Evaluation of Native Grass Cultivars for Mississippi Golf Course Natural Areas Under Variable Management: Part II — Soil pH of 6.5

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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 culti-

var 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. Liming is a common practice on golf courses in Mississippi since soils with a pH near 5 are common. In contrast, some areas of the state have soils with naturally high pH, such as those in the Blackland Prairie region. One of the objectives with natural areas is to minimize management. Some species and/or cultivars may perform better on limed, or calcareous soils. If so, these need to be identified.

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 adjusted to a pH of around 6.5. 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 adjusted (**Table 1**). All plots were limed at 4,879 kg/ha (100 pounds per 1,000 square feet) on 10 June 1999. Soil samples were taken in October 1999 and February 2000 to monitor pH. No additional liming was deemed necessary 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) reports that development of adventitious roots that are critical for seedling survival may not occur under

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	1.27	42	72	1624	110	3.1	183	6.7
Feb. 2000	1.03	33	78	1627	111	0.7	148	7.1

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 before liming and in October 1999 and February 2000 after liming.

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.) are covered in the first group, big bluestem (*Andropogon gerardii* Vitman) is covered in the second group, indiangrass [*Sorghastrum nutans* (L.) Nash] is covered in the third group, and switchgrass (*Panicum virgatum* L.) is 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

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.

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 being the earliest species to mature and indiangrass the latest.

Table 3. Average plant height comparison of big bluestem, switchgrass, and indiangrass cultivars in 1999 and 2000 grown at pH 6.5.							
Species	1999			2000				
	July	August	Sept.	May	June	July	August	Sept.
	cm	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
Big Bluestem	6.3	13.9	14.4	26.2	34.1	40.2	39.4	31.3
Switchgrass	9.6	33.2	43.6	73.1	86.3	93.9	97.6	97.2
Indiangrass	8.4	20.6	20.0	32.9	39.6	47.7	49.1	35.2

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 crab-

grass [*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 on that recommended by Hamilton Seed Company (16786 Brown Road, Elk Creek, Mississippi 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 seed was obtained from Hamilton Seed Company. Aldous, Blaze, and Camper little bluestem seed was 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).

The experimental design for little bluestem and broomsedge was a randomized complete block with repeated measures. There were three replications and six treatments

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.

(**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, the 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
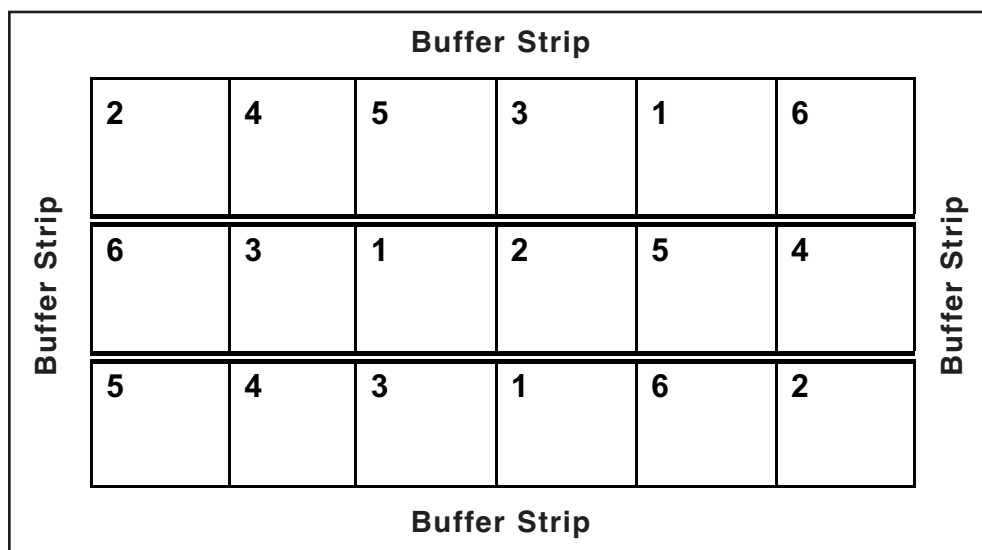

Figure 1. Plot plan for broomsedge (*Andropogon virginicus* L.) and little bluestem [*Schizachyrium scoparium* (Michx.) Nash] cultivars grown at a soil pH of 6.5. Cultivars: 1 = broomsedge, 2 = Aldous, 3 = Blaze, 4 = Camper, 5 = Cimarron, and 6 = Itasca little bluestem.

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. Data were analyzed using ANOVA in 1999 and 2000. Mean separations were calculated using Fisher's LSD test.

Winter weed coverage (percent) 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. The relationship between 2000 stand and winter weed cover was investigated 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.

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. 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 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 6.5.								
Species	1999			2000				
	July	August	Sept.	May	June	July	August	Sept.
	cm	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
Broomsedge	1.7	4.2	9.2	19.9	31.4	45.9	53.5	41.1
Little Bluestem	3.8	7.1	9.5	17.4	22.7	28.5	43.3	34.6
LSD (0.05)	**0.73**	**1.09**	**NS**	**NS**	**5.35**	**6.17**	**NS**	**NS**

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**). Aldous was significantly taller than all little bluestem cultivars on this date. Aldous also had the greatest average height across July, August, and September. It was significantly taller by September than all cultivars and broomsedge. Itasca had the shortest height at 4 weeks (3.3 cm) and on average (6.2 cm) in 1999. Despite these variations in height, the tallest average height recorded was for Aldous at only 12.5 cm. This may indicate little bluestem also exhibits some lag in growth during establishment.

In 2000, Camper started the year as the shortest little bluestem cultivar, although Blaze finished the year in September with the shortest height (**Table 7**). Aldous, Itasca, and Blaze had the greatest average height in May. By September, Aldous was significantly taller than all little bluestem cultivars at 51.2 cm, but not broomsedge. Jung et al. (1990) recorded a 3-year average height of Aldous little bluestem of 71 cm without supplemental nitrogen. This is

close to the largest height (65.3 cm) recorded in our study over a 2-year period, but not the average height. This may be an indication that little bluestem cultivars in our study may have more height potential if given more time.

Broomsedge was taller than little bluestem cultivars 2 out of 5 months during 2000. Broomsedge was at its tallest (53.2 cm) in August, but still shorter than Blaze. 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 with little bluestem, but no data of this type were collected. Broomsedge and all little bluestem

Table 6. Plant height of broomsedge and five cultivars of little bluestem in 1999 grown at pH 6.5.				
Cultivar	July	August	Sept.	Avg.
	cm	*cm*	*cm*	*cm*
Broomsedge	1.7	4.2	9.2	5.0
Aldous	4.7	8.3	12.5	8.5
Blaze	3.7	6.9	8.3	6.3
Camper	3.7	6.3	9.0	6.3
Cimarron	3.4	7.0	9.3	6.6
Itasca	3.3	6.9	8.4	6.2
LSD (0.05)	**0.88**	**1.34**	**2.07**	

Table 7. Plant height of broomsedge and five little bluestem cultivars in 2000 grown at pH 6.5.						
Cultivar	May	June	July	August	Sept.	LSD (0.05)
	cm	*cm*	*cm*	*cm*	*cm*	*cm*
Broomsedge	19.9	31.4	45.9	53.2	41.1	9.91
Aldous	23.3	29.8	36.5	49.2	51.2	8.54
Blaze	15.0	16.7	23.3	65.3	28.7	NS
Camper	12.7	20.2	23.6	34.7	29.3	7.49
Cimarron	14.6	22.8	31.1	36.5	38.8	7.97
Itasca	20.4	23.3	27.5	32.2	24.9	NS
LSD (0.05)	**5.40**	**6.73**	**7.73**	**NS**	**10.41**	

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 8**). The highest cover in 1999 was 13.5% for Aldous in September. Aldous also had the highest cover at 21.7% in July 2000. Only Aldous, Camper, and Cimarron little bluestems showed some increase in stand coverage between September 1999 and July 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.

Broomsedge had low stand cover in 1999 (1%) and the highest stand cover in 2000 (26.6%) compared with little bluestem cultivars. 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 1.7–4.7 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.) and cutleaf eveningprimrose (*Oenothera laciniata* Hill) were also observed. Like horseweed, corn spurrey and cutleaf evening-primrose were very common outside the study area and were most likely blown in from adjacent areas. In 2000, weed coverage was as high as 85% in Cimarron little bluestem plots during the study (**Table 9**). However, weed coverage did not negatively correlate with stand cover in this study. Pearson (*r*) correlation analysis indicated a coefficient of 0.109 which was not significant (*P*=0.666).

