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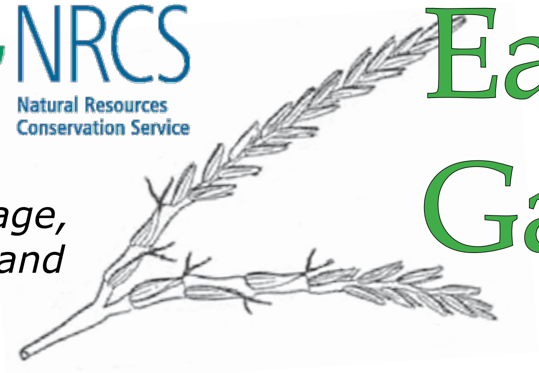

Eastern Gamagrass

A Plant for Forage, Conservation, and Bioenergy

Tripsacum dactyloides (L.) L.
plant symbol – TRDA3

Contents

Alternate Names

Tripsacum dactyloides (L.) L. var. *occidentale* Cutler & Anders., *Coix dactyloides* L., bullgrass, capim gigante, eastern mock gama, fakahatchee grass, Gamagras, herbe grama, maicillo oriental, pasto Guatemala, wild corn, zacate maicero

Description

General: Grass Family (Poaceae), tribe Andropogoneae, and subtribe Tripsacinae. It shares the same subtribe as corn (*Zea mays*). Eastern gamagrass is a native perennial bunchgrass and a distant relative of corn. It is a long-lived (to 50 years), warm-season species native to most of the eastern half of the United States. It ranges in height from 4 to 8 feet. The leaf blades are flat, long (12 to 30 inches) and wide (0.4 to 1.2 inches), with a well-defined midrib. It reproduces vegetatively from thick, knotty, rhizome-like structures called proaxes. The spikes are 6 to 10 inches long and are made up of one to several spikes. Similar to corn, eastern gamagrass has separate male and female flowers (monoecious). But unlike corn, each gamagrass spike contains both male and female flowers. Male flowers occupy the top three-fourths of the spike and female flowers the bottom one-fourth (Fig. 1).

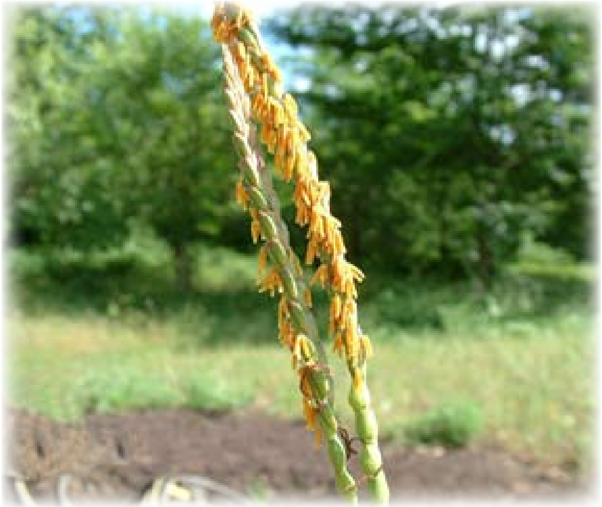

Fig. 1: Eastern gamagrass spike with male flowers on top with extruded anthers, and cupulate fruit-cases on the bottom. Courtesy of Missouri State University Herbarium.

Terminal spikes occur on the top of the stem, and lateral spikes occur at the leaf axil, which is the angle between the leaf and stem. Seed is produced from June to September, resulting in uneven maturation. The spike ripens from the top down and is susceptible to shattering. Gamagrass seed yield is low and it does not reseed adequately from established stands. A gynomonoecious form was found with both male and female (perfect) flowers on the top three-fourths and female flowers on the bottom one-fourth of the spike. The perfect flowers are male sterile except at the very tip (Dewald & Dayton, 1985). This plant is being used in breeding programs to increase seed production (Dewald & Sims, 1990; Salon, 1996; Salon & Earle, 1987). Eastern gamagrass occurs predominantly at the diploid ($2n = 2x = 36$) and tetraploid ($2n = 4x = 72$) levels although triploids ($2n = 3x = 54$), pentaploids ($2n = 5x = 90$), and hexaploids ($2n = 6x = 108$) have been reported (Farquharson, 1995). Only the diploid plants are sexual and cross-pollinated. The tetraploids and the rest of the polyploids are apomictic (Burson et al., 1990). They produce seed asexually that is genetically identical to the mother plant. Pollination of apomictic plants is required for seed set and endosperm development.

Fig. 2: Eastern gamagrass with visible leaf blades and terminal spikes. Courtesy of the USDA NRCS Big Flats Plant Materials Center.

Adaptation

The indigenous U.S. range of eastern gamagrass extends from central Texas to southeastern Nebraska and central Iowa and east to the Atlantic Ocean (Rechenthin, 1951). Eastern gamagrass's range extends to Central and South America and the Caribbean (Tropical Forages, 2006). Gamagrass flourishes under dryland conditions where annual precipitation exceeds 35 inches (Dewald et al., 2006). Respectable forage production can be achieved on good soils in regions with 25 inches of annual precipitation. It can be grown in areas with less annual precipitation on irrigated and subirrigated land.

Fig. 3: Eastern gamagrass exhibiting yellow leaves when grown on a high pH soil in New Mexico. Yellow leaves are presumably caused by an inability to uptake iron from a high pH soil. Courtesy of the USDA NRCS Los Lunas Plant Materials Center.

The eastern gamagrass cultivars 'Pete' and 'Iuka IV' exhibited yellow leaves when grown at Los Lunas, New Mexico on a Belen loam (Fig. 3) (J. Henson, personal communication, 2001). A pH range of 8.5 to 9.0 characterizes the Belen loam. Presumably, the yellow leaves are the result of iron deficiency due to the inability of gamagrass to take up iron from the high pH soil. A suggested minimum soil pH for eastern gamagrass is 5.1 (Foy et al. 1999) and the maximum is 7.5 (Sharp Brothers Seed Company, 1999). Another estimate of the optimum pH range is 5.4 to 6.0 (Roberts & Kallenbach, 2006). Gamagrass is intolerant of saline soils. Eastern gamagrass culm height was reduced when grown in a soil with an electrical conductivity of 0.72 dS/m in New Mexico (Henson, 1993).

Gamagrass does best in well drained to somewhat poorly drained soils. In the Northeast, gamagrass is susceptible to frost heaving on poorly drained soils. In some years, this may also occur on sites with moderately well-drained soils during the spring following establishment. Gamagrass is not particularly shade tolerant. The released cultivars of eastern gamagrass will tolerate up to five days of flooding, but some ecotypes from the Southeast will tolerate up to 23 days of inundation (Clubine, 1994; Gamagrass Seed Company, 2005).

Claypan soils and other soils with high mechanical impedance, low pH, and frequent waterlogged conditions cover extensive areas of the Midwest, Northeast and Southeast. The Soil Science Society of America defines a claypan as, “A dense, compact, slowly permeable layer in the subsoil having a much higher clay content than the overlying material, from which it is separated by a sharply defined boundary. Claypans are usually hard when dry, and plastic and sticky when wet.” Claypan layers hinder root growth into the soil, are acidic (pH <5.0), and may contain toxic levels of aluminum.

The roots of eastern gamagrass contain aerenchyma tissue, which is tissue with air passages (Alberts, 1997). Roots with aerenchyma are spongy, with large holes formed by cells either pulling apart or disintegrating. These holes run longitudinally through the roots. They enable roots in flooded soil to transport air from the aboveground parts of the plant. W. Doral Kemper, retired ARS scientist, explains “aerenchyma tissue enables roots to survive and punch through the claypan layer when it’s wet, the only time it’s soft enough to be penetrated. These roots live less than 2 years. But when they die, they decompose slowly and help hold channels open for new generations of roots, providing gamagrass with continued access to water in and below the clay pan.”

Perrygo et al. (2001) compared eastern gamagrass and tall fescue plots in Maryland for water infiltration and soil hydraulic properties. The water infiltration rates were significantly higher ($P<0.05$) in the gamagrass plots at both the surface and the 11.8-inch (30 cm) depth. The authors suggest that higher water infiltration rates in the gamagrass plots “may be attributed to the thicker and deeper rooting system of eastern gamagrass, which increases macropore flow.” The authors concluded that “eastern gamagrass increased the infiltration of water and improved soil physical and hydraulic properties. Eastern gamagrass may be recommended for planting as filter strips along the edges of agricultural fields to enhance infiltration and reduce surface runoff.”

In a study conducted in Missouri, roots of native eastern gamagrass stands effectively penetrated claypan layers with clay contents of 30-50 percent clay (Clark et al., 1998). Eastern gamagrass formed extensive root channels in the claypan layer, especially where the gamagrass had been growing for more than 50 years. In a series of experiments conducted in greenhouses, eastern gamagrass exhibited tolerance to low soil pH, high soil aluminum concentrations and high soil strength (Foy, 1997; Gilker et al., 2002). Pete eastern gamagrass and Sudangrass (*Sorghum bicolor* ssp. *drummondii*) were grown in polyvinyl columns containing aluminum-toxic Tatum Bt soil horizon material. Treatments were applied to the Tatum Bt horizon material. The treatments consisted of lime to achieve a pH of 3.5 and 4.8, and variations in bulk density and soil water potential to achieve a range in soil strengths (penetrometer resistances of 0.36, 1.15, and 1.88 MPa). Root growth of eastern gamagrass, in contrast to Sudangrass, was not inhibited by either acid or aluminum-toxic soil conditions. Neither low pH nor high soil strength adversely affected gamagrass root growth. The authors conclude, “The characteristics of tolerance to acid and aluminum and to high soil strength conditions make eastern gamagrass valuable in establishing grassed buffers, vegetative conservation barriers, and pastures.”

Foy (1999) determined the effect of liming a compact, acid, high aluminum soil in Maryland on the forage yield of Pete eastern gamagrass. The limed and nonlimed soil had a pH of 5.8 and 5.1, respectively. The gamagrass annual forage yield averaged 3.25 tons/acre across two years. There was no difference between the limed and nonlimed soil for forage yield. The high tolerance of eastern gamagrass to low soil pH and aluminum toxicity is in contrast to most crop plants. Krizek et al. (2003) conducted a 4-year (1997-2000) study in Maryland to determine the forage yield of Pete eastern gamagrass, when grown on an acid, compact soil. Variation in soil properties across a 6 percent slope and annual weather patterns were the variables in this study. Soil surface pH values across the study area ranged from 4.5 at the bottom of the slope to 5.1 at the top. Soil penetrometer values ranged from 1.34-2.28 MPa at plowed sites at the bottom of the slope to 4.28-5.42 MPa at unplowed sites at the top. Soil bulk densities at depths of 0-6, 6-12, and 12-18 inches ranged from 0.98-1.24 g/cm3 at the bottom of the slope to 1.16-1.64 g/cm3 at the top. Annual rainfall was below the location average during each year of the study. A high percentage of the 1999 rainfall occurred after the gamagrass growing season. Eastern gamagrass annual forage yield varied twofold across the study area. In general, forage yield varied with position on the slope, soil bulk density, and depth of topsoil, but not with soil pH. Gamagrass produced relatively high forage yields at the sites near the top of the slope, even though the soil at these sites had a pH of 4.3-4.4, high penetrometer resistance, and high bulk density. Gamagrass annual forage yield remained relatively high, averaging 2 tons/acre during 1997 to 2000 despite moisture deficits during each of these years, and a severe moisture deficit during 1999. In contrast, adjacent plots of corn and soybeans (*Glycine max*) exhibited severe stunting and reduced or zero grain yields during this period. Observations of gamagrass roots from pits dug adjacent to the plots indicate that gamagrass roots can penetrate acid, compact claypans to a depth of 3 to 6.5 feet. The authors state, "The fact that eastern gamagrass can withstand periods of moisture deficits may be related to its ability to send its roots deep into the soil early in the spring when the water table is frequently perched (as at our site), thereby enabling it to tap this reservoir of water when surface moisture is limiting. When properly fertilized, eastern gamagrass is ideally suited for reclamation of acid and compact soils and for production of high biomass of high quality forage."

In western Kentucky, cow-calf pairs were grazed on either eastern gamagrass or Caucasian bluestem (*Bothriochloa bladhii*) and bermudagrass (*Cynodon dactylon*) during June though early September (Pingel, 1999). The data from this study was not statistically analyzed, but the author observed that eastern gamagrass maintained more consistent forage production across the grazing season than Caucasian bluestem and bermudagrass. Gamagrass forage production did not decrease as rapidly as that of Caucasian bluestem and bermudagrass across an August-September low rainfall period.

Fig. 4: Evacuation displaying eastern gamagrass roots. Courtesy of the USDA NRCS Big Flats Plant Materials Center.

Uses

The major use of eastern gamagrass is as a forage crop. It is highly productive as intensively managed pasture, hay, and silage. Eastern gamagrass can be developed into an important component of forage for beef and dairy production systems (Dewald et al., 2006). The average daily gain for steers grazing eastern gamagrass in the Piedmont region of North Carolina was approximately twofold greater than steers grazing bermudagrass (Burns & Fisher, 2000). However, eastern gamagrass requires more grazing management than bermudagrass (Dewald et al., 2006).

Gamagrass is a native, long-term perennial alternative to annual, warm-season forages such as Sudangrass and earlier in the spring than other warm-season grasses, about 3 to 4 weeks earlier than bermudagrass (Nix, 2005). Since eastern gamagrass is a warm-season grass, the distribution of yield throughout the summer makes it a useful source of forage when cool-season grasses such as tall fescue (*Schedonorus phoenix*) are relatively unproductive or dormant (Roberts & Kallenbach, 2006). In New York, the Northeastern extent of its range, gamagrass produces forage 3 weeks later than cool-season grasses and legumes, which allows for sequential harvesting of these forages at their prime quality (P. Salon, personal communication, 2001).

