Review of Big Bluestem

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This report reviews big bluestems' life history, production, and establishment.

Big bluestem (*Andropogon gerardii* Vitman) belongs to the subfamily of grass called Panicoideae and the tribe Andropogoneae (Gould and Shaw 1983). Hitchcock (1971) describes big bluestem as follows:

Plants often glaucous; clums robust, often in large tufts, sometimes with short rhizomes, 1 to 2 m tall, usually sparingly branching toward the summit; lower sheaths and blades sometimes villous, occasionally densely so, the blades flat, elongate, mostly 5 to 10 mm. wide, the margins very scabrous; racemes on the long-exserted terminal peduncle mostly 3 to 6, fewer on the branches, 5 to 10 cm. long, usually purplish, sometimes yellowish; rachis straight, the joints and pedicels stiffly ciliate on one or both margins, the joints hispid at base; sessile spikelet 7 to 10 mm. long, the first glume slightly sulcate, usually scabrous, the awn geniculate and tightly twisted below, 1 to 2 cm. long; pedicellate spikelet not reduced, or but slightly so, awnless, staminate.

Big bluestem naturally ranges from Central Mexico to Canada (Gould and Shaw 1983). It is a major grass of North American Tallgrass Prairies on well aerated soils (Weaver 1968). Grelen and Hughes (1984) list big bluestem as a common herbaceous plant of the southern forest range.

Big bluestem has the C4 photosynthesis system and as a result produces most of its growth during the summer months (Gould and Shaw 1983). Production during the summer growing season will be covered under later sections of the report.

Big bluestem has the pancoid type of seedling root development with short coleoptiles. If seed are planted too deep to reach soil surface, the subcoletile internode elongates to push coleoptilar node to near soil surface. Adventitious roots develop from the coleoptilar node if moist conditions exist for several days (Moser and Newman 1988).

Roots may reach depths of 2 to 4 feet at the end of establishment year. Roots of well established plants may reach depths of 7 to 8 feet. Roots can be long lived, one test indicated 81% of big bluestem roots lived for three years (Weaver 1968). According to Walter et al. (1996), root and rhizosphere overlap among neighboring plants can transfer P among species including big bluestem.

Big bluestem tillers are the most obvious morphological feature of the grass.

McKendrick et al. (1975) described the development of vegetatively reproductive and vegetatively non-reproductive tillers in big bluestem. After remaining dormant during the winter season rhizome buds commenced to grow early the next spring around March 20th. Bud swelling was the first visible sign that growth was beginning. By about April 10th, buds that elongated had tips oriented horizontally and produced vegetatively reproductive tillers, while non-elongating buds' tips were oriented vertically and usually produced no vegetatively reporductive tillers.

Vegetatively reproductive tillers, which lived one growing season, were composed of a rhizome, leaves, roots and mature buds. As the tiller's 9 to 18 rhizome internodes elongated, cataphylls developed, encasing the rhizome. The first two to four rhizome internodes usually did not elongate; the next two to four elongated (4-10 mm each) and remained at maturity as a narrow stalk-like structure. The next six to eleven internodes elongated slightly less (2-7 mm each) and was the major storage and bud producing portion of the rhizome.

Current-year rhizomes (1970) constituted the largest age-class (about 45% by weight) of rhizomes at the end of the growing season indicating decomposition of rhizomes produced the previous year. Approximately half of the rhizomes produced during each of the years, 1968, 1969, and 1970, were vegetatively non-reproductive and contributed little to the total sod rhizome weight. Only a few vegetatively reproductive rhizomes older than three years were found, and none older than six years could be identified.

