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Eastern Gamagrass as a Potential Biofuel Crop

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ABSTRACT

Eastern gamagrass [*Tripsacum dactyloides* (L.) L] is a native warm season perennial grass with potential to produce large amounts of biomass in the southeastern states. Clipping frequency, fertility, and genotype greatly influences biomass production. Row crop equipment can be used to establish and produce eastern gamagrass commercially. Accession 9062680 has the yield potential, adaptation and disease resistance for further consideration as a biofuel crop. However, there are several questions that must be answered before this accession of eastern gamagrass can be recommended and utilized for biomass production in the southeastern U.S.

INTRODUCTION

Eastern gamagrass is a native grass that once covered thousands of acres in Texas but has been virtually eliminated due to poor grassland management (Polk and Adcock, 1964). However, because of the efforts of the plant materials program of the USDA-Natural Resources Conservation Service (NRCS) and the USDA-Agriculture Research Service, eastern gamagrass is steadily gaining popularity for forage and conservation of natural resources. In addition to its forage and soil conservation attributes, its use as a biofuel crop has been recognized (USDA, 1992). This paper summarizes the biological characteristics and production practices for eastern gamagrass. Information gained from this literature review will be used to assess potential use of eastern gamagrass as a biofuel crop on marginal cropland in the southeastern U.S.

1. Biological Characteristics

1.1. Plant description

Eastern gamagrass is a perennial, warm season bunchgrass with medium to erect growth habit that spreads by short rhizomes and produces seed from July to September on stems 3 to 9 feet tall (Hitchcock, 1951; Phillips Petroleum Co., 1963). Its inflorescence consists of one to several subdigitately arranged racemes. The grass is monoecious with the apical two-thirds to three-fourths of the racemes composed of male spikelets with one to several female spikelets (seed units) in the basal portion of the racemes. The female spikelets are individually sunken

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into the rachis internode. They are solitary with one functional floret, whereas the male spikelets are born in pairs with two functional florets (Dewald et al., 1987). The basal crowns of the plant, which range in size of 1 to 4 feet in diameter, are formed by a proliferation of compact shoots consisting of both vegetative and reproductive tillers in different stages of development (Dewald and Louthan, 1979; Phillips Petroleum Co., 1963). These shoots are interconnected through several tiller generations by a woody stem base (Dewald et al., 1996).

1.2. Geographical and ecological distribution

Eastern gamagrass is native throughout the southeastern U.S. (USDA-SCS, 1976) but may be found growing from Massachusetts to Michigan, Iowa and Nebraska south to Oklahoma and Texas (Hitchcock, 1950). Rechenthin (1951) reported that eastern gamagrass flourishes in areas receiving 36 to 50" of rainfall. It can be found growing in swales, along streambanks, and other lowland areas that are fertile and moist (Hitchcock, 1951; USDA-SCS, 1991). It is not adapted to alkaline sites (USDA-SCS, 1991).

1.3. Invasiveness

The literature did not indicate that this plant is invasive. From our knowledge and experience of this grass it does not possess or present any invasive characteristics. The cupulate fruitcase that protects seed from predation and damage as it passes through the digestive tract of animals may prolong seed viability in the soil (Anderson, 1990).

2. Production Practices

2.1. a. Clipping frequency

Eastern gamagrass grows continually throughout the growing season and rapid regrowth following defoliation allows for multiple harvests to be taken during the growing season. In southern Illinois, Faix et al. (1980) harvested eastern gamagrass three times during the growing season in 1975 and 1977 and four times during the growing season in 1976. The average yield was 7.8 ton/acre. Brakie (1998) reported that Texas genotypes of eastern gamagrass harvested at 30, 45, and 60 day clipping frequencies produced 4.4, 5.5 and 6.6 ton/acre, respectively in eastern Texas. A 30 day clipping frequency was found to be too short an interval for long term sustainable yields. Edwards et al. (1999) reported that eastern gamagrass cut on a 45 day clipping frequency produced 6.3 ton/acre in northern Mississippi. On a single cut harvest regime in central Florida, eastern gamagrass yielded 1.9 ton/acre (Mislevy et al., 1986).