Forage quality **–** Eastern gamagrass has a higher leaf-to-stem ratio than other warm-season grasses (Burns, 1992; P. Salon, personal communication, 2001). The reproductive tillers of gamagrass are thicker than other grasses and contain a pithlike material in the center, which results in digestibility comparable to that of the leaves (P. Salon, personal communication, 2001). Researchers have evaluated eastern gamagrass forage quality across many locations, soil fertility levels, and genotypes. The crude protein percentages of aboveground gamagrass usually exceed 12.5 at the boot and flowering growth stages. The boot stage is when the inflorescence is enclosed in the sheath of the uppermost leaf. Gamagrass harvested at these growth stages produces acceptable yields (Coblentz et al., 1999). In the Midwest and Northeast, with moderate nitrogen fertilization, crude protein percentages approaching 20.0 are common in aboveground tissue at the early boot stage (Coblentz et al., 1999; P. Salon, personal communication, 2001). The potential extent of the degradation of protein by ruminant animals from gamagrass in the boot stage is comparable with that in high quality forage legumes (Coblentz et al., 1999). But the degradation of the nitrogen in gamagrass by animals occurs at a slower rate than that in legumes; and the disappearance of dry matter and other fiber components exhibit a similar trend. Therefore, more research is needed to determine the management practices that will optimize the performance of animals utilizing gamagrass.

In New York, eastern gamagrass is very digestible when cut at the boot stage. An apparent digestibility study was conducted using sheep-fed gamagrass haylage (P. Salon, personal communication, 2001). The gamagrass haylage had 62.7 percent neutral detergent fiber (NDF), 35.2 percent acid detergent fiber (ADF), and 3.8 percent lignin. The dry matter apparent digestibility was 61.9 percent and the digestibility of the NDF and ADF (dNDF and dADF) was 72.5 percent and 67.2 percent respectively. A time-of-cutting study found first cutting in vitro true digestibility (IVTD) and dNDF averaged over three first-cutting dates and 2 years of 79.2 percent and 71.9 percent respectively; the average lignin in this study was 4.0 percent (Salon & Cherney, 2000). A study was conducted evaluating the nitrogen response of eastern gamagrass to increasing levels of nitrogen from 0 to 200 pounds per acre (P. Salon, personal communication, 2001). When the gamagrass was cut at early boot stage, the crude protein varied from 15.1 to 17.8 percent. There was no significant difference ($P<0.05$) across nitrogen levels for IVTD, NDF, dNDF, ADF, and lignin with average values of 80.7, 65.1, 70.4, 29.1, and 2.6 percent respectively. The average lignin levels in all of these studies are low compared to the fiber in most warm and cool season forages. Although the percent NDF is higher in eastern gamagrass than in alfalfa and corn silage, the dNDF is lower in these forages, approximately 50 percent compared to 70 percent for eastern gamagrass (P. Salon, personal communication, 2001).

Evidence suggests that eastern gamagrass exhibits better forage quality when grown in the Midwest and Northeast than in the Southeast (Coblentz et al., 1999). However, most of the forage quality studies conducted in the Southeast utilized cultivars composed of ecotypes with Midwest and Great Plains origins. The eastern gamagrass cultivar 'Highlander', an ecotype with a Tennessee origin, when grown in northern Mississippi with a moderately high level of applied nitrogen (240 lb N/ acre), exhibited a high in vitro dry matter digestibility (74 percent), but a low crude protein percentage (9 percent) (Douglas et al., 2000a). Edwards et al. (1999) compared the forage quality of 'Highlander' (tested under accession # 9062680) with 'Tifton-44' bermudagrass and 'Alamo' switchgrass (*Panicum virgatum*) in Mississippi. 'Highlander' exhibited a 10 percent crude protein compared with 7 percent for Tifton-44 and 8 percent for Alamo. The three cultivars exhibited similar percentages of acid detergent fiber and neutral detergent fiber. A statistical analysis was not presented for this data.

Rhoden et al. (2002) evaluated the forage quality of stockpiled eastern gamagrass at two locations, Beltsville, Maryland and Tuskegee, Alabama. Stockpiled forage was clipped for analysis 11 times at Beltsville (19 Nov. – 29 Apr.), and eight times at Tuskegee (29 Nov. – 2 Feb.). The ADF percentage of the stockpiled forage increased and both the NDF and crude protein percentages decreased as the amount of time that eastern gamagrass was stockpiled increased. The phosphorus, potassium, and iron content of the stockpiled forage were below the National Research Council (NRC) ranges for lactating beef cattle. In the stockpiled forage, the Ca:P and K:(Ca + Mg) ratios were maintained throughout the stockpiled period at levels conducive for beef cattle production.

Forage yield and animal performance **–** Some of the recorded values for annual forage yield of eastern gamagrass are summarized in Table 1. The three-year average for annual forage yield of 'Pete' eastern gamagrass, 'Plains' yellow bluestem (*Bothriochloa ischaemum* var. *ischaemum*), and a Caucasian bluestem accession (PI# 78758, KG 40 Caucasian) grown in adjacent plots in southern Illinois was 7.9, 5.8, and 5.4 tons per acre, respectively. The average daily gains of steers grazing continuously on eastern gamagrass across several studies conducted in the middle South ranged between 1.1 to 2.2 pounds per day (Aiken, 1997; Burns, 1992). In North Carolina, steers continuously grazing either Pete eastern gamagrass, 'Carostan' flaccidgrass (*Pennisetum flaccidum*), or 'Coastal' bermudagrass exhibited average daily gains of 1.8, 1.5, and 0.7 pounds, respectively (Burns, 1992). A series of studies conducted in North Carolina show that across the total grazing season, the average daily gain of steers grazing either Pete eastern gamagrass or 'Kanlow' switchgrass was about 2 pounds (Burns & Fisher, 2000). In contrast, the average daily gain for steers grazing the widely used tall fescue-bermudagrass system was about 1.6 pounds during the same period. During a dry year in North Carolina (rainfall during the pasture season about 10 inches below the average), Alamo switchgrass was the most productive forage as defined by steer gain per acre, but 'Iuka IV' eastern gamagrass was more productive than 'Rountree' big bluestem (*Andropogon gerardii*), Caucasian bluestem, and bermudagrass. In western Kentucky, cow-calf pairs were grazed on either eastern gamagrass or Caucasian bluestem and bermudagrass from June though early September (Pingel, 1999). The data from this study was not statistically analyzed, but the author observed that eastern gamagrass maintained more consistent forage production across the grazing season than either Caucasian bluestem or bermudagrass. Gamagrass forage production did not decrease as rapidly as that of Caucasian bluestem and bermudagrass across an August-September low rainfall period. Gamagrass provided fewer grazing days than either Caucasian bluestem or bermudagrass because of gamagrass's requirement for a long rest period between grazing cycles. The total gain per acre for steers grazing eastern gamagrass in Arkansas varied from 195 to 420 pounds per year across stocking rates (Aiken, 1997).

Eun et al. (2004) studied the *in vitro* fermentation of eastern gamagrass hay and silage, with or without supplemental corn grain, by mixed cultures of ruminal microorganisms. The five treatments offered for fermentation were: gamagrass hay – no corn, gamagrass silage – no corn, gamagrass silage – low level of corn, gamagrass silage – medium level of corn, and gamagrass silage – high level of corn. The researchers supposed that the additional energy provided by the supplemental corn to the microbes fermenting gamagrass might improve the microbial capture on gamagrass nitrogen. The results of the experiment showed that gamagrass hay and silage were similar in their effects on fermentation by mixed cultures of ruminal microorganisms. The total amount of substrate that was fermented to volatile fatty acids and gas increased linearly with increasing proportions of supplemental corn ($P<0.004$). Microbial nitrogen flow increased in cultures offered the silage-high corn treatment (quadratic effect, $P<0.02$). The authors concluded, "Increasing corn at greater than 50 percent of the dietary dry matter increased the daily output of microbial nitrogen. The large proportion of the extensively degradable fiber in gamagrass may make it suitable for corn supplementation as an effective strategy to increase the passage of microbial protein." Also, eastern gamagrass is "a potential base perennial forage for the dairy enterprise."

Sheep (Suffolk wethers) consuming eastern gamagrass hay retained more nitrogen as a percent of the total nitrogen fed than sheep consuming either switchgrass or flaccidgrass hay (Burns et al., 1996). Dry matter intake was similar for sheep that consumed either eastern gamagrass or switchgrass hay, while sheep consuming flaccidgrass (*Pennisetum flaccidum*) hay consumed less dry matter. Goetsch et al. (1997) compared four breed groups of ewes for dry matter intake and digestibility when consuming either eastern gamagrass or switchgrass hay from different cuttings. The sheep breed groups were St. Croix, St. Croix X Romanov, St. Croix X Texel and Gulf Coast Native. The breed groups did not interact with either hay species or cutting time for dry matter intake and digestibility. Hay digestibility was similar across the breed groups. The breed groups differed for dry matter intake, with St. Croix and St. Croix X Romanov > St. Croix X Texel > Gulf Coast Native. The authors conclude that the breed groups St. Croix and St. Croix X Romanov may be better suited to early to mid-gestation consumption of eastern gamagrass and switchgrass hay compared with the St. Croix X Texel group. Also, the need for supplementation for body weight maintenance when consuming gamagrass may be greatest for the Gulf Coast Native group. When harvested on the same day and supplemented with soybean meal, eastern gamagrass exhibited a higher organic matter digestibility than switchgrass. The organic matter digestibility of both grasses was lower for the late harvest of primary growth compared with the early primary growth and regrowth harvest.

Forage silage and haylage – Corn is the crop that is most frequently grown for silage in the United States. Many of the forage yields for eastern gamagrass in Table 1 compare favorably with corn silage dry matter yields of 5.5 to 6.6 tons per acre in the Piedmont region of the Southeast and 6.9 to 10.0 tons per acre in the Corn Belt. In a Missouri study, eastern gamagrass ensiled from a first-cut at either the seed development or inflorescence emergence stage and regrowth, and at the proper moisture content produced good quality silage, but with lower dry matter digestibility than corn silage: 54.1 percent for gamagrass silage and 70.7 percent for corn silage (Brejda et al., 1994).

Fig. 5: Eastern gamagrass hayfield. Courtesy of USDA NRCS Big Flats Plant Materials Center.

Table 1. Forage Yields of eastern gamagrass excluding establishment years, averaged across locations and years, and grown with moderate to high levels of applied fertility

Region	Cultivar or accession	Locations, years	Average annual yield and (range)	Reference
			Tons/acre of dry forage	
Illinois (southern)	Pete	1 year	3.7	Fick, 1993
Kansas	Pete	3 years	3.0 (1.9 to 3.7)	Moyer & Sweeney, 1992
Maryland	Pete	2 years	3.3 (3.2 to 3.3)	Foy et al., 1999
Missouri (northern)	Pete	2 locations, 3 years	5.0 (3.4 to 6.5)	Brejda et al., 1997
New York	Pete	5 years	3.4 (2.6 to 3.8)	P. Salon, pers. comm. 2001
Oklahoma (western)	Iuka IV	3 years	4.0 (3.4 to 4.8)	C. Dewald, pers. comm
	Pete	3 years	3.6 (3.1 to 3.6).	
Mississippi	Highlander	5 locations, 6 years	6.7 (5.4 to 9.6)	Edwards et al., 2000
Georgia	accessions	1 year	5.8 (2.9 to 8.7)	Surrency et al., 1996
Georgia	Pete	1 year	7.3	Surrency et al., 1996
Maryland	Pete	3 years	2.4 (1.9 to 3.0)	Krizek et al., 2003
Florida	accessions	2 locations, 2 years	3.6 (2.7 to 4.6)	Kalmbacher et al., 1990
Arkansas	Pete	3 years	3.0 (2.8 to 3.2)	Aiken & Springer, 1998
Tennessee	Pete	2 locations	3.4 (2.9 to 4.0)	Graves et al., 1997
Texas (eastern)	Jackson	3 years	7.1 (5.6 to 9.3)	Brakie, 1998

In contrast, other studies show that ensiled eastern gamagrass from earlier, first-cut growth stages has a dry matter digestibility percentage around 70 (P. Salon, personal communication, 2001). A deficiency of eastern gamagrass silage compared with corn silage is gamagrass's dramatically lower yield of developing grain and therefore, lower level of digestible energy. Ensiled eastern gamagrass had higher levels of acid detergent fiber than ensiled corn, which indicates that gamagrass has less digestible energy (Brejda et al., 1994; Grabowski et al., 2003). Producers must weigh the benefits of using gamagrass for silage, such as reduced annual input costs and reduced soil erosion, against the lower silage quality of gamagrass compared to that of corn.

Milk production trials at Ithaca and Cobleskill, New York were conducted to determine the role of eastern gamagrass in the feeding of lactating cows (Cherney et al., 2003). An eastern gamagrass total mixed ration was compared to a corn silage total mixed ration. The two rations were balanced for protein, energy, and minerals. Dry matter intake and milk production did not differ between the two diets at either location ($P<0.05$). The authors conclude, "Eastern gamagrass can be used to replace corn silage in total mixed rations of cattle producing moderate to high levels of milk. However, it requires the inclusion of more grain in the diet, resulting in lower forage to concentrate ratios, as well as more grain being purchased off farm." The economic feasibility will depend on the price of grain. If the grain is purchased off-farm, farmers must consider the impact of an increase in nutrient importation on nutrient management plans.

Eun et al. (2003), in North Carolina, evaluated the effect of eastern gamagrass, fed as either hay or silage and supplemented with corn grain, on milk production of dairy cows. Iuka IV eastern gamagrass, which was second-cut at the late vegetative stage, supplied the forage for hay and silage. The five dietary treatments were: gamagrass hay – no corn; gamagrass silage – no corn; gamagrass silage – low level of corn; gamagrass silage – medium level of corn; gamagrass silage – high level of corn. Gamagrass hay and silage were similar for crude protein, ADF, NDF, and fat. Cows did not differ in milk production when fed either only gamagrass hay or only silage. In contrast, cows fed only silage exhibited greater ($P<0.08$) yields of milk protein, lactose, and solids-not-fat than cows fed only hay. Feed conversion efficiency was greater for cows fed only silage than only hay (2.16 vs. 1.88 milk/dry matter intake ($P<0.01$). Also, the conversion of feed nitrogen to milk nitrogen was greater ($P<0.01$) for cows fed only silage than only hay. Supplementing gamagrass silage with corn grain tended to increase milk yield (66 vs. 71 lb milk/day for silage only versus silage with an average of the medium and high corn levels $P<0.08$). Supplementing gamagrass silage with corn decreased feed conversion efficiency. Feeding gamagrass silage significantly reduced the milk urea concentration, and feeding corn at the medium and high levels further reduced milk urea concentration ($P<0.05$). Increased dietary energy from supplemental corn increased the conversion of feed nitrogen into milk protein. Gamagrass fed as silage with or without corn improved the nitrogen status of the cows as indicated by lower milk urea concentrations. The authors state, “Gamagrass ensiled well, was well consumed by cattle, and offers potential to replace both corn and alfalfa (*Medicago sativa*) for dairy cattle enterprise.”