A total of 6 to 18 aerial leaves developed per tiller. Tillers producing an inflorescence had the maximum number of leaves. Each vegetatively reproductive big bluestem tiller averaged three to six adventitious roots per rhizome and were confined to the bud producing and storage portion of rhizomes. Roots emerged after at least one aerial leaf was fully exerted (about May 11th – 15th) from the upper and lower surfaces, in a plane generally perpendicular to the insertions of the cataphylls and buds. A flush of adventitious roots was initiated with late summer rains in August. Rhizomes ceased initiating roots at the end of the tiller's growing period; rhizomes that lived into a second growing season initiated no new roots. As big bluestem rhizome roots aged, their cortex loosened and decomposed, leaving a tough, woody core with a suberized surface and contained many reserve starch granules during autumn. Root cores persisted in the upper soil horizon three to five years, though not functional after the first year. Year-old roots must have temporarily served the next season's reproductive tillers until those tillers developed their own root systems.

Each mature vegetatively reproductive tiller had 6 to 14 buds in an alternating arrangement along both sides of its rhizome between the stalk structure and the culm. Buds were inserted in the cataphyll and true leaf axils. Buds near the rhizome extremities (stalk and aerial culm) were usually poorly developed. Normally, all buds remained quiescent during their parent tiller's growing season unless the parent's growing point died; thereafter, usually one sufficiently matured lateral bud developed into a secondary tiller.

Vegetatively non-reproductive tillers usually developed from among buds near the aerial culm-base and produced leaves and rudimentary buds, but not mature buds or aerial culms. Such tillers began dying midway into the growing season, often concurrently with drought stress about mid-July.

Big bluestem is a drought-resistant species with predominantly hypostomatal leaves that fold (adaxial surface inward) in response to low leaf water potential (Heckathorn and Delucia 1991). It has the ability to maintain high rates of carbon gain over a greater range of leaf temperatures and at lower leaf water potential than switchgrass (Knapp 1985).

Burning regimes have a major influence on big bluestem leaf content and characteristics. Leaf water potential was significantly lower in unburned prairie than in burned prairie early in the season but was higher in unburned prairie by late season. Leaf temperatures in big bluestem were greater in unburned prairie than in burned early in the season, but were nearly equal by the end of the growing season. Lower windspeed adjacent to leaves in unburned prairie resulting in reduced convective cooling may have caused higher leaf tempertures in the unburned site (Knapp 1984).

During active growth (May and June in Oklahoma) when temperatures were not limiting, photosynthesis (PS) was higher for burned relative to unburned plants; but during summer drought, PS declined and treatment rank reversed. Burned plots had much higher peak big bluestem leaf area indices than unburned plots. Apparently higher transpirational demand in burned plots lowered soil moisture, thereby increasing late season moisture stress and lowering PS relative to unburned plots. Data also indicated burned vs. unburned had higher peak values of percent leaf nitrogen (N) and more total leaf N (Svejcar and Browning 1988).

In big bluestem, photoperiod determines flowering time. Flowering is triggered by long days followed by days with decreasing day length. Big blue is considered a short day plant.

Southern strains moved North will be exposed to longer than normal photoperiods for same date because of latitude differences. They will stay vegetative longer and produce more forage. Northern strains moved South will be exposed to a shorter than normal photoperiod and will flower early. This will reduce forage yields and promote early dormancy (Waller and Lewis 1979).

Data on Southern big bluestem ecotypes grown at the Jimmy Carter Plant Materials Center (PMC) in Americus, Georgia indicated boot date ranged from July 18 – July 30, and bloom date ranged from August 6 – September 10 (unpublished data – Jimmy Carter PMC).

As with leaf characteristics, burning has a distinct effect on big bluestem inflorescence. Spring burns of big bluestem in Nebraska significantly increased flowering stem height and flowering stem numbers. This increase was observed when burns were conducted after May 12 but not before this date (Benning and Bragg 1992).

Big bluestem is cross-pollinated by wind and largely self-incompatible. Selfing or inbreeding causes substantial loss of vigor. Outcrossing results in heterosis (personal communication – Dr. Kenneth P. Vogel, University of Nebraska).

