiangrass seed did not begin normal germination until 14 to 18 months after harvesting.

Attempts have been made to improve germination characteristics through seed priming. Treating seed with acid scarification, sodium hypochlorite, and prechilling can increase germination and seedling shoot dry mass (Haynes et al., 1997). Gibberellic acid and prechilling treatments have improved germination in indiangrass (Watkinson and Pill, 1998). Additionally, Geng and Barnett (1969) observed cultivar differences in response to prechilling in indiangrass. Zarnstorff et al. (1994) found that postharvest storage of switchgrass seeds at 23°C from January to April (90 days) should ensure adequate germination at time of seeding. They went on to say that germination started to decline after 180 days to 2 years. However, seed priming of broadcast native grass seed under field conditions may not be feasible, as indicated by research with some commercial cultivars of big bluestem and switchgrass (Beckman et al., 1993). The Association of Official Seed Analysts (1991) uses both potassium nitrate and 2-week prechilling at 5°C as part of their protocol for germinating big bluestem, little bluestem, indiangrass, and switchgrass seeds. Germination temperatures are slightly variable from 15-30°C day-night regime for switchgrass to 20-30°C day-night regime for big bluestem, little bluestem, and indiangrass. More research is needed with regard to the influence of soil temperature on germination.

There is information indicating the importance of soil microorganisms in seedling establishment (Brejda et al., 1993; Brejda et al., 1998). Brejda et al. (1998) observed a 15-fold increase in shoot and root yield in switchgrass seedlings inoculated with rhizosphere microflora. In addition, Clark et al. (1999) indicated that symbiotic arbuscular mycorrhizal fungi (AMF) may play an important role in acid soil tolerance of switchgrass seedlings. However, Bona and Belesky (1992) evaluated switchgrass acid soil tolerance based more upon plant genetics. A considerable amount of work has been conducted on big bluestem-mycorrhizal relationships (Hetrick and Wilson, 1989; Hetrick et al., 1990; Hetrick et al., 1988; Kitt et al., 1988). The role of mycorrhizae in nutrient uptake is presented in the section on fertility.

Reeder (1957) indicates that many warm-season grasses have a mesocotyl (subcoleoptile internode), unlike cool-season grasses (Festucoid type). This mesocotyl in warm-season grasses is associated with placing the coleoptilar node near the soil surface (Moser, 2000). According to Elbersen et al. (1999), accuracy of soil surface placement of the mesocotyl in switchgrass is a heritable trait. This is believed to be responsible for survival of warm-season grass seedlings at deeper soil depths compared with cool-season grasses (Tischler and Voigt, 1987). However, broadcast planting, where water is not limiting, may help eliminate problems associated with planting seed of certain species too deep (Redmann and Qi, 1992).

The developmental morphology of native grasses varies. Switchgrass and big bluestem are determinate in growth habit (Mitchell and Moser, 2000), as are indiangrass (Dahl and Hyder, 1977) and certain other native warm-season grasses. The fact that culm growth terminates with inflorescence development is important when trying to evaluate usage, or placement, of these grasses for use on a golf course based upon plant height. Temperature and photoperiod are important environmental factors influencing plant growth (Briske, 1991; Gillen and Ewing, 1992). Growing degree days (GDD) and day of the year (Hendrickson, 1992; Mitchell et al., 1997) are important influences upon developmental morphology. Photoperiod can influence floral induction and subsequent developmental morphology (Briske, 1991). Both switchgrass and big bluestem are sensitive to photoperiod and require shortening day length for floral induction (Benedict, 1941). Indiangrass may be intermediate in flowering behavior by displaying complete or partial inhibition of flowering when days are too short or too long (Allard and Evans, 1941). Developmental morphology of certain big bluestem and switchgrass cultivars is predictable (Mitchell et al., 1997). Predictability can add validation to data with regard to estimates of maximum plant height. However, Sanderson and Wolf (1995) attribute 4-week maturation delays in switchgrass to differences in latitude. Therefore, the timing of maturation and flowering can be site-specific.

Despite the development of germination standards for big bluestem, little bluestem, indiangrass, and switchgrass in the laboratory (Association of Official Seed Analysts, 1991), problems with field germination remain an issue. Some of these problems may be inherent in the seed at planting, while others may be due to cultural aspects.

Burning

Research on burning to maintain native warm-season grasses is available (Allen et al., 1973; Benning and Bragg, 1993; Bentivenga and Hedrick, 1991; Cuomo et al., 1996; Cuomo et al., 1998; Dhillion and Anderson, 1993; Engle et al., 1993; Engle et al., 1998; Howe, 2000; Masters et al., 1992; Masters et al., 1993; Mitchell et al., 1994; Mitchell et al., 1996; Owensby et al., 1970; Peet et al., 1975; Rains et al., 1975; Schacht et al., 1998; Strait and Jackson, 1986; Svejcar and Christiansen, 1986; Vinton et al., 1993). Cuomo et al. (1998) observed increased tillering in big bluestem, indiangrass, and switchgrass subjected to spring burning, but burning in May can reduce yields (Cuomo et al., 1996). Little bluestem has shown adverse responses to late-growing-season burning (Volesky and Connot, 2000) but not from the removal of dead standing material in spring (Schacht et al., 1998). These studies illustrate the importance of timing when implementing burns.

In areas where burning is not permitted, thatch accumulation could become a successional problem, particularly with more productive species such as big bluestem and switchgrass (Howe, 2000; Sanderson et al., 1999). As a result, species composition may change (Howe, 2000). Based upon growth responses due to increased nutrient levels, Van Auken et al. (1992) speculated that thatch accumulation could lead to dominance by indiangrass over little bluestem.

Thatch removal or clipping harvest may be necessary on grass stands of little bluestem and other native grass species where burning is not permitted. Sanderson (2000) provides an excellent discussion on cutting management of warm-season native grasses from a forage perspective. There is some indication that timing of summer mowing of switchgrass is critical (Anderson and Matches, 1983) to stand persistence and should be conducted during spring or early summer vegetative growth. However, big bluestem may be more tolerant of midsummer mowing based upon grazing studies by Moser and Vogel (1995). Some tolerance may be partially due to region. Big bluestem has shown greater tolerance to defoliation in the Southern corn belt compared with areas farther west (Forwood and Magai, 1992). These studies may be valuable for golf courses that intend to control height of certain areas through mowing. However, winter mowing and/or harvesting of dead stand material may be more feasible.

Winter harvesting of dead stand material may have little effect upon growing season productivity of big bluestem, little bluestem, and switchgrass, according to Schacht et al. (1998). However, they did not determine long-term effects of dead stand material removal upon soil nutrient levels. Since most research with native grasses are forage studies, summer harvesting of biomass has been addressed. More research is needed regarding the influence of dead stand harvesting upon soil nutrients in Mississippi, particularly over a long period.

Weed Control and Herbicides

Weeds can be a major problem when establishing native grass stands (Cornelius, 1944). Mitchell and Britton (2000) provide a good discussion on weed management in native warm-season grasses. Burning to control weeds has also been studied (Engle et al., 1993; Masters et al., 1992; Masters et al., 1993). Burning may also assist in controlling native cool-season grasses where native warm-season grass monocultures are desired, although timing appears to be important (Howe, 2000; Mitchell et al., 1996). Research also indicates that an increase in forbs may result following late-growing-season burns in mid-successional tallgrass prairies (Engle et al., 1993; Engle et al., 1998). These studies indicate the importance of timing when using burning as a method for weed control.

Despite this research, burning may not provide adequate weed control for all weed species, or users. Additionally, burning is not an option on many golf courses, particularly those located in urban areas. Where burning does not provide adequate results or is not permitted, herbicides may offer an effective weed control alternative to burning.

Some research with preemergent herbicides has been conducted, but mostly for forages. There is some indication that atrazine applied in midspring at 2.2 kg of active ingredient per hectare (kg a.i./ha) can increase germinable seed number in stands of indiangrass (Masters et al., 1993). This atrazine rate has shown good results in stands of big bluestem during establishment (Masters, 1995). At this rate, no phytotoxicity was reported in indiangrass by Masters et al. (1993), or in big bluestem by Lawrence et al. (1995), Masters (1995), and Masters (1997). Genetic tolerance to atrazine in indiangrass seedlings has been observed (Kube et al., 1989). McKenna et al. (1991) recommended a 1.1 kg a.i./ha rate of atrazine for switchgrass, indicating that the 2.2 kg a.i./ha rate reduced yields. However, Hintz et al. (1998) and Vogel (1987) observed good results using a 2.8 kg a.i./ha rate of atrazine as a preemergent herbicide during planting of switchgrass and big bluestem. Lawrence et al. (1995) observed similar results with this rate on big bluestem.

It is possible that these herbicides can be used on a wide range of native grasses, but additional research is needed. Atrazine is a restricted-use herbicide due to ground and surface water concerns (Ahrens, 1994). Since many native grass areas are adjacent to water, the use of atrazine may have limitations in these areas. Simazine has similar weed control properties (Ahrens, 1994) for these areas, but it creates fewer environmental concerns.

Metolachlor has been recommended as a possible herbicide replacement for atrazine for establishing big bluestem (Masters, 1995). Metolachlor at 2.2 kg a.i./ha and 3.3 kg a.i./ha for preemergent weed control has shown good results in big bluestem establishments (Anderson et al., 1997; Masters, 1995). More preemergent herbicide research for natural areas is needed.

Where monostands of native grasses are desired, postemergent broadleaf weed control may be necessary. Atrazine has some early postemergent herbicide activity (Ahrens, 1994). Engle et al. (1993) researched the use of atrazine and 2,4-D following summer burning on little bluestem and other grasses. The 2,4-D treatments gave the best control of broadleaf weeds compared with atrazine. Stands were also better in 2,4-D-treated plots compared with atrazine and untreated plots. Following burning, Engle et al. (1993) observed similar results comparing atrazine and 2,4-D. Bromoxynil (0.56 kg a.i./ha) has shown good broadleaf control in stands of big bluestem and switchgrass (Peters et al., 1989).

Postemergence control of grass weeds would pose the greatest problem for native grasses, particularly warm-season grass weeds. Cool-season grasses can generally be controlled during the winter with glyphosate while native warm-season grasses are dormant (Mitchell and Britton, 2000).

Warm-season grass weeds, such as crabgrass (*Digitaria* sp.) (Cornelius, 1944), fall panicum (*Panicum dichotomiflorum* Michx.) (# PANDI), yellow foxtail [*Setaria glauca* (L.) Beauv.] (# SETLU), green foxtail [*Setaria viridis* (L.) P. Beauv.] (# SETVI) (Beran et al., 2000) and others, can be problematic in native grass stands. A limited amount of research has been conducted on this topic. Research with big bluestem and switchgrass conducted by Peters et al. (1989) has shown that fenoxaprop (0.22 kg a.i./ha) provides good control of grass weeds but causes injury. Both grasses showed the least amount of injury in sulfometuron (0.02 kg a.i./ha) treatments, which gave satisfactory control of green foxtail and marginal control of barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] (# ECHCG) and large crabgrass [*Digitaria sanquinalis* (L.) Scop.] (# DIGSA). Switchgrass also showed less injury to chlorsulfuron (0.09 kg a.i./ha) treatments. Despite these results both grasses showed less than 45% injury in the study. Switchgrass showed sensitivity to fenoxyprop (0.28 kg a.i./ha and 0.55 kg a.i./ha), fluazifop-P (0.21 kg a.i./ha and 0.42 kg a.i./ha), quizalofop (0.11 kg a.i./ha and 0.22 kg a.i./ha), and sethoxydim (0.32 kg a.i./ha and 0.64 kg a.i./ha) in a study conducted by Catanzaro et al. (1993).

Beran et al. (2000) researched the use of imazapic and imazethapyr for the control of grass weeds during the establishment of big bluestem. Their results with fall panicum were mixed with good control at one site but not at two other sites. Good control of yellow foxtail was obtained with both herbicides. Control of Pennsylvania smartweed (*Polygonum pennsylvanicum* L.) (# POLPY) was also observed with both herbicides.

Pitman (2000) has shown that shading by trees can influence weed competition in stands of switchgrass. Fertility (Berg, 1995) and soil depth (Van Auken et al., 1994) may also play a role in weed competition. More research is needed with herbicides labeled for golf course use. Estimating the number of years before weed eradication is required may be another issue. This estimation would be influenced by various environmental conditions, such as soil type, weather, native grass species, and the distance from weed inoculum.

Environmental issues are of utmost concern in natural areas. These issues should always be taken into consideration when deciding whether herbicides are needed and which ones work best. Users should always read and follow labels. Additional information regarding the environmental impacts of these products may be obtained from the Herbicide Handbook (Ahrens, 1994).

Fertility

A considerable amount of research has been conducted regarding fertility. Although Brejda (2000) provides an excellent overview of the literature, some major points will be discussed here. General cultural requirements for many of these cultivars have been established along with estimated geographic adaptations (USDA-SCS, 1991). The recommendation by the USDA and Ducks Unlimited Canada (Dickerson et al., 1997) is to add nitrogen and phosphorus at a 3:1 ratio the second year of establishment. Their recommendation calls for nitrogen rates of 100.8 kg per hectare (90 pounds per acre). Still, recommended N fertilizer rates vary from state to state, ranging from 67 to 110 kg/ha per year for seeded stands (Brejda, 2000). Indiangrass has been responsive to nitrogen fertility on infertile soils of the Ozarks (Brejda et al., 1995). Responses to nitrogen have also been looked at in big bluestem (Allen et al., 1973; Brejda, 2000; Hall et al., 1982; Mitchell et al., 1996), indiangrass (Hall et al., 1982), little bluestem (Allen et al., 1973; Berg, 1995; Brejda, 2000; Waller et al., 1975), and switchgrass (Berg, 1995; Brejda, 2000; Hall et al., 1982; Sanderson, 2000).

Native warm-season grasses may meet their phosphorus requirements on soils too low in P to support cool-season grasses (Brejda, 2000). This ability is associated with lower tissue-P requirements and greater P use efficiency in native warm-season grasses compared with cool-season grasses (Brejda, 2000). The benefits of P for switchgrass establishment have been shown on P-deficient soils (Brejda, 2000; McKenna and Wolf, 1990) but not on soil with adequate P (Hall et al., 1982). Excessive P has been associated with reduced yields and changes in species composition (Brejda, 2000). Increases in microbial growth in response to P applications — and subsequent N utilization by the organisms — have been attributed to reduced yields (Brejda, 2000). Problems with cool-season grasses, such as Kentucky bluegrass (*Poa pratensis* L.), can develop under elevated P levels (Brejda, 2000).

In general, native warm-season grasses have low potassium requirements and are able to adequately meet their requirements on low-K soils without fertilization (Brejda, 2000). This attribute may explain why K applications have shown no effect upon forage yield in certain studies (Brejda, 2000; Hall et al., 1982).

Tissue analyses are often used in turf, and tissue sufficiency levels of several essential nutrients have been established for some species, such as bermudagrass (*Cynodon* spp.) and perennial ryegrass (*Lolium perenne* L.) (Puhalla et al., 1999). There is some research with nitrogen concentrations in green tissues of some switchgrass (Madakadze et al., 1998; Madakadze et al., 1999b), indiangrass, and big bluestem cultivars (Madakadze et al., 1998) but not to the degree observed in turfgrass management (Puhalla et al., 1999). Research indicates that Alamo switchgrass is highly responsive to nitrogen fertility (Sanderson, 2000) and nitrogen concentration increases with increased fertility (Madakadze et al., 1999b). In addition, uptake of phosphorus by switchgrass has been shown to be five times higher than poplar (*Populus* sp.) (Sui, 1999). Jung et al. (1990) found variations in nitrogen concentrations when comparing switchgrass, big bluestem, and indiangrass cultivars.

Still less is known about the sufficiency levels of other essential elements in native grasses. Some research has been conducted on calcium distribution in little bluestem (Waller and Dodd, 1975).

Besides tissue analysis, other methods may have possibilities in detecting nitrogen concentrations in native grasses. There is some indication that chlorophyll meters can predict yield and nitrogen concentrations in switchgrass (Madakadze et al., 1999c). It is possible that this method may have applications for other native grass species. However, this method would have more practical applications in forages.

Despite fertility research, one of the objectives when implementing natural areas is to reduce inputs. This is reinforced by the fact that maximizing biomass is not as important in golf course natural areas as it is in forages. As a result, golf courses may call for a different approach with possibilities of no supplemental fertility or adjustments to soil pH.

Native grasses can serve multiple functions in golf course natural areas. Aesthetics, wildlife food, and wildlife habitat are among the benefits offered by native grasses on golf courses. Early studies on buffering indicated that their benefits may extend beyond their placement (Mersie et al., 1999; Meyer et al., 1995; Sanderson et al., 2001; Shields et al, 1995). Despite their many benefits, more information is needed regarding long-term cultural requirements of native grass species for golf course natural areas in Mississippi. There are many critical issues that need to be addressed to achieve long-term success of native grass areas on golf courses. Natural areas should serve many functions in the golf environment. Although this bulletin focuses primarily upon species' morphological characteristics, adaptation, appearance, and management, a multifunctional approach should be considered when choosing these grasses for golf course natural areas.