2.1. b. Fertility

Nitrogen fertilization is an important management practice for increasing forage production of warm season grasses (Hall et al., 1982). Brakie (1998) compared yield response of eastern gamagrass to N rates of 0, 125, 250 and 500 lb/acre/year in eastern Texas. The 0 lb/acre rate produced 3.1 ton/acre, 125 lb/acre rate produced 5.5 ton/acre, 250 lb/acre rate produced 6.7 ton/acre and 500 lb/acre rate produced 6.8 ton/acre. The author concluded that the optimum nitrogen rate for forage production in eastern Texas is 250–300 lb/acre. Mislevy (1986) reported a 0.9 ton/acre increased in yield of eastern gamagrass when 75 lb/acre N was applied compared to no N fertilizer.

2.1. c. Genotypes/cultivar

PMK-24 eastern gamagrass was informally released in 1974 by the USDA-Soil Conservation Service (SCS), and was later released as 'Pete' in 1988 by SCS and the Oklahoma Agriculture Experiment Station (Fine et al., 1990). Whether evaluated as PMK-24 or Pete, researchers have reported favorable yields and animal performance in areas where the cultivar is adapted (Aiken, 1997; Bredja et al., 1997; Burn et al., 1992; Fine et al., 1990; Faix et al., 1980). However, in parts of the southeastern U.S., Pete exhibits lower vigor and reduced yields as compared the more northern locations where the grass has been extensively tested (Brakie, 1998). At Coffeeville, Mississippi Pete is less vigorous and apparent productivity is less than the local ecotypes. Because Pete originated from a northern region it is likely that it will not do as well in the southern region. Generally, plants moved southward do not utilize the growing season, are less vigorous, more susceptible to diseases and are sensitive to day length (Thornburg, 1982). Tetraploid genotypes are more robust and capable of producing higher yields than diploids in the southeastern states.

In 1998, the USDA-NRCS East Texas Plant Materials Center released 'Jackson' eastern gamagrass, a tetraploid, for eastern Texas and western Louisiana. Yield comparisons of several Texas genotypes and Pete harvested on a 60 day clipping frequency at different N rates are presented below.

Average of the 1993-1994 dry matter yields of Texas Genotypes and Pete by N rates for a 60 day clipping frequency in eastern Texas (Brakie, 1998).

Accession/Cultivar	N Rates 0	125	250	500
	------------------------------lb/acre------------------------------			
9043762	7993	12334	20943	21690
9043740*	9197	18566	23469	17884
9043629	11600	15942	19291	16991
434493	5621	5994	12038	8503
Pete	5363	8545	7320	7081

* released as Jackson in 1998.

In 1994, the USDA-NRCS plant materials program began a study to evaluate the yield and quality of the 13 best genotypes from previous testing at southern plant materials centers (PMC). Results of the yield comparisons at PMCs in Americus, Georgia, Coffeeville, Mississippi and Booneville, Arkansas are presented on the next page. In this study, it was found that Florida genotypes were susceptible to winter kill at Booneville, Arkansas and Coffeeville, Mississippi. However, the Florida genotypes persisted in Americus, Georgia, which is in the lower region of the Deep South. A *Rhizoctonia* and *Pythium* disease complex may have caused major damage and mortality to genotypes at Coffeeville (J. Robbins, personal communication). However, accession 9062680 was apparently resistant to this complex and remained productive.

Accession 9062680, selected by the Jamie L. Whitten Plant Materials Center, Coffeeville, MS, will be further evaluated for potential release as an eastern gamagrass cultivar for the southeastern U.S. Selection attributes include high yield, quality, and resistance to *Rhizoctonia* and *Pythium*.

Total dry matter yield by year and average of eastern gamagrass genotypes at Booneville, Arkansas.