Sex allocation in *A. gerardii* is significantly male biased (from 60 to 89% male) when measured in currencies of biomass, energy, potassium, and calcium; there was no significant bias in the sex allocation (from 49 to 57% male) when measured in currencies of nitrogen, phosphorus, and magnesium (McKone et al. 1998). With such a large amount of resources going to male plants pollen characteristics are very important. Normal pollen size is 35 to 50 microns in diameter (Jones and Newell 1948). Pollen diameters are consistently larger in sessile than pedicellate spikelets (Springer et al. 1989). Pollen dispersal per plant may last 7-8 days because of varying maturity of tillers and florets. Peak time of pollen dispersal is 4-9 AM. Normally less than 5% of pollen disperses more than 100 feet (Jones and Newell 1946).

Meiosis is usually normal in microsporogenesis. Diploid pairing normally occurs with some quadravalent formation (Dewald and Jahal 1977). According to Gould (1956) big bluestem chromosone counts range from 20 to 100 with a base number of 10. Most of the developed big bluestem cultivars are 2n = 60 (Riley and Vogel 1982).

After inflorescence and pollination, the next important stage in the phenology of big bluestem is seed production. There are approximately 550 big bluestem seed per gram (Martin and Leonard 1967). 'Earl' a new cultivar from Texas can produce around 71 pounds of seed per acre (unpublished data – Knox City Plant Materials Center – Knox City, Texas). Seed harvest dates for southeastern ecotypes at Americus, Georgia ranges from September 16 to October 30 (unpublished data - Jimmy Carter Plant Materials Center – Americus, Georgia).

While most seed from the prairie states exhibit adequate germination characteristics, southeastern big bluestem lines grown in Americus, Georgia produce extremely high levels of dormant seed (personal communication – Dr. Edzard van Santen, Auburn University). Also seed grown at Americus can produce very high inert matter content (unpublished data – Jimmy Carter PMC).

Since these and other seed emergence problems occur with big bluestem, seed treatment studies have been conducted. In a greenhouse study, solid matrix seed priming (SMP) treatments increased big bluestem emergency by 18 percent. In the field, final seedling emergency from dry untreated big bluestem seed was equal to or higher than that of treated seed. The SMP treatments had no effect on adventitious root formation in either greenhouse or field experiments (Beckman et al. 1993).

Once the seed emerge, big bluestem establishment in a new area depends on seedling performance. A seedling morphology study of cool-season and warm-season forage grasses found Andropogoneae species reached third leaf emergence 3 to 5 days earlier than other warm-season grasses and 3 to 15 days earlier than cool-season grasses (Newman and Moser 1988).

Seedling growth of big bluestem is reduced dramatically at 20 degrees C when compared with 25 and 30 degrees C. Averaged across temperatures, big bluestem seedling weight at 28 days was lower than crabgrass, switchgrass, caucasion bluestem, and indiangrass (HSU et al. 1985).

In a separate study Weaver (1968) found big bluestem seeding to be very shade tolerant when compared to other warm-season grasses.

In addition to morphological and physiological aspects, other factors influence the life history of big bluestem.

Several diseases effect big bluestem. Kernel smut caused by *Sphacelotheca occidentalis* is characterized by gall-like structures that replace bluestem seeds. Culm smut caused by *Sorosporium provinciale* converts entire inflorescences into galls containing teliospores. Ergot of big bluestem is caused by *Claviceps purpurea*. Big bluestem leaf rust is caused by *Puccinia andropogonis.* Leaf spot of big bluestem can be attributed to *Phyllosticta andropogonivora* and *Ascochyte brachypodii* (personal communication – Manhattan Plant Materials Center (PMC), Manhattan, Kansas).

One of the most serious pests of big bluestem is the bluestem seed midge *Contarinia wattsi*. This insect pest can reduce seed yields by over 50%. There is no control; however, a wasp *Tetrastiches nebraskensis* parasitizes the midge in the Midwest (Vogel and Manglitz 1989).

