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Switchgrass, Big Bluestem, and Indiangrass

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SWITCHGRASS (*Panicum virgatum* L.), big bluestem (*Andropogon gerardii* Vitman), and indiangrass (*Sorghastrum nutans* [L.] Nash) are tall warm-season (C_4) grasses that predominated the North American tall-grass prairie (Weaver 1968). Although they are generally associated with the natural vegetation of Great Plains and the western Corn Belt, they occur widely in grasslands and nonforested areas throughout North America east of the Rocky Mountains and south of 55°N latitude (Stubbendieck et al. 1991) (Fig. 32.1). They have been seeded in mixtures in the Great Plains for over 50 yr as pasture and range grasses. In the past 20 yr they have become increasingly important as pasture grasses in the central and eastern US because of their ability to be productive during the hot months of summer when cool-season grasses are relatively unproductive (Fig. 32.2). Although there are differences among cultivars, in a specific adaptation zone switchgrass is generally the earliest of these grasses to be available for grazing and the earliest in flowering, and indiangrass is the latest (Gerrish et al. 1987) (Fig. 32.2). Although the grasses belong to different genera, they have similar areas of adaptation, uses, and management requirements. In this chapter specific differences among the species are explained when they affect management practices.

DISTRIBUTION AND ADAPTATION

Although these grasses were native to most of North America, they are most abundant in the Great Plains states. Plants of these species are all photoperiod sensitive. Their photoperiod requirement is based on the latitude where they evolved. Switchgrass, for example, requires short days to initiate flowering (Benedict 1941). Apparently in nature, flowering is induced by decreasing daylength during early summer. When grown at a common location in the central Great Plains,

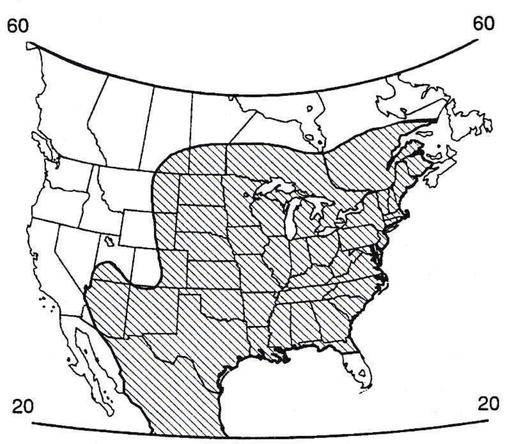

Fig. 32.1. General area of adaptation for switchgrass, big bluestem, and indiangrass. (Adapted from Stubbendieck et al. 1991.)

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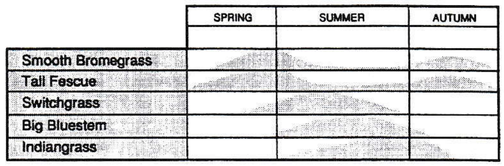

Fig. 32.2. Seasonal yield distribution of switchgrass, big bluestem, and indiangrass compared with that of the cool-season grasses, smooth bromegrass, and tall fescue. (Modified from Waller et al. 1986.)

switchgrasses from the Dakotas (northern ecotypes) flower and mature early and are short in stature, while those from Texas and Oklahoma (southern ecotypes) flower late and are tall (Cornelius and Johnston 1941; McMillian 1959). Moving northern ecotypes south gives them a shorter than normal photoperiod, and they flower early. The opposite occurs when southern ecotypes are moved north, and as a result they stay vegetative longer and produce more forage than northern strains moved south (Newell 1968).

Flowering of the tall bluestems, big and sand bluestem (*A. gerardii* var. *paucipilus* [Nash] Fern.), syn. (*A. hallii* Hack.), and indiangrass responds to photoperiod in a similar manner. The response to photoperiod can be modified by growing degree days to some extent since the flowering date of cultivars will vary from year to year.

The photoperiod response also appears to be associated with winter survival. Southern types moved too far north will not survive winters because they continue growth too late in the fall and do not winter harden properly. As a general rule, these grasses should not be moved more than 500 km north of their area of origin because of the possibility of stand losses due to winter injury. In addition to photoperiod, the other factor that determines specific adaptation is response to precipitation and the associated humidity. Cultivars that are naturally adapted to the more arid Great Plains states may develop foliar disease problems when grown in the more humid eastern states. Cultivars based on naturally adapted eastern germplasm may not be as tolerant to drought stress as cultivars based on western germplasm.

Since these grasses are native to most of North America (Fig. 32.1), ecotypes or strains evolved that were adapted to specific geographic regions, and the total range of each species is represented by a combination range of adapted, native ecotypes. Breeding programs of the USDA and some state experiment stations have resulted in the development and release of cultivars that are adapted to specific regions of the central and eastern US. Cultivar development programs for these grasses have received increased emphases in recent years.

The two primary factors determining area of adaptation of specific cultivars are response to photoperiod and precipitation and the associated humidity, both of which are indicated by the origin of the germplasm used to develop specific cultivars. Although much of the prairie and grasslands that were once occupied by these grasses has been plowed and converted into cropland, remanent prairie sites still exist in most areas and are an invaluable germplasm resource. Some extensive native tall-grass prairies are, most notably, the flint hills in Kansas, the Osage prairie in Oklahoma, and the sandhills of Nebraska.

PLANT DESCRIPTION

Switchgrass. Switchgrass is an erect warm-season (C_4) perennial grass. It grows from 0.5 to 2.0 m tall, and most tillers produce a seedhead when moisture is adequate. Although the plant resembles a loose bunchgrass, it has short rhizomes, and a stand has the potential to thicken and form a sod. The depth of switchgrass roots can be up to 3 m (Weaver 1968). The inflorescence is a diffuse panicle, 15-55 cm long, with spikelets at the end of long branches. Spikelets are two flowered, with the second floret being fertile and the first one sterile or staminate. The seed unit is a fertile floret. It is smooth and slick with an indurate lemma and palea that adhere tightly to the caryopsis. The seed threshes clean and is easy to process and plant. On average, there are 860,000 seeds kg^{-1}, but large seed weight differences exist among cultivars. Johnson and Boe (1982) found 100 seed weights from 103 to 201 mg. Switchgrass is a cross-pollinated plant that is largely self-incompatible (Talbert et al. 1983). Switchgrass has a basic chromosome number of nine, and several levels of ploidy exist (Nielsen 1944). Most switchgrass cultivars are either tetraploids or hexaploids (Riley and Vogel 1982).