Filter strip, Vegetative barrier, Nutrient management – In studies conducted in Arkansas and Maryland, the harvest of eastern gamagrass aboveground tissue removed more nitrogen from soil that was fertilized with high levels of poultry litter than the harvest of yellow bluestem, but less than the harvest of switchgrass (Staver, 2000; Tharel, 2000). Where nitrogen leaching was measured, only about 40 percent of the nitrogen applied in poultry litter was accounted for in aboveground tissue of both gamagrass and switchgrass, even though nitrogen leaching was minimal (Staver, 1999). This suggests that a large amount of nitrogen is sequestered in the below-ground biomass of these grasses. Another possibility, not discussed by the author, is that these grasses increased denitrification. Only about 12 percent of the phosphorus applied in the poultry litter was accounted for in aboveground tissue. Therefore, using poultry litter to supply the nitrogen requirements of either gamagrass or switchgrass would result in a rapid increase in soil phosphorus levels. The author concludes that in both a no-fertilizer/no-harvest management regime and a periodic harvest management regime, it is likely that nitrogen retention would remain effective for many years due to the potential of these grasses to sequester large amounts of carbon in the soil profile and thereby recycle nitrogen.

McLaughlin et al. (2004), in a study conducted in east-central Mississippi, compared six grasses: common and ‘Coastal’ bermudagrass, Pete eastern gamagrass, ‘Lometa’ Indiangrass (*Sorghastrum nutans*), Johnsongrass (*Sorghum halepense*) and Alamo switchgrass for the uptake of both macro and micronutrients. Swine effluent spray was applied to the soil for 8 years prior to the initiation of the experiment and during the first 2 years of the 3-year study. Bermudagrass, both Coastal and common, accumulated more nitrogen and phosphorus per acre into aboveground herbage than the other grasses ($P<0.05$). The N/P uptake ratios varied across years and ranged from 4.7 for Coastal bermudagrass to 9.3 for eastern gamagrass. When the objective of a swine waste nutrient management hay system is to provide nitrogen for optimum forage production while avoiding accumulation of excess phosphorus in the soil, forages with N/P ratios less than 10 are expected to satisfy the objective, but forages with ratios greater than 10 are not. The N/P uptake ratios of all six grasses were less than 10.0, with common bermudagrass and Indiangrass displaying the lowest ratios, and eastern gamagrass the highest. Forage K/(Ca + Mg) rations greater than 2.2 in cool-season grasses have been associated with grass tetany in grazing animals (Grunes & Welch, 1989). In the current study, only eastern gamagrass and Johnsongrass exhibited K/(Ca + Mg) ratios greater than 2.2. The K/(Ca + Mg) ratio of gamagrass was 2.9 and 3.1 in 2001 and 2002, respectively, and the K/(Ca + Mg) ratio of Johnsongrass was 2.3 in 2001. The authors state, “Although grass tetany is considered a grazing problem and grazing effluent-treated forage is not a recommended practice, the effects of feeding ruminant animals hay with the high K/(Ca + Mg) ratio of eastern gamagrass should be investigated.” In summary, the performance of the bermudagrass exceeded those of the other four grasses 83 percent of the time for dry matter yield and 76 percent of the time for nutrient uptake. The authors conclude “among the six grasses tested, common bermudagrass is the best choice for replacing Johnsongrass as a warm-season perennial grass hay crop for nutrient management in this swine effluent spray field.” But the native species, eastern gamagrass and switchgrass could be used in the current nutrient management system.

In a study conducted in west central Texas, eastern gamagrass (PI-434493) accumulated less nitrogen and phosphorus in aboveground herbage than ‘Aztec’ Maximilian sunflower (*Helianthus maximiliani*), Coastal bermudagrass, and Alamo switchgrass, but more than ‘Lometa’ Indiangrass, ‘Earl’ big bluestem, and T-587 yellow bluestem (Esquivel et al., 2000). In Mississippi, eastern gamagrass, giant reed (*Arundo donax*), big bluestem, Alamo switchgrass, and tall fescue established in filter strips adjacent to cotton fields were equally effective in reducing sediment runoff. Consequently, the grasses were equally effective in trapping soil-applied herbicides that were either attached or adsorbed to the soil (Rankins, 1998).

Eastern gamagrass, in comparison with tall fescue, increased the infiltration of water and improved soil physical and hydraulic properties (Perrygo et al. 2001). The authors recommend planting eastern gamagrass as filter strips along the edges of agricultural fields to enhance infiltration and reduce surface runoff.

Eastern gamagrass has received considerable attention for use in vegetative barriers for soil erosion control because the crown has the capacity to elevate coarse aerial foliage above sediment deposition and to anchor the plant with stout brace roots. Researchers in northern Mississippi compared vegetative barriers composed of one, two, three, or four rows of either eastern gamagrass or switchgrass (Becker, 2001; Dewald et al., 1996). One and two-row barriers were as resistant as three and four-row barriers to overtopping by flowing water that contained sediment. Switchgrass remained more erect and held back more water and sediment than eastern gamagrass.

Researchers evaluated the effect of vegetative barriers composed of eastern gamagrass and switchgrass planted on the field’s contour across corn and soybean fields in northern Missouri. The 4-foot-wide grass barriers were established between 50 to 90 feet of row crops. Competition from the crop plants on the establishing grass barrier was reduced by maintaining a 3-foot, crop-free border for 2 years after grass planting. Estimates of the reduction in sediment loss due to the grass barrier were made by comparing the measured soil loss after the barriers were established with the loss predicted by the Revised Universal Soil Loss Equation. The estimated reductions in sediment loss ranged between 20 and 70 percent. A more detailed report of this study is available from Roberts & Kallenbach (1999).

In North Carolina, eastern gamagrass fits into nutrient waste utilization plans as a component of pasture rotation schemes, in conjunction with bermudagrass (Nix, 2005). A disadvantage of eastern gamagrass in North Carolina is that hay production is problematic in high rainfall climates because hay quality is very dependent on the cutting time.

Phytoremediation – In a greenhouse experiment, the levels of sequestered zinc in eastern gamagrass roots exceed the level found in either roots or tops of many of the known hyperaccumulator species (Hinchman et al., 1996). The reduction of zinc from the soil solution by gamagrass, when the zinc concentration of the soil solution is several hundred parts per million, has major implications for the development of low-cost, low-tech, plant-based cleanup systems for contaminated soils, groundwater, and wastewater. Eastern gamagrass is ideally suited to plant-based, hydroponic wastewater treatment systems in which the plants are grown in a bed of pea gravel, through which the wastewater is trickled for purification. Because both tops and roots of gamagrass are uniform in development, the harvest of either of these organs would be relatively easy. A more detailed report of this study is available from Hinchman et al. (1996).

Bioenergy – Nelson et al. (1994) determined the energetic and economic feasibilities of the use of Conservation Reserve Program acreage for bioenergy production from the herbaceous energy crops of big bluestem/Indiangrass and eastern gamagrass. Energetic feasibility was expressed as an energy-profit ratio, which is defined as the ratio in the amount of energy contained in the biocrude divided by the amount of energy required to produce, transport, process, and convert the energy crop into the biocrude. The energy-profit ratio varied as function of crop yield and the amount of nitrogen fertilizer applied, and ranged from 2.57 to 3.23 for big bluestem/Indiangrass and from 2.31 to 3.21 for eastern gamagrass. The cost of bioenergy production for both big bluestem/Indiangrass and eastern gamagrass was competitive with current prices and future projections for other fuel sources such as natural gas and fuel oils.

Single and two-cut harvest systems were compared for maximum biomass production of ‘Highlander’ eastern gamagrass from 2000–2002 at the USDA-NRCS Jamie L. Whitten Plant Materials Center near Coffeeville, Mississippi (Grabowski et al., 2004). Results of this work found that a two-cut system, with the first cut in early June and a second cut in early September, produced 30 percent more biomass than a single cut made in either early June or September. Nitrogen and ash content of the harvested gamagrass was similar for each management practice within years, but varied between years. The average percent nitrogen and ash content was 1 and 4.5, respectively.

Staver (2002) compared eastern gamagrass with switchgrass for biofuel potential in Maryland. The study evaluated biofuel potential for use in direct combustion in small-scale boilers. Direct combustion of herbaceous material is problematic because high potassium levels in herbaceous tissue cause slagging in boilers. Potassium leaches readily from dead grass tissue. Therefore, delaying a single cut harvest of switchgrass until spring allows potassium to leach from the aboveground tissue. Also, switchgrass remains erect during winter and loss of aboveground biomass is small. In contrast, eastern gamagrass does not remain erect during winter. Consequently, gamagrass incurs considerable biomass loss and microbial decay during winter (K. Staver, personal communication, 2005). The author concluded that eastern gamagrass, compared to switchgrass, has little potential as a biofuel for direct combustion in small-scale boilers.

Establishment

Since eastern gamagrass is very palatable to livestock, it is one of the first grasses eliminated from mixed stands by grazing. Due to its high palatability in grazing systems, it is best to establish and utilize gamagrass in pure stands. However, John Dickerson, NRCS plant materials specialist, states, “Other species, particularly other native grasses, are compatible with eastern gamagrass in forage production fields if grazing and hay management is focused on the gamagrass. Also, a mixture of grasses may exclude weeds more effectively than a solid stand of gamagrass."

Seed dormancy – The caryopsis of eastern gamagrass is surrounded by a hard fruit-case. The botanical name for this fruit-case is cupule. Henceforth, an eastern gamagrass caryopsis and the surrounding cupulate fruit-case are referred to as a seed unit (Fig. 6) (Galinat, 1956). Eastern gamagrass establishment is hindered by seed unit dormancy (Ahring & Frank, 1968). Gamagrass seed dormancy is likely caused by several dormancy mechanisms, which include the physical inhibition of the caryopsis by the hard cupule (Springer et al., 2001) and factors in the pericarp and/or testa (Tian et al., 2002). A cold, moist stratification (35-40°F for 6 to 10 weeks), which softens the cupule is the most practical method to reduce the percentage of dormant seed units (Ahring & Frank, 1968; Anderson, 1985). Removing the cupule from the caryopsis (dehulling) eliminates some seed dormancy (Anderson, 1985; Tian et al., 2002). The germination of dehulled seed was increased 40 to 45.5 percent by treatment with a 300 g/kg hydrogen peroxide solution (Kindiger, 1994). Scarifying the pericarp over the embryo of dehulled seed resulted in germination of all dormant seed (Tian et al., 2002). At least one dormancy mechanism involves the caryopsis and is affected by gibberellic acid application (Tian et al., 2003). The application of gibberellic acid to caryopses with the cupule removed increased the total seed germination by 25 to 47 percentage points across commercial seed sources and seed production years. But the application of gibberellic to intact seed units did not enhance germination percentage. Also, the combination of 4 weeks of cold, moist stratification plus gibberellic acid application did not enhance the total germination percentage of intact seed units beyond that of cold, moist stratification alone (Rogis et al., 2004a). Solid matrix priming with incorporated gibberellic acid was not as successful at breaking dormancy of intact seed units as cold, moist stratification (Rogis et al., 2004b). Soaking intact seed units in solutions of sodium hypochlorite or applying KNO_3 as a moistening agent to intact seed units did not enhance germination percentage (Ahring & Frank, 1968). Soaking intact seed units in ethylene chlorohydrin solutions increased germination percentage, but was not as effective as cold, moist stratification. Surrounding intact seed units with an elevated ambient carbon dioxide concentration during cold stratification (moist or dry) did not increase the germination percentage (Anderson, 1985).

Fig. 6: Eastern gamagrass seed units (caryopsis surrounded by cupulate fruit-case). Photo by Steve Hurst at USDA NRCS PLANTS Database.

Gibson et al. (2005) determined the rate of seed dormancy loss and survivability of 'Pete' eastern gamagrass seed units in a central Iowa field planting. The results of this study suggest that most of the dormancy in Pete seed units was lost between mid-September and mid-November. This study indicates that gamagrass seed dormancy was quickly and almost completely released by several weeks of soil temperature below 59° F and adequate soil moisture. The rapidness, completeness, and irreversibility of seed dormancy caused by fall and winter climatic conditions has implications for the management of gamagrass plantings and the survival of gamagrass in managed and natural settings. The authors conclude that rapid and uniform establishment may be more critical for eastern gamagrass than for species that can spread by rhizomes and stolons or possess a persistent seed bank due to prolonged seed dormancy. “Poor establishment would result in within-row gaps devoid of eastern gamagrass plants. If these gaps exist at one year after planting, they are likely to remain for several years.” The authors suggest, “While a lack of regrowth potential under frequent and close defoliation limited the survival of eastern gamagrass on settled rangelands, low seed production and lack of long-term seed dormancy probably limited the survival of eastern gamagrass on settled rangelands, low seed production and lack of long-term seed dormancy probably limited its ability to repopulate rangelands and pastures if and when intense grazing pressures were removed.”

Winter planting of dormant seed units – One alternative is to plant nonstratified seed units during autumn or winter when the soil temperature in below 50° F, and rely on the cold, moist conditions of winter to stratify the seed (Graves et al., 1997; Gamagrass Growers Guide, 2005). If the seed units are planted too early in autumn, germination may occur during winter, which will increase the potential for winter injury. The successes of winter plantings rely on a high level of dormancy in the seed. A recommended practice is to determine the percentage dormancy of each seed lot using a combination of three germination tests: a rag doll test at a constant 86° F, a tetrazolium test, and a stratification test to confirm the estimate of the first two tests. Krizek et al. (2000) showed that 21 days at a constant temperature of 86° F is sufficient time for conducting eastern gamagrass germination tests. The recommended autumn/winter planting windows for several regions are shown in Table 2 on page 13.

Ahring & Frank (1968) obtained full stands, one gamagrass seedling every 6 to 8 inches, from plantings in Oklahoma during October though

Table 2. Recommended planting windows for autumn/winter plantings of nonstratified, dormant eastern gamagrass seed units.