Big bluestem is an obligately mycorrhiza-dependent grass. Strongly competitive effects of big bluestem disappeared in the absence of mycorrhiza indicating that its competitive dominance in Tallgrass prairie is highly dependent upon its mycorrhizal associations.

However, big bluestem exhibits reduced host plant benefit from mycorrhiza under crowded conditions (Hartnett et al. 1993). Mycorrhiza in big bluestem can also improve clipping tolerance (Hetrick et al. 1990). Wallace and Svejcar (1987) found when mycorrhizal colonization levels were lowered by soil fumigation, clipped big bluestem plants had significantly lower photosynthetic rates than plants with normal colonization levels. However, there were no significant differences between fumigated and nonfumigated unclipped plants. They seem to support Hetrick et al. (1990) when they reported greater mycorrhizal development in nonfumigated plants appeared to be beneficial only when the host plants were under defoliation stress. Although Hetrick et al. (1990) went on to state with repeated intensive clipping, significant changes in root/shoot ratio can occur and eventually mycorrhizal root colonization and growth benefit can be lost.

Delucia et al. (1992) studied the effects of soil temperature on big bluestem. Total big bluestem biomass and relative growth rate (RGR) were maximum at 25 degrees C soil temperature (T soil) and decreased at higher and lower temperatures. T soil had no effect on leaf area ratio.

During drought conditions, big bluestem and other C4 grasses, can experience decreased total plant N allocation to shoots and increased allocation to rhizomes. Drought-induced retranslocation may serve to protect plant N from loss to herbivory, fire, and volatilization during periods when soil N uptake and carbon assimilation are limited by water availability (Hayes 1985, Heckathorn and Delucia 1994).

The physiology and morphology of big bluestem, along with climate, other organisms, and edaphic conditions contribute to the ecological competitiveness of big bluestem. White (1991) conducted an interesting study concerning the competitive aspect of big bluestem in native plant communities.

It was found that western wheatgrass could compete with little bluestem or big bluestem if the soil contains considerable PO_4-P that is available for growth early in the season. Big bluestem can use PO_4-P released from organic matter decomposition when temperatures and plant growth are high in the summer and do not need a large reserve of available PO_4-P. He found soils supporting bluestem had larger mean organic matter contents than adjacent soils with western weatgrass. Fixation of PO_4-P in slightly decomposed organic matter would reduce the amount available to western weatgrass and enhance the competitive advantage of bluestem for the area.

Most literature concerning big bluestem involves investigations relative to clipping, grazing, burning, forage quality, fertility, or some other measure of productivity.

On shallow droughty soils in Missouri, clipping big bluestem for three successive years at the seed-ripened stage or later increased yields and spring-initiated tillering. Clipping at any time during the summer reduced yields, but clipping between floral initiation and anthesis was the most damaging to plants (Vogel et al. 1968). However, in an Oklahoma study, mowing every year about July 1 gave higher sustained yields of big bluestem than did mowing about September 1 (Hazel 1965).

Owensby et al. (1974) found increased clipping frequency of big bluestem could decrease tiller density, herbage yield, and total nonstructural carbohydrate content. They also found recovery of rhizome nitrogen percentages was rapid under rest from clipping.

Forwood and Magai (1992) studied clipping heights, they found big bluestem could be more intensively defoliated in the Southern Corn Belt (10-cm stubble) than in the Great Plains (20-40 cm stubble).

Clipping studies have determined big bluestem forage production for several areas of the United States.

In Iowa, 'Kaw' big bluestem produced 4 tons/ha of dry matter with 0 applied N and over 7 tons/ha when 150 kg N/ha was applied (Hall et al. 1982). In Minnesota, big bluestem can produce from 2-3.5 tons of forage per acre under moderate fertility (Sheaffer et al.). At El Reno Experiment Station, Oklahoma, 'Earl' big bluestem yielded 3.3 tons/ac of dry matter in 1978 and 5.4 tons/ac in 1979. Another line of big bluestem yielded 4.9 tons/ac in 1978 and 7.1 tons/ac in 1979 (unpublished data – Knox City PMC). This yield data indicates that big bluestem has potential as a biomass fuel producer.