Accession	DM yield 1996	1997	1998	Avg.
	---------------------------lb/acre-----------------------------			
434493	15 554	8805	9979	11 446
9043629	12 081	4936	7156	8058
Jackson	9185	5098	6943	7075
9043762	13 581	11 020	11 061	11 887
9055975	4051	*	*	
9059213	4999	*	*	
9059215	4168	*	*	
9058465	13 033	7730	9845	10 203
9058495	14 000	9916	12 657	12 191
9058569	12 332	5344	6985	8220
9062708	13 566	8400	9148	10 371
9062680	**12 403**	**11 864**	**14 228**	**12 832**
9066165	16 087	9048	11 551	12 229
Mean	12 229	8309	10 093	10 451
LSD (0.05)	4206	1592	2192	2590

* - Plots were winter killed.

Total dry matter yield by year and average of eastern gamagrass genotypes at Coffeeville, Mississippi.

Accession	DM yield 1996	1997	1998	Avg.
	--------------------------lb/acre----------------------------			
434493	12 528	12 525	†	
9043629	9442	12 186	†	
Jackson	8754	13 420	†	
9043762	11 311	†		
9055975	2032	*		
9059213	4971	*		
9059215	5950	*		
9058465	14 535	13 394	†	
9058495	12 877	20 019	†	
9058569	6859	12 101	†	
9062708	12 017	15 388	†	
9062680	**12 747**	**23 604**	**12 000**	**16 117**
9066165	14 149	12 120	†	
Mean	9859	10 366		
LSD (0.05)	3724	4525		

* winterkilled in 1996-1997.

† plants killed by *Rhizoctonia* and *Pythium* disease complex.

Total dry matter yield by year and average of eastern gamagrass genotypes at Americus, Georgia.

Accession	DM yield 1996	1997	1998	Avg.
	---------------------------lb/acre-------------------------			
434493	17 073	17 703	15 049	16 608
9043629	------*	11 249	11 693	11 471
Jackson	17 392	22 399	11 195	16 995
9043762	14 611	16 504	13 882	14 999
9055975	6535	7695	5722	6651
9059213	13 541	16 183	9863	13 196
9059215	15 318	17 953	11 103	14 791
9058465	15 300	16 074	11 872	14 415
9058495	16 162	12 794	9873	12 943
9058569	10 717	5916	2647	6427
9062708	17 358	16 449	14 476	16 094
9062680	**19 637**	**17 406**	**14 165**	**17 070**
9066165	19 267	16 973	14 102	16 781
Mean	15 243	15 023	11 203	13 726
LSD (0.05)	2144	2910	4297	2623

* Not harvested in 1996.

Establishment

2.2. a. Planting rate

A clean firm and smooth seedbed is critical for establishing eastern gamagrass. This is accomplished by disking, harrowing and firming the soil prior to planting. There is currently no standard ADSA testing procedure for determining germination. Secondly, laboratory germination tests may be misleading because of seed dormancy. Dewald (1996) reported there were 6000 good quality seed units in one pound of eastern gamagrass while the Jamie L. Whitten PMC has determined that there are 3400 seed units in one pound of 9062680. These differences may be contributed to ploidy levels in the grass. A diploid seed unit is smaller than a tetraploid seed unit; thus, they are more seed per lb in a diploid than a tetraploid. A seeding rate for a 6000 and 3400 seed unit per pound gamagrass planted on 40" rows (4-6 seed per linear ft.) is about 10 and 20 lb/acre, respectively. A 60" row spacing is suitable for hay and silage production while a 36" is recommended for seed production (USDA-SCS, 1991). Because seed quality of eastern gamagrass is variable, it would be advisable to determine percent seed fill before planting to avoid planting poor quality seed.

2.3. b. Vegetative establishment

Establishing stands of eastern gamagrass from vegetative rootstock has been evaluated with varying results (Ahring and Franks, 1968; Dewald and Sims, 1981). Transplanting rootstock during the dormant season has resulted in a 90-100 % survival rate. However, labor and specialized planting equipment limits this method of establishment. Also, the dormant season in the southeastern states is often too wet to plant, especially in the lowlands where this plant is adapted.