Region	Cultivar or germplasm release	Recommended planting window	Reference
Oklahoma	Not reported	Oct. – Dec.	Ahring & Frank, 1968
North Carolina (Piedmont)	Pete	Nov. – Jan.	Muller et al., 2000
Missouri	Not reported	Nov. – Feb.	Roberts & Kallenbach, 2006
Kansas	Pete	Feb. – Mar.	Ohlenbusch & Fine, 1990
Eastern Nebraska	Iuka IV	Jan. 15 – Feb. 15	Gamagrass Growers Guide, 2005
West Texas	San Marcos Iuka IV	Dec. – Feb. 15	M. Houck, pers. comm., 2004
Northeastern U.S.	Pete	After Nov. 1, recommended only for well-drained soils.	Dickerson, 1993
Mississippi	Not reported	Dormant seed plantings not recommended.	J. Douglas, personal communication, 2004
Iowa	Pete	Late Aug.	Aberle et al., 2003

December. In North Carolina, winter plantings of the cultivar Pete, in each of 3 years, produced either the same or greater density of mature plants and herbage weight as spring plantings of artificially stratified seed units (Muller et al., 2000). Treating the seed units with a fungicide did not affect stand density. The results from an experiment in central Iowa showed that planting nonstratified Pete gamagrass seed units from mid to late August produces better stands than planting either stratified or nonstratified seed in April and May (Aberle et al., 2003).

Ohlenbusch & Fine (1990) planted seed units of Pete eastern gamagrass at 2-week intervals from October though May during 1985-1987 at two Kansas locations. Planting dates were compared for the number of seedlings established. The best planting data ranged from 4 February to 1 April across the 2 years and locations. Both of these "best planting dates" produced few established seedlings at one location-year. The authors state, "Based on the data obtained in this study, the best seeding period for eastern gamagrass appears to be February and March with January being acceptable." A 5-year replicated treatment study conducted at the NRCS Big Flats Plant Materials Center in south-central New York compared the effectiveness of spring and autumn seeding dates for gamagrass establishment. The study produced variable results. The spring seeding data was superior in two of the years, the autumn seeding data superior in one of the years, and the seeding dates did not differ in two of the years. The timing and degree of saturated soil moisture conditions could be affecting emergence (P. Salon, personal communication, 2001). The Gamagrass Seed Company, which is located in Nebraska, states, "A winter planting of dormant seed units may not be the best choice in heavy-textured, poorly drained soils, because seed units are more likely to deteriorate in these soils; spring plantings may prove more efficacious in heavy-textured, poorly drained soils" (Gamagrass Growers Guide, 2005). The results from the studies in Kansas and New York and the information from the Gamagrass Seed Company suggest that the success of winter dormant seed plantings may vary across years and locations.

Spring planting of artificially stratified seed units – An artificial stratification of seed units in a cold cabinet will break gamagrass seed dormancy. The seed units must be stratified (exposed to cold, wet conditions) for 3 to 10 weeks prior to spring sowing (Row, 1998; Springer et al., 2001). A frequently used technique for artificial stratification (Graves et al., 1997; J. Grabowski, personal communication, 2005) is the following:

Fill a burlap bag about half full with eastern gamagrass seed units. Soak the bag containing the seed units in a 1 percent solution of a fungicide such as thiram for 10 to 12 hours. Check the label for clearance before using any fungicide. Drain the burlap bag that contains the seed units. Seal the burlap bag and then seal the burlap bag in a plastic bag. Store the treated seed units for 6 to 10 weeks at 35-45 degrees F. Do not freeze. When the seed units are removed from the cold cabinet, they should not be allowed to dry before planting.

According to a study by Row (1998), the use of thiram increased the percentage emergence of stratified seed units, but the percentages were not statistically different ($P < 0.05$). Some commercial eastern gamagrass seed producers recommended a longer cold period – up to 20 weeks (Dewald, 1993). The soil must remain

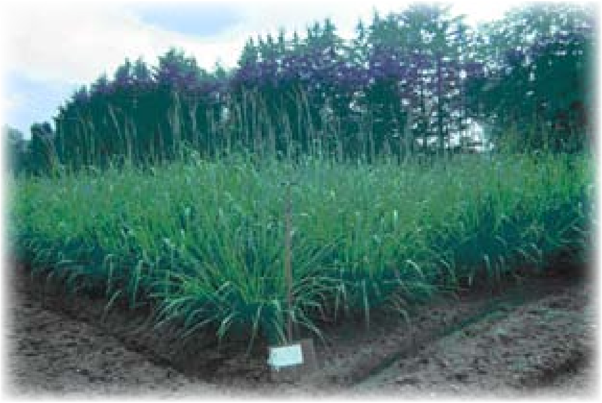

Fig. 7: Excellent stand of eastern gamagrass. Courtesy of USDA NRCS Big Flats Plant Materials Center.

moist after planting artificially stratified seed until the seed germinates. Graves et al. (1997) recommends planting into a moist seed bed because if the seed dries out before germination, the stand will be dramatically reduced. Some commercial seed producers sell pre-stratified seed units. These seed units are hydrated when purchased. A farmer must either plant pre-stratified seed units within 24 hours after receiving them or store the seed units in a moist, cold environment, otherwise the seed units will sprout prior to planting.

A commercial seed company, Gamagrass Seed Company of Falls City, Nebraska, has developed a proprietary process (Germtec II[1]), which is a priming process for eastern gamagrass seed units. The advantage of primed seed over pre-stratified seed units is that primed seed units are stable during shipping without moist, cold storage and immediate planting is not required. However, the germination percentage of primed seed units declines slowly across time (Krizek et al., 2000). Delaying planting 1 to 2 months after seed unit priming might result in a lower percentage of seedlings established. After an initial decline in seed germination percentage following priming, 2 years of cold storage (39˚ F) of Germtec II-treated seed units did not adversely affect germination percentage (Krizek et al., 2002a). The authors suggest that the germination percentage of Germtec II-treated seed units, after an initial decline in germination percentage, will still be higher than that of untreated seed. The authors recommend, “To aid growers, it would be desirable if the dormant fraction of eastern gamagrass seed was explicitly included on the seed label (instead of stating a single value for germ and hard); this would allow one to adjust the planting density to assure a good stand.” The results of this study indicate that 21 days at a constant temperature of 86 degrees F is sufficient time for conducting eastern gamagrass germination tests.

The recommended date for spring planting of eastern gamagrass stratified seed units is similar to that for corn (Graves et al., 1997). Roberts and Kallenbach (Roberts & Kallenbach, 2006) recommend planting stratified seed units in Missouri when soil temperatures reach 65˚ F. Janet Grabowski recommends planting stratified ‘Highlander’ eastern gamagrass seed units when soil temperatures are about 85˚ F (J. Grabowski, personal communication, 2005).

Planting techniques – Good stands of the cultivars Pete and ‘Iuka IV’ eastern gamagrass have been obtained using 8 to 10 pounds of high quality seed units per acre [about 45,000 to 56,250 pure live seeds (PLS) per acre] (Dewald et al., 2006). Currently, there is no standard AOSA testing procedure to determine germination of gamagrass, and laboratory tests may be misleading due to seed dormancy. It is advisable when comparing seed lots, to compare the 3-week germination test and not the total viability because the 3-week test is used to calculate PLS. Good quality seed of the cultivars Pete and Iuka IV, which are composed of Great Plains ecotypes, usually have 5000 to 7000 seed units per pound. Higher seeding densities (12-15 lb seed units/acre) of these cultivars should be used if the number of seed units per pound is less than 6000. In general, tetraploid ecotypes with Southeast origins have larger seed units and fewer seed units per pound than ecotypes from the Great Plains. The weight per seed unit of the cultivar ‘Jackson’, which is a tetraploid ecotype of southeast Texas origin, is larger than that of both Pete and Iuka IV. Therefore, Jackson should be planted at a minimum of 10 pounds of seed units per acre (J. Alderson, personal communication, 2001). The cultivar Highlander, a tetraploid ecotype with a northeast Tennessee origin, has about 2800 seed units per pound of high quality seed (J. Douglas, personal communication, 2001). Four high quality Highlander seed units per foot-row in 40-inch rows (39,204 seed units per acre) is equivalent to the seeding density of about 15

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pounds per acre. Suggested seeding densities for Highlander are: 13 to 27 pounds seed units per acre with a minimum row width of 24 inches when the planting will be used for forage, and 9 to 19 pounds seed units per acre with a minimum row width of 36 inches when the planting will be used for seed production (J. Grabowski, personal communication, 2005).

Springer et al. (2003) studied the affect of plant density on eastern gamagrass forage yield. The experiment was conducted in western Oklahoma with supplement irrigation and applied fertility of 285 pounds N per acre each year (split across three applications), and 250 pounds P_2O_5 per acre applied at the beginning of the third growing season. The eastern gamagrass was accession WW-1000, a strain that was collected from and is adapted to western Oklahoma. It is similar to other naturally occurring populations of gamagrass in western Oklahoma and the Texas panhandle. Forage yield increased as plant density increased, especially during the early years of establishment. The stand density of four plants per square yard (19,440 plants per acre) produced the highest sustainable forage yield after stand equilibrium was reached. The authors state, “Most planting recommendations for eastern gamagrass call for seeding 11.2 kg ha-1 (10 pounds per acre) of pure live seed into wide rows (0.9 to 1.2 m) (35 to 47 inches). These recommendations were developed for seed production stands where wider row spacing facilitated the use of cultivating and harvest equipment. Narrow row spacing and slightly higher seeding densities may hasten stand establishment for increased forage production early in the life of the stand.”

Stratified seed units should be planted 1 to 1.5 inches deep in medium textured soil or a little deeper in light textured soil because the soil may dry out faster (Dewald, 1993). Aberle et al. (2003) compared seeding depths of 1 and 2 inches using Pete eastern gamagrass in a study conducted across five planting dates and 2 years in Iowa. The two seeding depths did not differ significantly for the number of seedlings established at most of the planting dates and years ($P<0.05$). The 1-inch planting depth at the mid-August 1999 planting date resulted in a significantly higher number of seedlings established than the 2-inch depth ($P<0.05$). In contrast, the 1-inch planting depth at the 1 November planting date resulted in a significantly lower number of seedlings established ($P<0.05$). The authors suggest that fall plantings of eastern gamagrass in Iowa should be seeded deeper than 1 inch to ensure that dry spring conditions do not adversely affect seedling emergence.

A firm seedbed is desirable for planting eastern gamagrass. Planting site preparation should be the same as for planting corn. Gamagrass may be seeded with conventional equipment into a thoroughly prepared seedbed if the site has good weed control history. Early corn-planting season is the preferred planting time for spring plantings of gamagrass. Row planters (corn, cotton, peanut, etc.) are easily adjusted to plant gamagrass seed units in rows (Dewald et al., 2006). Row plantings can be cultivated in the early stages for weed control. Since gamagrass is a bunchgrass, established plants can have substantial bases. These can be rough to drive over with equipment. If haying is likely, consider planting in rows wide enough to minimize traffic over plants. Gamagrass stores an essential portion of its food reserves in the aboveground portion of the plant base. Reducing traffic on the plant crowns will result in less plant damage and faster regrowth.

Solid plantings can be made with most grain drills using the oat side of the drill feeder. Solid plantings offer no advantage over row plantings unless the seeding density is increased. Solid plantings may reduce weed growth, but the seed cost may be prohibitive (Dewald et al., 2006).

The use of a small grain nurse crop may be desirable if the potential for soil erosion exists. Gamagrass seed units can be planted in mid-winter into fall planted small grains by adjusting the shovels or discs on the row planter to create a shallow (1”) and narrow (6-10”) furrow to remove vegetation from and adjacent to the planted seed row (Dewald et al., 2006). If a nurse crop is used, it must be removed by mid-spring to reduce competition to the gamagrass. In the Northeast, common oat (*Avena sativa*) can be interseeded into newly established gamagrass during late July in conjunction with gamagrass cultivation. The oat will provide erosion control and possible frost heaving protection. The oat will frost-kill and not compete with the gamagrass in the spring (P. Salon, personal communication, 2001).

Autumn planting in the Northeast is difficult due to wet conditions during most years. Thus, a spring planting date is preferred (Dickerson, 1993). Gamagrass in the Northeast is prone to frost heaving during the first winter after a spring planting on some soils (Dickerson, 1993). The use of moderately well-drained or well-drained soils makes this possibility less likely. On soils with somewhat poor drainage, use all strategies to produce the largest possible gamagrass plants by the end of the first growing season. Observations indicate that plants with 15 to 20 culms are more resistant to frost heaving, while those with less than 10 culms are vulnerable.

Sites formerly in cool-season pastures or hayland should be sown without tillage to avoid exposing weed seeds to good germination conditions. With the proper equipment, gamagrass can be planted into a variety of seedbeds from conventional to no-till (Gamagrass Seed Company, 2005). In no-till plantings, several potential problems should be addressed to ensure successful stand establishment. In sod plantings, opener slots made by planting equipment provide a fracture line, which can open up during dry weather. This can effectively reduce planting depth or even expose the seed units, allowing them to dry out. Therefore, the Gamagrass Seed Company suggests seeding at a deeper depth when planting into sod. The fracture line caused by no-till drills may expose the seed units to rodents and insects. When no-tilling into a killed sod, the length of time since the complete kill of the sod was achieved is sometimes critical. Waiting 3 to 4 weeks after the sod has been killed is often needed to allow populations of damaging insects to decrease to insignificant levels. Consult your local extension office for information concerning potential insect damage and possible control measures.

In the Northeast, spray glyphosate on sod during the autumn prior to planting gamagrass. This allows some of the vegetation to decay and gives the producer a chance to touch up any escaped weeds or missed areas (P. Salon, personal communication, 2001). As an alternative to herbicides, plant a smother crop such as Sudangrass the year before. Follow the Sudangrass with autumn tillage and plant either oats or cereal rye (*Secale cereale*) for soil erosion control during winter.

Weed control for establishment – The time during establishment is the most critical period for weed control. Annual grasses, particularly, can cause problems in the establishment year. It is best to delay fertilization with nitrogen until the stand is established. Few herbicides are labeled for eastern gamagrass, although several are in development. For broadleaf weed control, 2, 4-D and dicamba are options; follow manufacturers label for pasture and hayland. Imazapic[1] is labeled for warm-season grasses in many states, but it is phototoxic to gamagrass post emergence and should not be used (Salon & van der Grinten, 2000). Research by Coffman & Vough (2002) indicates that eastern gamagrass is tolerant to several herbicides that are labeled for use on corn, but these herbicides are not currently labeled for use on eastern gamagrass. Some current information on herbicides is available from Roberts & Kallenbach, (1999). James Alderson, retired NRCS plant materials specialist, states "eastern gamagrass can be established in Texas without pre-emergent weed control if planted before 15 February" (Alderson, 1993).