Research Objectives

Due to the optimum pH requirements of certain turfgrass species, liming is often a standard management practice on golf courses (Beard, 1973a). During construction, natural areas close to tees and greens may receive lime as required for turf management. In some areas of the state, the soil pH may be naturally high, such as 6.5 or higher. However, soils elsewhere in Mississippi may be acidic with pH near 5 being common. One of the objectives with natural areas is to minimize management. If species and/or cultivars can be identified that do not require liming to a specific pH, this practice may be eliminated.

The first objective of this research was to evaluate commercial warm-season grass cultivars and species (native to Mississippi only by species) for use in golf course natural areas under full-sun conditions on soil with a pH of around 5. The second objective was to evaluate the performance of switchgrass cultivars under three management regimes: annual early spring mowing, harvesting, and burning.

Site Characteristics and General Comparison of Species

The site for this research was located at the Mississippi State University Plant Science Research Center east of Starkville, Mississippi. The soil was a Stough fine sandy loam (coarse-loamy, siliceous thermic fragiaquic paleudults). For this portion of the research, the pH of the soil was unadjusted (**Table 1**). In addition, since the goal was to minimize management, no other soil amendments or fertilization were applied during the study.

All plots were fumigated with methyl bromide at 488 kg/ha (1 pound per 100 square feet) before planting in June 1999 by Hendrix and Dail, Inc. (Greenville, NC 27835). Fumigation was to prevent possible seed base contamination from the soil, particularly by the same species.

Since many natural areas on golf courses are not irrigated, no supplemental irrigation was utilized. Rainfall amounts were below average during both years of the study (**Table 2**), particularly during July and August of 2000. During this time, there were two extended periods without rainfall. The first occurred from 1 July to 12 July and the second from 12 August to 6 September. In addition to low rainfall in 1999, there were 5 days with temperatures exceeding 37.8°C (100°F) with the highest temperature at 39.4°C (103°F) on 20 August. In 2000, there were 13 days with temperatures exceeding 37.8°C (100°F) with the highest temperature at 41.1°C (106°F) on 8 August. These factors may have resulted in poorer performance. Moser (2000)

Table 1. Soil organic matter (OM), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), and sulfur (S) taken from soil samples in February 1999 and 2000 and October 1999.

Month/Year	OM	P	K	Ca	Mg	Zn	S	pH
	%	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*
Feb. 1999	1.30	54	30	581	38	1.9	122	5.2
Oct. 1999	1.60	71	107	647	51	2.4	230	5.5
Feb. 2000	1.28	56	102	796	52	1.3	184	5.8

reports that adventitious roots, which are critical for seedling survival, may not develop under dry conditions. However, cultivars with better performance during low seasonal rainfall may also perform well in nonirrigated golf course natural areas in Mississippi. In addition, Vogel (2000) reports that released cultivars of these grasses are best adapted to annual precipitation in excess of 450 mm (17.7 inches). This is well below the precipitation level received just within the 7-month period in **Table 2**.

Native grass species were expected to perform differently during this research. For this reason, they were researched as four separate groups. Little bluestem [*Schizachyrium scoparium* (Michx.) Nash] and broomsedge (*Andropogon virginicus* L.) were covered in the first group, big bluestem (*Andropogon gerardii* Vitman) was covered in the second group, indiangrass [*Sorghastrum nutans* (L.) Nash] was covered in the third group, and switchgrass (*Panicum virgatum* L.) was covered in the fourth group.

This approach can be validated by comparing plant height characteristics among the three taller grass species (**Table 3**). Of these three, switchgrass obtained a greater height during both years of the study. During 1999, switchgrass had some tendency toward a slightly sigmoidal growth pattern. Although Moore et al. (1991) observed a linear response during the first year, a sigmoidal response occurred the second year. Indiangrass plant height was second, followed by big bluestem. The shorter height of big bluestem compared with switchgrass is an indication of later maturity. Mitchell et al. (1997) observed similar growth responses when comparing big bluestem with switchgrass. They found that switchgrass reaches seed production stage earlier than big bluestem, with data similar to those indicated in **Table 3.** This response in switchgrass is believed to be related to photoperiod (Mitchell et al., 1997). Moser and Vogel (1995) showed similar results with switchgrass the earliest species to mature and indiangrass the latest.

Table 2. Rainfall amounts during the summers of 1999 and 2000.

Month	1999	2000
	mm	*mm*
March	113.03[1]	92.20
April	114.05	221.77
May	76.45	57.45
June	91.44	112.04
July	102.62	16.03
August	22.10	13.97
September	90.68	43.71
Total	610.37	557.17

[1]Total monthly rainfall recorded daily at a weather station within 1 km of the study site.

Table 3. Average plant height comparison of big bluestem, switchgrass, and indiangrass cultivars in 1999 and 2000 grown at pH 5.2.

Species	1999			2000				
	July	August	Sept.	May	June	July	August	Sept.
	cm	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
Big Bluestem	9.2	23.7	24.9	48.5	44.4	47.8	46.6	36.5
Switchgrass	13.4	42.2	49.6	89.6	104.7	113.4	120.9	113.7
Indiangrass	12.1	29.7	31.4	59.4	49.6	56.5	66.6	54.1

SEED CONTAMINATION

Winter weeds are discussed separately later in this section. Although not considered a significant problem during this study, several summer weeds were also observed in the plots. Because the study area was fumigated, the summer weeds are believed to be seed contaminants that were planted with the native grasses. These included barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], common bermudagrass [*Cynodon dactylon* (L.) Pers.] (# CYNDA), common ragweed (*Ambrosia artemisiifolia* L.) (# AMBEL), fall panicum (*Panicum dichotomiflorum* Michx.), green foxtail [*Setaria viridis* (L.) Beauv.], ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq.] (# IPOHE), slimleaf lambsquarters [*Chenopodium leptophyllum* (Moq.) Nutt. ex S.Wats.] (# CHELE), smooth crabgrass [*Digitaria ischaemum* (Schreb. ex Schweig.) Schreb. ex Muhl.] (# DIGIS), southern crabgrass [*Digitaria ciliaris* (Retz.) Koel.] (# DIGSP), tumble pigweed (*Amaranthus albus* L.) (# AMAAL), and yellow foxtail [*Setaria glauca* (L.) Beauv.]. Many of these may have been contaminants with the native grass seed. For example, green foxtail only showed up on plots of Cave-in-Rock, Dacotah, and Shelter switchgrasses. Based upon similarities in seed size (Hitchcock, 1971), it is possible that green foxtail would be difficult to separate during seed harvesting. A similar observation was made regarding barnyardgrass. It was only observed in plots of Cheyenne, Holt, and Rumsey indiangrasses. Again, seed sizes on these two species are similar (Hitchcock, 1971). Others included common ragweed in Holt indiangrass, as well as fall panicum and slimleaf lambsquarters in Niagara big bluestem.

There were several native grasses that were contaminants in these plots. Blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.] and side-oats grama [*Bouteloua curtipendula* (Michx.) Torr.] were contaminants in Cimarron little bluestem. Although not native, yellow bluestem [*Bothriochloa ichaemum* (L.) Keng] was also a contaminant in Cimarron little bluestem. In addition, blue grama was a contaminant in Blaze and Itasca little bluestems. These contaminant species are of similar height compared with little bluestem and may not be a serious problem competitively. However, they may be a problem where a monostand is desired. Indiangrass was a contaminant in broomsedge and all cultivars of little bluestems. Although indiangrass was not identified in all plots, it has the potential to compete with little bluestem since it is a taller species. In addition, switchgrass was identified in Camper and Itasca little bluestems. Switchgrass also has the potential to be competitive. Others included switchgrass in all cultivars of big bluestem (except Bonilla) and all indiangrass cultivars. Since big bluestem, indiangrass, and switchgrass are all tallgrasses, some contamination may not be serious, except where monostands are desired.

Little Bluestem and Broomsedge

Materials and Methods

Seed from Missouri broomsedge ecotypes and five little bluestem cultivars were utilized for this portion of the study. Broomsedge was seeded at a rate of 5.6 kg of pure live seed per hectare (kg PLS/ha) (5 pounds per acre). All little bluestem cultivars were seeded at 14.6 kg PLS/ha (13 pounds per acre). The broomsedge planting rate is based upon that recommended by Hamilton Seed Company (16786 Brown Road, Elk Creek, MS 65464). The little bluestem rate was recommended by Stock Seed Farms (28008 Mill Road, Murdock, NE 68407).

The little bluestem cultivars were Aldous, Blaze, Camper, Cimarron, and Itasca (**Table 4**). All are Midwest cultivars, except Itasca, which is a northern cultivar. The broomsedge and Cimarron little bluestem seeds were obtained from Hamilton Seed Company. Aldous, Blaze, and Camper little bluestem seeds were obtained from Osenbaugh Grass Seeds (R.R. 1 Box 44, Lucas, IA 50151). Itasca little bluestem seed was obtained from Kaste, Inc. (R.R. 2 Box 153, Fertile, MN 56540).

Table 4. History of broomsedge and five cultivars of little bluestem used in this study.[1]

Cultivar	Origin	Release date
Broomsedge	Missouri	None
Aldous	Kansas	1966
Blaze	Nebraska	1967
Camper	Nebraska	1973
Cimarron	Kansas, Oklahoma	1979
Itasca	N. & S. Dakota, Minnesota	Pending

[1]From Alderson, J., and W.C. Sharp. 1994. Grass cultivars of the United States. Agric. Handbook 170. SCS-USDA, Washington D.C., except broomsedge from Hamilton Seed, Elk Creek, MO, and Itasca from Kaste, Inc., Fertile, MN.

The experimental design for little bluestem and broomsedge was a randomized complete block (RCB) design with repeated measures. There were three replications and six treatments (**Figure 1**.). Experimental unit (plot) sizes were 1.83 x 5.49 square meters (6 x 18 square feet). Seeds were hand planted on 21 June 1999. Before planting, seeds were mixed with damp sand as a carrier.

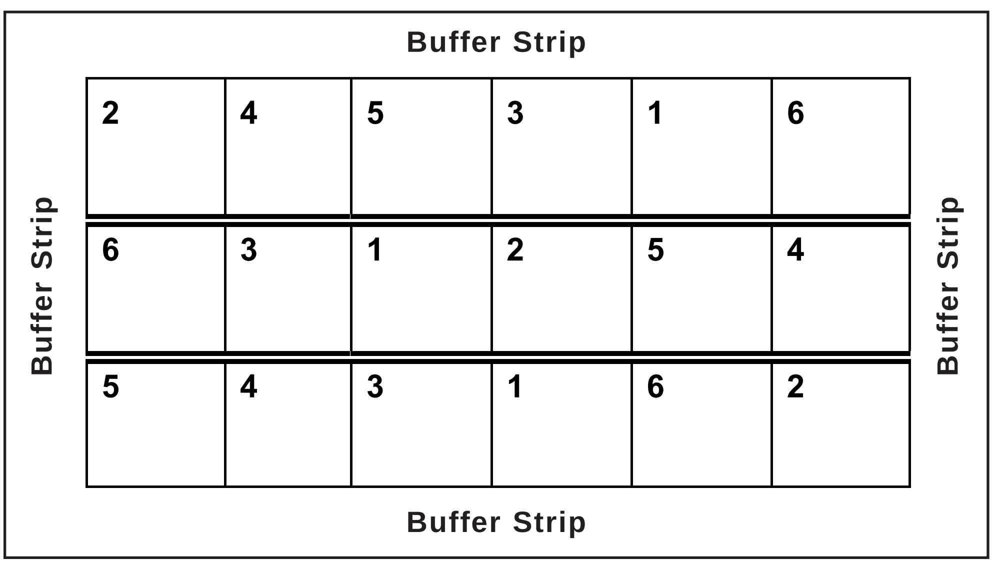

Figure 1. Plot plan for broomsedge (*Andropogon virginicus* L.) and little bluestem [*Schizachyrium scoparium* (Michx.) Nash] cultivars grown at a soil pH of 5.2. Cultivars: 1 = broomsedge, 2 = Aldous, 3 = Blaze, 4 = Camper, 5 = Cimarron, and 6 = Itasca little bluestem.

Plant height was recorded monthly from 16 July through 14 September in 1999 and from 12 May through 20 September in 2000. Due to uniformity across plots during 1999, only three height measurements were taken within each plot. During 2000, nine height measurements were taken within each plot. Plant height data were analyzed using analysis of variance (ANOVA) in 1999 and 2000. Mean separations were calculated using Fisher's least significant difference (LSD) test (SAS Institute Inc., 1988a).

Percent stand cover within each plot was recorded monthly from 16 July through 14 September in 1999. Due to uniformity within plots only three values were recorded for each plot. Stand coverage was recorded once on 26 July in 2000. Three values were recorded for each plot in 2000.

Winter weed coverage (percent) was recorded for each plot on 15 June 2000. Since the major weed species was horseweed [*Conyza canadensis* (L.) Cronq.] (# ERICA), this date allowed maximum time for development. The ANOVA procedure was used to analyze stand and weed cover data. Comparisons were made between 2000 stand and winter weed cover using Pearson Correlation Analysis (SAS Institute Inc., 1988b).

Plant color was determined using Munsell color charts for plant tissues (Munsell Color Charts for Plant Tissues, 2nd Ed. 1977, Kollmorgen Corp., Baltimore, MD 21218). Since growing season color was recorded on 9 November 2000, some fall color was included with certain cultivars. Dead stand or winter color was recorded on 22 January 2001. Where color was variable, both adaxial and abaxial leaf surfaces and stem colors may have been determined.

Soil samples from each plot were collected on 23 February 2000. Analyses are presented in **Table A.1**. These data were statistically analyzed using the ANOVA procedure. General soil sample results were not statistically analyzed and are presented in **Table 1**. There was not enough fuel in these plots to obtain an adequate burn. Therefore, no management practices were evaluated on these two species during this study.

Results and Discussion

Table 5. Average plant height comparison of broomsedge and little bluestem cultivars in 1999 and 2000 grown at pH 5.2.

Species	1999			2000				
	July	August	Sept.	May	June	July	August	Sept.
	cm	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
Broomsedge	1.7	6.3	9.3	20.2	31.4	39.0	46.2	52.2
Little Bluestem	4.6	9.4	11.6	20.5	22.8	28.3	33.9	30.2
LSD (0.05)	**0.73**	**1.67**	**NS**	**NS**	**4.58**	**5.34**	**7.33**	**7.50**

On average, little bluestem cultivars obtained more height than broomsedge during the first year of the study (**Table 5**). However, during the second year the height of broomsedge exceeded little bluestem. This may indicate that broomsedge has some lag in growth during establishment.

At 4 weeks after planting in 1999, little bluestem cultivars were significantly taller than broomsedge (**Table 6**). Blaze was significantly taller than all cultivars, except Aldous. Blaze little bluestem also had the greatest average height across July, August, and September. It was followed in descending order by Aldous and Cimarron little bluestems. It remained significantly taller by September than all cultivars and broomsedge, except Aldous. Camper and Itasca performed similarly, both with an average height of 7.3 cm for the 3 months in 1999. Despite these variations in height, the tallest average height recorded was for Blaze at only 15 cm. This may indicate little bluestem also exhibits some lag in growth during establishment.

In 2000, Camper started the year as the shortest cultivar, although Itasca finished the year in September with the shortest height (**Table 7**). Aldous, Blaze, and Cimarron had the greatest average height in May. By September, Cimarron was significantly taller than all little bluestem cultivars at 43.6 cm. Jung et al. (1990) recorded a 3-year average height of Aldous little bluestem of 71 cm without supplemental nitrogen. This is well in excess of the largest height (36.9 cm) recorded in our study over a 2-year period. This may be an indication that little bluestem cultivars in our study may have more height potential given more time.

Broomsedge was taller than little bluestem cultivars 3 out of 5 months during 2000. Although broomsedge was tallest (52.2 cm) in September, this difference was not significant. This was an improvement over 1999 and may indicate a growth lag during 2000. It is possible that significant root development took place during 1999 compared

Table 6. Plant height of broomsedge and five cultivars of little bluestem in 1999 grown at pH 5.2.

Cultivar	July	August	Sept.	Avg.
	cm	*cm*	*cm*	*cm*
Broomsedge	1.7	6.3	9.3	5.8
Aldous	4.9	10.4	12.8	9.4
Blaze	5.6	11.1	15.0	10.6
Camper	4.1	8.0	9.9	7.3
Cimarron	4.6	8.7	11.2	8.2
Itasca	3.8	8.9	9.3	7.3
LSD (0.05)	**0.80**	**1.97**	**2.87**	

Table 7. Plant height of broomsedge and five little bluestem cultivars in 2000 grown at pH 5.2.