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 6.5.				
Cultivar	1999			2000
	July	August	September	July
	%	%	%	%
Broomsedge	1.0	6.0	5.3	26.6
Aldous	2.3	8.7	13.3	21.7
Blaze	1.0	7.0	11.7	4.6
Camper	1.0	5.0	5.0	5.7
Cimarron	1.7	7.3	10.0	6.9
Itasca	1.7	6.0	6.7	6.6
LSD (0.05)	**0.77**	**NS**	**4.70**	**14.18**

Table 9. Stand coverage of broomsedge and five little bluestem cultivars in July 2000 grown at pH 6.5 compared with weed coverage on 15 June 2000.[1]		
Cultivar	Stand	Weeds
	%	%
Broomsedge	26.6	73.3
Aldous	21.7	80.0
Blaze	4.6	71.7
Camper	5.7	81.7
Cimarron	6.9	85.0
Itasca	6.6	73.3
LSD (0.05)	**14.18**	**NS**

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

Growing season colors were variable depending on 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).

Winter or dead stand colors were variable depending on 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 on 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 6.5.[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 6.5.[1]				
Cultivar	**Foliage colors**		**Sheath color[2]**	**Stem color**
	Adaxial	**Abaxial**		
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 randomized complete block with repeated measures. There were three replications and six treatments (**Figure 2**.). Experimental unit

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.

(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.

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).

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 sep-

arated using Fisher's LSD test. The relationship between 2000 stand and winter weed cover was investigated 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.
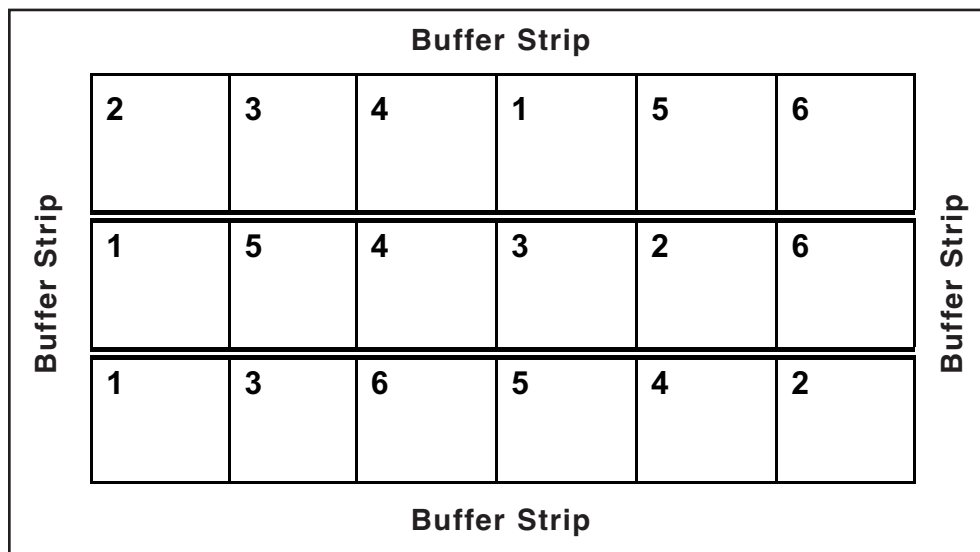
Figure 2. Plot plan for big bluestem (*Andropogon gerardii* Vitman) cultivars grown at a soil pH of 6.5. Cultivars: 1 = Bison, 2 = Bonilla, 3 = Kaw, 4 = Niagara, 5 = Pawnee, and 6 = Rountree.

Results and Discussion

Big bluestem plant heights (**Table 13**) showed significant differences every month during both years of the study. Bonilla was the tallest (6.9 cm) cultivar at 4 weeks (July) after planting in 1999. Although Kaw (6 cm) was next to the shortest cultivar on this date, it was the tallest (43.4 cm) by September of 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 on origin. The two northern plains cultivars, Bison from North Dakota and

Bonilla from South Dakota, were the tallest cultivars (6.8 cm and 6.9 cm, respectively) by week four of the study. However, Bison had the shortest height (22.9 cm) by the end of the study. It is not known how Bonilla will perform long-term, but it maintained next to the highest average height (34.3 cm) during 2000. The mid-plains 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. Kaw had the tallest average

Table 13. Plant height of six big bluestem cultivars in 1999 and 2000 grown at pH 6.5.										
Cultivar	1999				2000					
	July	August	Sept.	Avg.	May	June	July	August	Sept.	Avg.
	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
Bison	6.8	13.3	11.8	10.1	18.7	27.0	30.2	29.2	22.9	23.3
Bonilla	6.9	16.8	15.3	11.8	30.7	38.8	44.4	43.1	33.4	34.3
Kaw	6.0	13.0	16.6	9.5	31.0	42.8	56.0	56.3	43.4	41.1
Niagara	5.6	9.2	14.1	7.4	20.5	33.6	38.7	37.9	30.6	29.2
Pawnee	6.1	13.3	13.7	9.7	31.8	29.3	31.6	33.3	28.7	28.0
Rountree	6.3	17.6	15.1	11.9	24.8	32.7	39.7	36.7	28.0	29.5
LSD(0.05)	0.78	2.03	1.98	1.88	8.89	8.17	8.51	8.10	9.09	3.79

height (41.1 cm) in 2000. Niagara big bluestem from New York was the shortest (5.6 cm) at 4 weeks after planting. On average, it did not perform as well as the mid-plains cultivars during 1999, but performed similar to Pawnee and Rountree in 2000. All cultivars experienced some decline in height toward the end of 2000. This is 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 fertilization. These are in excess of those recorded here and may be an indication that cultivars in this study may have more height potential if given additional time.

Stand coverage was low for all big bluestem cultivars during this study, ranging from 2–4.3% at 4 weeks after planting (**Table 14**). Coverage of big bluestem cultivars was significant for only August 1999 and July 2000. Performance of cultivars was similar to plant height. Bison had the greatest coverage at 4 weeks after planting (4.3%). Rountree had the least amount of cover (2%). Despite this thin start, Niagara still finished with more cover (9%) than Bison (4.4%). Kaw had the greatest cover by September 1999 with 16.7%, followed by Bonilla and Pawnee (15% each). Kaw had significantly more cover than all cultivars, except Bonilla. 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 (2% and 9%,

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 0.078 with a probability of 0.577. Like broomsedge and little bluestem, stand coverage was low in big bluestem plots, ranging from 4.4–21.3% in July 2000. Big bluestem experienced problems with the same weed species during this period. Weed coverage ranged from 76.7–86.7% 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 on 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 ranging from 2.5R to 5R, which are red. Color values ranged

Table 14. Stand coverage of six big bluestem cultivars in 1999 and 2000 grown at pH 6.5.				
Cultivar	1999			2000
	July	August	September	July
	%	%	%	%
Bison	4.3	10.0	13.3	4.4
Bonilla	3.3	13.3	15.0	18.9
Kaw	3.3	13.3	16.7	21.3
Niagara	3.3	10.0	11.7	10.2
Pawnee	3.3	10.0	15.0	9.8
Rountree	2.0	10.0	10.0	9.0
LSD (0.05)	NS	2.71	NS	11.04

Table 15. Stand coverage of six big bluestem cultivars in July 2000 grown at pH 6.5 compared with weed coverage on 15 June 2000.[1]		
Cultivar	Big Bluestem	Weeds
	%	%
Kaw	21.3	81.7
Bonilla	18.9	76.7
Niagara	10.2	83.3
Pawnee	9.8	85.0
Rountree	9.0	86.7
Bison	4.4	81.7
LSD (0.05)	11.04	5.81

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

from 3 to 4, which are dark. Chromas ranged from 2 in the gray-maroon range to 8 in the red range.

Winter 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 6.5.[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 6.5.[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). 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 were analyzed using analysis of variance (ANOVA) in 1999 and 2000. Means were separated using Fisher's least-significant-difference (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. The relationship between 2000 stand and winter weed cover was investigated 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

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.

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.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.