If gamagrass is planted in rows, cultivation can be used to control weeds in the early years of

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establishment. In various studies, gamagrass has shown excellent tolerance to carryover from some of today's commonly used corn herbicides (i.e., atrazine, cyanazine, Accent[1] herbicide family, etc.), (Gamagrass Seed Company, 2005). Roberts & Kallenbach (1999) suggest that an option is to plant eastern gamagrass, either a winter or spring planting, into fields that have been planted to either corn or grain sorghum for several years prior to seeding gamagrass. If the herbicide atrazine was applied at the maximum rates for the previous crops, the carryover may provide some weed control for gamagrass during the establishment year (Roberts & Kallenbach, 2006). Also, gamagrass can be planted into either existing corn or grain sorghum stubble using a no-till drill. Paul Salon, NRCS agronomist in New York, states, "New regulations limit the application of atrazine to 1 pound per acre in order to prevent herbicide carry-over. A viable strategy for eastern gamagrass establishment is to plant gamagrass following several years of corn. Control perennial weeds such as quackgrass (*Elymus repens*), Johnsongrass and nutsedge (*Cyperus esculentus*) with herbicides, and do not apply manure to land being prepared for eastern gamagrass."

Weed Control After the Establishment Year **–** In Missouri, after the establishment year, eastern gamagrass will compete effectively with most weeds without any weed control other than proper grazing management and spring burning (Roberts & Kallenbach, 2006). Fields may be burned to control woody plants, reduce leaf diseases, improve grazing distribution, and stimulate new growth. The optimum time to burn is in the spring when the new green-growth is about 1 inch long.

Fig. 8: Eastern gamagrass after spring burn. Courtesy of USDA NRCS Manhattan Plant Materials Center.

Paul Salon, NRCS agronomist, states, "In the Northeast, grazing management and burning alone will not provide adequate weed control." Roundup[1] is labeled for use on pasture grasses; producers should follow the label instructions. Glyphosate can be applied "in early spring before desirable perennial grasses break dormancy and initiate green growth. Late fall application can be made after desirable perennial grasses have reached dormancy". For broadleaf weed control, 2, 4-D and dicamba are options; follow manufacturers' label for pasture and hayland.

Please contact your local agricultural extension specialist or county weed specialist to learn what works best in your area and how to use it safely. Always read label and safety instructions for each control method. Trade names and control measures appear in this document only to provide specific information. USDA-NRCS does not guarantee or warrant the products and control methods named, and other products may be equally effective.

Management

Forage / Grazing **–** Experience by livestock grazers over the past 150 years has shown that eastern gamagrass will be eradicated from pastures unless careful controlled grazing practices are followed (Dewald et al., 2006). Gamagrass is so palatable to livestock that it is one of the first grasses to be eliminated under

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continuous grazing. Gamagrass regrowth has been measured at a rate of 2 inches per day. This new regrowth is tender, nutritious and greatly preferred by livestock compared to older forage. This leads to spot grazing with the same plants being defoliated almost daily, resulting in reduced plant vigor and eventual death. Eastern gamagrass stores its carbohydrates and nitrogen for regrowth in the aboveground base of its stems. Therefore, grazing must be controlled so as to maintain a minimum 6- to 8-inch stubble height for all plants. But under actual grazing, the average stubble height must be considerably higher than 6 to 8 inches in order to maintain a minimum stubble height of 6 to 8 inches on most plants in the pasture. Closer grazing or clipping will reduce plant vigor and eventually reduce the stand. Short duration, high intensity rotation grazing programs that limit the cattle to 4 to 6 days per pasture with at least eight pastures will give each pasture a 28 to 42 day rest period to recuperate.

Rest periods of 28 to 45 days have been recommended under rotational stocking. As expected, clipping studies show that lower forage production and higher forage quality are obtained with the shorter rest periods. But evidence suggests that 28 to 30 day rest periods may not be long enough to maintain vigor. In a Kansas study, individual plants of 'Pete' were clipped to 6 to 8 inches at the early heading stage, with follow-up clipping at either 28 or 42 day intervals (Fick et al., 1991). Plants clipped at the 28-day interval lost vigor and many were almost dead after 3 years. In a Missouri study using Pete, 28-day rest periods produced less hay than 42 day rest periods in four of six comparisons (Brejda et al., 1996). Under drought conditions, it was necessary to extend rest periods to 56 days. In East Texas, the cultivars Pete, 'Jackson', and accessions of Texas origin were clipped at 30-, 45-, or 60-day intervals (Brakie, 1998). Plants clipped at 30-day intervals were smaller and less robust, after 2 years, than plants clipped at either 45- or 60-day intervals. The 45-day clipping interval was optimal for the combination of forage yield and quality. In northern Mississippi, the cultivar 'Highlander' grew slowly following winter dormancy when clipped at 30-day intervals, and the forage yield declined dramatically in the third year of clipping (Edwards et al., 2000). In contrast, when clipped at 45-day intervals, plants remained vigorous. Rest periods of 40 to 45 days appear to optimize the combination of maintaining stand vigor, forage yield, and forage quality. A 45-day rest period prior to killing frost is recommended to maintain stand health.

Robert Gillen compared continuous and rotational stocking of eastern gamagrass in western Oklahoma (Gillen et al., 2006). The rest periods under rotational stocking averaged 30 days. The stubble height at the end of the rotational periods averaged 13 to 20 inches. Continuous stocking thinned the eastern gamagrass stands because of excessive spot grazing, which weakened plants. The cover of live gamagrass crowns in the continuous stocked pastures decreased from 58 percent to 44 percent compared to a decrease from 56 percent to 50 percent in the rotationally stocked pastures. This larger decrease in crown cover in the continuously stocked pastures occurred, even though grazing was terminated 40 days earlier in the continuously stocked pastures during the last 2 years of a 3-year study. Beef production (pounds of beef per acre) was higher under rotational stocking because of the early termination of grazing in the continuously stocked pastures. The gamagrass plants in the rotationally stocked pastures remained uniform and appeared healthy, even though a rest period longer than 30 days may be needed for long-term stand maintenance. The crude protein levels in clipped forage were not different between continuously and rotationally stocked pastures. A more detailed report of this study is available from Gillen et al. (2006).

In a study in Arkansas, yearling steers were stocked continuously at three stocking densities on Pete eastern gamagrass until a target canopy height (12 to 15 inches) was reached (Aiken, 1997). Initial stocking densities were 1.2, 2, or 3 steers per acre, and the respective grazing seasons were 140, 116, and 86 days. The average daily gains ranged from 1.6 pounds per head per day in early May to no gain in late September. There were no differences in average daily gains between the stocking densities, probably because forage allowance was relatively high for all treatments. But total gain per acre increased dramatically, from 195 to 420 pounds, as stocking density increased. The lowest level of total gain, 195 pounds, occurred with the combination of longest grazing season and the lowest stocking density; the highest level of gain, 420 pounds, occurred with shortest grazing and the highest stocking density. New seedlings of eastern gamagrass emerged each spring in similar denseness across the pastures, regardless of stocking density (Aiken & Springer, 1998). Some seedlings survived, which caused plant denseness to increase across the 3 years of the study in pastures with the two lower stocking densities (1.2 and 2 steers per acre). The plant denseness remained constant in pastures with the highest stocking density (three steers per acre). The concentrations of nitrogen and total nonstructural carbohydrates in bases of gamagrass stems were not affected by stocking density. The authors conclude that "eastern gamagrass can persist under continuous stocking at a variety of stocking densities if grazing is deferred for the remainder of the growing season when the canopy height falls to 12 to 15 inches."

In North Carolina, eastern gamagrass was stocked continuously from early May to late August. Stocking density was adjusted during the growing season to maintain a stubble height of 8 to 13 inches (Burns, 1992). Average daily gain over the last two-thirds of the grazing period was 1.8 pounds per head per day, which is higher than that reported in other studies. It appears that grazing management that maintains the minimum stubble heights for plant health will produce the maximum average daily gains.

Eastern gamagrass exhibits a seasonal cycle of nutritive value that is typical of warm-season grasses (Gillen et al., 2006). The nutritive value of eastern gamagrass is high during early growth with a crude protein percentage commonly above 15 and dry matter digestibility above 65 percent. As the season progresses, the nutritive value declines rapidly and the crude protein percentage falls below eight by mid-July. By August, nutritive values are 6 to 7 percent for crude protein and 42 to 47 percent for dry matter digestibility. However, if forage allowance is adequate, the actual diets of grazing animals may be substantially higher in nutritive value. In the North Carolina study discussed in the previous paragraph, the dietary crude protein percentages of steers grazing gamagrass was 19.5 and 16.5 in May and July, respectively, with dry matter digestibility levels of 77 percent and 69 percent for the same months.

Eastern gamagrass begins growth earlier in the spring than most other warm-season grasses. Consequently, an eastern gamagrass-yellow bluestem sequential grazing system is advantageous in the southern Great Plains (Gillen et al., 1999). Each grass is grazed intensely during its period of most rapid growth and greatest nutrient value: gamagrass during May and August and yellow bluestem from June though July.

In summary, eastern gamagrass has several desirable qualities including high palatability and digestibility, relatively early green-up, and high production potential. Efficient forage use and stand maintenance require either rotational stocking with 40- to 45-day rest periods or continuous grazing over a shorter season. The coarse nature of the grass promotes selective grazing on previously grazed plants under continuous stocking, which can diminish stand density. Since eastern gamagrass establishment requires considerable time and expense, producers should be committed to upper-level management, including proper fertilization and grazing management in order to take advantage of its positive characteristics and ensure optimum returns.

***Forage / Hay* –** Eastern gamagrass stores its carbohydrates and nitrogen for regrowth in the aboveground base of its stems. Therefore, clipping gamagrass to a height of less than 6 to 8 inches will deplete the stores for re-growth and damage the stand (Gillen et al., 2006). Information from several studies indicate that clipping intervals of 40 to 45 days, beginning either at 40 to 45 days after spring green-up or at the boot stage, will optimize forage yield, quality, stand vigor, and longevity. After gamagrass reaches the boot stage, forage quality decreases rapidly as the plant matures. Eastern gamagrass hay production in high rainfall climates requires skillful management because hay quality is very dependent on the cutting time. A 45-day rest period prior to killing frost is recommended for gamagrass in order to maintain stand health. Detailed accounts of the clipping interval studies are presented in the "Forage / Grazing" section.

In contrast to grazed gamagrass, the crude protein percentage of harvested gamagrass cut for hay remains high across the growing season when nitrogen fertility is adequate, because clipping uniformly stimulates regrowth. The crude protein percentage of gamagrass hay, across clipping dates, ranged from 7 percent to 14.4 percent in northern Mississippi (Douglas et al., 2002), from 10.3 percent to 13.7 percent in western Oklahoma (Gillen et al., 2006), from 10.6 percent to 14.4 percent in northern Missouri (Brejda et al., 1996), and from 10.0 percent to 16.4 percent in New York (P. Salon, personal communication, 2001).

Fig. 9: Eastern gamagrass hay. Courtesy of USDA NRCS Big Flats Plant Materials Center.

Forage / Silage – In a Missouri study, eastern gamagrass ensiled from a first-cut at either the seed development or inflorescence emergence stage and re-growth and at the proper moisture content, produced good quality silage, but with lower dry matter digestibility percentage than corn silage: 54.1 percent for gamagrass silage and 70.7 percent for corn silage (Brejda et al., 1994). In a comparison in Mississippi, either two or three cuttings of Highlander eastern gamagrass produced more forage silage yield than corn (Grabowski et al., 2003). Ensiled Highlander and corn exhibited similar crude protein percentages, but Highlander had a lower dry matter digestibility percentage than corn: 59 percent for Highlander and 78 percent for corn. In contrast, studies conducted in the Northeast show that ensiled eastern gamagrass when first-cut of growth stages earlier than inflorescence emergence, has a dry matter digestibility percentage around 70 (P. Salon, personal communication, 2001).

The most important deficiency of eastern gamagrass silage compared with corn silage is gamagrass's dramatically lower yield of developing grain and therefore lower level of digestible energy. Ensiled eastern gamagrass displays higher levels of both neutral (NDF) and acid detergent fiber (ADF) than ensiled corn, which indicates that gamagrass has less digestible energy (Brejda et al., 1994; Grabowski et al., 2003). In Missouri, gamagrass silage was 12 and 13 percentage points higher than corn for NDF and ADF respectively; in Mississippi, gamagrass silage was 14 and 9 percentage points higher than corn for NDF and ADF respectively.

Silage quality is dependent on proper moisture content of the forage at the beginning of the fermentation process, and a rapid decrease in silage pH, which is caused by the growth of lactic acid producing bacteria during the fermentation process (Bolsen, 1995). The moisture percentage of eastern gamagrass in the field can vary by 10 percentage points between early morning and midafternoon. Eastern gamagrass silage quality is adversely affected if the moisture percentage of the ensiled forage is 80 or greater (Brejda et al., 1994). In New York, gamagrass is usually wilted prior to ensiling, and it has been effectively harvested and stored as balage and as haylage at 50-60 percent moisture (P. Salon, personal communication 2001). Inoculating gamagrass silage with lactic acid-producing bacteria, in combination with the addition of molasses, is an effective way to produce a rapid decline in silage pH (Turner, 1997). Wilting cut gamagrass forage prior to ensiling slows the rate of pH decline; this effect is not unique to gamagrass.

Fertilization – A reliable, general guideline for eastern gamagrass fertilization is to follow the recommendations for the fertilization of corn for silage (Roberts & Kallenbach, 2006). This is particularly true for lime, phosphorus, and potassium. Applications of these amendments should be made according to soil test recommendations. Soil should be tested before planting and both phosphorus and potassium applied at planting to reach a medium test level for corn. The optimum soil pH range for gamagrass is probably from 5.4 to 6.0. Another estimate of the soil pH range is a minimum of 5.1 (Foy, 1999) and a maximum of 7.5 (Sharp Brothers Seed Company, 1999). It is best to delay fertilization with nitrogen until the stand is established. The North Carolina Cooperative Extension Service suggests, in the absence of research, that the yield response of gamagrass to nitrogen is similar to that of bermudagrass (Nix, 2005).