Switchgrasses have been divided into lowland and upland types. Lowland types are taller, more coarse, and generally more rust (*Puccinia graminis*) resistant, they have a more bunch-type growth, and they may be more rapid growing than upland types. As indicated by the type description, lowland types are found on floodplains and other similar areas while upland types are found in upland areas that are not subject to flooding. Switchgrass can tolerate a wide range of soil conditions. It grows on sand to clay loam soils. Switchgrass tolerates soils with pH values ranging from 4.9 to 7.6 (Duke 1978).

Big Bluestem. Big bluestem was the dominant species of the tall-grass prairie; it made up as much as 80% of the vegetation on some sites (Weaver 1968). Today it can be found in remanent prairies, railroad right-of-ways, or old cemeteries throughout its former range of occurrence. In the tall-grass prairie in the eastern Great Plains it probably is the most abundant and highest-quality species present in good to excellent condition range. Sand bluestem is an ecotype or subspecies adapted to sandy soils such as the Nebraska sandhills. The Old World bluestems (*Bothriochloa* spp.), which were introduced, and little bluestem (*Schizachrium scoparium* [Michx.] Nash), a native, were formerly classified as *Andropogon* spp. and are discussed in Chapter 31. There are 15 other native *Andropogon* species in North America, but big bluestem is by far the most common and widely distributed member.

Big bluestem culms can grow to be 1-2 m tall. Plants often grow in clumps although most plants have short rhizomes (Stubbendieck et al. 1991). Sand bluestem has extensive rhizomes. Big bluestem has numerous basal leaves, and the leafy portions of the canopy seldom are over 50-60 cm high. The root system is very extensive and can be as deep as 2.0-2.5 m. Root mass in the top 10 cm of soil ranges from 7-10 mt ha^{-1} (Weaver 1968). In old plants, the crowns become very dense and tough, making plowing an old stand difficult.

The inflorescence is a purplish colored panicle with generally three digitate racemes, although it may vary from two to nine racemes. A common name for big bluestem is *turkey foot* since the inflorescence resembles a turkey's foot. Spikelets are single flowered and paired; the sessile spikelet is perfect, and under most conditions, the pedicellate one is staminate. Fertile pedicellate spikelets are found on some plants (Boe et al. 1983). The seed unit is the entire fertile, sessile spikelet that includes a rachis joint and the pedicel that supported the pedicellate spikelet. The seed has varying degrees of pubescence and has a twisted awn. These characteristics make unprocessed seed very fluffy and difficult to handle mechanically with conventional seeding equipment. Seed weights typically average 550 seed units/g for unprocessed big bluestem and 230 seed units/g for unprocessed sand bluestem (Wheeler and Hill 1957).

Big bluestem is cross-pollinated and largely self-incompatible (Law and Anderson 1940). The base chromosome number is 10 (Gould 1968). Most cultivars are 2n = 60 (Riley and Vogel 1982). However, 2n chromosome numbers of 60 and 80 occur naturally in the same location (Keeler et al. 1987). Big and sand bluestem plants (2n = 60) are completely interfertile with each other (Newell and Peters 1961). Big bluestem tolerates a wide range of soils except for sands. Sand bluestem grows well on sandy soils. Under native conditions in areas like the Nebraska sandhills, big bluestem grows in the subirrigated meadows where soil texture is finer and organic matter is higher, whereas sand bluestem grows on the sandy hills. On the benches above the subirrigated meadows (the transition between the meadows and the hills) natural hybrids of big bluestem and sand bluestem are found (Barnes 1986).

Indiangrass. Indiangrass is also a tall warm-season grass with short rhizomes. It has a loose, bunch-type growth habit since the rhizomes are generally shorter than 30 mm (McKendrick et al. 1975). Indiangrass generally ranges from 0.5 to 2.0 m tall and has a yellowish brown to black panicle that ranges from 10 to 30 cm in length. It belongs to the Andropogoneae tribe, as does big bluestem, and the spikelet and floret structures of the two species are similar. Spikelets are in pairs on the rachis, with the sessile one being fertile and the pedicellate one being rudimentary or absent (Stubbendieck et al. 1991). As with big bluestem, the spikelets disarticulate below the glumes, the glumes and florets are covered with pubescence, and the seed unit has a twisted awn. The seed units are extremely fluffy, and indiangrass is very difficult to seed unless it is processed. Seed weight of caryopses ranges from 120 to 150 mg/100 seeds. Some indiangrass seed lots have a considerable amount of dormancy (Emal and Conard 1973), depending on cultivar and the season of seed production.

A major portion of indiangrass tillers has been described as biennial (McKendrick et al. 1975). The first year the tillers grow vegetatively, and then after overwintering the same tillers will become reproductive. This characteristic can be easily seen by observation of the earliest growth in the spring. However, the tillers do not appear to be obligate biennials since indiangrass will flower the seeding year. Indiangrass initiates spring growth about the same time as big bluestem and switchgrass but does not develop as quickly. It normally may flower about 4-6 wk later than switchgrass collected in the same area (McKendrick et al. 1975). Although indiangrass has a later heading date than these other warm-season grasses, shoot apices begin to elongate earlier than those of big bluestem (Gerrish et al. 1987), and plants can become rather stemmy.

As the genus name *Sorghastrum* implies, indiangrass appears to be closely related to the sorghums (*Sorghum* spp.). Indiangrass is the only forage grass outside of the sorghum genus that is known to contain cyanogenic glucosides. Indiangrasses occurring in North America and improved cultivars all have 2n = 40 chromosomes (Riley and Vogel 1982). Indiangrass is cross-pollinated, but some plants will produce seed if selfed. Rooting can occur down to about 1.6 m, and it will grow on soils with a pH range from 5.6 to 7.1 (Duke 1978).

IMPORTANCE AND USE

In the past, these grasses have contributed immensely to the native ranges of the central Great Plains. They have additional importance as pasture and reseeded range grasses because of government agricultural programs. Beginning in the 1930s, they have been used to reseed former cropland during programs such as the Soil Bank and the Conservation Reserve Program. In these programs, several million hectares of land were seeded to either monocultures or mixtures containing these grasses. Improved cultivars and improved seeding and management practices have increased their use as pasture grasses independent of farm programs. The reason for their increased use is that they are the best-adapted warm-season grasses that can be used north of the areas where bermudagrass (*Cynodon dactylon* [L.] Pers.) and other subtropical grasses are adapted. In integrated grazing systems, based on cool-season grasses and legumes, they fill a needed niche for productive summer pastures.