Buffer Strip

7	4	2	6	5	1	3
3	1	5	7	4	2	6
6	4	2	3	7	1	5

Buffer Strip (left) / **Buffer Strip** (right)
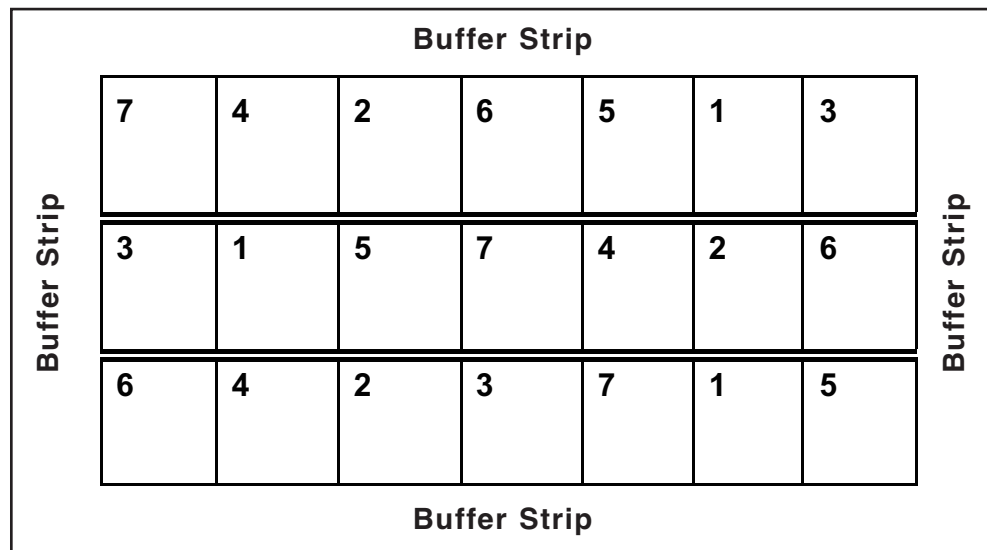
Buffer Strip

Figure 3. Plot plan for indiangrass [*Sorghastrum nutans* (L.) Nash] cultivars grown at a soil pH of 6.5. 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 July and August of 2000. Nebraska 54 was the tallest (10.2 cm) cultivar at 4 weeks after planting. Oto had the greatest average height in 1999, although Osage had the greatest average height in 2000. Tomahawk (the only northern Great Plains cultivar) and Holt tended to remain short throughout the 2-year study. In 1999, all cultivars except Nebraska 54 were similar in height, ranging from 7.8–8.6 cm 4 weeks after planting. By September of 1999, heights for these six cultivars ranged from 14.3–24.9 cm. By September of 2000, heights of the same cultivars ranged from 24.6–50.7 cm. These differences between cultivars — ranging from 0.8 cm at 4 weeks, to 10.6 cm at the end of 1999, to 26.1 cm at the end of 2000 — may indicate potential for greater differences had another year of data been collected. As with big bluestem cultivars, height reductions were observed between August and September of 2000. Most likely, this 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

Cultivar	1999				2000					
	July	August	Sept.	Avg.	May	June	July	August	Sept.	Avg.
	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
Cheyenne	8.1	22.4	21.8	15.3	36.6	41.6	48.2	48.9	36.3	38.9
Holt	7.8	17.0	15.9	12.4	30.4	33.9	41.5	39.5	24.6	31.0
Nebraska 54	10.2	22.3	19.0	16.3	28.6	45.5	54.5	48.6	42.6	39.8
Osage	7.9	19.1	21.2	13.5	36.5	41.6	52.3	57.5	50.7	43.4
Oto	8.3	24.9	25.8	16.6	33.5	34.0	43.0	43.4	25.0	34.2
Rumsey	8.6	24.0	22.1	16.3	38.8	44.6	52.3	60.3	40.3	43.1
Tomahawk	7.9	14.2	14.3	11.1	26.0	35.6	41.9	45.4	25.6	31.5
LSD (0.05)	**0.96**	**3.98**	**4.27**	**3.20**	**8.61**	**8.82**	**NS**	**NS**	**10.23**	**4.66**

Table 19. Plant height of seven indiangrass cultivars in 1999 and 2000 grown at pH 6.5.

Table 20. Stand coverage of seven indiangrass cultivars in 1999 and 2000 grown at pH 6.5.				
Cultivar	**1999**			**2000**
	July	**August**	**September**	**July**
	%	%	%	%
Cheyenne	4.3	13.3	16.7	11.9
Holt	2.0	10.0	13.3	12.7
Nebraska 54	6.3	18.3	20.0	29.9
Osage	2.7	13.3	16.7	42.2
Oto	3.3	10.0	15.0	13.0
Rumsey	3.0	10.0	16.7	30.6
Tomahawk	3.3	10.0	11.7	13.0
LSD (0.05)	**NS**	**2.74**	**NS**	**18.77**

Table 21. Stand coverage of seven indiangrass cultivars in July 2000 grown at pH 6.5 compared with weed coverage on 15 June 2000.[1]		
Cultivar	**Indiangrass**	**Weeds**
	%	%
Osage	42.2	73.3
Rumsey	30.6	68.3
Nebraska 54	29.9	85.0
Oto	13.0	76.7
Tomahawk	13.0	85.0
Holt	12.7	83.3
Cheyenne	11.9	78.3
LSD (0.05)	**18.77**	**7.16**

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

105 cm, respectively, under no supplemental nitrogen. Compared with the tallest heights in our study of 48.9 cm, 54.5 cm, and 57.5 cm for these cultivars, this indicates that there is more height potential if provided additional time.

Stand coverage was low for all indiangrass cultivars during 1999, ranging from 2–6.3% at 4 weeks after planting (**Table 20**). Significant differences in coverage were observed in August 1999. Coverage was much higher by July 2000, ranging from 11.9% in Cheyenne plots to 42.2% in Osage plots. As with plant height, coverage in Holt plots remained low throughout the 2-year study. Osage indiangrass had significantly more plot coverage compared with Cheyenne, Holt, Oto, and Tomahawk in July 2000. Osage and Rumsey had more plot coverage than other cultivars during this period, but differences were not significant. Pitman (2000) in west Louisiana found that Osage indiangrass had poorer performance compared with Lometa. Although Lometa indiangrass was not included in our study, Osage had the greatest cover in July 2000. Cheyenne, Holt, and Oto did not show coverage increases between September 1999 and July 2000. Coverage of Nebraska (66%) and Osage (44%) were higher in a study by Jung et al. (1990) at year nine with no supplemental nitrogen compared with July 2000 of our study (29.9% and 42.2%, 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 -0.349 (p=0.005). Unlike broomsedge and little bluestem, stand coverage was higher in indiangrass plots, ranging from 11.9–42.2% 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 68.3–85% on average. Pitman (2000) had problems with weed establishment in indiangrass in west Louisiana but noted less 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 on 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.

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

Table 22. Growing season color range of seven indiangrass cultivars grown at pH 6.5.[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 6.5.[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.

dark. Chromas ranged from 2 (dark gray-green) to 4 (dark green). However, unlike big bluestem, the red fall coloration was not observed in indiangrass. Based on 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. Alamo and Blackwell switchgrass seeds were obtained from Hamilton Seed Company. Cave-in-Rock, Nebraska 28, and Sunburst seeds were obtained from Osenbaugh Grass Seeds. Forestburg and Dacotah switchgrass seeds were obtained from Kaste, Inc. Shawnee switchgrass seed was obtained from Ernst Conservation Seeds. Trailblazer seed was obtained from Stock Seed Farms.

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. Seeds were hand planted on 21 June 1999. Before planting, seeds were 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 (kilograms of biomass per hectare) and plant tissue samples were taken for nutrient analysis. Tissue samples were analyzed by the Mississippi State University Extension Service Soil Testing Laboratory. Biomass, soil temperature, and tissue sample data were analyzed using the analysis of variance (ANOVA) pro-cedure. Mean separations were calculated using Fisher's least-significant-difference (LSD) test (SAS Institute Inc., 1988a). The relationship between soil temperature and biomass and stand and weed coverage were investigated 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 was collected in 1999, 2000, and 2001. 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

Table 24. History of the 10 switchgrass cultivars used in this study.				
Cultivar	**Origin**[1]	**Type**[2]	**Release date**[1]	**2n**[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, WI.

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. The relationship between 2000 stand and winter weed cover was investigated 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

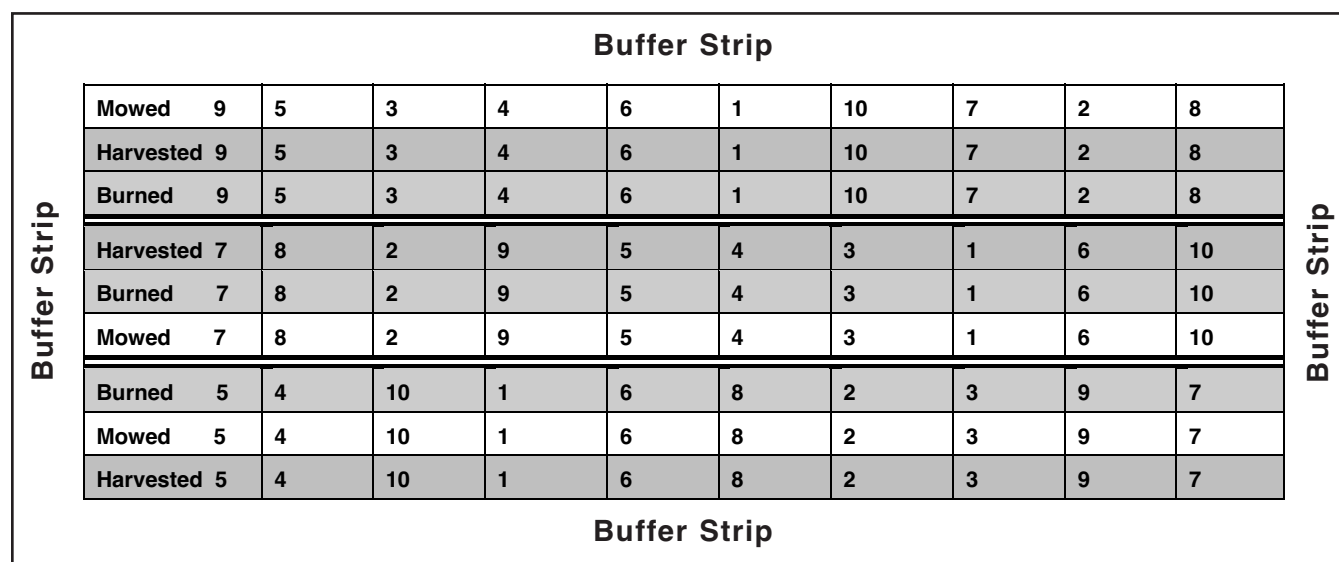(Left and right margins labeled **Buffer Strip**)