In most nitrogen fertilization studies on eastern gamagrass, the grass was harvested by clipping rather than grazing. In a study in western Oklahoma using supplemental irrigation, researchers applied 100, 250, or 400 pounds nitrogen per acre in split applications (Dewald et al., 2006). The 250-pound application produced a higher forage yield and greater economic return than the 100-pound application. The 400-pound application produced slightly more forage than the 250-pound application, but was not economical at current hay and fertilizer prices. In a study in east Texas with the eastern gamagrass cultivars Jackson, Pete, and accessions of Texas origin, the forage yield response to nitrogen was curvilinear. The nitrogen level that produced the highest forage yield ranged from 250 to 500 pounds nitrogen per acre, across entries (Brakie, 1998). The recommended application level from this study is 250 pounds nitrogen per acre. In northern Missouri, researchers compared the effect of five nitrogen levels on gamagrass forage yield at two locations for 2 years (Brejda et al., 1996). At Elsberry, Missouri, forage yield peaked both years at the 200-pound per acre application level, which was the highest level applied. In contrast, at Clifton Hill, Missouri, forage yield increased linearly with applied nitrogen up to 200 pounds, which suggests that optimum nitrogen level at this location may be higher than 200 pounds. In New York, researchers evaluated annual nitrogen applications of 0 to 200 pounds per acre to eastern gamagrass across 4 years. The nitrogen was applied at gamagrass spring green-up. The 200 pounds per acre nitrogen treatment produced more forage than the 100 pounds per acre treatment in only one of the 4 years (van der Grinten & Salon, 1995). Douglas et al. (2002) studied the affect of nitrogen fertility levels on seasonal forage yield of Highlander eastern gamagrass at three Mississippi locations: Coffeeville, Prairie, and Starkville. The nitrogen was split across three equal increments. The first increment of nitrogen was applied in the spring when the plants reached a height of 6 inches. Subsequent applications were made after each cutting. At Prairie, the response of forage yield to nitrogen fertility levels was positive and linear in both 2001 and 2002. The highest forage yield occurred at the highest nitrogen fertility level of 480 pounds N per acre. At both Coffeeville and Starkville, the response of forage yield to nitrogen fertility levels was positive and curvilinear in both years. The optimal nitrogen fertility level across both locations and years was 360 pounds N per acre.

Springer et al. (2003) studied the affect of plant density on eastern gamagrass forage yield. The experiment was conducted in western Oklahoma, with supplemental irrigation and applied fertility of 285 pounds N per acre each year (split across three applications), and 250 pounds P_2O_5 per acre applied at the beginning of the third growing season. Five years after establishment, the forage yield of the stands declined. Although only one fertility level was tested, the authors suggest that the fertility regimen did not supply sufficient nutrients for the eastern gamagrass stand. They suggest that growers should monitor the N, P, and K requirements of irrigated eastern gamagrass by soil testing. Growers should apply nutrients to meet the need of each harvest rather than the entire growing season.

In summary, nitrogen is more efficient when the total seasonal application is split across the hay and grazing season. For example, the initial nitrogen application is made at gamagrass green-up and additional nitrogen applied following each cutting or grazing period. A reliable, general guideline for eastern gamagrass fertilization is to follow the recommendations for the fertilization of corn for silage. This is particularly true for lime, phosphorus, and potassium. Studies suggest that the optimum level for nitrogen fertilizer is between 200 and 300 pounds N per acre per year, and a lower level may be optimum in regions with less than 35 inches of annual precipitation or with a cooler and shorter growing season. Growers should monitor the N, P, and K requirements of irrigated eastern gamagrass and apply nutrients to meet the need of each harvest.

Eastern gamagrass-legume mixtures – In Kansas, Gil & Fick (2001) determined net soil nitrogen mineralization in ‘Cimarron’ alfalfa, red clover (*Trifolium pratense*) and Pete eastern gamagrass monocultures, and eastern gamagrass-legume mixtures. No fertilizer was applied. The inclusion of a legume into the eastern gamagrass stand significantly increased the amount of soil nitrogen that was mineralized ($P<0.05$). Soil in the alfalfa treatments, both monoculture and gamagrass-alfalfa mixture, had more soil nitrogen mineralized than soil in the red clover treatments. The authors suggest that the greater soil nitrogen mineralization in the alfalfa and alfalfa-gamagrass treatments is because alfalfa produces litter of better quality than red clover. Clear differences between treatments for soil nitrogen mineralization were observed by the second year after crop establishment. This suggests that changes in soil nitrogen mineralization processes due to changes in plant species composition can occur in a short time. The annual, total forage yield of the gamagrass-alfalfa and gamagrass-red clover mixtures, averaged across 2 years and two locations, was 3.1 and 2.1 tons per acre, respectively; the researches did not statistically compare these forage yields. In three of the four locations-years, alfalfa in monoculture produced significantly more forage that the gamagrass-alfalfa mixture ($P<0.05$).

Salon & van der Grinten (2002) studied the intercropping of cool-season pasture legumes and grasses with eastern gamagrass at three sites in New York. Alfalfa, birdsfoot trefoil (*Lotus corniculatus*), black medic (*Medicago lupulina*), red clover (*Trifolium pratense*), white clover (*Trifolium repens*), or common oat (*Avena sativa*) were interseeded during July into spring-established eastern gamagrass stands. Interseeding produced good stands of all the companion crops. Forage yield of eastern gamagrass was reduced by each of the perennial companion crops. The reduction in gamagrass yields was caused by competition from the perennial companion crops, and more weed invasion in the gamagrass-companion crop plots. The presence of the companion crops precluded the use of Roundup when the gamagrass was dormant and 2,4-D for weed control. The authors do not recommend perennial, cool-season forage legumes as companion crops to eastern gamagrass in the Northeast. In contrast, common oat, when interseeded in July, winterkilled and was not competitive with eastern gamagrass. The authors observed that interseeded oats provided winter cover for soil erosion control, and they suggest that an oat companion crop may reduce frost heaving of soil during the first winter following gamagrass establishment.

Pests and Potential Problems

A Missouri farmer sent photographs of eastern gamagrass to the Plant Diagnostic Clinic of the University of Missouri. These photographs depicted plants with dead and diseased leaves and crowns that appeared dead or rotted. Barb Corwin, diagnostic clinic director, concluded that the disease was “take-all” (*Gaeumannomyces graminis*) (Clubine, 2001), a fungus that persists in soil and crop residues. The fungus is usually more severe under high moisture conditions, high soil pH, and low soil nitrogen. The soil pH level in the field with the take-all infected plants was 6.5.

Two viruses, “sugarcane mosaic virus strain maize dwarf mosaic virus B” and “maize dwarf mosaic virus” can infect eastern gamagrass (Seifers et al., 1993). Both viruses are transmitted by aphids. These viruses can infect, and then overwinter on eastern gamagrass. Piper et al. (1996) describes the disease symptoms, “The disease symptoms caused by these viruses vary from a general mosaic to oblong, chlorotic and necrotic spots throughout the leaf. The mosaic symptoms can vary from a pale green, very mild mosaic to a very distinct, bright mosaic on the entire plant, and are most apparent in early to midseason as the plants emerge from dormancy. Severely affected plants can develop water-soaked lesions and necrotic spots that appear later, usually becoming more pronounced in mid-summer”. Severe levels of the diseases caused by these viruses can reduce gamagrass growth and yield.

Larva of the southern corn stalk borer [*Diatraea crambidoides* (Grote)] has been identified in the crown tissue of eastern gamagrass (Fig. 10) (Krizek et al., 2002b). The authors state, “This pest occurs from Delaware/Maryland to Florida and the inland states (Kansas, Ohio, Oklahoma, Mississippi, and Arizona). This pest feeds upon corn, grain sorghum, and Johnson grass and attacks eastern gamagrass. The best strategy for avoiding damage to eastern gamagrass from the southern corn stalk borer is to remove thatch from the crop before winter. Farmers should be alert for this pest because it is highly destructive and can result in severe losses in crop yield of eastern gamagrass. Through rigorous management practices to prevent accumulation of thatch on the fields, it is possible to minimize the pest problem.”

Fig.10: Southern corn stalk borer larva. Courtesy of Clemson University – USDA Cooperative Extension Slide Series.

Eastern gamagrass plants infested with the maize billbug [*Sphenophorus maidis* (Chittenden)] were found in a germplasm nursery at Woodward, Oklahoma and in a 12-year-old grazed, gamagrass ‘Pete’ pasture at Fort Supply, Oklahoma (Fig. 11) (Maas et al., 2003). Random sampling indicated that nearly 100 percent of the plants at both locations were infested. Adult, larval, and pupal stages of the maize billbug were collected from infested plants. The authors describe maize billbug damage as, “Underground gamagrass shoots were hollowed out during larva feeding and then used for pupation. Injury to the shoot bases by newly hatched larva often resulted in partial dieback of one side of the leaf blade from the midrib outwards.” Feeding injury by adult billbug was observed; this injury, characteristic of corn, consists of transverse holes across the leaf blade. The authors state, “Damage infected during the life cycle of the pest will have a negative impact on seed production from the loss of reproductive tillers. Maize billbug damage may also contribute to the rate of center "die-out" of the plant crowns of eastern gamagrass. The control measures used in corn production may not be effective for eastern gamagrass. Research is needed to characterize the life cycle of maize billbug in eastern gamagrass and to determine effective methods of control."

Fig. 11: Maize billbug. Courtesy of Jeffery Lotz, Florida Department of Agricultural Customer Service – Department of Plant Industry.

Springer et al. (2004) estimated the potential loss in eastern gamagrass forage yield due to the combined infestation of both the southern corn stalk borer and maize billbug. In a previous experiment, conducted from 1976 to 1982, researchers measured the number of shoots per crown and crown diameter of gamagrass plants. At that time, monocultures of eastern gamagrass were rare and the corn stalk borer and maize billbug were not present in economically damaging numbers. In the current experiment, the researchers randomly sampled gamagrass plants at weekly intervals from a field that was infested with these two insects. They determined the number of insects per gamagrass shoot type (vegetative or reproductive). Based on the minimum and maximum number of insects observed per plant and the measurements from 1976-1982 experiment, the authors estimated a minimum, maximum, and average gamagrass forage yield loss of 0.08, 0.6 and 0.3 tons per acre. These estimated forage yield losses, when compared with the forage yields reported in Table 1, indicate that infestations of these two insects could significantly reduce gamagrass forage yield and stand longevity. The corresponding estimate of economic loss in eastern gamagrass hay production was from about $3.00 to $23.00, with an average of $11.00 per acre. These estimates are based on a $40.00 per ton price for gamagrass hay. The authors state, "Unless the damage to eastern gamagrass plants was severe, the cost of chemical control would be greater than the return from the forage and it is not known if chemical control would be effective…. An integrated approach to their control is likely the best. The first step is to develop eastern gamagrass cultivars with resistance to these pests…. Management strategies might include using trap crops, changing harvest dates to remove forage before insects bore into culms, or late fall burning or grazing to kill some larva and remove thatch from plants which makes insects more vulnerable to freezing."

Two years before the take-all fungus was identified on eastern gamagrass, a commercial seed producer in Clifton Hill, Missouri noticed take-all like symptoms on gamagrass. The producer contacted Chet Dewald, researcher at the USDA-ARS Southern Plains Range Research Station in Woodward, Oklahoma. While not acknowledging a name for the disease, Chet Dewald suggested burning the gamagrass residue in the spring and applying nitrogen fertilizer. The producer followed these suggestions and the disease symptoms disappeared. The suggested management practices to control take-all in eastern gamagrass are to apply adequate nitrogen fertility, leave good height residuals 45 days before frost, and burn the gamagrass residue every second or third spring.

The eastern gamagrass cultivars ‘Highlander’, ‘Jackson’, and ‘Pete’ were compared in replicated entry trials for either one or two years (2001-2002) at three locations (Coffeeville, Prairie, and Raymond, Mississipppi) (Grabowski et al., 2003). None of the plants of Jackson survived after 2001 at Coffeeville. These plants showed signs of damage from disease symptoms caused by *Pythium* species and *Rhizoctonia* species (Figs. 12 & 13).

Fig. 12: Disease symptoms caused by Pythium and Rhizoctonia species on ‘Jackson’ eastern gamagrass. Courtesy of the USDA NRCS Jamie L. Whitten Plant Materials Center.

Fig. 13: Close-up of disease symptoms caused by Pythium and Rhizoctonia. Courtesy of the USDA NRCS Jamie L. Whitten Plant Materials Center.

Ergot was observed on spikes of Highlander eastern gamagrass in Mississippi (Fig.14) (J. Grabowski, personal communication, 2005). Although it has not been positively identified, this ergot is believed to be *Claviceps tripsaci*, which has previously been reported on eastern gamagrass seedheads (Hardison, 1953).

Fig. 14: Ergot sclerotia (cream colored) protruding from seed units on female portion of eastern gamagrass spike. Courtesy of the USDA NRCS Jamie L. Whitten Plant Materials Center.

Seeds and Plant Production

Researchers at the USDA-ARS Southern Plains Range Research Station in Woodward, Oklahoma recommend planting gamagrass for seed production in rows 40 to 48 inches wide, with 4 to 6 seed units planted per foot (Dewald et al., 2006).

Investigations with two seed lots revealed that only 35 to 37 percent of seed units contained a caryopsis (Row, 1998). The percentage of seed units containing a caryopsis has a major impact on seed purity, germination test results, and ultimately field emergence. An increase in the percentage of gamagrass seed units that contained a caryopsis was obtained by partitioning seed units using either an air fractionating aspirator (Carter-Day, Model No. GF 21, Minneapolis, Minnesota) or a gravity separator (Oliver MFG, Rocky Ford, Colorado) following the cleaning of gamagrass seed units with an air seed cleaner (Clipper M2B. A.T. Ferrell and Co., Saginaw, Michigan) (Douglas et al., 2000b). Krizek et al., (2000) showed that 21 days at a constant temperature of 86° F is sufficient time for conducting eastern gamagrass germination tests.

Fig. 15: Eastern gamagrass seed harvest. Courtesy of the USDA NRCS Big Flats Plant Materials Center.