In addition to being valuable as forage crops, these grasses also are used for conservation purposes including roadside plantings, waterways, railroad and other right-of-ways, and wildlife cover. Since switchgrass is a high-yielding perennial crop, today there is interest in using switchgrass for a biomass crop for conversion into alcohol fuels (Parrish et al. 1990). Yields up to 16-17 mt ha^{-1} have been reported (Cherney et al. 1990; Parrish et al. 1990). Assuming a 75% extraction efficiency (Dobbins et al. 1990), ethanol yield would be 330 L of ethanol per mt of biomass, which suggests ethanol yields up to 5300-5600 L ha^{-1} could be produced from switchgrass.

CULTIVARS

Breeding work first began on these grasses in the Great Plains states during the 1930s. Initially, numerous accessions (ecotypes or strains) were collected and evaluated (Vogel and Gabrielsen 1986). One or more of the better accessions were selected and increased for evaluation in additional environments, often with the assistance of the Soil Conservation Service. Based on these tests, the accessions often were released directly as cultivars without any additional breeding work. The switchgrass cultivars 'Blackwell' and 'Nebraska 28' were released based on this ecotype evaluation procedure. This same system continues to be used to develop the initial cultivars of these species for geographic or climatic areas where adapted cultivars are not available.

More recently, other cultivars have been developed using more-sophisticated breeding procedures. Currently, grass breeders working on these species are using population improvement breeding procedures including restricted recurrent phenotypic selection (RRPS) and modifications of between and within family selection (Vogel and Pedersen 1993). The switchgrass cultivar 'Trailblazer' was developed using RRPS. Breeding work on these grasses is currently being conducted at several state and USDA research stations. The breeding work emphasizes improving establishment, forage yield and quality, and disease resistance. Genetic studies in each of the species indicates that there is genetic variation for all the traits studied to date and that it should be possible to develop improved cultivars of these grasses (Vogel and Moore 1993).

The principal cultivars that are available for use as forage grasses are listed in Table 32.1. Since latitude of origin and photoperiod response are the primary determinates of area of adaption with growing degrees days having modifying effects, the adaptation zone for cultivars can be based on the USDA plant hardiness zone map (Fig. 32.3). Released cultivars of these grasses are best adapted and most productive in areas where annual precipitation exceeds 450 mm.

CULTURE AND MANAGEMENT

Stand Establishment. These warm-season

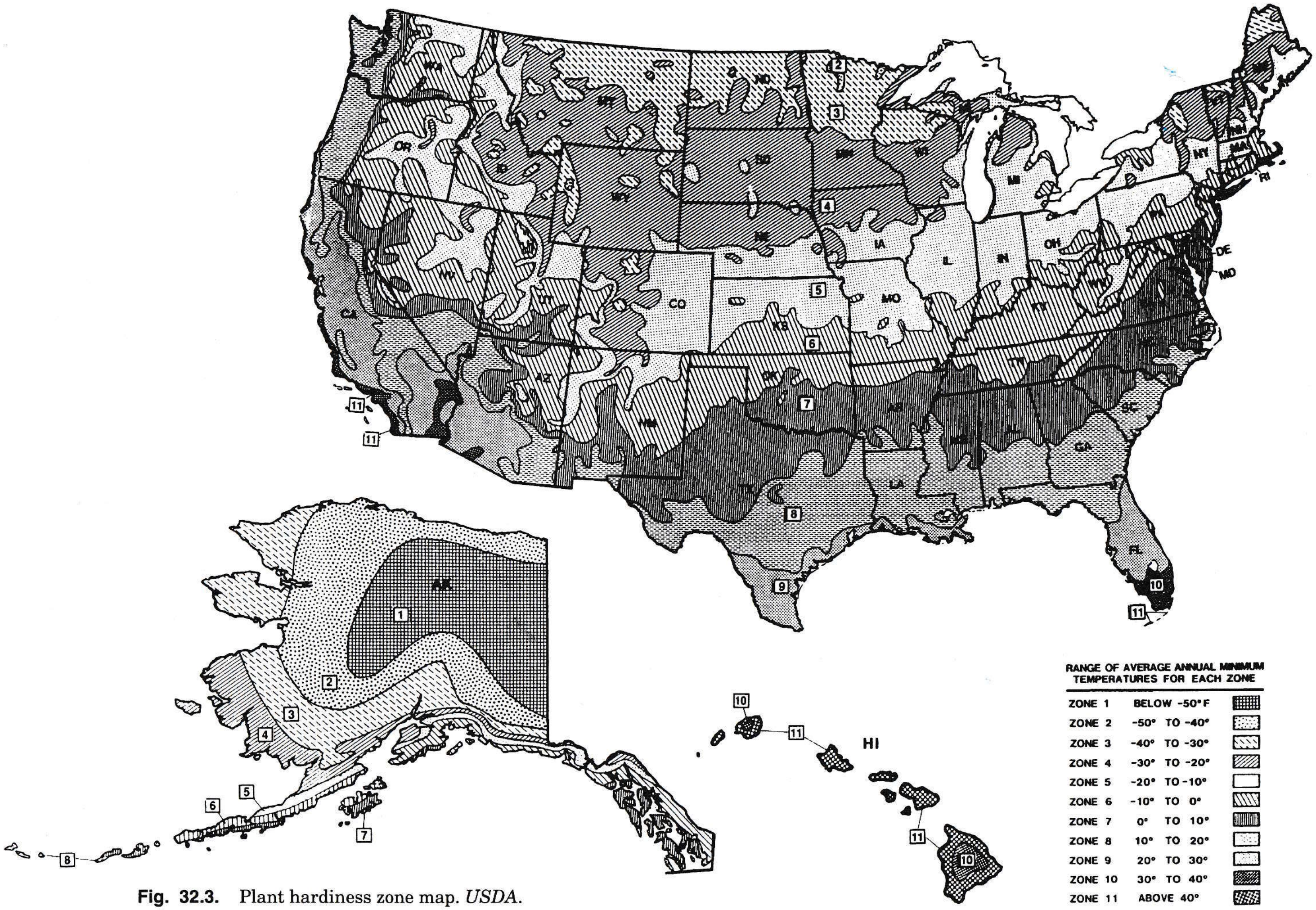

Fig. 32.3. Plant hardiness zone map. *USDA.*

TABLE 32.1. Principal cultivars of switchgrass, big bluestem, and indiangrass and their area or areas of adaptation