Buffer Strip

Figure 4. Plot plan for 10 switchgrass (*Panicum virgatum* L.) cultivars grown under three management regimes at a soil pH of 6.5. 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 more cover (5.7%) than all other cultivars at 4 weeks after planting, but differences were not significant (**Table 25**). However, by September Alamo had significantly more cover than all cultivars, except Cave-in-Rock. Alamo also had the greatest cover in July of 2000 (90.9%). Forestburg and Nebraska 54 each had 3% cover at 4 weeks after planting in 1999. Although Dacotah had more cover at this time, it had significantly less cover than all cultivars by July 2000, except Sunburst. Blackwell, Cave-in-Rock, and Shawnee had between 70% and 86.7% cover by July 2000. These grasses, in addition to Alamo, apparently perform well on soils with a pH of 6.5. Blackwell switchgrass has also shown substantial tolerance to acid soil during the seedling stage (Hopkins and Taliaferro, 1997). A third group consisting of Forestburg, Shelter, and Trailblazer obtained coverages of 40.6%, 44.4%, and 50%, respectively.

Table 25. Stand coverage of 10 switchgrass cultivars in 1999 and 2000 grown at pH 6.5.

Cultivar	1999			2000
	July	August	September	July
	%	%	%	%
Alamo	5.7	46.7	71.7	90.9
Blackwell	5.0	30.0	33.3	70.0
Cave-in-Rock	4.3	35.0	51.7	86.7
Dacotah	3.7	13.3	25.0	5.1
Forestburg	3.0	18.3	26.7	40.6
Nebraska 28	3.0	13.3	18.3	27.2
Shawnee	3.7	18.3	36.7	70.6
Shelter	4.0	15.0	21.7	44.4
Sunburst	3.3	13.3	18.3	18.9
Trailblazer	4.3	18.3	28.3	50.0
LSD (0.05)	**NS**	**13.83**	**20.29**	**16.80**

Table 26. Stand coverage of 10 switchgrass cultivars in July 2000 grown at pH 6.5 and compared with weed coverage on 15 June 2000.[1]		
Cultivar	**Switchgrass**	**Weeds**
	%	%
Alamo	90.9	20.7
Cave-in-Rock	86.7	13.3
Shawnee	70.6	43.3
Blackwell	70.0	33.3
Trailblazer	50.0	55.0
Shelter	44.4	70.0
Nebraska	27.2	83.3
Forestburg	40.6	56.7
Sunburst	18.9	75.0
Dacotah	5.1	75.0
LSD (0.05)	**16.80**	**16.53**

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

Table 27. Plant height of 10 switchgrass cultivars in 1999 grown at pH 6.5.				
Cultivar	**July**	**August**	**September**	**Average**
	cm	cm	cm	cm
Alamo	11.6	53.2	72.1	45.6
Blackwell	10.6	36.3	51.9	32.9
Cave-in-Rock	12.7	47.0	58.3	39.3
Dacotah	9.2	24.6	30.6	21.4
Forestburg	9.8	27.2	26.9	21.3
Nebraska 28	7.4	22.1	37.7	22.4
Shawnee	10.2	37.3	51.7	33.1
Shelter	9.2	36.2	44.8	30.1
Sunburst	6.3	18.9	24.7	16.6
Trailblazer	9.0	29.0	37.1	25.0
LSD (0.05)	**1.02**	**3.64**	**4.98**	**5.18**

It is not clear whether weather, soil pH, or climate played a role in the poor performance of Dacotah, Nebraska 28, and Sunburst in this study. However, Dacotah and Sunburst were selected from the northern Great Plains, unlike most of the switchgrass cultivars in this study. Because these cultivars had cover similar to other cultivars at 4 weeks after planting, it might be assumed that climate was the major contributing factor in the poor performance of these two cultivars. However, Forestburg (also from the northern plains) had better coverage (40.6%) than Nebraska 28 (27.2%) in this portion of the study. Even though 40.6% coverage is not considered high, this raises questions regarding generalizations about correlations between northern origin switchgrasses and poor performance on southern sites.

Sanderson et al. (1999) observed poor performance of switchgrass under drought conditions in Texas. Research by Smart and Moser (1997) indicated 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 -0.797, which is higher than the 0.078 and -0.349 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 at 11.6 cm and Cave-in-Rock at 12.7 cm were significantly taller than all cultivars, except Blackwell (10.6 cm) at 4 weeks after planting in 1999 (**Table 27**). Shawnee at 10.2 cm was next followed by Forestburg at 9.8 cm, Dacotah and Shelter at 9.2 cm, Trailblazer at 9 cm, Nebraska 28 at 7.4 cm, and Sunburst at 6.3 cm. Alamo and Cave-in-Rock also had significantly greater average heights in 1999 at 45.6 cm and 39.3 cm, respectively. On average, Shawnee (33.1 cm) was not sig-

Table 28. Plant height of 10 switchgrass cultivars in May 2000 grown at pH 6.5.					
Cultivar	**Mowed**	**Harvested**	**Burned**	**LSD**	**Avg.**
	cm	cm	cm	cm	cm
Alamo	106.7	112.1	112.0	NS	110.2
Blackwell	87.5	83.6	86.0	NS	85.6
Cave-in-Rock	84.7	91.1	91.1	NS	88.9
Dacotah	43.9	39.7	36.7	NS	40.1
Forestburg	59.8	67.4	64.4	NS	63.9
Nebraska 28	61.2	73.7	70.9	NS	68.8
Shawnee	77.1	85.9	71.3	10.80	78.1
Shelter	71.8	74.3	72.7	NS	72.9
Sunburst	55.3	57.4	42.6	11.21	51.8
Trailblazer	61.0	88.0	71.8	17.46	73.0
LSD (0.05)	**19.26**	**16.47**	**21.83**		**11.09**

Table 29. Plant height of 10 switchgrass cultivars in June 2000 grown at pH 6.5.					
Cultivar	**Mowed**	**Harvested**	**Burned**	**LSD**	**Avg.**
	cm	cm	cm	cm	cm
Alamo	131.3	135.1	133.3	NS	133.3
Blackwell	99.7	99.9	96.2	NS	98.6
Cave-in-Rock	106.3	105.4	111.1	NS	107.6
Dacotah	44.8	47.8	38.7	NS	43.7
Forestburg	63.6	65.2	67.1	NS	65.3
Nebraska 28	73.0	91.9	67.0	16.99	77.3
Shawnee	102.3	98.1	94.0	NS	98.2
Shelter	98.6	82.0	92.9	NS	91.2
Sunburst	78.3	62.4	46.9	14.26	63.2
Trailblazer	84.0	88.1	79.9	NS	84.0
LSD (0.05)	**19.87**	**21.11**	**23.56**		**12.40**

Table 30. Plant height of 10 switchgrass cultivars in July 2000 grown at pH 6.5.					
Cultivar	Mowed	Harvested	Burned	LSD	Avg.
	cm	*cm*	*cm*	*cm*	*cm*
Alamo	151.1	145.9	162.1	NS	153.0
Blackwell	107.1	116.9	101.6	NS	108.5
Cave-in-Rock	121.9	120.9	126.7	NS	123.2
Dacotah	35.4	38.8	43.0	NS	39.1
Forestburg	68.8	73.8	73.2	NS	71.9
Nebraska 28	68.2	75.9	75.6	NS	73.2
Shawnee	112.4	111.4	115.3	NS	113.1
Shelter	108.2	108.4	117.8	NS	111.5
Sunburst	62.6	54.9	45.4	11.07	54.3
Trailblazer	85.4	95.3	92.1	NS	91.0
LSD (0.05)	**20.30**	**22.34**	**26.32**		**12.84**

Table 31. Plant height of 10 switchgrass cultivars in August 2000 grown at pH 6.5.					
Cultivar	Mowed	Harvested	Burned	LSD	Avg.
	cm	*cm*	*cm*	*cm*	*cm*
Alamo	154.2	182.8	178.0	NS	171.7
Blackwell	114.6	105.1	101.0	NS	106.9
Cave-in-Rock	137.1	126.0	134.6	NS	132.6
Dacotah	37.8	53.2	34.4	11.73	41.8
Forestburg	63.4	61.4	75.8	10.48	66.9
Nebraska 28	68.7	70.0	71.2	NS	70.0
Shawnee	114.0	121.3	120.8	NS	118.7
Shelter	106.1	114.0	109.9	NS	110.0
Sunburst	53.6	61.0	55.7	NS	56.7
Trailblazer	83.9	107.4	110.3	16.40	100.6
LSD (0.05)	**22.87**	**22.90**	**26.03**		**13.66**

nificantly taller than Blackwell at 32.9 cm in 1999. Sunburst at 16.6 cm had the shortest average height during 1999.