The affect of several agronomic parameters on eastern gamagrass seed unit production was examined in a study conducted in central Iowa (Lemke et al., 2003). The parameters were cultivar, ‘Pete’ and ‘Iuka IV’, applied nitrogen (0, 50, 100, 200 pounds nitrogen per acre), seed unit harvest time, and defoliation (spring, fall or no defoliation) to a height of 17.7 inches (45 cm), which was designed to stimulate grazing. Pete produced significantly more seed unit yield than Iuka IV in both years of the study ($P<0.05$); averaged across years, Pete produced 65 percent more seed unit yield than Iuka IV. The authors suggest that plants were more intensely selected for visual forage value during the development of Iuka IV than of Pete. This more intense selection for forage value may have reduced Iuka IV’s seed production. The application of 50 lb nitrogen per acre significantly increased the number of seed units in the second year of the study ($P<0.05$). However, the number of seed units did not increase at nitrogen amounts above this level. In fact, an increase in nitrogen from 100 to 200 lb per acre decreased seed unit numbers. The harvest time that optimized the number of seed units collected was approximately 2 weeks after the terminal spikes began shattering. Spring defoliation reduced seed unit production for Iuka IV in the first year and for Pete in both years. However, the number of seed units of spring defoliated plants was not much different than that of nondefoliated plants after mid-August. The authors state, “If seed and livestock producers with eastern gamagrass stands are willing to accept moderate seed yield reductions, they have the option of managing stands for both forage and seed production. Spring defoliated fields should be the last fields harvested for seed.”

A suggested seeding density for the cultivar ‘Highlander’ is 9 to 19 pounds seed units per acre with a minimum row width of 36 inches when the planting will be used for seed production (J. Grabowski, personal communication, 2005). The effect of nitrogen fertilization was evaluated on the production of fertile and vegetative tillers, seed unit yield, seed unit fill, grain weight, and seed unit germination of Highlander eastern gamagrass (J. Douglas, personal communication, 2005). Nitrogen was applied as ammonium nitrate in single and split applications of 0, 100 and 200 pounds per acre to replicated plots at Coffeeville, Prairie, and Starkville, Mississippi during 2001-2003. The single application and first of the split applications of 0, 50, and 100 pounds per acre were applied when spring regrowth reached 15 to 25 cm (6 to 10 inches), and the second application was applied when 50 percent of the fertile tillers were in the boot stage. Nitrogen increased vegetative tillers 24 percent and fertile tillers 28 percent, but the increase in fertile tiller numbers did not produce a corresponding increase in seed yield; the authors suggest that this effect was due to environmental influences and seed shattering prior to harvest. Nitrogen had a minimal effect on seed yield, grain weight, percent seed fill, and germination. There was no advantage, pertaining to the seed production parameters, from splitting the nitrogen applications. Results of this study suggest that seed producers of Highlander eastern gamagrass in the upper southeastern states should apply nitrogen fertilizer in a single application of 50 to 75 pounds per acre when spring regrowth reaches 10 inches. Environmental influences and timing of harvest were critical factors impacting seed yield and quality of Highlander.

Eastern gamagrass terminal spikes occur on the top of the stem, and lateral spikes occur at the leaf axil, which is the angle between the leaf and stem. Seed units on the terminal spikes mature earlier than seed units on the lateral spikes. Field observations suggest that a good indicator of the

Table 3. Summary of eastern gamagrass cultivar and germplasm release geographical information.

Cultivar or germplasm release	Location of selection	Anticipated uses	State symbols or region where cultivar or germplasm release is adapted
Pete	Manhattan, KS	Forage and Conservation	AR, IA, IL, IN, KS, KY, MD, MS, MO, NC, NE, NY, OH, OK, PA, TN, VA, WV
Iuka IV	Woodward, OK	Forage and Conservation	AR, IA, IL, IN, KS, KY, LA, MS, MD, MO, NC, NE, NM, OH, OK, TN, TX, WA, WV
Jackson	Nacogdoches, TX	Forage and Conservation	AL, AR, GA, MS, LA, SC, TX
San Marcos	Knox City, TX	Forage and Conservation	OK, TX
Highlander	Coffeeville, MS	Forage and Conservation	AL, AR, GA, LA, MS, NC, OK, SC, TN, TX, VA
Medina	Nacogdoches, TX	Forage and Conservation	AL, GA, LA, MS, SC, TX
Bumpers	Booneville, AR	Forage and Conservation	AR, MO, OK
St. Lucie	Brooksville, FL	Ornamental and Conservation	FL
Martin	Brooksville, FL	Ornamental and Conservation	FL
Verl	Woodward, OK	Forage and Conservation	Southern Great Plains & eastern U.S.

optimum harvest time for Highlander eastern gamagrass is when the anthers of approximately 75 percent of the flowers on the lateral spikes have shed their pollen (Grabowski, personal communication, 2005).

Cultivars, Improved, and Selected Materials

Cultivars – Geographical information for eastern gamagrass cultivars and germplasm releases are summarized in Table 3.

The eastern gamagrass cultivar 'Pete' was developed at the USDA, NRCS Plant Materials Center in Manhattan, Kansas (Fine et al., 1990; USDA-NRCSa, 2006). Seed collections were made from natural eastern gamagrass stands across Kansas and Oklahoma during 1958. Original seed from 70 of these collections was bulked to form the first generation of a composite. The composite was advanced through three generations by combine harvesting and replanting of open-pollinated seed. Pete closely resembles the wild strains of eastern gamagrass in Kansas and Oklahoma. It is nonuniform and widely adapted. The expected area of use for Pete includes the eastern third of Nebraska, the eastern halves of Kansas and Oklahoma, and the adjacent areas of Arkansas, Iowa, and Missouri. It can be grown farther west on irrigated and subirrigated sites. Pete and all other cultivars are intolerant of saline soils and may exhibit yellow leaves on soils with a pH greater than 8.5. Pete has been established successfully in southern New York. Pete is marginally adapted to selected sites in southeastern South Dakota and southern Minnesota (USDA Hardiness Zone 4b). The National Grass Variety Review Board approved Pete for certification. Breeder and foundation seed are maintained at the UDSA, NRCS Plant Materials Center, 3800 South 20 St., Manhattan, Kansas, 66502.

The eastern gamagrass cultivar 'Iuka IV' was developed by the USDA, ARS Southern Plains Range Research Station in Woodward, Oklahoma (Dewald et al., 2006). Twenty-one eastern gamagrass accessions were selected at Woodward, Oklahoma from over 500 accessions for apparent forage value. Nine of the accessions were of Oklahoma origin, six of Texas origin, four of Kansas origin, one of Arkansas origin, and one selection from the cultivar Pete. Each of the 21 accessions, plus a mixture of the Oklahoma accessions were vegetatively transplanted into an 800-foot row under irrigation at Iuka, Kansas. Plants in the 22 rows were allowed to open pollinate. The first seed crop from the 22 rows was harvested with a combine and the seed units were planted in a block that was isolated from all other gamagrass. This process was repeated for four generations. Presumably, selection occurred for plants that germinate during the first year of establishment and for uniformity of seed maturity. Farmers and ranchers have established Iuka IV in the Great Plains from southern Texas (30th parallel north) to southern Nebraska and eastern New Mexico. Also, farmers and ranchers have established Iuka IV in the region from Iowa to Maryland and southward to Louisiana. In Kansas, Iuka IV was established on a commercial seed production field, with a soil pH range from 6.9 to 8.0. A good stand exists across the whole field, but both seed and forage production are less in the area of the field where the soil pH is 8.0 than where the soil pH is less than 8.0.

The eastern gamagrass cultivar 'Jackson' was developed by the USDA, NRCS Plant Materials Center in Nacogdoches, Texas (USDA-NRCSb, 2006). Jackson was collected and evaluated as accession number 9043740. It was assigned PI-595896 after it was released. Seed of PI-595896 was collected in 1986 from a native stand in Jackson County, Texas. The PI-595896 collection was selected from 93 collections representing approximately 60 counties in Texas. The PI-595896 collection was selected for forage abundance, seed production, vigor, persistence, dry matter yield, and digestibility. There was no selection or manipulation within the PI-595896 collection. Multiplication of PI-595896 plants for seed production was by vegetative means. Little variation from seed is anticipated because the

PI-595896 collection is an apomictic tetraploid and is therefore genetically stable. The expected area of use of Jackson extends from the eastern half of Texas through the southeastern states, excluding Florida. The Breeders seed of Jackson is maintained at the USDA, NRCS Plant Materials Center, Route 3, Box 2970, Nacogdoches, Texas, 75964.

The eastern gamagrass selected class of natural germplasm San Marcos was developed by the USDA, NRCS James E. ‘Bud’ Smith Plant Materials Center in Knox City, Texas (USDA-NRCSc, 2006). Seed of the San Marcos germplasm (accession number 434493) was originally collected from plants located in Hays County, Texas, near the town of San Marcos. Elevation of the area of collection is approximately 800 feet; the soil at the collection site is classified as a Houston Black Clay. Average annual precipitation for the collection area is about 33 inches. San Marcos was compared with 55 other accessions during 1968 though 1971. Selection of the San Marcos germplasm was based on seed and forage production. San Marcos is a selection of naturally occurring germplasm and has not been altered from its original collection. The San Marcos germplasm is a tetraploid ($2n = 4x = 72$). San Marcos may be used in monocultures for pasture and hay or as a component in seed mixtures for range plantings. Wildlife can utilize both vegetative parts and seed for food, and the plants provide ground nesting cover for quail. It is anticipated that San Marcos will be adapted to the following NRCS Major Land Resources Areas (MLRA) in central Texas and southern Oklahoma: 78B, 78C, 78D, 80A, 80B, 81B, 81C, 82, 83A, 84B, 84C, 85, 86A, 86B, 87A, and 87B. San Marcos is adapted to a wide range of soil types, but will perform best on sandy loams, clay loams, and clays. It is well adapted to low, moist subirrigated sites. It is productive in areas with annual precipitation less than 28 inches only if supplied with supplemental irrigation. Generation 0 seed of San Marcos (equivalent to Breeder seed) will be maintained at the USDA, NRCS Plant Materials Center, 3776 FM 1292, Knox City, Texas, 79529.

The eastern gamagrass cultivar ‘Highlander’ was developed jointly by the USDA, NRCS Jamie L. Whitten Plant Materials Center in Coffeeville, Mississippi, the USDA, NRCS Jimmy Carter Plant Materials Center in Americus, Georgia, and the Mississippi Agricultural and Forestry Experiment Station, Mississippi State University, Mississippi (Grabowski et al., 2005). Highlander was collected in 1990 in Montgomery Country, Tennessee (MLRA 122), and evaluated as accession 9062680. Seeds were collected from plants on the Fort Campbell Army Base along Woodland Road at 36° 32’ latitude and 88° 30’ longitude. Elevation of the collection site is 182 meters (600 feet) and average annual precipitation for this location is 1016 millimeters (40 inches). Highlander is a tetraploid ($2n = 4x = 72$), (Chet Dewald, personal communication). Little variation from seed is anticipated because the Highlander is an apomictic tetraploid and is therefore genetically stable. Highlander was compared at Coffeeville, Mississippi with 72 other accessions that were collected from across nine states in the Southeast and Great Plains. Also, Highlander was compared with 11 accessions and the cultivar Jackson in a replicated entry trial at six locations across the Southeast and southern Great Plains (Table 4). Highlander was selected for superior vigor, growth form and development, forage yield and disease resistance. Highlander is recommended for hay production. It is best used as a hay crop, but it can be grazed if managed to prevent damage to the plant stand (i.e. rotational grazing). It also has potential as a perennial silage crop and as a source of biomass for energy production. It can be used in many types of conservation plantings, such as buffers, vegetative barriers, wildlife habitat, and water quality improvement. Highlander is well adapted for use in the eastern portions of USDA Hardiness Zones 6b to 8a, using Interstate 35 as its western limit. Current testing has not completely substantiated Zone 6b as the northern limit of adaptation, so it may be adapted in more northern zones.

The eastern gamagrass cultivar ‘Medina’ was developed by the USDA, NRCS Plant Materials Center in Nacogdoches, Texas (USDA-NRCSb, 2006). The permanent number assigned to Medina eastern gamagrass is PI-595897. Medina seed was originally collected in 1986 from a native stand in the Hondo Creek bottom of Median County, Texas. Medina was evaluated at Nacogdoches, Texas with 85 other collections for the following criteria: forage abundance, seed production, plant vigor, and stand persistence. These collections were from approximately 60 counties throughout Texas. Medina was one of three collections chosen for superior performance. Medina is a versatile cultivar with potential for forage uses that include pasture, hay, green chop, and silage. Other uses include animal waste management systems and conservation buffers. Medina, without irrigation, is adapted to areas that receive 25 or more inches of annual rainfall throughout USDA Hardiness Zones 8 to 9 (excluding Florida). Medina is adapted to many soil types, but deep sandy soils are not suitable. The classes of Breeder, Foundation, Registered, and Certified seed are recognized. The USDA, NRCS Plant Materials Center in Nacogdoches, Texas maintains breeder seed blocks (USDA-NRCSb, 2006). Medina seed is available from the USDA, NRCS Plant Materials Center in Nacogdoches, Texas and the Texas Foundation Seed Service.

The eastern gamagrass cultivar ‘Bumpers’ was developed by the USDA, NRCS Plant Materials Center in Booneville, Arkansas (USDA-NRCSe, 2006). The original seed of Bumpers was collected from a native roadside stand in Yell County, Arkansas (MLRA 118) and was tested under the accession 9058495. Bumpers, along with 250 other accessions were collected from 20 counties in eastern Oklahoma and 75 counties in Arkansas in 1989 and evaluated at Booneville, Arkansas for dry-matter production, plant vigor, disease resistance, seed production, and quality. Bumpers was one of three accessions chosen for the superior attributes listed above. Bumpers, as with other cultivars of this species, has the projected potential for livestock forage utilization. When used primarily in a grazing situation, appropriate grazing management techniques should be applied, such as rotational grazing to prevent damage to the plant community and stand population. Other forage options are for perennial hay, silage, and green chop. Conservation uses include nutrient sinks for conservation vegetative barriers and riparian buffers which influence water quality. Bumpers is well adapted for use in the mid-south portions of USDA Hardiness Zones 6a through 8a and for rainfall areas of 40 to 60 inches. This cultivar is recommended for western Arkansas, southern Missouri, and eastern Oklahoma. Bumpers Breeders seed is maintained at the USDA, NRCS Plant Materials Center, 6883 South State Highway 23, Booneville, Arkansas, 72927.