Cultivar	Origin of collection	Type	Adaptation zones[a]
Switchgrass			
Dacotah	North Dakota	upland	2, 3, upper 4
Forestburg	South Dakota	upland	3, 4
Sunburst	South Dakota	upland	3, 4
Nebraska 28	Nebraska	upland	3, 4
Summer	Nebraska	upland	3, 4, 5
Pathfinder	Nebraska, Kansas	upland	4, 5
Trailblazer	Nebraska, Kansas	upland	4, 5
Blackwell	Oklahoma	upland	lower 5, 6, 7
Cave-in-Rock	Southern Illinois	upland/lowland	5, 6, 7
Kanlow	Oklahoma	lowland	6, 7
Alamo	Texas	lowland	7, 8, 9
Tall bluestems			
Bison	North Dakota	big bluestem	2, 3
Bonilla	South Dakota	big bluestem	3, upper 4
Niagara	New York	big bluestem	3, 4, upper 5
Champ	Nebraska, Iowa	intermediate	4
Pawnee	Nebraska	big bluestem	lower 4, 5
Roundtree	Iowa	big bluestem	4, 5, upper 6
Kaw	Kansas	big bluestem	lower 5, 6, 7
Goldstrike	Nebraska	sand bluestem	4, 5
Garden	Nebraska	sand bluestem	4, 5
Indiangrass			
Tomahawk	North and South Dakota		3, upper 4
Holt	Nebraska		4
Nebraska 54	Nebraska		lower 4, 5
Oto	Nebraska, Kansas		5, upper 6
Rumsey	Illinois		5, 6
Osage	Kansas, Oklahoma		6, 7
Lometa	Texas		lower 6, 7, 8
Llano	New Mexico		7, 8

[a]Zones are indicated in Figure 32.3.

prairie grasses may be difficult to establish if recommended establishment practices are ignored. The problem in obtaining satisfactory stands may be due to competition with weeds, planting too deep, problems in metering seed, and problems with low-quality or dormant seed. Seed of both big bluestem and indiangrass are considered to be "chaffy" because of pubescence, awns, and other appendages that remain with the seed (Chap. 31). Seed, as harvested, may contain a considerable amount of stem pieces and other inert matter, so cleaning the seed to a high level of purity may be impossible. Special grassland drills with aggressive seed-feeding mechanisms and agitators are needed to handle this chaffy seed. The seed can be aggressively processed to remove the hair and awns (Brown et al. 1983), which makes it possible to plant this chaffy grass seed with conventional seeding equipment. Switchgrass seed is slick and dense and can be cleaned to a very high purity, so seeding with many types of seeders is possible.

These grasses can be seeded as monocultures or as mixtures. Switchgrass is best managed as a monoculture since it tends to be earlier than other warm-season grasses and is very competitive. If switchgrass is used in a mixture, not more than 20% of the mixture by seed count should be switchgrass. Growth of big bluestem and indiangrass is quite compatible, and a mixture of these two diversifies the pasture species base. Seed lots of these grasses, particularly if they have not been processed, can have low purity, and germination may be low due to dormant seed. As a result, seed should be priced and seeded on a pure live seed (PLS) basis.

Pure live seed is calculated by multiplying the purity (the ratio of actual seed to total weight) by the germination. For example, if the seed tag indicated 85% purity and 90% germination,

$$\text{PLS} = 0.85\ (\text{purity}) \times 0.90\ (\text{germination}) = 0.765,$$

or 77% PLS. This means that 1 kg of bulk seed would contain 0.77 kg of PLS. If the desired seeding rate for a grass, like big bluestem, is 7 kg ha^{-1}, then 7 kg $ha^{-1} \div 0.77 =$ 9.1 kg ha^{-1} bulk seed is required. About 9 kg of bulk seed from that particular seed lot would need to be planted per hectare. The actual amount of bulk seed needed to supply the recommended amount of PLS will vary due to seed lot quality. Seeding rates for pure stands of these grasses generally range from 200 to 400 PLS m^{-2}, which is about 2.4-4.8 kg PLS ha^{-1} for switchgrass, 5.7-11.4 kg PLS ha^{-1} for big bluestem, and 5.2-10.4 kg PLS ha^{-1} for indiangrass if an average value is used of 860,000, 350,000, and 385,000 seeds kg^{-1} for switchgrass, big bluestem, and indiangrass, respectively (Anderson 1989). Due to variation in average seed weight (number of seeds per kilogram), and difficulty in determining seed units and germinable seed, Wolf and Parrish (1992) suggest that germinants per unit of bulk seed could be more accurate and be of more use to the producer.

Seed dormancy may be a problem with certain cultivars and seed lots of these grasses. Seeding failures may result if the amount of seed dormancy is not taken into consideration. Although alive, dormant seed will not germinate under normal field conditions. Simple dormancy will be broken if the seed is aged long enough or if it is cold stratified. The normal germination test carried out according to Association of Official Seed Analysts procedures (Justice 1988) includes a period of cold stratification where seed is allowed to imbibe water and then is chilled at 4°C for 2-4 wk before the germination test is conducted at higher temperatures. Therefore, the germination percentage on the seed tag includes dormant seed and does not represent the actual amount of seed that will germinate within 2-4 wk upon planting since the grasses are usually seeded in late spring into warm soil. Producers should run a germination test without chilling if they suspect dormant seed and want to see how much of the seed will actually germinate when they plant it. Much of the dormancy can be broken with aging, so using year-old seed will often overcome dormancy. Seed should have high germination (>75%) and should not be older than 3 yr. Old seed can have good laboratory germination but may have poor seedling vigor under field conditions.