Alamo at 110.2 cm and Cave-in-Rock at 88.9 cm had the greatest average height in May 2000 (**Table 28**). With the exception of Alamo (110.2 cm), Dacotah (40.1 cm), and Sunburst (51.8 cm), the remaining cultivars were similar in height ranging from 88.9–63.9 cm. In general, mowed plots tended to have shorter heights but not for every cultivar. Management was significant for only three cultivars in May. Harvested plots were expected to be shorter due to the loss of nutrients from plant removal. This trend was only observed in six of the 10 cultivars. Conversely, plants were significantly taller in harvested treatments compared with burned treatments in Shawnee and Sunburst. Trailblazer was similar, but harvested plots were significantly taller than mowed treatments. No explanation can be provided for this trend in stands of Shawnee, Sunburst, and Trailblazer in May.

Only Nebraska 28 and Sunburst showed a significant response to management in June 2000 (**Table 29**). Plants of Nebraska 28 were significantly taller in harvested treatments compared with those in both burned and mowed treatments. A similar trend was observed in May 2000 but was not sig-

nificant. Plants of Sunburst were significantly taller in mowed treatments compared with those in burned treatments. This exact management trend in plants of Sunburst was not observed in May 2000. Alamo was still tallest at 133.3 cm followed by Cave-in-Rock at 107.6 cm, which was only slightly taller than Blackwell (98.6 cm) and Shawnee (98.2 cm). Dacotah (43.7 cm), Forestburg (65.3 cm), and Sunburst (63.2 cm) still had the shortest mean heights.

Trends were similar in July 2000 for average switchgrass heights (**Table 30**). On average, Alamo was significantly taller (153 cm) than all other cultivars. The management response observed in Sunburst plants was still significant in July. Plants in mowed treatments were significantly taller (62.6 cm) than plants in burned plots (45.4 cm). No other significant management responses were observed in July.

In August 2000, Sunburst plants showed no significant response to management treatments (**Table 31**). Previous trends were lost as well, with taller plants (61 cm) observed in harvested treatments. This raises questions regarding previous monthly responses to management observed in Sunburst plots. It is possible that the influence of mowing is short-term. Significant management responses were observed in Dacotah, Forestburg,

Table 32. Plant height of 10 switchgrass cultivars in September 2000 grown at pH 6.5.					
Cultivar	Mowed	Harvested	Burned	LSD	Avg.
	cm	*cm*	*cm*	*cm*	*cm*
Alamo	166.4	169.9	178.4	NS	171.6
Blackwell	120.3	122.1	128.7	NS	123.7
Cave-in-Rock	124.1	114.1	129.6	NS	122.6
Dacotah	28.7	23.9	30.0	NS	27.5
Forestburg	68.9	75.7	63.1	NS	69.2
Nebraska 28	53.9	77.3	71.4	15.20	67.6
Shawnee	126.0	113.1	126.8	NS	122.0
Shelter	112.2	112.7	122.8	NS	115.9
Sunburst	59.7	57.3	56.0	NS	57.7
Trailblazer	70.8	108.2	99.7	25.81	92.9
LSD (0.05)	**25.46**	**24.70**	**25.28**		**14.66**

Table 33. Lodging tendency and 2000 plant height of 10 switchgrass cultivars grown at pH 6.5.[1]				
Cultivar	Lodging			Height
	1999	2000	2001	
				cm
Alamo	No	Yes	Yes	148.2
Blackwell	No	No	Yes	104.8
Cave-in-Rock	No	No	Yes	115.0
Dacotah	No	No	No	38.4
Forestburg	No	No	No	67.4
Nebraska 28	No	No	No	71.3
Shawnee	No	No	Yes	106.0
Shelter	No	No	Yes	100.3
Sunburst	No	No	No	56.7
Trailblazer	No	No	Yes	88.4

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

and Trailblazer. Dacotah plants in harvested treatments were significantly taller (53.2 cm) than those in both burned (34.4 cm) and mowed (37.8 cm) treatments. However, this trend was not observed in July and may be questionable. Forestburg and Trailblazer were comparable since both had the tallest plants in burned treatments. As with Dacotah, August management responses in plants of Forestburg and Trailblazer were not observed in the previous month, raising questions regarding this trend. Although not significant, Forestburg and Trailblazer had similar trends in July and September with the tallest plants in harvested treatments.

By September, Alamo was 47.9 cm taller than the next tallest cultivar Blackwell (123.7 cm) (**Table 32**). This difference was significant. Management responses were significant only in plants of Nebraska 28 and Trailblazer. Both showed significantly taller plants in harvested treatments. Long-term studies should take this into consideration when addressing the influence of management on switchgrass. Both cultivars had the shortest plants in mowed treatments in August and July but not June. These fluctuations make it difficult to determine the influence of management on 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 on 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 treatments late in the season but not early. However, these differences were small and were not statistically analyzed. Still, long-term studies may provide more information regarding the influence of management on plant height. The responses to management regime were, for the most part, different depending on the cultivar. This may be an indication that cultivars may respond differently.

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 6.5.
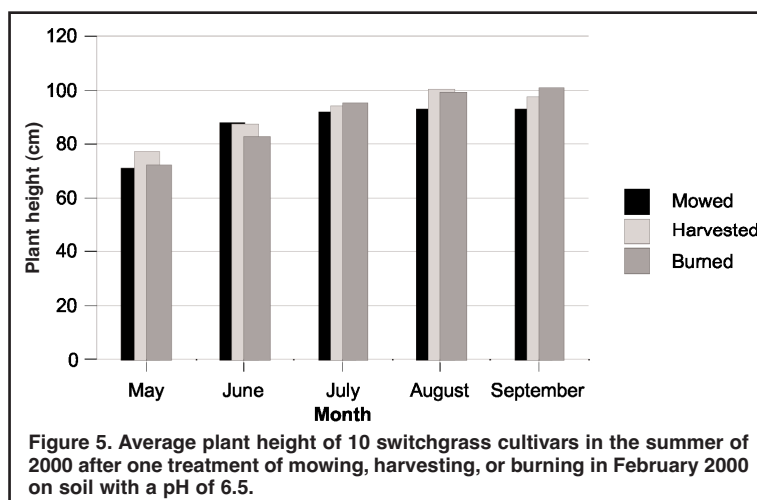
A view of average heights from May through September of 2000 shows the peak at the end of the summer in August and September. It is not clear if plant heights will continue to increase given additional years of growth. A third year, and possibly more years, may be necessary for many of these cultivars to reach 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 in this study was obtained in September 2000 at 57.7 cm. 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 is far less than the 171.6 cm and 123.7 cm September 2000 averages recorded for these cultivars in our study. This 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.

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 (171.7 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 unclear if the addition of nitrogen fertilizer would have compounded the problem with lodging.

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 fertilization, 10 switchgrass cultivars exhibited high variability in dead standing biomass produc-

Table 34. Dead standing biomass of 10 switchgrass cultivars in spring 2000 and 2001 grown at pH 6.5.		
Cultivar	2000	2001
	kg/ha	kg/ha
Alamo	1345	7394
Cave-in-Rock	742	2261
Shawnee	497	1756
Blackwell	412	2720
Trailblazer	303	1439
Shelter	202	1218
Forestburg	172	345
Nebraska 28	130	805
Dacotah	104	67
Sunburst	83	166
LSD (0.05)	529.2	2386.8

tion (**Table 34**). Alamo had significantly more biomass than other cultivars in both the 2000 and 2001 harvest (1,345 kg/ha and 7,394 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 west Louisiana. Cave-in-Rock was next in 2000 at 742 kg/ha, just below Blackwell (2,720 kg/ha) at 2,261 kg/ha in 2001. Jung et al. (1990) compared dry matter yield between Alamo and Blackwell but 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 2,720 kg/ha of biomass harvested during the second year of our study. However, Hall et al. conducted multiple harvests during the growing season under fertilization. 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 on 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 Blackwell, Cave-in-Rock, Shawnee, Trailblazer, and Shelter (2,720 kg/ha, 2,261kg/ha, 1,756 kg/ha, 1,439 kg/ha, and 1,218 kg/ha, respectively). The third group had very little biomass production and included Nebraska 28, Forestburg, Sunburst, and Dacotah (805 kg/ha, 345 kg/ha, 166 kg/ha, and 67 kg/ha, respectively). Biomass production is not necessarily a positive characteristic in golf course natural areas. Some biomass is required to provide cover for wildlife and soil protection, and aesthetics. However, as discussed previously, Alamo was also the first cultivar to lodge. This 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 on 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 both high and low soil temperature extremes.