Another unique aspect to the ecology of big bluestem is grazing. Weaver (1968) describes big bluestem as a decreaser species in grazing environments. A study in Oklahoma utilized pastures dominated by big bluestem, little bluestem, indiangrass, and switchgrass. Short duration rotation or continuous grazing systems and two stocking rates were evaluated. Total standing crop was significantly higher in the rotation units in September. Dead standing crop was also higher in the rotation units in September. Stocking rate had significant effects on total, live and dead standing crops at two sample dates (Cassels et al. 1995).

Grazing interacts with several other aspects of forage grass management. Grazing influences the combustion losses of nitrogen. Losses due to burning in the absence of grazing can be almost double those observed when grazing was present. Grazing can conserve approximately $1 g\text{-}m^{-2}.yr^{-1}$ N that would have otherwise been lost as a result of combustion (Hobbs et al. 1991). Wallace (1990) found that grazed big bluestem plants had significantly higher rates of photosynthesis than either clipped or control plants. The photosynthesis/transpiration ratio as well as stomatal sensitivity to humidity indicate that leaves of grazed plants may have developed in a higher light and lower moisture environment than that of their clipped counterparts.

Burning has long been an accepted practice for the management of native warm-season grasses. Burning can have a large impact on yield. Early or mid-spring burning can increase June big bluestem forage production by at least 52%, and mid or late-spring burning can increase August production by at least 70% compared with no burning (Mitchell et al. 1994).

Svejcar and Browning (1988) found burning resulted in a doubling of big bluestem tiller numbers. Peak aboveground biomass of big bluestem was about three times higher on burned relative to unburned prairie during two years of study.

A study evaluating big bluestem, little bluestem, and indiangrass showed density and production of flower stalks were usually greater on annually burned sites (Knapp and Hulbert 1986).

Types of burning regimes can also affect production. A Tallgrass prairie with dominant species of big bluestem, switchgrass, indiangrass, and little bluestem was subjected to late spring headfires and backfires. Headfires produced 21% more tallgrass standing crop in August than backfires and 40% more tallgrass standing crop in August than unburned plots (Bidwell et al. 1990).

Burning can also influence big bluestem beyond just yield and productivity. Annual late-spring burns in the Kansas Flint Hills significantly increased big bluestem percent composition. However, big bluestem is not adversely affected by fire exclusion when mulch accumulations inhibit competition from other species (Towne and Owensby 1984).

On a poorly drained claypan prairie of Missouri, Kucera and Dahlman (1968) determined an interval of three years between fires as a maximum period to effectively maintain vigorous stands of big bluestem. On plots from which fire was excluded for periods longer than three years, stands showed less root-rhizome dry matter.

Some studies have sought to determine the causes of fire effects. Warmer soil temperatures and more light on burned sites have been attributed to initiating early season growth (Peet et al. 1975). Hulbert (1988) states the greatest effect of burning is to increase light intensity near the soil early in the growing season. Having ample light for early growth of grasses may be important partly because it stimulates growth at the time when water supplies are most favorable. He goes on to suggest nitrogen fixation by blue-green algae might be stimulated by the higher light intensity. However, his results also suggest that soil temperature increases associated with burning seem to be a minor cause of fire effects. He found no effect due to ash, direct soil surface heating, or burned soil as a result of burning.

Some studies have combined burning with fertilization to evaluate effects on big bluestem forage quality. Rains et al. (1975) determined the effects of nitrogen fertilization and burning in the Flint Hills of Kansas. Total nonstructural carbohydrate reserves were highest, and nitrogen reserves were lowest, under burned conditions when there was no nitrogen fertilization during growth and storage periods. Big bluestem TNC benefited most with burning, regardless of nitrogen fertilization rate. During the dormant period, TNC was lowest in unburned, heavily fertilized pastures, but did not approach the critically low levels of early spring. Applying nitrogen in the spring and not burning may lower plant vigor the following year, resulting in lowered big bluestem competitive ability.