Cultivar	May	June	July	August	Sept.	LSD (0.05)
	cm	*cm*	*cm*	*cm*	*cm*	*cm*
Broomsedge	20.2	31.4	39.0	46.2	52.2	8.93
Aldous	22.6	22.9	32.0	36.9	33.7	6.51
Blaze	22.2	27.0	30.2	32.7	28.8	6.13
Camper	16.4	18.3	21.1	30.7	24.7	6.73
Cimarron	22.2	28.6	35.9	47.2	43.6	6.94
Itasca	19.2	17.3	22.2	22.1	20.4	NS
LSD (0.05)	**4.79**	**5.58**	**6.36**	**8.65**	**8.94**	

with little bluestem, but no data of this type was collected. Broomsedge and all little bluestem cultivars showed significant increases in height during 2000. However, all little bluestem cultivars showed some decline in height between August and September. It is not clear why little bluestem growth declined during this last month, although dry weather may have played some role in this reduction.

In 1999 and 2000, stand coverage was low for all little bluestem cultivars (**Table 7**). The highest cover in 1999 was 15% for Blaze in September. Cimarron had the highest cover at 17.8% in 2000. Aldous, Camper, and Cimarron little bluestems all showed some increase in stand coverage between 1999 and 2000. Jung et al. (1990) showed Aldous coverage of 72% after 9 years. It is possible that some increase in stand coverage in our study would occur with additional time.

Compared with little bluestem cultivars, Broomsedge had the lowest stand cover in 1999 but the highest in 2000 at 26.7%. According to the seed label, 24% of the broomsedge seed was dormant. Some warm-season grasses require a 4-week wet chill treatment to break dormancy (Emal and Conard, 1973). It is possible that some broomsedge seed may have germinated late in 1999 or early in 2000, contributing to the increase in cover.

It is highly likely that dry weather played a major role in poor stand cover of both species. Very few adventitious roots have been observed on grasses of the Andropogoneae tribe even at the three-leaf stage (Newman and Moser, 1988). With heights of only 1.7 cm to 5.6 cm at 4 weeks after planting for the two species, adventitious rooting may have been inadequate for survival.

Despite fumigation of plots before planting, winter weeds were a problem within the first year of the study. The primary weed species was horseweed [*Conyza canadensis* (L.) Cronq.]. Since the seed is wind-disseminated, it is likely that seed was carried into study plots by wind. In addition to horseweed, corn spurrey (*Spergula arvensis* L.) (# SPRAR) and cutleaf eveningprimrose (*Oenothera laciniata* Hill) (# OEOLA) were also observed. Like horseweed, corn spurrey and cutleaf eveningprimrose were very common outside the study area and were most likely blown in from adjacent areas. In 2000, weed coverage was as high as 91.7% in Cimarron little bluestem plots during the study (**Table 9**). Weed coverage did not negatively correlate with stand cover in this study. Pearson (r) correlation analysis indicated a coefficient of 0.205, which was not significant (p=0.414).

Higher seeding rates may be necessary to obtain adequate cover for golf course use of these cultivars. More research regarding seeding rates is needed. Plant heights are expected to be similar despite low coverage. Although lodging may be a possibility under higher seeding rates, it was not observed on broomsedge and little bluestem during this study.

Table 8. Stand coverage of broomsedge and five little bluestem cultivars in 1999 and 2000 grown at pH 5.2.

Cultivar	1999			2000
	July	August	September	July
	%	%	%	%
Broomsedge	0.5	5.0	7.3	26.7
Aldous	2.0	10.7	11.7	13.3
Blaze	2.0	11.7	15.0	13.3
Camper	1.0	5.7	5.0	6.0
Cimarron	1.7	11.0	10.0	17.8
Itasca	1.3	8.3	6.7	4.1
LSD (0.05)	**0.57**	**NS**	**NS**	**8.87**

Table 9. Stand coverage of broomsedge and five little bluestem cultivars in July 2000 grown at pH 5.2 compared with weed coverage on 15 June 2000.[1]

Cultivar	Stand	Weeds
	%	%
Broomsedge	26.7	90.0
Aldous	13.3	88.3
Blaze	13.3	90.0
Camper	6.0	88.3
Cimarron	17.8	91.7
Itasca	4.1	88.3
LSD (0.05)	**8.87**	**NS**

[1]Primary weed species was horseweed [*Conyza canadensis* (L.) Cronq.](ERICA).

Growing season colors were variable depending upon species, cultivar, and location on the leaf (**Table 10**). Broomsedge colors were more toward green with chromas of 4 and 6. Little bluestems had colors more toward gray with chromas of 2 and 4 generally. Aside from one leaf tip value of 3, all values were in the middle range of 4-6. Since coloration was recorded during the fall, leaf tip coloration was observed in the little bluestem cultivars. Leaf tip colors ranged from maroon (5R3/4 and 2) to gray-maroon (2.5R4/2 and 5R4/2). Some little bluestem cultivars exhibited more color variation than others. Aldous ranged from gray (7.5GY5/2) to gray-green in color (5GY4/4 and 7.5GY4-5/4). Blaze was similar but with a lower range in gray (5G6/2). Camper had the same low range of gray (5G6/2 and 2.5G6/2) as well as gray-green (5GY4-5/4). Cimarron ranged from a dark gray-green (7.5YR3-4/4) to a gray (5G6/2 and 7.5GY6/2). Itasca foliage color was slightly different, ranging from olive-green (5GY4/6) to a dark gray (7.5GY4-5/2).

Dead stand or winter colors were variable depending upon species, cultivar, side and part of the leaf, and location on the plant (**Table 11**). The leaf surface of broomsedge was slightly darker (7.5YR7/4) on the adaxial side compared with the abaxial surface (7.5YR6-7/6). Much of the yellow winter color associated with this species apparently comes from the stem and sheath (including bract) colors (2.5Y 8/4 and 7/6). Aldous little bluestem had a purple coloration (10R4/2) on the adaxial side of the leaf with brown (2.5YR5/4) abaxial surface. The stems were much lighter in color (7.5YR7/4-6). Foliage colors of Blaze, Camper, Cimarron, and Itasca were similar. All had foliage colors of medium brown to gray-brown with values of 5YR5 to 5YR6 and chromas of 2 and 4. Based upon these data, little bluestems lacked the gold coloration exhibited by broomsedge during winter. This color is often more desirable for golf course use, since it assists in providing good contrast between maintained turf and out-of-play native grass areas.

Table 10. Summer color range of broomsedge and five little bluestem cultivars grown at pH 5.2.[1]

Cultivar	Foliage colors			Leaf tips
Broomsedge	7.5GY5/4	5GY6/6	5GY4/4	N/A
Aldous	5GY4/4	7.5GY5/2-4	7.5GY4/4	2.5R4/2
Blaze	5G6/2	7.5GY5/2-4	5GY5/4	5R3/4
Camper	2.5G6/2	5GY4-5/4	5G6/2	5R3-4/2
Cimarron	7.5GY3-4/4	5G6/2	7.5GY6/2	2.5R4/2
Itasca	7.5GY4-5/2	5GY4/6	N/A	2.5R4/2

[1]Foliage color recorded on 9 November 2000 using Munsell Color Charts for Plant Tissues, Kollmorgen Corp., Baltimore, MD 21218.

Table 11. Winter color range of broomsedge and five little bluestem cultivars grown at pH 5.2.[1]

Cultivar	Foliage colors		Sheath	Stem
	Adaxial	Abaxial	color[2]	color
Broomsedge	7.5YR7/4	7.5YR6-7/6	2.5Y8/4	2.5Y7/6
Aldous	10R4/2	2.5YR5/4	N/A	7.5YR7/4-6
Blaze	5YR6/4	5YR5/4	7.5YR7/6	N/A
Camper	5YR6/2	5YR5/2	7.5YR6/6	N/A
Cimarron	5YR5/2	5YR5/4	7.5YR7/4	N/A
Itasca	5YR6/4	5YR5/4	N/A	7.5YR8/4

[1]Dead (dormant) stand foliage color recorded on 22 January 2001 using Munsell Color Charts for Plant Tissues, Kollmorgen Corp., Baltimore, MD 21218.
[2]Sheath color includes both leaf sheath and the bracts of the flowering culms.

BIG BLUESTEM

Materials and Methods

Seed from six big bluestem cultivars were utilized for this portion of the study. All cultivars were seeded at a rate of 22.4 kg PLS/ha (20 pounds per acre). This rate was recommended by Stock Seed Farms (28008 Mill Road, Murdock, NE 68407).

The big bluestem cultivars were Bison, Bonilla, Kaw, Niagara, Pawnee, and Rountree (**Table 12**). All are Great Plains selections, except Niagara, which is a northeastern cultivar. Bison and Bonilla big bluestem seeds were obtained from Kaste, Inc. (R.R. 2 Box 153, Fertile, MN 56540). Kaw and Pawnee were obtained from Stock Seed Farms (28008 Mill Road, Murdock, NE 68407). Niagara big bluestem seed was obtained from Ernst Conservation Seeds (9006 Mercer Pike, Meadville, PA 16335). Rountree big bluestem seed was obtained from Osenbaugh Grass Seeds (R.R. 1 Box 44, Lucas, IA 50151).

The experimental design for big bluestem was a RCB design with repeated measures. There were three replications and six treatments (**Figure 2**.). Experimental unit (plot) sizes

Table 12. History of the six big bluestem cultivars used in this study.[1]

Cultivar	Origin	Release date
Bison	North Dakota	1989
Bonilla	South Dakota	1987
Kaw	Kansas	1950
Niagara	New York	1985
Pawnee	Nebraska	1963
Rountree	Missouri	1983

[1]From Alderson, J., and W.C. Sharp. 1994. Grass cultivars of the United States. Agric. Handbook 170. SCS-USDA, Washington D.C.

were 1.83 x 5.49 square meters (6 x 18 square feet). Seeds were hand-planted on 21 June 1999. Before planting, seeds were mixed with damp sand as a carrier.

Plant height was recorded monthly from 16 July through 14 September in 1999 and from 12 May through 20 September in 2000. Due to uniformity across plots during 1999, only three height measurements were taken within each plot. During 2000, nine height measurements were taken within each plot. Plant height data was analyzed using ANOVA in 1999 and 2000. Mean separations were calculated using Fisher's LSD test (SAS Institute Inc., 1988a).

Visual estimates of stand cover within each plot were recorded monthly from 16 July through 14 September in 1999. Due to uniformity within plots, three values were recorded for each plot. Stand cover was recorded once on 26 July in 2000. Three values were recorded for each plot in 2000. Stand cover was recorded as percent cover. Winter weed cover (percent cover) was recorded for each plot on 15 June 2000. Since the major weed species was horseweed [*Conyza canadensis* (L.) Cronq.], this date allowed maximum time for development. The ANOVA procedure was used to analyze stand and weed cover data. Means were separated using Fisher's LSD test. Comparisons were made between 2000 stand and winter weed cover using Pearson Correlation Analysis (SAS Institute Inc., 1988b).

Plant color was determined using Munsell color charts for plant tissues (Munsell Color Charts for Plant Tissues, 2nd Ed. 1977, Kollmorgen Corp., Baltimore, MD 21218). Since growing season color was recorded on 9 November 2000, some fall color was included with certain cultivars. Dead stand or winter color was recorded on 22 January 2001. Where color was variable, both adaxial and abaxial leaf surfaces and stem colors may have been determined.

Soil samples from each plot were collected on 23 February 2000. Analyses are presented in **Table A.2**. These data were statistically analyzed using the ANOVA procedure. Mean separations were calculated using Fisher's LSD test. General soil sample results were not statistically analyzed and are presented in **Table 1**. There was not enough fuel to obtain an adequate burn in these plots during the study. Therefore, no management practices were evaluated on big bluestem. It is possible that plots needed more time to develop, since Hall et al. (1982) obtained Kaw big bluestem yields comparable to Blackwell switchgrass during the fourth, fifth, and sixth years of their study.

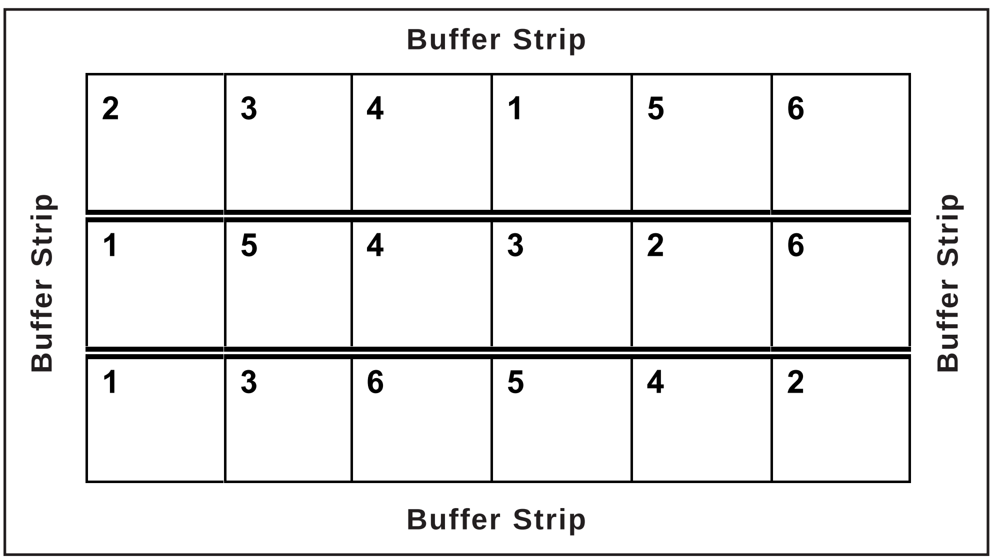

Figure 2. Plot plan for big bluestem (*Andropogon gerardii* Vitman) cultivars grown at a soil pH of 5.2. Cultivars: 1 = Bison, 2 = Bonilla, 3 = Kaw, 4 = Niagara, 5 = Pawnee, and 6 = Rountree.

Results and Discussion

Big bluestem plant heights (**Table 13**) showed significant differences every month during both years of the study. Bonilla was the tallest (10.9 cm) cultivar at 4 weeks after planting. Although Kaw (8.4 cm) was next to the shortest cultivar on this date, it was the tallest (47.5 cm) by September 2000. This indicates that seedling vigor is not a reflection of long-term performance of these big bluestem cultivars. There may be a pattern based upon origin. The two northern plains cultivars — Bison from North Dakota and Bonilla from South Dakota — were the tallest cultivars (9.9 cm and 10.9 cm, respectively) by week 4 of the study. However, Bison had the shortest height (28.1 cm) by the end of the study. It is not known how Bonilla will perform long-term, but it maintained the highest average height (53.7 cm) during 2000. The midplains cultivars — Kaw from Kansas, Pawnee from Nebraska, and Rountree from Missouri — tended to start short and increase in height consistently over the 2-year period. Niagara big bluestem from New York was

Table 13. Plant height of six big bluestem cultivars in 1999 and 2000 grown at pH 5.2.

Cultivar	1999				2000					
	July	August	Sept.	Avg.	May	June	July	August	Sept.	Avg.
	cm	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
Bison	9.9	20.0	22.9	17.6	41.0	33.3	32.0	36.8	28.1	34.2
Bonilla	10.9	26.0	32.3	23.1	54.0	53.4	60.0	58.6	42.5	53.7
Kaw	8.4	21.0	22.1	17.2	44.3	50.6	57.3	54.9	47.5	51.0
Niagara	7.9	22.7	22.6	17.7	41.5	41.3	45.9	42.9	31.8	40.7
Pawnee	9.0	24.3	25.4	19.6	55.2	47.6	45.2	43.5	36.1	45.5
Rountree	8.9	28.4	24.3	20.6	55.4	40.0	46.0	42.7	32.8	43.5
LSD(0.05)	**1.03**	**3.86**	**4.50**	**3.03**	**10.23**	**9.66**	**9.17**	**8.35**	**8.25**	**4.35**

the shortest (7.9 cm) at 4 weeks after planting. On average, it did not perform as well as the midplains cultivars during 1999 and 2000, but it did perform better than Bison. All cultivars experienced some decline in height toward the end of 2000. This decline was most likely due to drought during that period. Jung et al. (1990) recorded 3-year average heights of Kaw, Niagara, and Pawnee at 88 cm, 114 cm, and 85 cm, respectively, with no supplemental fertility. These heights are in excess of those recorded here and may be an indication that cultivars in this study have more height potential if given more time.

Stand coverage was low for all big bluestem cultivars during this study, ranging from 3% to 6.3% at 4 weeks after planting (**Table 14**). Coverage of big bluestem cultivars was not significant for any month during 1999, but it was significant in July 2000. Performance of cultivars was similar to plant height. Bison and Bonilla had the greatest coverage at 4 weeks after planting (5% and 6.3%, respectively). Niagara and Rountree had the least amount of cover (3%). Despite this thin start, Niagara still finished with more cover (18.2%) than Bison (13%). Bonilla and Pawnee had the greatest cover by September 1999, each with 31.7%. Likewise, Bonilla and Pawnee had the greatest cover in July 2000 (33.6% and 40%, respectively). Pawnee had significantly more cover than Bison, Niagara, and Rountree in July 2000. Of the two northern plains cultivars, Bonilla had significantly more cover than Bison in July 2000. Rountree big bluestem started and finished with low cover (13% and 8.3%, respectively). The highest percent cover in this study was much lower than that achieved by Jung et al. (1990). However, percent cover of big bluestem in their study was conducted 9 years after planting. It is likely that cover in our study will continue to increase.