Table 35. Dead standing biomass and soil temperature of 10 switchgrass cultivars in spring 2001 grown at pH 6.5.		
Cultivar	Biomass	Soil temp.
	kg/ha	*°C*
Alamo	7394	58.7
Blackwell	2720	65.7
Cave-in-Rock	2261	64.4
Shawnee	1756	65.0
Trailblazer	1439	64.9
Shelter	1218	68.1
Nebraska 28	805	67.7
Forestburg	345	67.6
Sunburst	166	67.2
Dacotah	67	68.8
LSD (0.05)	**2386.8**	**4.61**

However, some of this effect may be due to the reduction of wind velocity (Bilbro and Fryrear, 1997), particularly in larger grasses such as switchgrass. In the spring of 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 no significant (P=0.0515) correlation between the amount of dead standing biomass on plots and the soil temperature, although a probability of 0.0515 is very close to significant at the 0.05 level. This correlation was negative (-0.359), 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 affects spring green-up or winter survival of a given cultivar or how it affects wildlife that may inhabit natural areas throughout the course of the year. Although not addressed in this study, cover may have some influence on 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 on growing season productivity of big bluestem, little bluestem, and switchgrass. However, they did not determine long-term effects of dead stand material removal on soil nutrient levels. In our study,

Table 36. Nitrogen, phosphorus, and potassium tissue samples taken in February 2001 from 10 switchgrass cultivars grown at pH 6.5.									
Cultivar	Nitrogen			Phosphorus			Potassium		
	%	kg/ha	g/kg	%	kg/ha	g/kg	%	kg/ha	g/kg
Alamo	0.66	49.8	6.6	0.05	4.08	0.53	0.06	3.42	0.57
Blackwell	0.71	18.1	7.1	0.05	1.36	0.50	0.03	0.73	0.33
Cave-in-Rock	0.63	14.4	6.3	0.04	0.90	0.40	0.03	0.76	0.27
Dacotah	0.75	0.5	7.5	0.05	0.04	0.53	0.07	0.05	0.70
Forestburg	0.77	2.6	7.7	0.05	0.19	0.50	0.04	0.13	0.40
Nebraska 28	0.68	5.2	6.8	0.06	0.44	0.57	0.05	0.44	0.47
Shawnee	0.70	12.1	7.0	0.04	0.65	0.37	0.05	0.79	0.47
Shelter	0.68	8.0	6.8	0.05	0.59	0.50	0.05	0.40	0.47
Sunburst	0.81	1.4	8.1	0.05	0.06	0.47	0.03	0.04	0.33
Trailblazer	0.58	8.5	5.8	0.06	0.89	0.63	0.04	0.52	0.37
LSD (0.05)	**NS**	**16.16**	**NS**	**NS**	**1.606**	**NS**	**0.026**	**0.930**	**NS**

**Table 37. Calcium, magnesium, and iron from tissue samples
taken in February 2001 from 10 switchgrass cultivars grown at pH 6.5.**

Cultivar	Calcium			Magnesium			Iron		
	%	kg/ha	g/kg	%	kg/ha	g/kg	ppm[1]	kg/ha	g/kg
Alamo	0.19	13.26	1.87	0.040	2.90	0.40	24.7	0.183	0.025
Blackwell	0.31	7.13	3.07	0.033	0.84	0.33	44.7	0.126	0.045
Cave-in-Rock	0.28	5.36	2.83	0.030	0.68	0.30	33.0	0.076	0.033
Dacotah	0.20	0.13	2.03	0.033	0.02	0.33	49.7	0.003	0.050
Forestburg	0.32	1.18	3.20	0.030	0.10	0.30	37.3	0.013	0.037
Nebraska 28	0.34	2.54	3.37	0.030	0.27	0.30	35.7	0.027	0.036
Shawnee	0.23	4.06	2.33	0.033	0.58	0.33	38.3	0.066	0.038
Shelter	0.38	4.36	3.80	0.033	0.39	0.33	36.0	0.041	0.036
Sunburst	0.38	0.55	3.83	0.020	0.03	0.20	58.0	0.008	0.058
Trailblazer	0.32	4.23	3.20	0.027	0.42	0.27	48.0	0.067	0.048
LSD (0.05)	**NS**	**5.074**	**NS**	**NS**	**0.88**	**NS**	**NS**	**0.0922**	**NS**

[1]ppm = mg/g.

tissue samples were taken from spring dead standing biomass harvests to determine if any significant loss of nutrients was occurring in harvested plots. Only one 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 (g/kg sample). Although Alamo had the highest amount of nitrogen (49.8 kg/ha) and phosphorus (4.08 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 is higher than the 18.1 kg/ha of N per year removed from Blackwell plots in our study. Based on findings by Jung et al. (1990), it is possible that nitrogen applications in our study would have increased the amount of nitrogen in harvests. Most cultivars had similar concentrations of nitrogen and phosphorus, ranging from 5.80–8.10 g/kg of N and 0.37–0.63 g/kg of P.

There was significantly more potassium (3.42 kg/ha) in Alamo biomass compared with other cultivars. The closest cultivar was Shawnee with 0.79 kg/ha of K. Unlike nitrogen and phosphorus, this may have been due in part to higher concentrations of potassium in Alamo tissue. However, Alamo did not have significantly higher concentrations of potassium in tissues (0.57 g/kg of K) 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

that compares rooting depths of switchgrass cultivars.

Based on these data, it is possible that removal of clippings could lead to soil deficiencies, especially when growing switchgrass cultivars like Alamo, Blackwell, Cave-in-Rock, and Shawnee. USDA and Ducks Unlimited Canada (Dickerson et al., 1997) recommend the addition of nitrogen and phosphorus at a 3:1 ratio during the second year of establishment. Their recommendations call for nitrogen rates of 100.8 kg/ha (90 pounds per acre). However, according to our study, it would take approximately 3 years (Alamo) to 4 years (Blackwell, Cave-in-Rock, and Shawnee) to lose this much nitrogen through spring biomass harvests. In addition, the 3:1 ratios for soil applications do not correspond with the ratios found in dead standing tissues in our study. By averaging concentrations in percent across all 10 cultivars, the ratio is 0.697:0.05 (or 14:1). Using the same method, the N:P:K ratio was 0.697:0.05:0.045 (or 15.5:1.1:1). 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 fertilization. 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). More than 5% for nitrogen; 0.5% or 0.4%, respectively, for phosphorus; and 4% or 2.5%, respectively, for potassium are high sufficiency levels for bermudagrass and 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 on these data, it is possible that nitrogen deficiencies may result from yearly 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 fertilization is necessary — especially since most of the switchgrass cultivars had good performance in this study with-

Cultivar	Manganese			Zinc			Copper		
	ppm [1]	kg/ha	g/kg	ppm	kg/ha	g/kg	ppm	kg/ha	g/kg
Alamo	190.0	1.46	0.19	14.7	0.102	0.015	4.7	0.034	0.005
Blackwell	226.0	0.69	0.23	11.0	0.027	0.011	9.0	0.028	0.009
Cave-in-Rock	272.3	0.62	0.27	9.0	0.031	0.009	9.7	0.032	0.010
Dacotah	267.3	0.02	0.27	19.3	0.001	0.019	9.3	0.001	0.009
Forestburg	336.7	0.11	0.34	12.0	0.004	0.012	5.3	0.002	0.005
Nebraska 28	364.3	0.20	0.36	11.0	0.007	0.011	5.3	0.004	0.005
Shawnee	209.0	0.37	0.21	6.7	0.012	0.007	3.7	0.007	0.004
Shelter	332.7	0.48	0.33	7.7	0.007	0.008	6.3	0.007	0.006
Sunburst	360.0	0.08	0.36	11.3	0.001	0.011	4.7	0.001	0.005
Trailblazer	232.7	0.38	0.23	14.7	0.025	0.015	9.0	0.014	0.009
LSD (0.05)	**NS**	**0.684**	**NS**	**NS**	**0.0314**	**NS**	**NS**	**NS**	**NS**

[1] ppm=mg/g.

out supplemental fertilizer. 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, magnesium, and iron concentrations were generally similar across the 10 switchgrass cultivars (**Table 37**), except for Alamo. Although not significant, Alamo had higher concentrations of magnesium but lower concentrations of calcium and iron compared with other cultivars. 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 13.3 kg/ha of Ca, 2.9 kg/ha of Mg, and 0.18 kg/ha of Fe. However, concentrations of Ca, Mg, and Fe in Alamo tissue samples were not significantly higher than 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 24.7–58 ppm (mg/g), 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 apparent 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 on plant height long term.