These grasses germinate at higher temperatures than cool-season grasses. Minimum germination temperatures for indiangrass, big bluestem, and switchgrass are 8.6°, 8.9°, and 10.3°C, respectively (Hsu et al. 1985a). Optimum germination temperatures for switchgrass may be lower than those for seedling development (Panciera and Jung 1984). Seedling growth of all three of these grasses at 20° is much slower than at 25° or 30°C (Hsu et al. 1985b). Although seedlings develop slowly, planting in early spring is advantageous even though the soil is cold. Early spring planting will help overcome a dormancy problem. Best stands of switchgrass in Iowa were obtained with early to midspring plantings (Vassey et al. 1985). In the northeastern US, a planting window beginning 3 wk before and extending to 3 wk after the recommended corn (*Zea mays* L.) planting date has been suggested (Panciera and Jung 1984). In some areas, particularly the northern Great Plains, "dormant plantings" are made very late in the fall, late enough that the seed will not germinate. The seed will overwinter, and the cool, moist conditions of spring will put the seed through a natural cold stratification so it will germinate as the weather warms. Spring seedings are normally preferred over dormant plantings. Warm-season grasses should not be planted in late summer because they do not have time to develop sufficiently before winter, and they will winterkill.

Planting too deeply often leads to seeding failures with these warm-season grasses. Switchgrass, big bluestem, and indiangrass should be planted about 1 cm deep and no deeper than 2 cm. If a clean seedbed is used, it should be firm (Chap. 7). No-till seeding into crop residues, particularly sorghum or soybean stubble, or chemically killed sods is often very effective. These grasses have the panicoid type of seedling root development (Chap. 2). The subcoleoptile internode elongates to push the coleoptilar node to the soil surface. Adventitious roots develop from the coleoptilar node if moist conditions exist for several days (Moser and Newman 1988). If surface moisture is not available for adventitious root initiation, establishment may not be successful even though seedlings have emerged (Newman and Moser 1988). Corrective applications of phosphorus (P) or potassium (K) should be made before seeding, but nitrogen (N) applications are generally not made until the grass is established because it will stimulate excessive weed growth during the seeding year. Phosphorus levels should exceed 25 mg kg^{-1} P (Rehm et al. 1976; Rehm 1984). Switchgrass and sand bluestem seedlings have been shown to be mycorrhizal dependent when planted in very sandy soils (Brejda et al. 1993).

Weed competition is one of the major reasons for stand failure of these warm-season prairie grasses. Warm-season grass seedlings do not develop rapidly until conditions are warm, which is the same time that annual weeds develop. Most dicot (broadleaf) weeds can be controlled with 2,4-D (2,4-dichlorophenoxyacetic acid). Generally, 2,4-D should be applied after the seedlings have five leaves and there is a canopy of weeds above the seedlings so most of the spray lands on the weed canopy. Switchgrass and big and sand bluestem have seedling atrazine (6-chloro-N-ethyl-N'-[methylethyl]-1,3,5-triazine-2,4-diamine) tolerance (Martin et al. 1982), and atrazine has been previously approved for use as a preemergence herbicide on these grasses. These grasses have seedling and mature plant tolerance to other herbicides (R. A. Masters and K. P. Vogel, personal communication), but at present, they are not labeled for use on these grasses except for special conditions. Herbicide labels change annually, and a herbicide may not be approved for use on a specific grass even though the grass is tolerant of the herbicide. Producers need to check labels and local sources of herbicide information for recommendations. In many cases the only way weed competition may be reduced is by infrequent clipping or grazing for a short period with a high stocking rate (mob-grazing). A seeding of these grasses generally will not be ready to graze the establishment year, but vegetation may be removed as hay during the establishment year.

Fertilization. These warm-season prairie grasses require adequate soil fertility levels to maintain optimum sustained yields although they can tolerate low-fertility conditions better than most cool-season grasses. On an acid, low-P soil, unfertilized switchgrass and big bluestem were found to yield 50% as much as cool-season grasses that received high levels of lime and fertilizer (Jung et al. 1988). Another study shows switchgrass yields were 12% less on soils with 5 mg kg^{-1} P as compared with soils with 35 mg kg^{-1} P while cool-season grass yields were 35% smaller on the low-P soils (Panciera and Jung 1984). On acidic, low water-holding capacity soils, first-cut switchgrass yields were found to be two to three times greater than those of tall fescue (*Festuca arundinacea* Schreb.) yields on sites with N and four times greater on sites without N, which shows that N use efficiency was greater for switchgrass than for tall fescue (Staley et al. 1991).

These warm-season prairie grasses usually are effective users of organic N in the soil since their greatest N demand comes when the soil is warm and mineralization is proceeding rapidly. The timing of N application is critical in the maintenance of warm-season grass stands. Nitrogen fertilizer should be added in late spring, when the warm-season grass has started active growth and invading cool-season plants have completed most of their spring growth (Rehm et al. 1976). If N is applied too early in the spring or in the previous autumn, cool-season plants will utilize it since the warm-season grasses are not active. The stimulated cool-season invaders will increase rapidly and utilize the soil moisture in spring. Later, during the period of warm-season grass growth, soil moisture will be depleted and the warm-season plants will decline in stand and productivity. Eventually, the reduced vigor allows them to be replaced by cool-season plants. Nitrogen fertilizer should be applied in amounts that will be fully utilized by the warm-season grasses during the growing season, with no carryover N to stimulate cool-season growth in the autumn. On most soils, N and P are the only fertilizers that are required on a routine basis. Nitrogen fertilization rates can be estimated based on annual precipitation. In areas that receive 450 mm of precipitation, 50 kg ha^{-1} of N are often adequate while areas that receive over 750 mm may often require over 100 kg ha^{-1} of N to optimize forage yields.

Grazing and Harvest Management. These grasses will be ready to graze in late spring, about the time the cool-season grasses have completed their spring growth. Since switchgrass is the earliest of these grasses, a common mistake is to begin grazing switchgrass too late. If switchgrass availability exceeds the livestock needs, the plants will mature, producing stemmy reproductive tillers. Forage quality and utilization will be very poor, and animal performance will be unsatisfactory. Big bluestem is later in maturity than switchgrass, and forage quality does not decrease as rapidly with maturity as it does with switchgrass. Indiangrass is generally-less mature at any given calendar date than switchgrass or big bluestem. Grazing of indiangrass pastures should not be delayed, because once indiangrass reaches the heading stage, it becomes rather stemmy and does not retain its quality very well.