Trends in reserve N were linear with increased rate of nitrogen fertilization. Nitrogen added at the 40-lb rate apparently was used to increase forage production, but the 80-lb N rate apparently exceeded the plants' needs, because over time the nitrogen accumulated.

A combination of burning and adding 0, 40, or 80 lb. N/acre did not lower constituent reserves below those of unburned, nonfertilized pastures. Plant vigor may be increased in the True Prairie by burning. Nitrogen fertilization plus burning, over a 2-year period, did not adversely affect big bluestem TNC and nitrogen reserves.

In addition to burning and fertilization, maturation and composition influence forage quality. Leaf maturity in big bluestem is more responsible for lower quality forage than the amount of stem material present in the stand (Forwood and Magai 1992). Griffin et al. (1980) reached similar conclusions. He stated that forage quality of big bluestem declines with maturity. Big bluestem harvested after heading decreased in IVDMD 0.4 to 0.5% units per day. In a study involving indiangrass, big bluestem, and switchgrass Perry and Baltensperger (1979) found leaf IVDMD was highest in indiangrass followed by big bluestem and switchgrass. Rapid declines occurred in leaf crude protein and IVDMD throughout the growing season, indicating leaf maturation primarily is responsible for declining forage quality rather than increasing stem proportion. A test comparing big bluestem and switchgrass stated big bluestem leaves were higher in CP but lower in NDF than switchgrass leaves. At early head emergence, percentage leaf tissue for big bluestem and switchgrass averaged 34 and 44% respectively. Griffin and Jung (1983) found a decline in leaf and stem CP, IVDMD and P with maturation was less pronounced in leaf tissue while an increase in NDF and lignin with maturity was greater in stems than in leaves. Therefore, it would appear that a decline in forage quality with maturation depends upon the proportion of stem to leaf fraction and their decline in quality.

Fertility can contribute significantly to differences between native forage grass production. Big bluestem can produce more than double the dry matter (leaf and total) production per kg of N than indiangrass or switchgrass (Perry and Baltensperger 1979). K treatments significantly increased big bluestem dry matter yields in 1989 while neither P nor K treatments effected indiangrass dry matter yields (Brejda et al. 1991).

The establishment of big bluestem is an extremely important part of the cultural management of this grass.

In the Central Great Plains of North America, big bluestem stands were successfully established in three of four environments evaluated when seeded at 110 pls m^{-2}, and in all environments when seeded at 220 to 440 pls m^{-2} (Master 1997).

Lawrence et al. (1995) reported acceptable big bluestem stands developed in 1987 and 1988, with 14 and 6 plants m^{-2} respectively, on areas treated with Atrazine. On two sites subsequent big bluestem yields were at least 1.2 Mg ha greater on areas treated with Metolachlor than on areas not so treated. Also Atrazine increased big bluestem yields by 1.2 and 2.4 Mg ha-1 at two study sites (Masters 1997).

Adequate establishment stands of big bluestem at Americus, Georgia have been obtained by planting 10 pounds pls/ac, 1/4 - 1/2 inch deep into a clean well prepared firm seedbed (unpublished data – Jimmy Carter PMC).

Nutrient management for proper establishment should also be considered. In most areas, N and P may be the only deficient elements. Normally adequate P is needed to maximize response from N. N should be applied after spring greenup to prevent invasion by weedy species. Also N should be applied only after stand establishment during year of planting (Rehm et al. 1977).

Released cultivars of big bluestem for propagation includes ‘Bison’, ‘Bonilla’, ‘Kaw’, ‘Niagara’, ‘Rountree’, ‘Earl’, ‘Pawnee’, ‘Champ’, and ‘Sunnyview’ (Everett 1991).

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