The total amount of manganese and zinc harvested in tissue samples was significantly higher from Alamo plots compared with other cultivars (**Table 38**). The total amount of copper was highest from Alamo plots but was not significantly higher than that harvested from other cultivars. Copper tissue levels from Cave-in-Rock (0.032 kg/ha of Cu) and Blackwell (0.028 kg/ha of Cu) were similar to Alamo (0.034 kg/ha of Cu). There were no significant differences in concentrations of these nutrients across the 10 cultivars. Average concentrations of Mn and Cu in dead standing tissue samples of switchgrass in this study were comparable to those in living tissues of bermuda-

Table 39. Pearson correlation coefficients (*r*) 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 6.5.

Variable		2000 Cover	2001					
			Biomass	N	P	K	Ca	Mg
		kg/ha	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg
2000 Cover	r	-	0.690	-0.421	-0.133	-0.337	-0.404	0.184
	P	-	0.0001	0.021	0.482	0.069	0.027	0.331
2001 Biomass	r		-	-0.269	0.035	-0.121	-0.489	0.341
	P		-	0.151	0.856	0.525	0.006	0.065
2001 N	r			-	-0.162	0.230	0.152	0.028
	P			-	0.391	0.222	0.422	0.882
2001 P	r				-	0.162	0.233	-0.144
	P				-	0.393	0.215	0.447
2001 K	r					-	-0.148	0.554
	P					-	0.436	0.002
2001 Ca	r						-	-0.376
	P						-	0.041

Variable		2000 Cover	2001 Biomass	Fe	Mn	Zn	Cu
		kg/ha	g/kg	g/kg	g/kg	g/kg	g/kg
2000 Cover	r	-	0.690	-0.454	-0.012	-0.150	0.149
	P	-	0.0001	0.012	0.948	0.430	0.431
2001 Biomass	r		-	-0.384	-0.203	0.026	0.057
	P		-	0.037	0.282	0.890	0.764
2001 Fe	r			-	-0.140	0.312	0.314
	P			-	0.460	0.093	0.091
2001 Mn	r				-	-0.129	0.170
	P				-	0.499	0.369
2001 Zn	r					-	0.460
	P					-	0.001

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 6.5.

grass (Puhalla et al., 1999). Average Mn concentrations in switchgrass (279.1 ppm) in this study were comparable to the tissue sufficiency range of medium for bermudagrass (25–300 ppm). Average Cu concentrations (6.7 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 (0.021) negative (-0.421) correlation between cover and nitrogen concentration in dead standing tissue (**Table 39**). As percent cover increased, the N concentration decreased. There is some indication of competition between plants for nitrogen, especially since nitrogen apparently has more influence on tiller weight than number (Sanderson, 2000). However, comparisons between biomass and nitrogen concentrations were not significant. Correlations between calcium concentrations in tissues and biomass also showed a significant ($P=0.006$) negative ($r=-0.489$) correlation. Correlations between calcium concentrations in tissue and percent cover were similar ($P=0.027$; $r=-0.404$). Iron

concentrations also showed significant ($P=0.037$ and $P=0.012$, respectively) negative ($r=-0.384$ and $r=-0.454$, respectively) correlations with biomass and percent cover (**Table 40**). As with nitrogen, there may have been some competition between plants for these nutrients during the study.

Correlations between Ca and Mg were negative ($r=-0.376$), indicating inverse responses between these two nutrients in tissue (**Table 39**). There were also significant negative correlations between magnesium and iron ($r=-0.468$; $P=0.009$), magnesium and manganese ($r=-0.372$; $P=0.043$), and potassium and manganese ($r=-0.364$; $P=0.048$) (**Table 41**). These correlations are not clear as those with biomass and cover.

There were significant positive correlations between concentrations of several nutrients in plant tissue during the study. Significant correlations between K and Mg concentrations were positive ($r=0.554$), indicating that the two nutrients increased simultaneously in plant tissue (**Table 39**). There were also significant positive correlations between copper and zinc ($r=0.460$; $P=0.001$) (**Table 40**), calcium and iron ($r=0.390$; $P=0.033$), and potassium and zinc ($r=0.465$; $P=0.010$) concentrations in tissue samples (**Table 41**). These

Variable		N	P	K	Ca	Mg
		g/kg	g/kg	g/kg	g/kg	g/kg
Fe	r	0.081	0.141	-0.045	0.390	-0.468
	P	0.671	0.457	0.816	0.033	0.009
Mn	r	0.225	-0.110	-0.364	0.050	-0.372
	P	0.233	0.562	0.048	0.793	0.043
Zn	r	0.109	0.345	0.465	-0.209	0.164
	P	0.565	0.062	0.010	0.268	0.387
Cu	r	-0.286	0.061	-0.041	-0.171	-0.183
	P	0.126	0.750	0.830	0.367	0.334

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 6.5.

<table>
<tr><td colspan="2">Table 42. Foliage damage from grasshoppers recorded 19 October 2000 on 10 switchgrass cultivars grown at pH 6.5.[1]</td></tr>
</table>

Cultivar	Foliar loss
	%
Dacotah	16.7
Alamo	26.7
Nebraska 28	40.0
Forestburg	40.0
Sunburst	43.3
Trailblazer	50.0
Blackwell	53.3
Shawnee	56.7
Shelter	56.7
Cave-in-Rock	60.0
LSD (0.05)	**16.74**

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

Table 43. Growing season color range of 10 switchgrass cultivars grown at pH 6.5.[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.

correlations are not fully understood. 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. Dacotah showed the least amount of damage (16.7%) followed by Alamo (26.7%) (**Table 42**). Cave-in-Rock showed the greatest amount of damage (60%). 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). Breeding for improved insect tolerance or resistance may require a considerable length of time (20+ years) 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 on the desired function of the natural area. If grasshoppers are considered desirable, then a cultivar such as Cave-in-Rock may be a possibility. If they are not desired, Dacotah or Alamo may be a possibility. Keeping in mind that Dacotah and Alamo performed differently in this study, 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 2–4, which is a coloration ranging from medium gray-brown to light chocolate-brown. Hue values of the other cultivars were variable, ranging from 4–8 with chromas ranging 2–6. These are colors of light gray-brown (7.5YR7/2), gray-brown (7.5YR6/2, 5YR4-5/2, and 2.5YR), medium brown

Table 44. Winter color range of 10 switchgrass cultivars grown at pH 6.5.[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.

(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 4–6. Most cultivars had stem colors in this color range. Shawnee showed some lighter foliage coloration, as well.

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 colorations in big bluestem cultivars were 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 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 on 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 on spring green-up. However, Alamo had both the highest biomass and earliest spring green-up. It is not clear how this 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, this may be a desirable characteristic. However, it may not be desirable for areas where aesthetics are of concern.

Summer colorations of switchgrass cultivars were 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. A better understanding of the influence of mixed stands on switchgrass lodging is also needed. It is possible that shorter species mixed with taller switchgrass cultivars may reduce, or prevent, lodging. The studies reported in this bulletin were planted early in the growing season. The influence of planting date on 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. Information of 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 6.5 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 6.5.

Cultivar	OM	P	K	Ca	Mg	Zn	S
	%	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
Broomsedge	0.97	32.2	70.3	1972.8	135.8	0.78	156.2
Aldous	1.04	33.9	73.4	1830.2	120.7	0.87	167.9
Blaze	0.96	30.6	70.7	1787.1	128.8	0.77	155.3
Camper	0.97	30.6	73.7	1732.4	131.4	0.67	156.9
Cimarron	0.97	29.2	68.2	1782.9	129.9	0.80	155.7
Itasca	2.10	33.0	70.8	2106.8	129.4	0.73	162.8
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**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 6.5.

Cultivar	OM	P	K	Ca	Mg	Zn	S
	%	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
Bison	1.14	40.8	88.0	2112.5	142.2	1.47	183.1
Bonilla	1.09	38.7	91.2	1947.6	124.3	0.92	175.5
Kaw	1.14	39.8	90.2	2023.4	146.2	0.80	184.3
Niagara	1.06	34.7	93.5	1721.8	130.4	0.90	170.9
Pawnee	1.17	40.8	93.1	1624.8	125.1	1.31	188.3
Rountree	1.09	42.9	103.0	1586.1	123.6	1.03	175.1
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**0.429**	**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 6.5.