Stand coverage did not correlate significantly with weed coverage (**Table 15**). Correlation analysis showed a coefficient of 0.236 with a probability of 0.09. Like broomsedge and little bluestem, stand coverage was low in big bluestem plots, ranging from 8.3% to 40% in July 2000. Big bluestem experienced problems with the same weed species during this period. Weed coverage ranged from 88.3% to 95% on average. These data indicate an excess of 100% coverage when adding weed and stand coverage. This is due to height difference between big bluestem and horseweed. Coverage is based upon leaf coverage, not stem coverage. Horseweed was tallest on 15 June 2000 and therefore was able to shade the big bluestem plots. Since ratings were recorded approximately 1 month apart, some variance could be due to timing.

Unlike little bluestem cultivars, growing season colors among big bluestem cultivars were very similar (**Table 16**). All cultivars had dark-green leaf colors in the 7.5GY4-5/4 range. Niagara also exhibited colors of 7.5GY4/2, which are dark gray-green. Leaf tips showed more variation in color,

Table 14. Stand coverage of six big bluestem cultivars in 1999 and 2000 grown at pH 5.2.

Cultivar	1999			2000
	July	August	September	July
	%	%	%	%
Bison	5.0	15.0	16.7	13.0
Bonilla	6.3	25.0	31.7	33.6
Kaw	4.0	15.0	21.7	30.2
Niagara	3.0	13.3	18.3	18.2
Pawnee	4.7	21.7	31.7	40.0
Rountree	3.0	15.0	20.0	8.3
LSD (0.05)	**NS**	**NS**	**NS**	**19.09**

Table 15. Stand coverage of six big bluestem cultivars in July 2000 grown at pH 5.2 compared with weed coverage on 15 June 2000.[1]

Cultivar	Big Bluestem	Weeds
	%	%
Pawnee	40.0	91.7
Bonilla	33.6	91.7
Kaw	30.2	90.0
Niagara	18.2	95.0
Bison	13.0	88.3
Rountree	8.3	88.3
LSD (0.05)	**19.09**	**4.59**

[1]Primary weed species was horseweed [*Conyza canadensis* (L.) Cronq.](ERICA).

ranging from 2.5R to 5R, which are red. Color values ranged from 3 to 4, which are dark. Chromas ranged from 2 in the gray-maroon range to 8 in the red range.

Winter or dead stand colors were much more variable than growing season colors (**Table 17**). Unlike little bluestem, differences in color between adaxial and abaxial leaf surfaces were not observed in big bluestem. Many of the colors ranged from brown (7.5YR6/4, 7.5YR4/2, and 2.5YR5-6/4) to gray-brown (7.5YR5-6/2, 5YR5-6/2, and 10R6/2).

Table 16. Growing season color range of six big bluestem cultivars grown at pH 5.2.[1]

Cultivar	Foliage colors			Leaf tips
Bison	7.5GY4-5/4	N/A	2.5R4/8	5R3/2-6
Bonilla	7.5GY4-5/4	N/A	2.5R4/6	5R3/2-6
Kaw	7.5GY4-5/4	N/A	2.5R4/6	5R3/2-4
Niagara	7.5GY4-5/4	7.5GY4/2	5R3/2	N/A
Pawnee	7.5GY4-5/4	N/A	5R3/2-6	N/A
Rountree	7.5GY4-5/4	N/A	2.5R4/6	5R3/2-4

[1]Foliage color recorded on 9 November 2000 using Munsell Color Charts for Plant Tissues, Kollmorgen Corp., Baltimore, MD 21218.

Table 17. Winter color range of six big bluestem cultivars grown at pH 5.2.[1]

Cultivar	Foliage colors		
Bison	7.5YR5-6/2	N/A	N/A
Bonilla	7.5YR5/2	5YR5-6/2	N/A
Kaw	5YR5-6/4	5YR5/2	N/A
Niagara	7.5YR4/2	2.5YR6/4	2.5YR5/4
Pawnee	7.5YR5-6/2	10R6/2	5YR6/2
Rountree	7.5YR6/4	7.5YR5/2	2.5YR5/4

[1]Dead (dormant) standing foliage color recorded on 22 January 2001 using Munsell Color Charts for Plant Tissues, Kollmorgen Corp., Baltimore, MD 21218.

Indiangrass

Materials and Methods

Seed from seven indiangrass cultivars were utilized for this portion of the study. All cultivars were seeded at a rate of 34.7 kg PLS/ha (31 pounds per acre). This rate was recommended by Stock Seed Farms.

The indiangrass cultivars were Cheyenne, Holt, Nebraska 54, Osage, Oto, Rumsey, and Tomahawk (**Table 18**). All are Great Plains selections. Tomahawk was selected from northern ecotypes. Cheyenne and Rumsey indiangrass seeds were obtained from Hamilton Seed Company. Holt and Nebraska 54 seeds were obtained from Osenbaugh Grass Seeds. Osage and Oto were obtained from Stock Seed Farms. Tomahawk indiangrass seed was obtained from Kaste, Inc.

The experimental design for indiangrass was a randomized complete block with repeated measures. There were three replications and seven treatments (**Figure 3**). Experimental unit (plot) sizes were 1.83 x 5.49 square meters (6 x 18 square feet). Seed was hand-planted on 21 June 1999. Before planting, seeds were mixed with damp sand as a carrier.

Plant height was recorded monthly from 16 July through 14 September in 1999 and from 12 May through 20 September in 2000. Due to uniformity across plots during 1999, only three height measurements were taken within each plot. During 2000, nine height measurements were taken within each plot. Plant height data were analyzed using ANOVA in 1999 and 2000. Means were separationed using Fisher's LSD test (SAS Institute Inc., 1988a).

Stand cover within each plot was recorded monthly from 16 July through 14 September in 1999. Due to uniformity within plots only one value was recorded for each plot. Stand cover was recorded once on 26 July in 2000. Three values were recorded for each plot in 2000. Stand cover was recorded as percent cover. Winter weed cover (percent cover) was recorded for each plot on 15 June 2000. Since the major weed species was horseweed [*Conyza canadensis* (L.) Cronq.], this date allowed maximum time for development. The ANOVA procedure was used to analyze stand and weed cover data. Mean separations were calculated using Fisher's LSD test. Comparisons were made between 2000 stand and winter weed cover using Pearson Correlation Analysis (SAS Institute Inc., 1988b).

Plant color was determined using Munsell color charts for plant tissues (Munsell Color Charts for Plant Tissues, 2nd Ed. 1977, Kollmorgen Corp., Baltimore, MD 21218). Since growing season color was recorded on 9 November 2000, some fall color was included with certain cultivars. Winter or dead stand color was recorded on 22 January 2001. Where color was variable, both adaxial and abaxial leaf surfaces and stem colors may have been determined.

Table 18. History of the seven indiangrass cultivars used in this study.[1]

Cultivar	Origin	Release date
Cheyenne	Oklahoma	1945
Holt	Nebraska	1960
Nebraska-54	Nebraska	1957
Osage	Kansas, Oklahoma	1966
Oto	Kansas, Nebraska	1970
Rumsey	Missouri	1983
Tomahawk	N. and S. Dakota	1988

[1]From Alderson, J., and W.C. Sharp. 1994. Grass cultivars of the United States. Agric. Handbook 170. SCS-USDA, Washington D.C.

Soil samples from each plot were collected on 23 February 2000. Analyses are presented in **Table A.3**. These data were statistically analyzed using the ANOVA procedure. Mean separations were calculated using Fisher's LSD test. General soil sample results were not statistically analyzed and are presented in **Table 1**. There was not enough fuel to obtain an adequate burn in these plots during the study. Therefore, no management practices were evaluated on indiangrass. It is possible that plots needed more time to develop, since Hall et al. (1982) obtained Nebraska 54 indiangrass yields only slightly lower than Blackwell switchgrass during the fourth, fifth, and sixth years of their study.

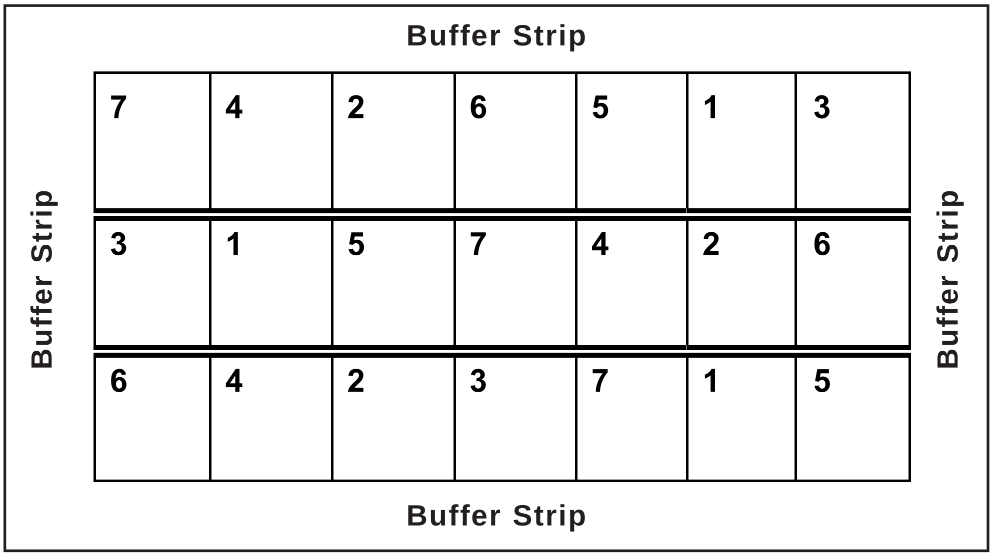

Figure 3. Plot plan for indiangrass [*Sorghastrum nutans* (L.) Nash] cultivars grown at a soil pH of 5.2. Cultivars: 1 = Cheyenne, 2 = Holt, 3 = Nebraska 54, 4 = Osage, 5 = Oto, 6 = Rumsey, and 7 = Tomahawk.

Results and Discussion

Indiangrass plant heights (**Table 19**) showed significant differences every month during both years of the study, except May 2000. Rumsey was the tallest (15.6 cm) cultivar at 4 weeks after planting. It also had the greatest average height in 1999 and 2000. Tomahawk, the only northern Great Plains cultivar, tended to remain short throughout the 2-year study. On average, it was significantly shorter than all other cultivars during 1999 and 2000. In 1999, all cultivars except Tomahawk were similar in height, ranging from 10.4 cm to 15.6 cm at 4 weeks after planting. By September 1999, heights for these six cultivars ranged from 29 cm to 39.7 cm. By September 2000, heights of the same cultivars ranged from 40 cm to 75.4 cm. These differences between cultivars — ranging from 5.2 cm at 4 weeks, to 10.7 cm at the end of 1999, to 15.4 cm at the end of 2000 — may indicate potential for greater differences if another year of data had been collected. As with big bluestem cultivars, height reductions were observed between August and September of 2000. Most likely, this reduction also was due to dry weather conditions during this period. Because of dry weather, it is difficult to determine if any cultivars reached maximum height during the 2-year period. However, a study by Jung et al. (1990) may indicate potential for additional height if provided more time. They recorded heights of Cheyenne, Nebraska 54, and Osage at 111 cm, 119 cm, and 105 cm, respectively, under no supplemental nitrogen. Compared with the tallest heights in

Table 19. Plant height of seven indiangrass cultivars in 1999 and 2000 grown at pH 5.2.

Cultivar	1999				2000					
	July	August	Sept.	Avg.	May	June	July	August	Sept.	Avg.
	cm	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
Cheyenne	13.3	31.8	39.7	28.3	54.6	58.4	70.3	88.6	75.4	69.4
Holt	10.4	30.2	30.4	23.7	63.9	45.6	52.5	56.3	40.0	51.6
Nebraska 54	14.2	32.9	31.9	26.3	51.8	42.7	56.4	63.3	44.2	51.7
Osage	11.1	26.2	30.7	22.7	50.9	48.1	56.5	63.3	59.3	55.6
Oto	11.3	28.7	29.0	23.0	61.9	54.5	56.6	66.3	53.6	58.6
Rumsey	15.6	37.2	38.3	30.4	68.4	67.2	71.3	86.0	69.8	72.6
Tomahawk	8.7	20.7	19.8	16.4	64.6	31.0	32.2	42.8	35.3	40.9
LSD (0.05)	**1.46**	**4.38**	**5.02**	**3.58**	**NS**	**10.01**	**9.48**	**16.53**	**14.07**	**8.27**

Table 20. Stand coverage of seven indiangrass cultivars in 1999 and 2000 grown at pH 5.2.

Cultivar	1999			2000
	July	August	September	July
	%	%	%	%
Cheyenne	7.0	23.3	30.0	57.1
Holt	3.7	15.0	21.7	49.4
Nebraska 54	7.0	18.3	26.7	28.3
Osage	4.0	15.0	16.7	36.0
Oto	5.7	18.3	20.0	43.9
Rumsey	4.7	28.3	31.7	63.3
Tomahawk	3.7	13.3	13.3	14.9
LSD (0.05)	**NS**	**NS**	**NS**	**28.01**

Table 21. Stand coverage of seven indiangrass cultivars in July 2000 grown at pH 5.2 compared with weed coverage on 15 June 2000.[1]

Cultivar	Indiangrass	Weeds
	%	%
Rumsey	63.3	73.3
Cheyenne	57.1	53.3
Holt	49.4	86.7
Oto	43.9	85.0
Osage	36.0	88.3
Nebraska 54	28.3	78.3
Tomahawk	14.9	95.0
LSD (0.05)	**28.01**	**11.78**

[1]Primary weed species was horseweed [*Conyza canadensis* (L.) Cronq.](ERICA).

our study of 88.6 cm, 63.3 cm, and 63.3 cm, respectively, for these cultivars, this is an indication that these plants have more height potential if provided additional time.

Stand coverage was low for all indiangrass cultivars during 1999, ranging from 3.7% to 7% at 4 weeks after planting (**Table 20**). No significant differences in coverage were observed within any of the 3 months during 1999. Coverage was much higher by July 2000, ranging from 14.9% in Tomahawk plots to 63.3% in Rumsey plots. As with plant height, coverage in Tomahawk plots remained low throughout the 2-year study. Cheyenne, Holt, Oto, and Rumsey indiangrasses had significantly more plot coverage compared with Tomahawk in July 2000. Nebraska 28 and Osage had more plot coverage than Tomahawk during this period, but differences were not significant. This is somewhat consistent with a study conducted by Pitman (2000) in West Louisiana. Osage indiangrass had poorer performance compared with Lometa. However, Lometa indiangrass was not included in our study. All cultivars showed some coverage increase between 1999 and 2000. Cheyenne coverage in our study was higher (57.1%) in July 2000 than that achieved by Jung et al. (1990) at year 9 with no supplemental nitrogen. However, coverage of Nebraska (66%) and Osage (44%) were higher in their study compared with July 2000 of our study (28.3% and 36%, respectively). It is highly likely that most of the indiangrass cultivars in our study will exhibit increased coverage with additional time.

Stand coverage showed a significant negative correlation with weed coverage (**Table 21**). Correlation analysis showed a coefficient of -0.419 with a probability of 0.0006. Unlike broomsedge and little bluestem, stand coverage was higher in indiangrass plots, ranging from 14.9% to 63.3% in July 2000. As with broomsedge, little bluestem, and big bluestem, horseweed was the most problematic weed species during this period. Weed coverage ranged from 53.3% to 95% on average. Cheyenne indiangrass had significantly less weed cover (53.3%) than any other cultivar, but it did not have the greatest plant coverage (57.1%). If not for these discrepancies, the correlation coefficient may have been higher than -0.419. Pitman (2000) had problems with weeds when establishing indiangrass in West Louisiana, but he noted fewer weed problems in shaded plots. As with big bluestem, these data indicate an excess of 100% coverage when adding weed and stand coverage. Again, this is due to height difference between indiangrass and horseweed. Coverage is based upon leaf coverage, not stem coverage. Horseweed was taller than indiangrass on 15 June 2000 and therefore was able to overlap the indiangrass plots. Since ratings were recorded approximately 1 month apart, some variance could be due to timing.

Table 22. Growing season color range of seven indiangrass cultivars grown at pH 5.2.[1]

Cultivar	Foliage colors	
Cheyenne	7.5GY5/4	7.5GY5/2
Holt	7.5GY4/2	7.5GY5/2-4
Nebraska 54	7.5GY4/4	7.5GY5/4
Osage	7.5GY5/4	7.5GY4/2
Oto	7.5GY4/4	7.5GY5/2-4
Rumsey	7.5GY4/4	N/A
Tomahawk	7.5GY5/4	7.5GY4/2

[1]Foliage color recorded on 9 November 2000 using Munsell Color Charts for Plant Tissues, Kollmorgen Corp., Baltimore, MD 21218.