Grazing of switchgrass should begin when it is about 30 cm tall. Cattle will graze switchgrass rather uniformly, taking it layer by layer if stocked so consumption nearly equals growth rate. With an appropriate stocking rate, switchgrass can be continuously stocked until the forage is gone. Stocking rate may have to be adjusted to keep the removal rate equal to the rate of growth. This means that switchgrass will provide quality forage for grazing for several months in early summer but will not be available for late summer use. A short period of grazing to partially defoliate switchgrass in late spring can shift a major portion of the yield to later in the summer and improve summer switchgrass quality (George and Obermann 1989; Anderson and Matches 1983).

Switchgrass can be intensively grazed by stocking the pasture sufficiently heavy so the forage is removed in about 3 wk. The switchgrass should be allowed to grow for at least 30 d, depending on moisture, before the regrowth is grazed. This will provide pasture early in the season and again toward the end. If the growing season is sufficiently long, a second regrowth period might provide adequate forage for a third grazing. Switchgrass stands can be damaged by overgrazing. At least 10 cm should be left after grazing during the summer, and 20 cm should be left in the fall after grazing ceases (Mitchell et al. 1994).

Similar management practices should be followed for big bluestem and indiangrass, although big bluestem may be defoliated a little closer. Big bluestem will be grazed in a more patchy manner than switchgrass, so it responds well to rotational stocking. Big bluestem will maintain quality better during the growing season than switchgrass. Switchgrass and the other tall prairie grasses need to have adequate leaf area to produce storage carbohydrates for a period of 4-6 wk before a killing frost. They should not be cut for hay or grazed heavily during this period.

To optimize yield and still obtain adequate forage quality, tall prairie grasses used for hay should be cut when the seed heads begin to emerge. Hay harvested at this stage is usually used for wintering beef cows. If hay is to be used for livestock with higher nutrient requirements, hay should be harvested during the early boot stage. In most areas, the second growth is grazed and is not cut again. The earlier these grasses are grazed or removed as hay, the larger regrowth yields will be (Fig. 32.4).

Indiangrass, like the sorghums, contains a cyanogenic glucoside, dhurrin (Gorz et al. 1979), so pure stands should not be grazed when short or stunted. Upon mastication, prussic acid (HCN) is released from the forage and can be fatal to the grazing ruminant. To our knowledge, there have been no reported cases of prussic acid poisoning of livestock by indiangrass, but this is likely due to indiangrass rarely being used as a monoculture.

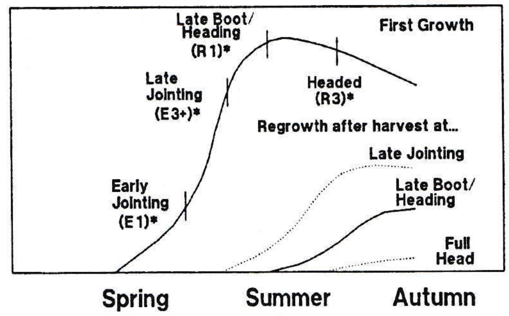

Fig. 32.4. Growth and development of switchgrass (Mitchell et al. 1994; growth stages according to Moore et al. 1991.).

Pure stands of indiangrass should not be grazed until the extended leaf height is 20 cm since the dhurrin concentration falls below the dangerous level at that height (Vogel et al. 1987).

Sheep grazing 'Cave-in-Rock' switchgrass in West Virginia had photosensitization problems that resulted in the death of some lambs (Pouli et al. 1992). Symptoms included marked edema of facial tissue, drooping ears, elevated rectal temperatures, and scab formation on the nose, around the eyes, and on the back of ears. Lambs sought shade and were reluctant to move. Histopathological examinations showed liver damage. The compound causing damage is unknown, but it is expected to be similar to the compound(s) causing a similar problem in kleingrass (*Panicum coloratum* L.). Cattle grazing either switchgrass or kleingrass are apparently not affected by the problem.

Switchgrass, big bluestem, and indiangrass evolved with repeated prairie fires. Prescribed burning is an important management practice that is desirable in many situations. Prescribed or controlled burning, not to be confused with wildfires, may be used in late spring, about the time the growth of the warm-season grass is 2-4 cm, to remove excess plant material. Also, burning is especially important because it keeps cool-season vegetation or brush species from invading (Bragg and Hulbert 1976). Late spring burning may be the only practical way to keep cool-season introduced grasses such as Kentucky bluegrass (*Poa pratensis* L.) and smooth bromegrass (*Bromus inermis* Leyss.) from invading the stand. Forage quality also is increased with spring burning. Periodic prescribed burning will keep these tall warm-season grass stands in excellent condition. Proper burning procedures (Masters et al. 1990) and local burning laws should be followed so prescribed burning is a safe procedure. Burning warm-season grass pastures periodically will aid in maintaining vigorous stands.

Generally, seedings of these grasses have not included legumes since most forage legumes initiate their growth earlier than warm-season grasses. When switchgrass and indiangrass were grown with legumes native to the tall-grass prairie, both yields and crude protein content of the forage were increased. Native legume-grass stands persisted well, but cicer milkvetch (*Astragalus cicer* L.) eliminated the grass stands after 3 yr (Posler et al. 1993). Further research on legume mixtures with switchgrass, big bluestem, and indiangrass is needed.

SEED PRODUCTION

Most seed production practices have resulted from those outlined by Cornelius (1950) and from the experiences of seed producers. Most seed of these grasses is produced in the central Great Plains. Seed fields are usually planted in rows about 1 m apart. In established seed fields 50-112 kg ha^{-1} of N is applied in the spring. Phosphorus is applied if a soil test indicates that it is low. Fields are often burned and cultivated in spring to keep the fields clean and keep the grass in rows, which improves seed yields. Some seed fields are irrigated, but many are not. Approved herbicides are applied as needed for weed control.

Seed is usually harvested by direct combining. The optimum time to combine is when over two-thirds of the spikelets have seed in the hard dough stage and some panicles are beginning to shatter seed (Cornelius 1950). Seed yields of switchgrass often range from 220 to 560 kg ha^{-1} but can be over 1000 kg ha^{-1}. Seed yields of big bluestem and indiangrass range from 150 to over 500 kg ha^{-1}. The seed is usually air dried or dried with minimum heat after harvesting. Processing or debearding the seed of big bluestem and indiangrass after harvesting and drying greatly improves the flowability of the seed in drills and makes it easier to clean and test the seed. The debearding machines used are modified commercial barley debearders (Brown et al. 1981).