Cultivar	OM	P	K	Ca	Mg	Zn	S
	%	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
Cheyenne	1.24	37.0	90.6	1572.9	126.3	1.11	199.4
Holt	1.19	44.7	95.5	2226.9	150.0	0.90	191.4
Nebraska 54	1.00	31.9	72.4	1777.9	126.6	0.92	161.0
Osage	1.11	40.7	87.9	2176.3	147.8	1.12	178.2
Oto	1.10	43.1	86.4	1697.9	128.2	1.11	181.6
Rumsey	1.03	38.3	86.4	1949.5	132.0	1.05	166.5
Tomahawk	1.18	41.7	89.4	1704.4	136.5	0.76	190.9
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table A.4. Percent soil organic matter in 2000 and 2001 for 10 switchgrass cultivars grown at pH 6.5.

Cultivar	2000				2001			
	Mowed	Harvested	Burned	LSD	Mowed	Harvested	Burned	LSD
	%	%	%	%	%	%	%	%
Alamo	1.10	1.17	1.09	NS	1.33	1.11	1.20	NS
Blackwell	0.95	1.01	1.01	NS	1.17	1.14	1.18	NS
Cave-in-Rock	0.99	1.21	1.10	0.158	1.26	1.29	1.16	NS
Dacotah	1.08	1.07	1.06	NS	1.03	1.16	1.13	NS
Forestburg	0.91	1.12	1.18	NS	1.06	1.20	1.21	NS
Nebraska 28	0.95	1.01	1.00	NS	1.29	1.16	1.16	NS
Shawnee	1.05	1.11	1.04	NS	1.12	1.28	1.13	NS
Shelter	0.93	1.10	1.06	NS	1.20	1.04	1.12	NS
Sunburst	0.95	1.11	0.96	NS	1.13	1.07	0.99	NS
Trailblazer	1.01	0.97	0.97	NS	0.96	1.10	1.17	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 6.5.

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	41.4	40.7	37.3	NS	31.7	34.0	34.0	NS
Blackwell	39.6	36.6	36.2	NS	28.7	30.6	28.7	NS
Cave-in-Rock	37.3	39.6	34.0	NS	28.0	31.4	29.5	NS
Dacotah	29.1	33.6	34.3	NS	19.4	32.9	28.4	NS
Forestburg	32.1	36.2	37.0	NS	23.2	28.0	26.1	NS
Nebraska 28	42.2	40.3	39.6	NS	35.1	34.7	34.7	NS
Shawnee	33.2	33.6	32.5	NS	24.6	25.0	22.8	NS
Shelter	38.1	32.1	38.1	NS	28.7	26.9	28.0	NS
Sunburst	31.7	30.2	31.4	NS	24.6	21.3	23.9	NS
Trailblazer	40.3	34.0	35.8	NS	34.7	28.4	29.1	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 6.5.

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	79.5	78.8	78.8	NS	68.3	67.9	71.3	NS
Blackwell	81.8	86.2	90.0	NS	71.3	84.0	66.1	NS
Cave-in-Rock	80.3	89.2	87.7	NS	70.6	76.5	76.2	NS
Dacotah	90.0	105.3	100.4	NS	62.3	87.7	72.4	NS
Forestburg	84.8	93.3	88.9	NS	79.2	82.9	79.9	NS
Nebraska 28	98.9	100.1	79.9	NS	70.6	70.6	66.1	NS
Shawnee	88.9	94.8	88.1	NS	65.7	34.0	62.3	NS
Shelter	76.9	84.4	87.7	NS	70.2	69.4	60.1	NS
Sunburst	85.5	84.0	97.4	NS	79.2	81.8	69.1	NS
Trailblazer	83.6	78.4	85.1	NS	78.8	82.9	79.1	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 6.5.

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	1632.6	1568.3	1503.8	NS	822.4	834.4	1140.2	NS
Blackwell	1865.1	1547.8	1578.9	NS	888.9	861.6	827.7	NS
Cave-in-Rock	1804.7	1989.9	1826.7	NS	894.9	1125.9	1034.1	NS
Dacotah	1421.6	1634.9	1596.8	NS	691.8	856.0	866.1	NS
Forestburg	1956.6	2057.8	1898.7	NS	1086.4	1003.9	1200.6	NS
Nebraska 28	1625.5	1614.7	1446.3	NS	762.4	882.9	869.1	NS
Shawnee	1633.7	1599.0	1635.2	NS	857.9	883.7	871.7	NS
Shelter	1666.9	1595.2	1699.4	NS	887.4	820.6	851.2	NS
Sunburst	1734.1	1377.9	1362.7	NS	869.5	734.4	721.6	NS
Trailblazer	1899.9	1748.7	1594.9	NS	1030.7	981.5	827.7	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 6.5.

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	126.2	118.4	119.8	3.83	76.9	86.6	80.3	NS
Blackwell	127.7	119.8	124.7	NS	78.8	91.1	83.3	NS
Cave-in-Rock	126.2	137.4	134.0	NS	78.8	95.6	92.2	11.77
Dacotah	104.2	121.0	120.6	NS	65.3	87.7	87.7	16.32
Forestburg	117.6	133.3	134.0	NS	86.2	97.4	106.0	NS
Nebraska 28	125.4	126.6	118.7	NS	82.5	94.1	87.4	NS
Shawnee	117.6	117.2	121.0	NS	72.1	89.2	80.6	8.59
Shelter	124.0	121.0	129.9	NS	81.0	86.6	85.1	NS
Sunburst	120.2	106.8	113.1	NS	82.1	78.4	73.6	NS
Trailblazer	122.5	119.5	118.4	NS	87.4	89.6	82.5	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 6.5.

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	1.12	1.05	0.82	NS	3.32	0.41	0.37	NS
Blackwell	1.05	1.01	0.86	NS	0.37	1.20	0.41	NS
Cave-in-Rock	1.20	0.97	0.82	NS	0.41	0.37	0.45	NS
Dacotah	1.16	1.01	0.93	NS	0.26	0.64	0.26	NS
Forestburg	1.64	0.93	0.75	NS	0.11	0.41	0.26	NS
Nebraska 28	1.12	0.90	0.67	NS	0.45	0.11	0.49	NS
Shawnee	1.31	0.82	0.86	NS	0.11	0.19	0.75	NS
Shelter	0.93	0.82	1.01	NS	0.26	0.19	0.11	NS
Sunburst	1.05	0.86	0.97	NS	0.30	0.37	0.34	0.388
Trailblazer	1.31	0.90	1.16	NS	0.49	0.26	0.56	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 6.5.

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	177.3	188.9	175.8	NS	213.9	178.8	193.4	NS
Blackwell	153.4	163.5	163.5	NS	189.3	184.4	189.7	NS
Cave-in-Rock	160.2	195.6	176.6	25.11	202.7	207.2	186.3	NS
Dacotah	174.7	173.2	171.0	NS	166.9	186.3	182.2	NS
Forestburg	146.4	181.1	190.8	NS	171.0	194.1	196.0	NS
Nebraska 28	153.8	163.2	160.9	NS	207.6	186.3	186.7	NS
Shawnee	169.5	178.5	168.0	NS	180.7	205.7	181.8	NS
Shelter	150.1	177.7	170.2	NS	193.0	168.0	180.7	NS
Sunburst	152.7	179.2	154.6	NS	181.4	171.7	160.2	NS
Trailblazer	162.4	156.4	155.7	NS	154.6	178.1	188.2	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 6.5 and soil organic matter (OM), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), and sulfur (S) in 2000 and 2001.

Variable		2000 Cover	2001						
			OM	P	K	Ca	Mg	Zn	S
2000 Cover	r	-	0.478	0.341	-0.014	0.417	0.383	0.058	0.479
	P	-	0.0001	0.001	0.898	0.0001	0.0002	0.587	0.0001
2000 O.M.	r	0.362	-	0.781	0.353	0.551	0.715	-0.085	0.999-
	P	0.0004	-	0.0001	0.0006	0.0001	0.0001	0.425	0.0001
2000 P	r	0.374	0.799	-	0.463	0.388	0.578	-0.072	0.781
	P	0.0003	0.0001	-	0.0001	0.0002	0.0001	0.502	0.0001
2000 K	r	-0.176	0.476	0.490	-	0.098	0.298	0.073	0.353
	P	0.098	0.0001	0.0001	-	0.359	0.004	0.493	0.0006
2000 Ca	r	0.368	0.424	0.439	0.035	-	0.875	-0.222	0.551
	P	0.0004	0.0001	0.0001	0.746	-	0.0001	0.036	0.0001
2000 Mg	r	0.451	0.643	0.655	0.233	0.893	-	-0.201	0.715
	P	0.0001	0.0001	0.0001	0.027	0.0001	-	0.058	0.0001
2000 Zn	r	-0.042	0.223	0.354	0.429	-0.088	-0.029	-	-0.084
	P	0.692	0.035	0.0006	0.0001	0.408	0.785	-	0.431
2000 S	r	0.361	0.999-	0.799	0.478	0.424	0.643	0.224	-
	P	0.0005	0.0001	0.0001	0.0001	0.0001	0.0001	0.034	-

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