Table 23. Winter color range of seven indiangrass cultivars grown at pH 5.2.[1]

Cultivar	Foliage colors		
Cheyenne	7.5YR6/4	2.5YR5/4	N/A
Holt	7.5YR7/4	7.5YR5-6/2	N/A
Nebraska 54	7.5YR7-8/4	N/A	N/A
Osage	7.5YR6-7/4	5YR5/4	N/A
Oto	7.5YR6/4	7.5YR5/2	2.5YR5/4
Rumsey	7.5YR5/2	5YR6-7/2	2.5YR5/4
Tomahawk	7.5YR5/4	7.5YR5-6/2	5YR4-5/2

[1]Dead (dormant) stand foliage color recorded on 22 January 2001 using Munsell Color Charts for Plant Tissues, Kollmorgen Corp., Baltimore, MD 21218.

Growing season colors among indiangrass cultivars, like big bluestem, were very similar (**Table 22**). All cultivars had dark green to dark gray-green leaf colors in the 7.5GY4-5/2-4 range. Leaf color values ranged from 4 to 5, which are dark. Chromas ranged from 2, which is dark gray-green to 4, which is dark green. However, unlike big bluestem, the red fall coloration was not observed in indiangrass. Based upon these observations, little variation in color between indiangrass cultivars was observed. Additionally, Greenlee (1992) considers the bright yellow of the anthers in the inflorescence of indiangrass aesthetically attractive.

As with big bluestem, indiangrass winter or dead stand foliage colors were much more variable than growing season colors (**Table 23**). In addition, no color differences between adaxial and abaxial leaf surfaces were observed in these indiangrass cultivars. Most of the colors ranged from medium-brown (7.5YR5-6/4, 5YR5/4, and 2.5YR5/4) to gray-brown (7.5YR5-6/2 and 5YR4-6/2). Additionally, some light-brown foliage coloration was observed in Holt (7.5YR7/4), Nebraska 54 (7.5YR7-8/4), Osage (7.5YR7/4), and Rumsey (5YR7/2) indiangrasses.

SWITCHGRASS

Materials and Methods

Seed from 10 switchgrass cultivars were utilized for this portion of the study. All cultivars were seeded at a rate of 11.6 kg PLS/ha (10.4 pounds per acre). This rate was recommended by Stock Seed Farms.

The switchgrass cultivars were Alamo, Blackwell, Cave-in-Rock, Dacotah, Forestburg, Nebraska 28, Shawnee, Shelter, Sunburst, and Trailblazer (**Table 24**). Most are Great Plains selections. Dacotah, Forestburg, and Sunburst were selected from northern ecotypes. Cave-in-Rock and Shelter are northeastern selections. All are upland cultivars, except Alamo, which is lowland. In addition, Alamo and Dacotah are tetraploids, while all other cultivars are octaploids.

The experimental design for switchgrass was a strip plot with repeated measures and three replications (**Figure 4**). Strips were management regimes of either mowed, harvested, or burned once annually in the spring. Experimental units were 1.83 x 1.83 square meters (6 x 6 square feet) in size. Seed was hand-planted on 21 June 1999. Before planting, seed was mixed with damp sand as a carrier.

For management, the mowing heights were 9 cm (3.5 inches). Mowed and harvested dead stand management treatments were conducted on 8 February 2000 and 2 February 2001. Burning was conducted on 10 February 2000. Management practices were conducted during early spring to reduce stress to the plants and provide maximum benefit from canopy cover for wildlife and color. Soil temperatures were recorded from harvested treatments before harvest in 2001. Biomass from harvested treatments was weighed (kg/ha of biomass), and plant tissue samples were taken for nutrient analysis. Tissue samples were analyzed by the Mississippi State University Extension Service Soil Testing Laboratory in Starkville, Mississippi. Biomass, soil temperature, and tissue sample data were analyzed using the ANOVA procedure. Mean separations were calculated using Fisher's LSD test (SAS Institute Inc., 1988a). Comparisons were made using Pearson Correlation Analysis (SAS Institute Inc., 1988b).

Plant height was recorded monthly from 16 July through 14 September in 1999 and from 12 May through 20 September in 2000. Each month, nine height measurements were taken within each experimental unit. Plant height data were analyzed using ANOVA in 1999 and 2000. Mean separations were calculated using Fisher's LSD test. Lodging data were collected in 1999, 2000, and 2001, but not in a form suitable for statistical analysis. Therefore, data is presented as either "yes" or "no" and not statistically analyzed.

Visual estimation of stand cover within each experimental unit was recorded once monthly from 16 July through 14 September in 1999. Stand cover was recorded once on 26 July in 2000. Stand cover was recorded as percent cover. Winter weed cover (percent cover) was recorded for each experimental unit on 15 June 2000. Since the major weed species was horseweed [*Conyza canadensis* (L.) Cronq.], this date allowed maximum time for development. The ANOVA procedure was used to analyze stand and weed cover data.

Table 24. History of the 10 switchgrass cultivars used in this study.

Cultivar	Origin [1]	Type [2]	Release date [1]	2*n* [2]
Alamo	Texas	Lowland	1978	36
Blackwell	Oklahoma	Upland	1944	72
Cave-in-Rock	Illinois	Upland	1975	72
Dacotah	North Dakota	Upland	1989	36
Forestburg	South Dakota	Upland	1987	72
Nebraska 28	Nebraska	Upland	1949	72
Shawnee	Illinois	Upland	1995	72
Shelter	New York	Upland	1987	72
Sunburst	South Dakota	Upland	1983	72
Trailblazer	Nebraska, Kansas	Upland	1984	72

[1]From Alderson, J., and W.C. Sharp. 1994. Grass cultivars of the United States. Agric. Handbook 170. SCS-USDA, Washington D.C., except Shawnee from Vogel, et al. 1996. Registration of Shawnee switchgrass. Crop Sci. 36:1713.
[2]Vogel, K.P. 2000. Improving warm-season forage grasses using selection, breeding, and biotechnology. p. 83-106. *In* K.J. Moore et al. (ed.) Native warm-season grasses: Research trends and issues. Crop Sci. Soc. of America, Madison, WS.

Mean separations were calculated using Fisher's LSD test. Comparisons were made between 2000 stand and winter weed cover using Pearson Correlation Analysis.

Foliage damage from Carolina (*Dissosteria carolina* L.) and redlegged (*Melanoplus femurrubrum* DeGeer) grasshoppers was recorded on 19 October 2000. Data was recorded as percent foliage damage (loss) and analyzed using the ANOVA procedure. Mean separations were calculated using Fisher's LSD test.

Plant color was determined using Munsell color charts for plant tissues (Munsell Color Charts for Plant Tissues, 2nd Ed. 1977, Kollmorgen Corp., Baltimore, MD 21218). Since growing season color was recorded on 9 November 2000, some fall color was included with certain cultivars. Dead (dormant) stand, or winter color was recorded on 22 January 2001. Where color was variable, both adaxial and abaxial leaf surfaces and stem colors may have been determined.

Soil samples from each experimental unit were collected on 23 February 2000. Analyses are presented in **Tables A.4-A.10**. These data were statistically analyzed using the ANOVA procedure. Mean separations were calculated using Fisher's LSD test. Pearson correlation analyses of soil nutrient data are presented in **Table A.11**. General soil sample results were not statistically analyzed and are presented in **Table 1**.

Buffer Strip

Mowed	**9**	**5**	**3**	**4**	**6**	**1**	**10**	**7**	**2**	**8**
Harvested	**9**	**5**	**3**	**4**	**6**	**1**	**10**	**7**	**2**	**8**
Burned	**9**	**5**	**3**	**4**	**6**	**1**	**10**	**7**	**2**	**8**
Harvested	**7**	**8**	**2**	**9**	**5**	**4**	**3**	**1**	**6**	**10**
Burned	**7**	**8**	**2**	**9**	**5**	**4**	**3**	**1**	**6**	**10**
Mowed	**7**	**8**	**2**	**9**	**5**	**4**	**3**	**1**	**6**	**10**
Burned	**5**	**4**	**10**	**1**	**6**	**8**	**2**	**3**	**9**	**7**
Mowed	**5**	**4**	**10**	**1**	**6**	**8**	**2**	**3**	**9**	**7**
Harvested	**5**	**4**	**10**	**1**	**6**	**8**	**2**	**3**	**9**	**7**

Buffer Strip

Buffer Strip **Buffer Strip**

Figure 4. Plot plan for 10 switchgrass (*Panicum virgatum* L.) cultivars grown under three management regimes at a soil pH of 5.2. Cultivars: 1 = Alamo, 2 = Blackwell, 3 = Shawnee, 4 = Cave-in-Rock, 5 = Forestburg, 6 = Nebraska 28, 7 = Sunburst, 8 = Shelter, 9 = Dacotah, and 10 = Trailblazer. Management regimes: (1) mowed, (2) harvested, or (3) burned once annually in spring.

Results and Discussion

In 1999, Alamo switchgrass had significantly more cover than all other cultivars at 4 weeks after planting (**Table 25**). Alamo also had the greatest cover in July of 2000. Trailblazer and Dacotah had 7.7% and 5.7% cover, respectively at 4 weeks after planting in 1999. Although Dacotah had more cover at this time than seven other cultivars, it had significantly less cover than all cultivars by July 2000. By July 2000, all cultivars were in between Alamo (97%) and Dacotah (7.2%). Blackwell, Cave-in-Rock, Nebraska 28, Shawnee, Shelter, and Trailblazer had between 69.9% and 90% cover by July 2000. These grasses apparently perform well on soils with a pH of 5.2.

Blackwell switchgrass has shown substantial tolerance to acid soil during the seedling stage (Hopkins and Taliaferro, 1997). Cave-in-Rock, Nebraska 28, Shawnee, Shelter, and Trailblazer may also have acid soil tolerance,

Table 25. Stand coverage of 10 switchgrass cultivars in 1999 and 2000 grown at pH 5.2.

Cultivar	1999			2000
	July	August	September	July
	%	%	%	%
Alamo	11.7	56.7	78.3	97.0
Blackwell	4.7	23.3	45.0	84.4
Cave-in-Rock	5.0	56.7	75.0	90.0
Dacotah	5.7	30.0	38.3	7.2
Forestburg	4.0	23.3	38.3	45.6
Nebraska 28	3.0	13.3	26.7	69.9
Shawnee	4.3	50.0	53.3	89.4
Shelter	3.0	16.7	25.0	73.9
Sunburst	3.3	18.3	21.7	39.4
Trailblazer	7.7	36.7	53.3	71.1
LSD (0.05)	**2.58**	**13.79**	**15.33**	**14.84**

Table 26. Stand coverage of 10 switchgrass cultivars in July 2000 grown at pH 5.2 and compared with weed coverage on 15 June 2000.[1]

Cultivar	Switchgrass	Weeds
	%	%
Alamo	97.0	4.0
Cave-in-Rock	90.0	4.0
Shawnee	89.4	10.0
Blackwell	84.4	18.3
Shelter	73.9	41.7
Trailblazer	71.1	40.0
Nebraska	69.9	81.7
Forestburg	45.6	73.3
Sunburst	39.4	76.7
Dacotah	7.2	93.3
LSD (0.05)	**14.84**	**15.38**

[1]Primary weed species was horseweed [*Conyza canadensis* (L.) Cronq.].

Table 27. Plant height of 10 switchgrass cultivars in 1999 grown at pH 5.2.

Cultivar	July	August	September	Average
	cm	cm	cm	cm
Alamo	18.1	60.3	74.9	51.1
Blackwell	13.6	39.4	48.4	33.8
Cave-in-Rock	18.0	52.6	59.0	43.2
Dacotah	13.1	33.6	35.1	27.3
Forestburg	10.4	32.3	37.0	26.6
Nebraska 28	10.7	36.9	46.2	31.3
Shawnee	15.4	50.9	59.3	41.9
Shelter	10.1	40.9	50.6	33.9
Sunburst	8.3	29.4	36.1	24.6
Trailblazer	16.0	45.0	49.2	36.9
LSD (0.05)	**1.31**	**3.78**	**4.83**	**5.43**

including Alamo switchgrass. Clark et al. (1999) indicate that symbiotic arbuscular mycorrhizal fungi (AMF) may play an important role in acid soil tolerance of switchgrass. It is not clear whether this factor, weather, soil pH, or climate played a role in the poor performance of Dacotah, Forestburg, and Sunburst in this study. However, all three cultivars were selected from the northern Great Plains, unlike the other seven switchgrass cultivars in this study. The fact that these cultivars had cover similar to other cultivars at 4 weeks after planting might lead to the assumption that climate was the major contributing factor in the poor performance of these three cultivars.

Sanderson et al. (1999) observed poor performance of switchgrass under drought conditions in Texas. Research by Smart and Moser (1997) indicates mid-March planting dates can advance morphological development over later planting dates. Our results indicate that establishment success with summer planting of certain switchgrass cultivars in Mississippi can be achieved even in dry years.

There is some indication that coverage of varieties such as Blackwell may persist longer than Alamo. Jung et al. (1990) observed coverage of Alamo at 51% compared with Blackwell at 92% after 9 years without supplemental nitrogen. It is not clear how these varieties will perform in our study given more time.

There was a highly significant (P=0.0001) negative correlation between percent switchgrass and weed cover in 2000 (**Table 26**). The correlation coefficient was -0.742, which is higher than the 0.236 and -0.419 observed in big bluestem and indiangrass plots during this period. It is highly likely that switchgrass was much more competitive with horseweed than the other species during these studies.

Alamo (18.1 cm) and Cave-in-Rock (18 cm) were significantly taller than other cultivars at 4 weeks after planting in 1999 (**Table 27**). Trailblazer (16 cm) was next followed by Shawnee (15.4 cm), Blackwell (13.6 cm), Dacotah (13.1 cm), Nebraska 28 (10.7 cm), Forestburg (10.4 cm), Shelter (10.1 cm), and Sunburst (8.3 cm). Alamo and Cave-in-Rock also had the greatest average heights in 1999 at 51.1 cm and 43.2 cm, respectively. In 1999, Cave-in-Rock was not significantly taller than Shawnee (41.9 cm). Sunburst (24.6 cm) had the shortest average height during 1999.

Table 28. Plant height of 10 switchgrass cultivars in May 2000 grown at pH 5.2.

Cultivar	Mowed	Harvested	Burned	LSD	Avg.
	cm	cm	cm	cm	cm
Alamo	95.9	124.9	120.3	NS	113.7
Blackwell	80.0	96.8	103.6	17.38	93.4
Cave-in-Rock	85.7	112.0	106.1	16.50	101.3
Dacotah	78.4	54.4	74.4	17.29	68.9
Forestburg	87.0	72.7	71.9	NS	77.2
Nebraska 28	81.8	94.8	93.9	NS	90.0
Shawnee	87.4	94.2	107.4	NS	96.4
Shelter	72.3	96.0	97.9	14.62	88.7
Sunburst	58.4	69.1	73.6	NS	67.0
Trailblazer	91.2	95.2	108.2	11.03	98.2
LSD (0.05)	**20.40**	**12.27**	**10.05**		**10.96**

Table 29. Plant height of 10 switchgrass cultivars in June 2000 grown at pH 5.2.

Cultivar	Mowed	Harvested	Burned	LSD	Avg.
	cm	cm	cm	cm	cm
Alamo	148.8	150.7	160.8	NS	153.4
Blackwell	113.0	113.9	117.3	NS	114.7
Cave-in-Rock	124.7	121.1	117.8	NS	121.2
Dacotah	62.1	63.0	67.9	NS	64.3
Forestburg	74.0	85.9	78.3	NS	79.4
Nebraska 28	97.0	94.8	96.0	NS	95.9
Shawnee	120.4	119.3	120.8	NS	120.2
Shelter	109.8	114.2	118.8	NS	114.3
Sunburst	76.3	69.7	84.0	NS	76.7
Trailblazer	104.7	109.1	105.6	NS	106.4
LSD (0.05)	**15.74**	**12.10**	**10.75**		**7.51**

Table 30. Plant height of 10 switchgrass cultivars in July 2000 grown at pH 5.2.

Cultivar	Mowed	Harvested	Burned	LSD	Avg.
	cm	*cm*	*cm*	*cm*	*cm*
Alamo	166.1	157.4	160.8	NS	161.4
Blackwell	124.2	127.7	139.2	NS	130.4
Cave-in-Rock	141.2	149.6	136.7	NS	142.5
Dacotah	68.7	73.2	62.6	7.20	68.2
Forestburg	81.4	84.2	79.4	NS	81.7
Nebraska 28	86.2	98.2	109.3	NS	97.9
Shawnee	117.0	136.1	135.0	NS	129.4
Shelter	116.2	127.4	130.0	NS	124.6
Sunburst	72.4	69.8	85.0	11.20	75.7
Trailblazer	120.4	116.6	129.3	NS	122.1
LSD (0.05)	**20.90**	**16.91**	**15.50**		**10.43**

Table 31. Plant height of 10 switchgrass cultivars in August 2000 grown at pH 5.2.