DISEASES AND PESTS

There are several diseases that affect these grasses including *Panicum* mosaic virus of switchgrass, various leaf rusts (*Puccinia* spp.), and leaf spot or blotch diseases caused by *Colletotrichum candatum* (Zeiders 1987) (indiangrass) and *Phyllosticta andropogoniva* (Krupinska and Tober 1990) (big bluestem). There are no economical or approved controls for these diseases other than resistant cultivars. Using cultivars that are adapted for specific areas is the best method of reducing losses to diseases. Fortunately, most cultivars and ecotypes of these grasses are genetically diverse and have significant levels of resistance to most diseases that affect these species.

The most serious insect problem that occurs on these grasses is the big bluestem seed midge (*Contarinia wattsi* Gagne). This seed midge can reduce seed yield by over 50% in some years (Carter et al. 1988; Vogel and Manglitz 1990). Presently, there is no control. A chalcidoid wasp, *Tetrastiches nebraskensis* (Girault), parasitizes the midge but does not appear to provide economical levels of control.

QUESTIONS

1. Describe how the growth habits of these grasses are changed if southern ecotypes are moved north and northern ecotypes are moved south.
2. What is the relationship of big and sand bluestems, and what are the conditions of adaptation of each?
3. Why do these grasses play an important role in season-long grazing systems?
4. Describe the barriers that may limit successful stand establishment.
5. Describe the PLS system for calculating seeding rates and why these grasses are seeded on a PLS basis.
6. Describe how seed dormancy is broken in the seed-testing process and how a producer can deal with dormant seed when planting these grasses.
7. Describe N fertilizer management for these grasses and reasons for such management.
8. Describe effective grazing systems for the tall warm-season grasses.
9. Describe management that will keep cool-season grasses from invading warm-season grass stands.
10. Compare the soil conditions required by these warm-season grasses compared with those required by the cool-season grasses.

REFERENCES

Anderson, B. 1989. Establishing Dryland Forage Grasses. Nebr. Coop. Ext. Serv. NebGuide G81-543.

Anderson, B, and AG Matches. 1983. Forage yield, quality, and persistence of switchgrass and caucasian bluestem. Agron. J. 75:119-24.

Barnes, PW. 1986. Variation in the big bluestem

(*Andropogon gerardii*) -sand bluestem (*Andropogon hallii*) complex along a local dune/meadow gradient in the Nebraska sandhills. Am. J. Bot. 73:172-84.

Benedict, HM. 1941. Effect of day length and temperature on the flowering and growth of four species of grasses. J. Agric. Res. 61:661-72.

Boe, AA, JG Ross, and R Wynia. 1983. Pedicellate spikelet fertility in big bluestem from eastern South Dakota. J. Range Manage. 36:131-32.

Bragg, TB, and LC Hulbert. 1976. Woody plant invasion of unburned Kansas bluestem prairie. J. Range Manage. 29:19-24.

Brejda, JJ, DH Yocum, LE Moser, and SS Waller. 1993. Dependence of 3 Nebraska sandhills warm-season grasses on vesicular-arbuscular mycorrhizae. J. Range Manage. 46:14-20.

Brown, RR, J Henry, and W Crowder. 1983. Improved processing for high quality seed for big bluestem (*Andropogon gerardi*) and yellow indiangrass (*Sorghastrum nutans*). In JA Smith and VW Hays (eds.), Proc. 14th Int. Grassl. Congr., Lexington, Ky. Boulder, Colo.: Westview, 272-74.

Carter, MR, GR Manglitz, MD Rethwisch, and KP Vogel. 1988. A seed midge pest of big bluestem. J. Range Manage. 41:253-54.

Cherney, JH, KD Johnson, JJ Volenec, EJ Kladivko, and DK Greene. 1990. Evaluation of Potential Herbaceous Energy Crops onMarginal Croplands: (1) Agronomic Potential. Final Rep.: ORNL/Sub/85-27412/5/P1. Oak Ridge, Tenn: Oak Ridge National Lab.

Cornelius, DR. 1950. Seed production of native grasses. Ecol. Monogr. 20:1-27.

Cornelius, DR, and CO Johnston. 1941. Differences in plant type and reaction to rust among several collections of *Panicum virgatum* L. J. Am. Soc. Agron. 33:115-24.

Dobbins, CL, P Preckel, A Mdafri, J Lowenberg-DeBoer, and D Stucky. 1990. Evaluation of potential herbaceous biomass crops on marginal crop lands: (2) Economic potential. Final Rep.: 1985-89. ORNL/Sub/85-27412/5&P2. Oak Ridge, Tenn.: Oak Ridge National Lab.

Duke, JA. 1978. The quest for tolerant germplasm. In GA Jung (ed.), Crop Tolerance to Suboptimal Land Conditions, Spec. Publ. 32. Madison, Wis.: American Society of Agronomy, 1-61.

Emal, JG, and EC Conard. 1973. Seed dormancy and germination in indiangrass as affected by light, chilling, and certain chemical treatments. Agron. J. 65:383-85.

George, JR, and D Obermann. 1989. Spring defoliation to improve summer supply and quality of switchgrass. Agron. J. 81:47-52.

Gerrish, JR, JR Forwood, and CJ Nelson. 1987. Phenological development of eleven warm-season grass cultivars. In Proc. Forage and Grassl. Conf. Lexington, Ky.: American Forage and Grassland Council, 249-51.

Gorz, HJ, FA Haskins, R Dam, and KP Vogel. 1979. Dhurrin in *Sorghastrum nutans*. Phytochem. 18:20-24.

Gould, FW. 1968. Grass Systematics. New York: McGraw-Hill.

Hsu, FH, CJ Nelson, and AG Matches. 1985a. Temperature effects on germination of perennial warm-season forage grasses. Crop Sci. 25:215-20.

———. 1985b. Temperature effects on seedling development of perennial warm-season forage grasses. Crop Sci. 25:249-55.

Johnson, P, and AA Boe. 1982. Seed size variation in three switchgrass (*Panicum virgatum* L.) varieties. In Proc. S.Dak. Acad. Sci. 61:159.