The eastern gamagrass selected class of natural germplasm St Lucia was developed by the USDA NRCS Plant Materials Center in Brooksville, Florida (USDA-NRCSd, 2006). The original germplasm of St. Lucia (accession number 9059278) was vegetatively collected from St. Lucia County, Florida in 1990. St. Lucia was selected from 114 accessions for its blue color, growth habit, and ability of the foliage to maintain its blue color following a light frost. St. Lucia was selected for use as an ornamental landscape plant in xeriscape and for use in buffer strips. St. Lucia is a diploid ($2n = 2x = 36$) and will outcross, producing progeny with varying color characteristics. Vegetative propagation is necessary to maintain the blue foliage characteristic. St. Lucia is adapted to USDA Hardiness Zones 8 to 10, but it will not survive temperatures below 0° F for extended periods of time. Vegetative propagules of St. Lucia will be maintained at the USDA NRCS Plant Materials Center in Brooksville Florida, and are available for propagule increases.

The eastern gamagrass selected class of natural germplasm Martin was developed by the USDA NRCS Plant Materials Center in

Brooksville, Florida (USDA-NRCS, 2006). The original germplasm of Martin (accession number 9056069) was vegetatively collected from Martin County, Florida (MLRA 155) in 1989. Martin was selected from 114 accessions for its blue color, growth habit, and ability of the foliage to maintain its blue color following a light frost. Martin was selected for use as an ornamental landscape plant in xeriscape and for use in buffer strips. Martin is a diploid ($2n = 2x = 36$) and will outcross, producing progeny with varying color characteristics. Vegetative propagation is necessary to maintain the blue foliage characteristic. Martin is adapted to USDA Hardiness Zones 8 to 10, but it will not survive temperatures below 0° F for extended periods of time. Vegetative propagules of Martin will be maintained at the USDA NRCS Plant Materials Center in Brooksville, Florida, and are available for propagule increases.

The eastern gamagrass cultivar ‘Verl’ was released in 2005 by the USDA, ARS, in cooperation with the Oklahoma Agricultural Experiment Station and the USDA, NRCS. (Springer et al., 2006). Verl is a fertile triploid ($2n = 3x = 54$) that reproduced predominately by apomixis. It was produced from a controlled pollination of a gynomonoecious sex form (GSF) diploid ($2n = 2x = 36$) with a monoecious tetraploid ($2n = 4x = 72$). Verl was selected at Woodward, Oklahoma for female fertility (seed set), male fertility (pollen stainability), and forage production attributes from 234 first generation progeny resulting from the cross GSF-1 (PI 483447)/WW-1724. Verl was tested as accession ‘FT-II’ and assigned PI 543890. Verl is recommended for pasture and hay in the eastern and southern United States. Verl can be harvested two to four times per year, depending on length of the growing season and available moisture, with a 45-day interval between harvests. Verl has excellent seed production. At Woodward, Oklahoma, Verl produced an equivalent seed yield of 152 pounds per acre. Verl is susceptible to feeding damage from the maize billbug and the southern cornstalk borer. Infestation by these insects reduces seed production of eastern gamagrass. Verl may be susceptible to *Rhizoctonia*, *Pythium*, and *Bipolaris* species. These organisms were recovered from dying plants of Verl at Coffeeville, Mississippi. Breeder seed will be available from the USDA-ARS. Foundation seed will be under the direction of the Oklahoma Foundation Seed Stocks, Inc., Department of Plant and Soil Sciences, Oklahoma State University, Stillwater, Oklahoma, 74078.

Comparison of Cultivars – The 4-year average for annual forage yield of Iuka IV was 19 percent greater than that of Pete in a replicated entry yield trial at Woodward, Oklahoma (Table 4). The difference between Iuka IV and Pete for forage yield was statistically significant ($P<0.05$). In Tennessee, the annual forage yield of Iuka IV was greater than that of Pete when both cultivars were grown in a bottomland soil ($P<0.05$). Pete, when grown on an upland soil, produced more annual forage yield than both Pete and Iuka IV growing on bottomland soil ($P<0.05$).

The 3-year average for annual forage yield of both Jackson and Median were greater than that of Pete ($P<0.05$) in a replicated entry yield trial under dryland conditions at Nacogdoches, Texas. Jackson and Median were not different for annual forage yield ($P<0.05$).

The cultivars Highlander and Jackson were compared for forage yield in replicated entry trial at six locations (Table 5). Within these locations, Highlander either had greater forage yield than Jackson ($P<0.05$) or the two cultivars did not differ. Jackson did not survive the first winter after planting at Knox City, Texas. All the plants of Jackson succumbed to disease by the third year of the trial at Coffeeville, Mississippi.

The cultivars Pete and Verl were compared for forage yield in small plot, replicated entry trials at seven locations across southern and eastern United States (Table 7). Averaged across the seven locations, the annual forage yield of Verl was 11 percent greater than that of Pete ($P<0.05$) (Springer et al., 2006). The two cultivars were not different for either seasonal average crude protein percentage or in vitro digestible dry matter percentage (P<0.05). In a replicated trial at Woodward, Oklahoma, Verl produced 159 pounds pure seed per acre, which was significantly (P<0.01) greater than the 109 pounds per acre produced by Pete.

The cultivars Highlander, Jackson, and Pete were compared for forage yield in replicated entry trials for either one or two years (2001-2002) at three locations in Mississippi (Table 6). None of the plants of Jackson survived after 2001 at Coffeeville. These plants showed signs of damage from disease symptoms caused by *Pythium* species and *Rhizoctonia* species. The cultivars were significantly different (P<0.05) for seasonal forage yield only at Prairie, where Jackson had higher forage yield than Pete.

The cultivars Pete and Iuka IV are comprised primarily of Great Plains ecotypes that were collected from the northern portion of the eastern gamagrass range. Cultivars comprised of northern ecotypes, such as Pete and Iuka IV, initiate growth earlier in the spring than cultivars comprised of ecotypes from the southern portion of the range, such as Jackson and Highlander. Malcome Kirkland, NRCS agronomist, reports that Pete produces more forage yield during the early spring at Americas, Georgia, than southern ecotypes. During middle and late summer the southern ecotypes were more productive than Pete. Malcome Kirkland suggests that farmers can lengthen the gamagrass grazing season in the southern region of the gamagrass range, by utilizing both northern and southern ecotype cultivars. The northern ecotype cultivars will provide more forage early in the spring and the southern ecotype cultivars more forage during middle and late summer. According to NRCS agronomist Sharon Pfaff, native Florida ecotypes are not dormant during winter. Therefore, this strategy would be ineffective in Florida. This strategy may also prove ineffective in the northern portion of the gamagrass range because many southern ecotypes are not winter hardy in this region.

Table 4. Comparison of four eastern gamagrass cultivars for average annual forage yield at three locations.

	Location (State symbol¶)			
Cultivar	OK	TN (bottom soil)	TN (upland soil)	TX
	-------Tons/acre of dry forage-------			
Iuka IV	3.6a§	3.2b		
Jackson				8.3a
Median				7.9a
Pete	3.0b	2.9c	4.0a	3.9b

¶ Woodward, OK, cultivar means averaged across 4 years (source: C. Dewald, pers. comm.); Knoxville TN, trial conducted for 1 year (source: Graves et al., 1997; Nacogdoches, TX, cultivar means averaged across 3 years (source: Brakie, 1998 & 2005).

§ Cultivar and soil type comparisons for average annual yield within a location followed by the same letter did not differ at P < 0.05.

Table 5. Comparison of the eastern gamagrass cultivars Highlander and Jackson for average annual forage yield across 3 years, at six locations. (source: Grabowski et al., 2003)

	Location (State symbol¶)					
Cultivar	AR	FL	GA	MS	East TX	West TX
	-------Tons/acre of dry forage------					
Highlander	6.4a§	3.4a	8.5a	8.1	5.7a	5.0
Jackson	3.5b	1.4a	8.5a	5.5‡	6.5a	†

¶ Booneville, AR; Brooksville, FL; Americus, GA; Coffeeville, MS; Nacogdoches, TX (east); Knox City, TX (west).

§ Cultivar comparisons for average annual yield within a location followed by the same letter did not differ at P < 0.05.

‡ Plants of the cultivar 'Jackson' were not harvested during the 3rd year of the study because they succumbed to disease.

† Indicates that plants winterkilled during the first winter.

Figure 16: Eastern gamagrass pasture. Courtesy of Eastern Gamagrass Seed Company[1].

Table 6. Comparison of the eastern gamagrass cultivars Highlander, Jackson, and Pete for average annual forage yield at three locations in Mississippi. (source: Grabowski et al., 2003)

	Location		
Cultivar	Coffeeville	Prairie	Raymond
	-----------------Tons/acre of dry forage-----------------		
Highlander	6.2a§	6.8ab	9.6a
Jackson†	5.5a	7.8a	8.1a
Pete	4.9a	5.4b	11.7a

§ Cultivar comparisons for average annual yield within a location followed by the same letter did not differ at $P < 0.05$.

† None of the plants of cultivar 'Jackson' survived at Coffeeville after 2001. These plants showed signs of damage from Pythium ssp. and Rhizoctonia ssp. damage.

Table 7. Comparison of eastern gamagrass cultivars for annual forage yield at 7 locations (source: T. Springer, personal communication, 2006)

	Location (State symbol¶)						
Cultivar	FL	KS	MS	MO	NY	OK	TX
	------------------------------ Tons/acre of dry forage ------------------------------						
Pete	2.5a§	2.2b	4.9a	2.7b	3.5b	2.1a	1.1a
Verl	3.1a	2.7a	5.0a	3.9a	4.9a	2.5a	1.3a
Highlander			5.9a				
Jackson			5.1a				

¶ Brooksville, FL; Manhattan, KS; Coffeeville, MS; Elsberry, MO; Big Flats, NY; Woodward, OK; Knox City, TX (west).

§ Cultivar comparisons for average annual yield within a location followed by the same letter did not differ at $P < 0.05$.

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Glossary and Abbreviations

Table 8. Glossary and abbreviations

Abbreviation	Term	Definition
	Accession	Plant material (plant, seed, or vegetative part) collected and assigned a number to maintain its identity during evaluation, increase, and storage.
ADF	Acid detergent fiber	ADF is subfraction of NDF. It is the percentage of highly indigestible plant material in forage. The ADF level is inversely related to the energy value of forage.
	Anther	The pollen-bearing apical part of the stamen.
	Apomixis	Production of seeds by asexual methods.
	Axil of leaf	The upper angle between a leaf and the stem.
	Boot stage	The developmental stage at which a grass inflorescence is enclosed by the sheath of the uppermost leaf.
	Caryopsis	A dry one-seeded fruit (as in grasses). *Synonym:* kernel.
	Crude protein	Crude protein is the sum of true protein and nonprotein nitrogen. It is a measure of a forage's ability to meet the protein needs of livestock.
	Cultivar	An assemblage of plants that has been selected for a particular attribute of combination of attributes, that is clearly distinct, uniform, and stable in these characteristics, and that when propagated by appropriate means retains these characteristics.
	Cupule	Cuplike structure as the base of some fruits.
	Denitrification	Reduction of nitrogen oxides (usually nitrate NO_3 and nitrite NO_2) to molecular nitrogen N_2 or nitrogen oxides with a lower oxidation state of nitrogen by bacterial activity (denitrification) or by chemical reactions involving nitrite (chemodenitrification). The end products N_2 and N_2O are gasses which become part of the atmosphere.
	Digestibility	Digestibility is the extent to which forage is absorbed as it passes though an animal's digestive tract.
dADF	Digestible ADF	The digestible portion of ADF.
dNDF	Digestible NDF	The digestible portion of NDF.
	Diploid (2n=2x=36), tetraploid (2n=4x=72), etc.	An individual with cells that have two sets of the basic chromosome number x. A diploid (2n=2x=36) plant has cells with two sets of the basic chromosome number = 18. A tetraploid (2n=4x=72) plant has cells with four sets of the basic chromosome number = 18.
	Ecotype	A variety or strain within a species that maintains its distinct identity by adaptation to a specific environment.

Abbreviation	Term	Definition
	Flowering stage	The physiological stage of a grass plant in which anthesis (blooming) occurs, or flowers are visible in nongrass plants.
	Grass tetany	Condition of cattle and sheep marked by titanic staggers, convulsions, coma, and frequently death. Characterized by a low level of blood magnesium.
	Gynomonoecious	Having both perfect and female flowers on the same plant
	In vitro	Outside a living organism.
IVTD	In vitro true digestibility	Digestibility determined by incubating a ground forage sample with rumen fluid in a test tube.
	Lignin	Lignin is another component found in plant cell walls. It is almost completely indigestible. Therefore, as the lignin percentage increases, forage digestibility decreases.
NDF	Neutral detergent fiber	The total fiber content of forage. NDF represents the indigestible or slowly digestible components in plant cell walls. As NDF increases above 35 per cent of dry matter, animal feed intake declines.
	Nitrogen mineralization	The conversion of nitrogen from an organic form to an inorganic state as a result of microbial activity.
	Pericarp	The tissue that surrounds (in grasses) the single ovule.
	Polyploidy = triploid, tetraploid, pentaploid, or hexaploid	An individual with cells that have more than two sets of the basic chromosome number x.
$P<0.01$	Probability of less than 0.01	Indicates that there is a 99 percent probability that the differences between two or more treatments (for example, yields of two or more cultivars) did not occur by random change.
$P<0.05$	Probability of less than 0.05	Indicates that there is a 95 percent probability that the differences between two or more treatments (for example, yields of two or more cultivars) did not occur by random change.
	Rhizome	Any prostrate, more or less elongated stem growing partly or completely beneath the surface of the ground, usually rooting at the nodes and from which nodes ascending stems can arise.
	Spike	An inflorescence with the flowers sessile on a more or less elongated axis.
	Stockpiled forage	To allow forage to accumulate for grazing at a later period. Forage is often stockpiled for autumn and winter grazing.
	Stolon	Horizontal stem produced along or above ground, rooting at some nodes.
	Testa	The matured outer layer of the seed.

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Dedication

This technical note is dedicated to the memory of Chet Dewald, USDA-ARS geneticist and researcher with eastern gamagrass.

For More Information

For more information about this and other plants, please contact your local NRCS field office or Conservation District, and visit the PLANTS Web site<http://plants.usda.gov> or the Plant Materials Program Web site <http://plant-materials.nrcs.usda.gov>