Cultivar	Mowed	Harvested	Burned	LSD	Avg.
	cm	*cm*	*cm*	*cm*	*cm*
Alamo	178.4	183.8	178.2	NS	179.5
Blackwell	130.6	135.3	146.2	NS	137.4
Cave-in-Rock	148.6	141.2	145.7	NS	145.2
Dacotah	63.3	65.6	71.6	NS	66.8
Forestburg	88.6	76.1	96.4	15.32	87.0
Nebraska 28	109.7	97.7	109.3	NS	105.6
Shawnee	130.6	140.2	146.0	NS	138.9
Shelter	139.8	127.9	148.1	15.87	138.6
Sunburst	81.2	79.3	85.6	NS	82.0
Trailblazer	131.3	123.7	130.4	NS	128.5
LSD (0.05)	**21.30**	**17.24**	**16.55**		**10.71**

Alamo (113.7 cm) and Cave-in-Rock (101.3 cm) had the greatest average height in May 2000 (**Table 28**). With the exception of Dacotah (68.9 cm), Forestburg (77.2 cm), and Sunburst (67 cm), the remaining cultivars were similar in height to Alamo and Cave-in-Rock. In general, mowed plots tended to have shorter heights. Plants were significantly shorter in mowed plots of Blackwell, Cave-in-Rock, Shelter, and Trailblazer. In addition, most cultivars showed no significant differences between management regimes. Due to removal of nutrients in harvested plots, they would be expected to be shortest. This was only observed in Dacotah plots.

No cultivars showed a significant response to management in June 2000 (**Table 29**). Alamo (153.4 cm) was still tallest, followed by Cave-in-Rock (121.2 cm), which was only slightly taller than Shawnee (120.2 cm). Dacotah (64.3 cm), Forestburg (79.4 cm), and Sunburst (76.7 cm) still had the shortest mean heights.

Trends were similar in July 2000 for average switchgrass heights (**Table 30**). However, the management response observed in May 2000 was reversed with the harvested plots having the tallest plants (73.2 cm). Plants in harvested plots were significantly taller than plants in burned plots (62.6 cm). Conversely, plants in burned Sunburst plots were significantly taller than plants in either mowed or harvested plots.

In August 2000, plants in Forestburg and Shelter burned plots were significantly taller than plants in harvested plots, but height differences were not significant in Sunburst plots (**Table 31**). September showed similar fluctuations with plants being significantly taller in burned plots of Cave-in-Rock (141.9 cm) and Shawnee (149.9 cm) compared with plants in mowed plots (118.1 cm and 122.2 cm, respectively) (**Table 32**).

These fluctuations make it difficult to determine the influence of management upon the switchgrass cultivars during this study. It is likely that a longer duration under these management regimes may indicate clearer differences. In order to obtain some idea of the influence of management upon these switchgrasses during the study, averages were calculated across the 10 species for each management regime (**Figure 5**). From these data, there is some indication that plants on average were taller in burned plots. However, these differences were small and were not statistically analyzed. Still, long-term studies may provide more information regarding the influence of management upon plant height.

Table 32. Plant height of 10 switchgrass cultivars in September 2000 grown at pH 5.2.

Cultivar	Mowed	Harvested	Burned	LSD	Avg.
	cm	*cm*	*cm*	*cm*	*cm*
Alamo	173.7	194.0	191.2	NS	186.3
Blackwell	126.3	134.6	142.0	NS	134.3
Cave-in-Rock	118.1	131.2	141.9	18.06	130.4
Dacotah	36.8	51.0	40.8	NS	42.9
Forestburg	88.9	75.8	75.8	10.20	80.2
Nebraska 28	89.1	107.8	95.9	NS	97.7
Shawnee	122.2	139.7	149.9	15.54	137.3
Shelter	126.3	122.1	128.8	NS	125.7
Sunburst	76.9	76.0	85.7	NS	79.5
Trailblazer	123.6	119.3	124.8	NS	122.6
LSD (0.05)	**19.22**	**18.76**	**18.19**		**11.03**

Table 33. Lodging tendency and 2000 plant height of 10 switchgrass cultivars grown at pH 5.2.[1]

Cultivar	Lodging			Height
	1999	2000	2001	
				cm
Alamo	No	Yes	Yes	158.9
Blackwell	No	No	Yes	122.0
Cave-in-Rock	No	No	Yes	128.1
Dacotah	No	No	No	62.2
Forestburg	No	No	No	81.1
Nebraska 28	No	No	No	97.5
Shawnee	No	No	Yes	124.4
Shelter	No	No	Yes	118.4
Sunburst	No	No	No	76.2
Trailblazer	No	No	Yes	115.6

[1]Average across three managements and 5 months during 2000.

The responses to management regime were, for the most part, different depending upon the cultivar. This may be an indication that cultivars respond differently to management. Long-term studies should take this into consideration when addressing the influence of switchgrass management.

A view of average heights from May through September of 2000 shows the peak at the end of the summer in July, August, and September for most cultivars. It is not clear if plant heights will continue to increase given additional years of growth. A third year, and possibly more, may be necessary for many of these cultivars to obtain their full height. However, Cave-in-Rock grown in eastern Canada obtained heights of 169.9 cm (Madakadze et al., 1999a). It obtained an average height of 145.2 cm in August 2000 in this study. This may indicate that Cave-in-Rock plant heights were near their maximum by the second year of the study. This may not be the case for other cultivars. For example, Madakadze et al. (1999a) recorded a height of 177.8 cm for Sunburst in eastern Canada. The greatest average height of Sunburst (82 cm) in this study was obtained in August. However, it is possible that since Sunburst was selected in South Dakota, it is not as adapted and may never obtain its full potential in this study. The average heights of Alamo and Blackwell were recorded at 91 cm and 93 cm, respectively, by Jung et al.(1990) over a 3-year period in Pennsylvania. This growth is far less than the 186.3 cm and 134.3 cm in July 2000 averages recorded for these cultivars in our study. This difference may be an indication that these cultivars are near their maximum heights. Due to inconsistencies between studies, more time may be needed to determine which cultivars have obtained their maximum heights.

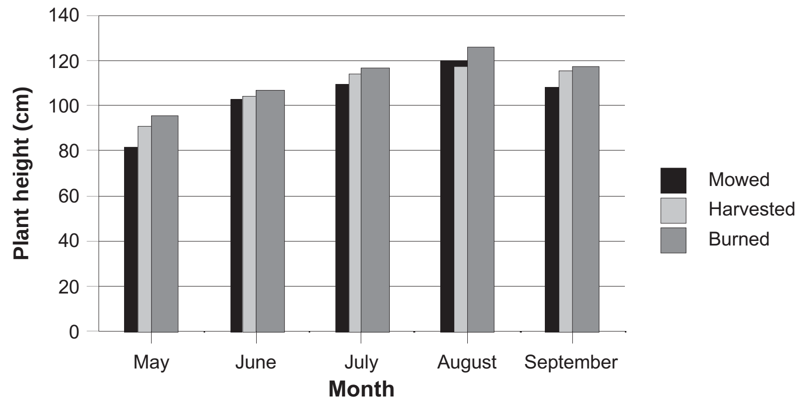

Figure 5. Average plant height of 10 switchgrass cultivars in the summer of 2000 after one treatment of mowing, harvesting, or burning in February 2000 on soil with a pH of 5.2.

Despite a potential for additional height, most cultivars had a tendency to lodge (**Table 33**). No correlation analysis was utilized with the height and lodging data, but Alamo had the tallest average height (158.9 cm) in 2000 and was the only cultivar that lodged in 2000. By the summer of 2001, all of the taller cultivars were lodging. No lodging was observed during the establishment year. It is uncertain if the addition of nitrogen fertilizer would have compounded the problem with lodging.

Table 34. Dead standing biomass of 10 switchgrass cultivars in spring 2000 and 2001 grown at pH 5.2.

Cultivar	2000	2001
	kg/ha	*kg/ha*
Alamo	2400	7167
Cave-in-Rock	1222	4164
Shawnee	863	3456
Trailblazer	638	2125
Blackwell	403	3569
Nebraska 28	362	855
Shelter	284	2068
Forestburg	213	680
Dacotah	126	244
Sunburst	66	623
LSD (0.05)	**353.7**	**1119.2**

The effect of nitrogen fertilization on biomass has been researched in Alabama (Sladden et al., 1995), Iowa (Hall et al., 1982), and Pennsylvania (Jung et al., 1990). In our study under no supplemental fertility, 10 switchgrass cultivars exhibited high variability in dead standing biomass production (**Table 34**). Alamo had significantly more biomass than other cultivars in both the 2000 and 2001 harvest (2,400 kg/ha and 7,167 kg/ha, respectively). This is similar to the 5,580 kg/ha of annual Alamo biomass obtained by Pitman (2000) during the summer of 1996 under longleaf pine (*Pinus palustris* Mill.) in western Louisiana. Cave-in-Rock was next for both years at 1,222 kg/ha and 4,164 kg/ha. Jung et al. (1990) compared dry matter yield between Alamo and Blackwell and found the highest yields from Blackwell. Hall et al. (1982) harvested dry matter yields of 6,330 kg/ha and 5,510 kg/ha during the fourth and fifth years, respectively, from Blackwell in Iowa. These values are greater than the 3,569 kg/ha of biomass harvested during the second year of our study. However, Hall et al. conducted multiple harvests during the growing season under fertility. In addition, it is possible that third- and fourth-year harvest yields in our study would be higher. Despite these inconsistencies between studies, there appears to be three groups in our study based upon 2001 biomass production. Alamo was by far the highest producer. It is also the only lowland type in this study. Sanderson et al. (1999) observed similar biomass results with Alamo in Texas. The second group appeared to be Cave-in-Rock (4,164 kg/ha), Blackwell (3,569 kg/ha), Shawnee (3,456 kg/ha), Trailblazer (2,125 kg/ha), and

Shelter (2,068 kg/ha). The third group had very little biomass production — Nebraska 28 (855 kg/ha), Forestburg (680 kg/ha), Sunburst (623 kg/ha), and Dacotah (244 kg/ha). Biomass production is not necessarily a positive characteristic in golf course natural areas. Some biomass is required for aesthetics and to provide soil protection and cover for wildlife. However, as discussed previously, Alamo was also the first cultivar to lodge. This factor may be an indication that some middle ground needs to be considered when selecting a cultivar for use in natural areas.

There has been some indication that plant cover has some influence upon soil temperatures. Various types of covers have been utilized in turfgrass to provide an insulating effect during cold weather (Beard, 1973b). It is likely that a similar response occurs with natural cover. Such cover most likely prevents temperature extremes, although some of this effect may be due to the reduction of wind velocity (Bilbro and Fryrear, 1997), particularly with larger grasses such as switchgrass. These extremes may include both high and low soil temperatures. In spring 2001, soil temperatures under natural dead standing cover of 10 switchgrass cultivars were recorded (**Table 35**). Correlation analyses were used to compare dead standing biomass and soil temperature. There was a highly significant (*P*=0.0001) correlation between the amount of dead standing biomass on plots and the soil temperature. This correlation was negative (-0.724), indicating that as biomass increases, soil temperature decreases. Conversely, soil temperatures in this study tended to be higher in plots with less cover. Although this may be true, it is not clear how this finding impacts spring green-up, winter survival of a given cultivar, or wildlife that may inhabit natural areas. Although not addressed in this study, cover may have some influence upon moisture evaporation from the soil surface and possibly drought stress.

According to Schacht et al. (1998), winter harvesting of dead stand material may have little effect upon growing season productivity of big bluestem, little bluestem, and switchgrass. However, they did not determine long-term effects of dead stand material removal upon soil nutrient levels. In our study, tissue samples were taken from spring dead standing biomass harvests to determine if any significant loss of nutrients was occurring in harvested plots. Only 1 year of data was collected for this portion of the study. There were significant differences in the amount of nitrogen, phosphorus, and potassium removed in harvested biomass (**Table 36**). However with regard to nitrogen and phosphorus, this was apparently due to the amount of biomass and not concentration of nutrients in the samples (measured in grams per kilogram [g/kg]). Although Alamo had the highest amount of nitrogen (37.9 kg/ha) and phosphorus (5.85 kg/ha) in total biomass, it was not significantly different from other cultivars in nutrient concentration. Jung et al. (1990) harvested 45.5 kg/ha of N per year from Blackwell switchgrass plots with no supplemental nitrogen. This amount is higher than the 23.6 kg/ha of N per year removed from Blackwell plots in our study. Based upon findings by Jung et al. (1990), it is possible that if we had applied nitrogen applications in our study, the amount of nitrogen in harvests would have increased. Most cultivars had similar concentrations of nitrogen and phosphorus, ranging from 5.40 g/kg to 8.97 g/kg of N and 0.40 g/kg to 0.80 g/kg of P.

Table 35. Dead standing biomass and soil temperature of 10 switchgrass cultivars in spring 2001 grown at pH 5.2.

Cultivar	Biomass	Soil temp.
	kg/ha	*°C*
Alamo	7167.1	53.4
Cave-in-Rock	4164.3	55.7
Blackwell	3569.4	56.0
Shawnee	3456.1	56.0
Trailblazer	2124.6	57.3
Shelter	2068.0	59.6
Nebraska 28	854.8	59.7
Forestburg	679.9	61.9
Sunburst	623.3	62.5
Dacotah	244.2	64.1
LSD (0.05)	**1119.2**	**2.35**

Table 36. Nitrogen, phosphorus, and potassium tissue samples taken in February 2001 from 10 switchgrass cultivars grown at pH 5.2.

Cultivar	Nitrogen			Phosphorus			Potassium		
	%	kg/ha	g/kg	%	kg/ha	g/kg	%	kg/ha	g/kg
Alamo	0.54	37.9	5.40	0.08	5.85	0.80	0.07	4.90	0.70
Blackwell	0.67	23.6	6.67	0.04	1.43	0.40	0.02	0.75	0.20
Cave-in-Rock	0.65	27.4	6.53	0.05	2.22	0.53	0.02	0.67	0.17
Dacotah	0.90	2.2	8.97	0.06	0.15	0.60	0.04	0.09	0.37
Forestburg	0.76	5.4	7.63	0.05	0.31	0.47	0.03	0.25	0.33
Nebraska 28	0.69	5.7	6.93	0.05	0.38	0.47	0.03	0.20	0.30
Shawnee	0.63	22.6	6.33	0.05	1.56	0.47	0.03	1.20	0.33
Shelter	0.62	12.8	6.23	0.05	0.97	0.50	0.03	0.57	0.27
Sunburst	0.75	4.5	7.47	0.06	0.40	0.63	0.04	0.28	0.40
Trailblazer	0.65	13.8	6.50	0.05	0.96	0.47	0.03	0.69	0.33
LSD (0.05)	**NS**	**9.77**	**NS**	**NS**	**1.983**	**NS**	**0.026**	**1.428**	**0.255**

Table 37. Calcium, magnesium, and iron from tissue samples taken in February 2001 from 10 switchgrass cultivars grown at pH 5.2.

Cultivar	Calcium			Magnesium			Iron		
	%	kg/ha	g/kg	%	kg/ha	g/kg	ppm[1]	kg/ha	g/kg
Alamo	0.20	14.6	2.00	0.040	2.81	0.40	43.0	0.31	0.043
Blackwell	0.25	9.2	2.50	0.033	1.13	0.33	37.3	0.13	0.037
Cave-in-Rock	0.22	9.2	2.20	0.023	0.97	0.23	52.3	0.22	0.052
Dacotah	0.24	0.6	2.37	0.020	0.05	0.20	40.7	0.01	0.041
Forestburg	0.23	1.6	2.33	0.020	0.14	0.20	35.3	0.02	0.035
Nebraska 28	0.22	1.9	2.17	0.020	0.17	0.20	33.7	0.03	0.034
Shawnee	0.21	7.1	2.10	0.027	0.94	0.27	45.3	0.16	0.045
Shelter	0.21	4.8	2.13	0.027	0.58	0.27	81.3	0.15	0.081
Sunburst	0.32	2.1	3.20	0.023	0.16	0.23	53.7	0.03	0.054
Trailblazer	0.28	5.9	2.83	0.027	0.56	0.27	32.0	0.07	0.032
LSD (0.05)	**NS**	**4.23**	**NS**	**0.0111**	**0.478**	**0.112**	**NS**	**0.096**	**NS**

[1]ppm = mg/g.