Jung, GA, JA Shaffer, and WL Stout. 1988. Switchgrass and big bluestem responses to amendments on strongly acid soil. Agron. J. 80:669-76.

Justice, OL. 1988. Rules for testing seeds. J. Seed Tech. 12:1-109.

Keeler, KH, B Kwankin, PW Barnes, and DW Galbraith. 1987. Polyploid polymorphism in *Andropogon gerardii*. Genome 29:374-79.

Krupinsky, JM, and DA Tober. 1990. Leafspot disease of little bluestem, and sand bluestem caused by *Phyllosticta andropogonivara*. Plant Dis. 74:442-45.

Law, AG, and KL Anderson. 1940. The effect of selection and inbreeding on the growth of big bluestem (*Andropogon furcatus* Muhl.). J. Am. Soc. Agron. 32:931-43.

McKendrick, JD, CE Owensby, and RM Hyde. 1975. Big bluestem and indiangrass vegetative reproduction and annual reserve carbohydrate and nitrogen cycles. Agric-Ecosyst. 2:75-93.

McMillian, C. 1959. The role of ecotypic variation in the distribution of the central grassland of North America. Ecol. Monogr. 29:285-308.

Martin, AR, RS Moomaw, and KP Vogel. 1982. Warm-season grass establishment with atrazine. Agron. J. 74:916-20.

Masters, RA, R Stritzke, and SS Waller. 1990. Conducting a Prescribed Burn and Prescribed Burning Checklist. Univ. Nebr. Coop. Exp. Serv. Ext. Circ. EC 90-121.

Mitchell, R, BA Anderson, SS Waller, and LE Moser. 1994. Managing Switchgrass and Big Bluestem for Pasture and Hays. Univ. Nebr. NebGuide G94-1198-A.

Moser, LE, and PR Newman. 1988. Grass seedling development. In JR Johnson and MK Beutler (eds.), Northern Plains Grass Seed Symp., Pierre, S.Dak., 1-37 to 1-47.

Newell, LC. 1968. Effects of strain source and management practice on forage yields of two warm-season prairie grasses. Crop Sci. 8:205-10.

Newell, LC, and LV Peters. 1961. Performance of hybrids between divergent types of big bluestem and sand bluestem in relation to improvement. Crop Sci. 1:370-73.

Newman, PR, and LE Moser. 1988. Grass seedling emergence, morphology, and establishment as affected by planting depth. Agron. J. 80:383-87.

Nielsen, EL. 1944. Analysis of variation in *Panicum virgatum*. J. Agric. Res. 69:327-53.

Panciera, MT, and GA Jung. 1984. Switchgrass establishment by conservation tillage: Planting date responses of two varieties. J. Soil and Water Conserv. 39:68-70.

Parrish, DJ, DD Wolf, WL Daniels, DH Vaughan, and JS Cundiff. 1990. Perennial Species for Optimum Production of Herbaceous Biomass in the Piedmont. Final Rep.: ORNL/Sub/85-274132/5. Oak Ridge, Tenn.: Oak Ridge National Lab.

Posler, GL, AW Lenssen, and GL Fine. 1993. Forage yield, quality, compatibility, and persistence of warm-season grass-legume mixtures. Agron. J. 85:554-60.

Pouli, JR, RL Reid, and DP Belesky. 1992. Photosensitization in lambs grazing switchgrass. Agron. J. 84:1077-80.

Rehm, GW. 1984. Yield and quality of a warm-season grass mixture treated with N, P, and atrazine. Agron. J. 76:731-34.

Rehm, GW, RC Sorensen, and WJ Moline. 1976. Time and rate of fertilizer application for seeded warm-season and bluegrass pastures. I. Yield and botanical composition. Agron. J. 68:759-64.

Riley, RD, and KP Vogel. 1982. Chromosome numbers of released cultivars of switchgrass, indiangrass, big bluestem, and sand bluestem. Crop Sci. 22:1081-83.

Staley, TE, WL Stout, and GA Jung. 1991. Nitrogen use by tall fescue and switchgrass on acidic soils of varying waterholding capacity. Agron. J. 83:732-38.

Stubbendieck, J, SL Hatch, and CH Butterfield. 1991. North American Range Plants. Lincoln: Univ. of Nebraska Press.

Talbert, LE, DH Timothy, JC Burns, JO Rawlings, and RH Moll. 1983. Estimates of genetic parameters in switchgrass. Crop Sci. 23:725-28.

Vassey, TL, JR George, and RE Mullen. 1985. Early-, mid-, and late-spring establishment of switchgrass at several seeding rates. Agron. J. 77:253-57.

Vogel, KP, and BC Gabrielsen. 1986. Breeding to improve native warm-season grasses. In Warm-season Grasses. Balancing Forage Programs in the Northeast and Southern Corn Belt. Ankeny, Iowa: Soil Conservation Society of America.

Vogel, KP, and GR Manglitz. 1990. Evaluation of furadan and orthene against a bluestem seed midge, 1986 and 1987. Insectic. and Acaracide Tests 15:175-76.

Vogel, KP, and KJ Moore. 1993. Native North American grasses. In J Janick and JE Simon (eds.), New Crops, Proc. 2d. Natl. Symp. New Crops., 6-9 Oct. 1991, Indianapolis, Ind. New York: Wiley, 284-93.

Vogel, KP, and JF Pedersen. 1993. Breeding systems for cross-pollinated perennial grasses. Annu. Rev. Plant Breed. 11:251-74.

Vogel, KP, FA Haskins, and HJ Gorz. 1987. Potential for hydrocyanic acid poisoning of livestock by indiangrass. J. Range Manage. 40:506-9.

Waller, SS, LE Moser and B Anderson. 1986. A Guide for Planning and Analyzing a Year-round Forage Program. Nebr. Coop. Ext. Serv. Bull. EC 86-113-C.

Weaver, JE. 1968. Prairie Plants and Their Environment. Lincoln: Univ. of Nebraska Press.

Wheeler, WA, and DD Hill. 1957. Grassland Seeds. Princeton, N.J.: D. Van Nostrand.

Wolf, DD, and DJ Parrish. 1992. Bluestem germination and seed testing: Meeting the growers needs. Am. Soc. Agron. Abstr. Madison, Wis., 164.

Zeiders, KE. 1987. Leaf spot of indiangrass caused by *Colletotrichum candatum*. Plant Dis. 71:348-50.