There was much more potassium (4.90 kg/ha) in Alamo biomass compared with other cultivars. The closest cultivar was Shawnee with 1.2 kg/ha of K. Unlike nitrogen and phosphorus, this finding may have been due in part to higher concentrations of potassium in Alamo tissue. Alamo had significantly higher concentrations of potassium in tissues (0.7 g/kg) than other cultivars. It is unclear why potassium concentrations were higher in Alamo. Since Alamo was the tallest, it may have a deeper root system with the ability to obtain soil nutrients that other cultivars were unable to reach. Sunburst switchgrass has been known to obtain nitrogen at soil depths below 120 cm (Huang et al., 1996). Conversely, Staley et al. (1991) compared fertilizer-N recovery between tall fescue (*Festuca arundinacea* Schreb.) and switchgrass on shallow soil. They found that switchgrass had a 31% fertilizer-N recovery compared with 19% in tall fescue. However, the cultivar was not specified, and it is not known if research has been conducted which compares rooting depths of switchgrass cultivars.

Based upon these data, it is possible that removal of clippings could lead to soil deficiencies — especially in switchgrass cultivars like Alamo, Blackwell, Cave-in-Rock, and Shawnee. The recommendation by the USDA-SCS and Ducks Unlimited Canada (Dickerson et al., 1997) is to add nitrogen and phosphorus at 3:1 ratio the second year of establishment. Their recommendation calls for nitrogen rates of 100.8 kg/ha (90 pounds per acre). However, according to our study, the loss of this much nitrogen through spring biomass harvests, would take approximately 3 (Alamo) to 4 years (Blackwell, Cave-in-Rock, and Shawnee). In addition, the 3:1 ratios for soil applications do not correspond with those found in dead standing tissues in our study. By averaging concentrations across all 10 cultivars the ratio is 0.686:0.054, or 13:1. Using the same method, the N:P:K ratio was 0.686:0.054:0.034, or 20:1.6:1. These data indicate far higher nitrogen concentrations in dead standing tissue compared with phosphorus and potassium.

Nitrogen concentrations in green tissues of these cultivars are most likely higher, since Madakadze et al. (1999b) found 12.4 g/kg of N in tissue under no fertility. Green tissue samples from bermudagrass (*Cynodon* spp.) and perennial ryegrass (*Lolium perenne* L.) also show much higher concentrations of nitrogen, phosphorus, and potassium (Puhalla et al., 1999). These concentrations provide high sufficiency levels for the two species: more than 5% N in both species; 0.5% P in bermudagrass and 0.4% P in perennial ryegrass; and 4% K in bermudagrass and 2.5% K in perennial ryegrass. Despite the high N:P ratio in this study, the average nitrogen concentration was still less than one-fifth that considered high in bermudagrass and perennial ryegrass.

Based upon these data, it is possible that nitrogen deficiencies may result from annual harvest over several years, particularly with cultivars that produce higher biomass. However, there is no indication that nonharvested plots will develop deficiencies. It is possible, at least in nonharvested plots, that no additional fertility is necessary since most of the switchgrass cultivars had good performance in this study without supplemental fertility. Thus, the soil nutrient levels at the initiation of this study may be adequate for the establishment of most of the 10 switchgrass cultivars.

Calcium (Ca), magnesium (Mg), and iron (Fe) concentrations were generally similar across the 10 switchgrass cultivars (**Table 37**). There were significant differences in the total amount of each nutrient across the cultivars. As expected, Alamo had significantly higher amounts of all three nutrients with 14.6 kg/ha of Ca, 2.81 kg/ha of Mg, and 0.31 kg/ha of Fe. However, concentrations of Ca and Fe in Alamo tissue samples were not significantly higher than other cultivars. Alamo had significantly higher concentrations of Mg compared with other cultivars. As with N, P, and K, Ca and Mg concentrations were below the concentrations considered low for bermudagrass and perennial ryegrass (Puhalla et al., 1999). However, Fe concentrations ranged from 32 ppm to 81.3 ppm, which are comparable to living bermudagrass tissue sufficiency levels of below low to medium. General tissue sufficiency levels for these nutrients have not been established for these cultivars. Since no appar-

Cultivar	Manganese			Zinc			Copper		
	ppm[1]	kg/ha	g/kg	ppm	kg/ha	g/kg	ppm	kg/ha	g/kg
Alamo	396.0	2.75	0.40	20.7	0.146	0.021	13.3	0.100	0.013
Blackwell	480.0	1.67	0.48	9.7	0.032	0.010	6.0	0.021	0.006
Cave-in-Rock	559.3	2.37	0.56	16.7	0.072	0.017	14.7	0.064	0.015
Dacotah	761.0	0.18	0.76	14.7	0.004	0.015	6.3	0.002	0.006
Forestburg	597.7	0.41	0.60	10.3	0.007	0.010	5.7	0.004	0.006
Nebraska 28	362.0	0.25	0.36	12.3	0.008	0.012	5.0	0.004	0.005
Shawnee	462.3	1.62	0.46	13.7	0.051	0.014	12.7	0.050	0.013
Shelter	377.7	0.76	0.38	18.3	0.040	0.018	15.7	0.032	0.016
Sunburst	808.0	0.27	0.48	16.7	0.010	0.017	8.7	0.005	0.009
Trailblazer	271.7	0.60	0.27	9.7	0.021	0.010	6.3	0.013	0.006
LSD (0.05)	**NS**	**1.112**	**NS**	**NS**	**0.0453**	**NS**	**NS**	**0.0516**	**NS**

Table 38. Manganese, zinc, and copper from tissue samples taken in February 2001 from 10 switchgrass cultivars grown at pH 5.2.

[1]ppm=mg/g.

ent deficiencies were observed during this study, the levels of each in the soil at planting may have been adequate, particularly for cultivars that performed well. It is not clear what impact the removal of these nutrient amounts will have upon long-term plant height.

The total amount of manganese (Mn) and zinc harvested in tissue samples was significantly higher from Alamo plots compared with other cultivars (**Table 38**). The total amount of copper (Cu) was highest from Alamo plots, but it was not significantly higher than that harvested from Cave-in-Rock plots. There were no significant differences in concentrations of these nutrients across the 10 cultivars. Average concentrations of Mn and Cu in switchgrass dead standing tissue samples in this study were comparable to those in living tissues of bermudagrass (Puhalla et al., 1999). Average Mn concentrations in switchgrass (507.6 ppm) in this study were comparable to the tissue sufficiency range of high for bermudagrass (more than 300 ppm). Average Cu concentrations (9.4 ppm) were comparable to the tissue sufficiency range of medium for bermudagrass (5-50 ppm). As with Ca, Mg, and Fe, it is difficult to assess the long-term impacts of harvests on soil reserves of these nutrients. No general tissue sufficiency levels for these nutrients have been established for these cultivars. However, no apparent deficiencies were observed during the study.

Correlation analyses indicate a significant (p=0.0006) negative (-0.591) correlation between cover and N concentration in dead standing tissue (**Table 39**). As percent cover increased, the N concentration decreased. There is some indication of competition between plants for N, especially since nitrogen apparently has more influence on tiller weight than number (Sanderson, 2000). Comparisons between biomass and N concentrations showed a similar trend with a correlation coefficient of -0.591 (p=0.0022). Correlations between

Table 39. Pearson correlation coefficients (*P*) for comparisons between 2000 stand cover, 2001 biomass, and 2001 nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) biomass from dead standing tissue samples of 10 switchgrass cultivars grown at pH 5.2.

Variable		2000	2001					
		Cover	Biomass	N	P	K	Ca	Mg
		kg/ha	*g/kg*	*g/kg*	*g/kg*	*g/kg*	*g/kg*	*g/kg*
2000 Cover	*r*	-	0.734	-0.591	-0.077	-0.110	-0.215	0.376
	P	-	0.0001	0.0006	0.686	0.565	0.255	0.0404
2001 Biomass	*r*		-	-0.537	0.231	0.267	-0.215	0.560
	P		-	0.0022	0.221	0.154	0.254	0.0013
2001 N	*r*			-	-0.129	0.046	0.048	-0.345
	P			-	0.498	0.809	0.802	0.062
2001 P	*r*				-	0.120	0.028	0.236
	P				-	0.529	0.885	0.210
2001 K	*r*					-	0.186	0.279
	P					-	0.325	0.135
2001 Ca	*r*						-	-0.196
	P						-	0.300

Table 40. Pearson correlation coefficients (*P*) for comparisons between 2000 stand cover, 2001 biomass, and 2001 iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) biomass from dead standing tissue samples of 10 switchgrass cultivars grown at pH 5.2.

Variable		2000	2001				
		Cover	Biomass	Fe	Mn	Zn	Cu
		kg/ha	*g/kg*	*g/kg*	*g/kg*	*g/kg*	*g/kg*
2000 Cover	*r*	-	0.734	0.040	-0.463	-0.113	0.288
	P	-	0.0001	0.832	0.010	0.953	0.122
2001 Biomass	*r*		-	0.028	-0.230	0.259	0.431
	P		-	0.882	0.222	0.167	0.017
2001 Fe	*r*			-	-0.018	0.360	0.542
	P			-	0.923	0.051	0.002
2001 Mn	*r*				-	0.266	0.074
	P				-	0.155	0.698
2001 Zn	*r*					-	0.646
	P					-	0.0001

Mn concentrations in tissues and percent cover also showed a significant (*p*=0.01) negative (*r*=-0.463) correlation (**Table 40**). As with N, there may have been some competition between plants for Mn during the study.

It is not clear why there was a significant positive correlation between percent cover and Mg concentrations in tissue samples (**Table 39**). However, the correlation coefficient was lower at 0.376 (*p*=0.04). Comparisons between biomass and Mg concentrations were similar (*r*=0.560, *p*=0.0013). Cu concentrations also showed significant (*p*=0.017) positive (*r*=0.431) correlation with biomass (**Table 40**). As with Mg, this response is not clearly understood. There were no significant correlations between N, P, K, Ca, and Mg (**Table 39**). However, there were other significant correlations between certain nutrients in tissue samples. There was significant (*p*=0.002) positive (*r*=0.542) correlation between Cu and Fe concentrations in tissue samples (**Table 40**). Also, there were significant (*p*=0.0001) positive (*r*=0.646) correlation between Cu and Zn concentrations in tissue samples. Mn concentrations in tissue showed significant positive correlations with N (*r*=0.424; *p*=0.019) concentrations and significant negative correlations with Ca (*r*=-0.375; *p*=0.041) concentrations (**Table 41**). Zn concentrations in tissue showed significant positive correlations with P (*r*=0.561; *p*=0.001). Apparently, there are correlations between these nutrients within the living plant, but it is unclear how these correlations can be interpreted in dead standing tissue.

In 2000, grasshopper damage was observed in switchgrass plots. There is apparently some variability in the resistance of the cultivars in this study to Carolina (*Dissosteria carolina* L.) and redlegged (*Melanoplus femurrubrum* DeGeer) grasshoppers. Alamo showed the least amount of damage (21.7%). Shawnee showed the greatest amount of damage (56.7%). It has been noted that low seed yields that occur periodically in the Great Plains region are probably due to insect predation (Vogel, 2000). Although not identified in this study, the big bluestem seed midge (*Contarinia wattsi* Gagne) is a serious pest in native grass production areas (Carter et al., 1988).

Additionally, field studies on field crickets (*Gryllus pennsylvanicus* Burmeister) have shown high activity-densities in switchgrass filter strips (Carmona et al., 1999).

Table 41. Pearson correlation coefficients (*P*) for comparisons between 2001 nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) biomass from dead standing tissue samples of 10 switchgrass cultivars grown at pH 5.2.

Variable		N	P	K	Ca	Mg
		g/kg	*g/kg*	*g/kg*	*g/kg*	*g/kg*
Fe	*r*	0.034	0.257	-0.133	-0.063	-0.157
	P	0.859	0.171	0.484	0.742	0.407
Mn	*r*	0.424	0.070	-0.172	-0.375	-0.153
	P	0.019	0.714	0.363	0.041	0.419
Zn	*r*	-0.016	0.561	0.170	-0.202	0.347
	P	0.932	0.001	0.369	0.285	0.060
Cu	*r*	-0.334	0.302	-0.138	-0.150	0.075
	P	0.072	0.104	0.466	0.429	0.692

Table 42. Foliage damage from grasshoppers recorded 19 October 2000 on 10 switchgrass cultivars grown at pH 5.2.[1]

Cultivar	Foliar loss
	%
Alamo	21.7
Dacotah	33.3
Trailblazer	45.0
Forestburg	46.7
Nebraska 28	46.7
Sunburst	46.7
Blackwell	46.7
Cave-in-Rock	53.3
Shelter	53.3
Shawnee	56.7
LSD (0.05)	**10.19**

[1]Carolina (*Dissosteria carolina* L.) and redlegged (*Melanoplus femurrubrum* DeGeer) grasshoppers.

Table 43. Growing season color range of 10 switchgrass cultivars grown at pH 5.2.[1]

Cultivar	Foliage colors	
Alamo	7.5GY5/2-4	N/A
Blackwell	7.5GY5/2-4	7.5GY4/2
Cave-in-Rock	7.5GY4-5/2	N/A
Dacotah	7.5GY4-5/2	7.5GY5/4
Forestburg	7.5GY4/2-4	7.5GY5/2
Nebraska 28	7.5GY4/2-4	7.5GY5/4
Shawnee	7.5GY4/2-4	N/A
Shelter	7.5GY4/2-4	7.5GY5/4
Sunburst	7.5GY4-5/2	N/A
Trailblazer	7.5GY5/4	7.5GY4/2

[1]Foliage color recorded on 9 November 2000 using Munsell Color Charts for Plant Tissues, Kollmorgen Corp., Baltimore, MD 21218.

Breeding for improved insect tolerance or resistance may require a considerable length of time (20 years or more), according to Vogel (2000). In addition, insecticides may assist in protecting seed from predation at planting (McKenna and Wolf, 1990). However, it should be reiterated that the focus of this study is natural areas. Since grasshoppers are eaten by birds and other fauna, they may be considered desirable with regard to food webs. As a result, this data may be used differently depending upon the desired function of the natural area. If grasshoppers are considered desirable, then a cultivar such as Shawnee may be a possibility. If they are not desired, Alamo may be a possibility. However, all characteristics should be considered when selecting a cultivar.

Growing season colors were very similar across the 10 switchgrass cultivars (**Table 43**). All colors were within the hue range of 7.5GY with hue values of 4 or 5. Chromas ranged from a gray-green of 2 to a green of 4. Unlike big bluestem and indiangrass, no reddish fall coloration was observed in switchgrass leaf tips.

Despite the similarity in growing season colors, dead (dormant) stand or winter colors were variable (**Table 44**). Alamo, Blackwell, Forestburg, and Shelter showed some variability between adaxial and abaxial leaf surface colors. Most foliage colors were within the hues of 2.5, 5, and 7.5YR. Only Alamo was different with a hue of 10R, a hue value of 5, and chromas of 2 to 4, which is a coloration ranging from medium gray-brown to light chocolate-brown. Hue values of the other cultivars were variable ranging from 4 to 8 with chromas ranging 2 to 6. These are colors of light gray-brown (7.5YR7/2), gray-brown (7.5YR6/2, 5YR4-5/2, and 2.5YR), medium brown (7.5YR6/4, 5YR6/4, 5YR5-6/4, and 2.5YR5/4), and light brown (7.5YR7-8/4-6).

Stem colors were different from leaf colors (**Table 44**). Switchgrass stem colors tended to contribute more to winter color compared with big bluestem and indiangrass. Unlike switchgrass, internodes tended to be less visible and have the same color as the foliage on big bluestem and indiangrass culms. Cultivars had stem color hues of 7.5YR or 2.5Y. The hue colors of 7.5YR were light brown (7.5YR7-8/4-6). The hue colors of 2.5Y ranged from light yellow-brown (2.5Y8/4-6) to medium yellow-brown (2.5Y7/4-6). The lighter winter colors of certain switchgrass cultivars in this study were attractive, particularly those with hue values of 8 and chromas of 4 to 6. Most cultivars had stem colors in this color range. Shawnee showed some lighter foliage coloration, as well.

Table 44. Winter color range of 10 switchgrass cultivars grown at pH 5.2.[1]

Cultivar	Foliage colors			Stem Colors	
	Adaxial		Abaxial		
Alamo	10R5/2-4	N/A	10R5/4	2.5Y8/4	N/A
Blackwell	7.5YR7/4	2.5/5YR5/4	7.5YR6/4	7.5YR8/4	2.5Y8/4
Cave-in-Rock	7.5YR7/4-6	5YR6/4	N/A	7.5YR7/6	2.5Y8/4-6
Dacotah	7.5YR7/4	N/A	N/A	7.5YR8/4	2.5Y7-8/4
Forestburg	7.5YR6/4	5YR6/4	7.5YR6/2	7.5YR6-8/4	2.5Y7/4
Nebraska 28	7.5YR6-7/4	5YR4-5/2	N/A	7.5YR8/4	2.5Y7-8/4
Shawnee	7.5YR7-8/4	5YR5/4	N/A	7.5YR8/4	2.5Y7/4
Shelter	7.5YR7/2-4	5YR5/2	5YR5/4	7.5YR8/4	2.5Y7/6
Sunburst	7.5YR7/4	2.5YR5/4	N/A	7.5YR7/6	2.5Y7-8/4
Trailblazer	7.5YR6-7/2-4	2.5YR5/4	N/A	7.5YR8/4	2.5Y7-8/4

[1]Dead (dormant) stand foliage color recorded on 22 January 2001 using Munsell Color Charts for Plant Tissues, Kollmorgen Corp., Baltimore, MD 21218.

CONCLUSIONS

There was considerable height variation both within and across native grass species evaluated in these studies. Broomsedge and all little bluestem cultivars appear to obtain heights acceptable for use adjacent to tee complexes. Coverage was a problem for broomsedge during the first year of establishment, but significant improvement was made during the second year. Coverage was a problem for all little bluestem cultivars planted at 14.6 kg PLS/ha (13 pounds per acre). Higher coverage can be obtained through increased seeding rates, particularly during the first year of establishment. However, during the second year of establishment, rates in excess of 29.2 kg PLS/ha (26 pounds per acre) did not differ significantly. This lag in establishment should be considered when determining seeding rates for little bluestem. Summer color of little bluestem cultivars tended toward shades of gray. However, summer color of broomsedge tended toward shades of green. In general, winter color of broomsedge was lighter and more gold compared with little bluestem cultivars. Some purple coloration was also observed in little bluestem cultivars.

Many of the tallgrass cultivars, particularly switchgrass, were too tall for use around tee complexes. There was a great amount of height variation between cultivars within big bluestem and indiangrass. In most cases, shorter cultivars also had less coverage, which would be considered less desirable. Certain cultivars of these two species would be suitable for natural areas further away from tee complexes. Summer coloration in big bluestem cultivars was similar to little bluestem with tendencies toward gray. Like little bluestem, purple coloration on leaf tips of big bluestem cultivars in the fall was observed. Summer coloration of indiangrass cultivars was similar to big bluestem, but it was more uniform between cultivars.

Switchgrass obtained the greatest height during the studies. As with other species, cultivars that obtained shorter heights also had the least amount of coverage. Tall cultivars, such as Alamo, may be suitable for screening. These cultivars also yielded higher biomass. This increased biomass may be desirable for wildlife cover, although lodging occurred in the six tallest cultivars, which may not be desirable aesthetically. High biomass could lead to succession if allowed to accumulate. Higher biomass resulted in greater nutrient losses from dead stand harvesting. However, switchgrass responses to this and other management treatments were difficult to detect during these studies. Based upon nitrogen losses from dead stand harvests, it is possible that these harvests in the spring may reduce growing season heights of certain cultivars with more time. Soil temperatures were cooler under high biomass cultivars during the 2001 harvest. This might be expected to have some influence upon spring green-up. However, Alamo had both the highest biomass and earliest spring green-up. It is not clear how this factor may affect wildlife.

Alamo had the least amount of grasshopper feeding activity, while Pawnee had the greatest. Since certain species of birds feed on grasshoppers, increased availability of the insects may be a desirable characteristic. However, it may not be desirable for areas where aesthetics are of concern.

Summer coloration of switchgrass cultivars was similar. All were shades of gray-green. Winter coloration was more variable, although shades of brown were common. Winter coloration of stems was generally lighter and may have a tendency to lighten the overall color of switchgrass stands in the winter.

A longer study of this type would be beneficial, particularly with regard to the influence of management on stand height and coverage, weed coverage, and succession. Greater understanding of the influence of mixed stands upon switchgrass lodging is also needed. It is possible that shorter species mixed with taller switchgrass cultivars may reduce or prevent lodging. The studies described in this bulletin were planted earlier in the growing season. The influence of planting date upon establishment also needs to be addressed. Additionally, it is possible that annual ryegrass could be inter-seeded with these grasses in the fall for winter soil stabilization. More research is needed on this seeding method. All species in these studies were warm-season grasses. The performance of native cool-season grasses for use in golf course natural areas is also needed. Currently, tall fescue, which is native to Europe, is the most common cool-season grass used in Mississippi golf course natural areas.

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APPENDIX A

Soil Sample Analyses for Native Grass Study Grown on pH 5.2 Soil

Table A.1. Percent organic matter (OM), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), and sulfur (S) from soil samples taken in 2000 from broomsedge and five little bluestem cultivars grown at pH 5.2.

Cultivar	OM	P	K	Ca	Mg	Zn	S
	%	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*
Broomsedge	1.14	45.4	92.5	970.4	58.4	1.20	184.2
Aldous	1.34	59.5	112.0	2043.1	60.1	1.79	206.8
Blaze	1.18	43.4	87.9	1112.5	53.8	1.05	190.7
Camper	1.22	50.0	99.3	1292.2	55.9	1.29	196.0
Cimarron	1.17	41.8	85.9	1043.0	52.6	1.00	188.3
Itasca	1.31	48.5	102.5	1228.9	63.6	1.24	211.9
LSD (0.05)	**NS**	**10.28**	**17.84**	**NS**	**6.59**	**NS**	**NS**

Table A.2. Percent organic matter (OM), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), and sulfur (S) taken from soil samples in 2000 from six big bluestem cultivars grown at pH 5.2.

Cultivar	OM	P	K	Ca	Mg	Zn	S
	%	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*
Bison	1.42	59.1	120.3	782.0	61.4	1.38	228.4
Bonilla	1.49	89.7	137.0	732.1	57.7	1.95	240.9
Kaw	1.55	76.3	125.2	643.4	61.0	1.84	249.6
Niagara	1.48	79.3	132.9	626.6	55.1	1.98	238.7
Pawnee	1.56	73.1	129.2	624.2	50.4	1.88	250.8
Rountree	1.46	86.9	119.3	682.0	53.4	2.10	235.1
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table A.3. Percent organic matter (OM), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), and sulfur (S) from soil samples taken in 2000 from seven indiangrass cultivars grown at pH 5.2.

Cultivar	OM	P	K	Ca	Mg	Zn	S
	%	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*
Cheyenne	1.49	69.1	118.5	679.1	47.2	1.62	225.5
Holt	1.54	92.6	129.2	651.8	60.1	1.90	249.1
Nebraska 54	1.41	51.5	115.2	868.3	62.2	1.32	227.9
Osage	1.52	74.8	127.6	617.6	60.7	1.90	245.9
Oto	1.46	80.3	120.2	639.6	47.7	1.90	236.2
Rumsey	1.49	84.0	125.3	788.4	50.0	1.88	240.2
Tomahawk	1.54	83.1	134.0	623.0	60.2	2.08	247.8
LSD (0.05)	**NS**	**21.18**	**NS**	**NS**	**11.40**	**NS**	**NS**

Table A.4. Percent soil organic matter in 2000 and 2001 for 10 switchgrass cultivars grown at pH 5.2.

Cultivar	2000				2001			
	Mowed	Harvested	Burned	LSD	Mowed	Harvested	Burned	LSD
	%	*%*	*%*	*%*	*%*	*%*	*%*	*%*
Alamo	1.53	1.62	1.56	NS	1.57	1.28	1.41	NS
Blackwell	1.55	1.28	1.47	NS	1.32	1.23	1.28	NS
Cave-in-Rock	1.68	1.37	1.61	NS	1.34	1.29	1.44	NS
Dacotah	1.53	1.41	1.76	NS	1.33	1.21	1.49	NS
Forestburg	1.39	1.47	1.39	NS	1.35	1.35	1.34	NS
Nebraska 28	1.65	1.37	1.43	NS	1.30	1.28	1.36	NS
Shawnee	1.51	1.42	1.52	NS	1.44	1.21	1.39	0.122
Shelter	1.50	1.30	1.43	NS	1.40	1.20	1.31	NS
Sunburst	1.55	1.21	1.25	NS	1.39	1.04	1.26	NS
Trailblazer	1.42	1.40	1.42	NS	1.13	1.23	1.38	NS
LSD (0.05)	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

Table A.5. Soil phosphorus in 2000 and 2001 for 10 switchgrass cultivars grown at pH 5.2.

Cultivar	2000				2001			
	Mowed	Harvested	Burned	LSD	Mowed	Harvested	Burned	LSD
	kg/ha	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*
Alamo	91.5	80.6	109.8	NS	86.2	70.6	97.8	NS
Blackwell	61.2	60.9	84.8	NS	57.1	53.8	71.7	NS
Cave-in-Rock	84.4	79.5	90.4	NS	72.1	81.8	87.0	NS
Dacotah	82.5	74.7	97.4	NS	81.4	73.9	81.0	NS
Forestburg	75.4	76.9	84.0	NS	74.3	81.8	80.6	NS
Nebraska 28	101.2	84.4	121.7	27.73	85.9	84.0	109.8	NS
Shawnee	98.9	84.4	107.5	NS	91.8	75.0	101.2	NS
Shelter	61.2	58.6	86.2	NS	55.3	50.0	74.7	NS
Sunburst	59.0	49.7	66.5	NS	55.3	45.9	52.6	NS
Trailblazer	60.5	73.2	90.4	NS	55.3	87.7	80.3	NS
LSD (0.05)	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

Table A.6. Soil potassium in 2000 and 2001 for 10 switchgrass cultivars grown at pH 5.2.

Cultivar	2000				2001			
	Mowed	Harvested	Burned	LSD	Mowed	Harvested	Burned	LSD
	kg/ha	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*
Alamo	140.4	131.4	123.2	NS	136.6	91.5	115.4	NS
Blackwell	119.8	110.1	135.2	NS	107.9	85.1	110.9	13.30
Cave-in-Rock	147.8	120.6	133.3	NS	115.7	103.0	89.6	NS
Dacotah	138.1	112.8	134.0	NS	148.6	112.4	145.6	NS
Forestburg	121.0	111.3	126.6	NS	119.1	103.8	107.9	NS
Nebraska 28	142.2	124.3	137.8	NS	130.7	113.9	147.8	NS
Shawnee	158.3	112.0	160.5	NS	150.1	102.7	130.7	NS
Shelter	115.7	111.6	115.7	NS	98.0	75.0	100.8	NS
Sunburst	122.8	95.6	109.8	NS	87.7	89.2	81.0	NS
Trailblazer	137.0	132.2	147.1	NS	107.9	107.2	122.5	NS
LSD (0.05)	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

Table A.7. Soil calcium in 2000 and 2001 for 10 switchgrass cultivars grown at pH 5.2.

Cultivar	2000 Mowed	2000 Harvested	2000 Burned	2000 LSD	2001 Mowed	2001 Harvested	2001 Burned	2001 LSD
	kg/ha	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*
Alamo	1517.3	958.7	1441.8	NS	1929.0	571.5	1140.2	NS
Blackwell	618.2	604.5	721.3	NS	443.2	389.0	328.2	NS
Cave-in-Rock	886.7	711.2	657.4	NS	601.8	573.4	387.9	NS
Dacotah	675.4	523.0	853.8	NS	383.0	331.5	412.5	NS
Forestburg	676.8	565.6	632.5	NS	430.4	336.3	348.0	NS
Nebraska 28	1218.9	960.2	1379.8	NS	618.2	831.4	644.8	NS
Shawnee	1133.4	777.3	1007.7	NS	2310.6	538.7	1320.5	NS
Shelter	632.8	638.7	774.7	NS	390.1	526.7	513.7	NS
Sunburst	635.0	532.8	755.7	NS	412.2	362.9	407.7	NS
Trailblazer	1031.9	1138.7	1234.2	NS	625.3	876.2	797.1	NS
LSD (0.05)	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

Table A.8. Soil magnesium in 2000 and 2001 for 10 switchgrass cultivars grown at pH 5.2.

Cultivar	2000 Mowed	2000 Harvested	2000 Burned	2000 LSD	2001 Mowed	2001 Harvested	2001 Burned	2001 LSD
	kg/ha	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*
Alamo	59.0	56.0	48.9	NS	45.6	35.1	34.7	NS
Blackwell	52.3	46.3	48.9	NS	38.5	30.6	28.8	NS
Cave-in-Rock	57.9	56.8	59.4	NS	40.0	38.8	33.6	NS
Dacotah	51.5	42.6	48.2	NS	33.2	28.9	31.4	NS
Forestburg	50.8	49.7	55.3	NS	37.3	38.1	35.8	NS
Nebraska 28	53.4	51.5	50.4	NS	35.5	34.3	34.0	NS
Shawnee	51.9	45.6	50.4	NS	41.8	27.3	33.6	8.59
Shelter	52.3	51.2	49.3	NS	39.2	30.6	35.1	NS
Sunburst	46.3	40.0	42.6	NS	32.9	28.0	30.2	NS
Trailblazer	55.6	56.4	52.3	NS	40.7	36.2	32.1	NS
LSD (0.05)	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

Table A.9. Soil zinc in 2000 and 2001 for 10 switchgrass cultivars grown at pH 5.2.

Cultivar	2000 Mowed	2000 Harvested	2000 Burned	2000 LSD	2001 Mowed	2001 Harvested	2001 Burned	2001 LSD
	kg/ha	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*
Alamo	1.79	1.57	2.09	NS	0.97	1.98	1.01	NS
Blackwell	1.46	2.20	2.02	NS	1.12	1.12	1.16	NS
Cave-in-Rock	1.60	1.98	2.35	NS	1.08	1.38	1.87	NS
Dacotah	2.28	2.02	2.99	NS	1.53	1.72	1.23	NS
Forestburg	2.88	1.76	2.02	NS	1.27	1.23	1.23	NS
Nebraska 28	2.28	1.87	2.46	NS	1.16	1.46	1.57	NS
Shawnee	2.21	2.13	2.24	NS	1.20	1.46	1.53	NS
Shelter	1.57	2.02	2.02	NS	1.01	0.82	1.16	NS
Sunburst	1.57	1.49	1.38	NS	1.27	0.75	0.67	0.388
Trailblazer	1.31	1.46	1.98	NS	1.16	0.60	1.01	NS
LSD (0.05)	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

Table A.10. Soil sulfur in 2000 and 2001 for 10 switchgrass cultivars grown at pH 5.2.								
Cultivar	**2000**				**2001**			
	Mowed	**Harvested**	**Burned**	**LSD**	**Mowed**	**Harvested**	**Burned**	**LSD**
	kg/ha	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*	*kg/ha*
Alamo	246.8	262.1	251.6	NS	253.1	206.5	228.1	NS
Blackwell	249.4	205.7	237.1	NS	212.4	198.2	206.8	NS
Cave-in-Rock	271.0	221.0	260.2	NS	216.2	208.3	231.5	NS
Dacotah	246.4	227.4	284.5	NS	215.4	195.6	240.1	NS
Forestburg	224.4	237.4	224.8	NS	217.3	217.3	215.8	NS
Nebraska 28	265.4	221.8	230.4	NS	209.1	206.8	218.8	NS
Shawnee	242.7	229.6	244.5	NS	232.6	194.5	223.6	19.50
Shelter	242.7	209.8	230.7	NS	225.5	193.4	210.6	NS
Sunburst	249.8	195.3	201.2	NS	224.4	167.3	203.8	NS
Trailblazer	229.6	225.1	228.9	NS	182.6	197.9	222.1	NS
LSD (0.05)	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

Table A.11. Pearson correlation coefficients (*r*) for comparisons between 2000 stand cover for 10 switchgrass cultivars grown at pH 5.2 and soil organic matter (OM), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), and sulfur (S) in 2000 and 2001.									
Variable		**2000**	**2001**						
		Cover	**OM**	**P**	**K**	**Ca**	**Mg**	**Zn**	**S**
2000 Cover	*r*	-	0.044	0.135	-0.067	0.210	0.118	-0.065	0.043
	P	-	0.684	0.206	0.532	0.047	0.267	0.542	0.691
2000 OM	*r*	-0.004	-	0.303	0.032	-0.144	0.615	0.481	0.999
	P	0.971	-	0.004	0.765	0.175	0.0001	0.0001	0.0001
2000 P	*r*	0.168	0.408	-	0.558	0.188	0.049	0.529	0.302
	P	0.113	0.0001	-	0.0001	0.077	0.646	0.0001	0.004
2000 K	*r*	0.140	0.418	0.572	-	0.408	-0.076	0.194	0.032
	P	0.188	0.0001	0.0001	-	0.0001	0.476	0.067	0.766
2000 Ca	*r*	0.195	-0.010	0.356	0.372	-	0.058	-0.445	-0.144
	P	0.065	0.924	0.0006	0.0003	-	0.590	0.0001	0.175
2000 Mg	*r*	0.126	0.417	0.022	0.358	-0.095	-	0.156	0.614
	P	0.235	0.0001	0.837	0.0005	0.371	-	0.142	0.0001
2000 Zn	*r*	-0.065	0.259	0.566	0.375	-0.174	0.150	-	0.480
	P	0.542	0.014	0.0001	0.0003	0.101	0.158	-	0.0001
2000 S	*r*	0.043	0.999	0.407	0.416	-0.012	0.417	0.259	-
	P	0.691	0.0001	0.0001	0.0001	0.911	0.0001	0.014	-

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