2.4. c. Seed quality

Planting quality seed is one of several factors necessary for establishing successful stands of eastern gamagrass. Indeterminate seed maturity is another factor that indirectly affects seed quality. A typical combine-run harvest consists of complete seed units (cupulate fruitcase with filled seed), incomplete seed units (cupulate fruitcase with unfilled seed) and other non-viable inert matter. Inability to adequately separate filled seeds from unfilled seeds may lead to poor establishment (Ahring and Franks, 1968). Douglas et al. (2000) found that seed quality can be greatly improved with an air fractionating aspirator or gravity separator as opposed to a standard air screen cleaner. A summary of these findings is presented below.

Percent seed fill by lot and fraction for two cleaning techniques.

	AFA[1/]			GS[2/]
	Lot			
Fraction	**A**	**B**	**C**	**C**
	--------------------------------%----------------------------------			
1	93	90	87	90
2	90	90	80	30
3	57	73	43	--
4	10	20	20	--
Air Screen Cleaner	47	23	23	23
LSD (0.05)	22	12	25	30

1/ - Air Fractionating Aspirator
2/ - Gravity Separator

Percent germination by lot and fraction for two cleaning techniques.

	AFA[1/]			GS[2/]
	Lot			
Fraction	**A**	**B**	**C**	**C**
	------------------------------%----------------------------------			
1	43	21	24	48
2	35	29	25	15
3	15	15	18	--
4	3	3	3	--
Air Screen Cleaner	22	22	16	22
LSD (0.05)	12	12	10	13

1/ - Air Fractionating Aspirator
2/ - Gravity Separator

2.5. d. Seed treatment

Seed of eastern gamagrass is protected between a rachis internode and an outer glume association known as a cupulate fruitcase (Galinat, 1956). This seed structure has been shown to inhibit germination in some genotypes of eastern gamagrass, but germination can be enhanced with cold-moist stratification for 60 days followed by exposure to temperatures of at least 30° C (Anderson, 1990). Planting stratified seed increases establishment success of eastern gamagrass. Many seed dealers offer stratified seed as an option to dry seed. If dry seed is purchased it will need to be either artificially stratified or fall or winter planted to allow the seed to undergo a natural stratification process.

2.6. e. Seed Depth

Seed should be planted 1 and 1-1/2 inches deep (Dewald, 1996), especially seed that has been stratified. Planting stratified seed too shallowly may result in secondary dormancy if the seed is allowed to dry out before germinating (Martin et al., 1976).

2.7. f. Planting Date

Plant stratified seed in April-May in the southeastern states. Although fall planting has been considered as an alternative to artificial stratification this strategy has given mixed results in the Midwest due to fluctuations in winter weather patterns from year to year (Row, 1998).

2.8. g. Planting Equipment

Eastern gamagrass seed can be drilled planted with a row crop planter. Because of the similarities to a corn seed, a corn planter has been recommended for planting eastern gamagrass seed (USDA-SCS, 1991). Broadcast plantings are not recommended.

2.9. h. Weed Control

There are no labeled herbicides for establishment of eastern gamagrass. 2,4-D is recommended for broadleaf weed control. Because eastern gamagrass is planted in rows, cultivation can be an effective weed control method.

2.10. i. Seed Production and Harvesting

Eastern gamagrass seed can be direct harvested with a conventional combine. The average seed yield of Pete at the Manhattan, KS PMC has been 159 lb/acre (Blan, 1990). As far as we know, there has been no seed yields recorded for eastern gamagrass in the southeastern states.

Questions that need to be answered before advancing accession 9062680 eastern gamagrass as a biofuel crop for marginal cropland in the southeastern states.

1. What is the best cutting management regime for the grass in the Southeast?
2. How does it compare to Alamo switchgrass and standard introduced grasses (bermudagrass, and bahiagrass) in terms of biomass production when managed as a biofuel crop?
3. What are the fuel quality estimates of eastern gamagrass?
4. How do fuel quality estimates compare to other biofuel crops such as switchgrass?
5. How deep to plant gamagrass seed that has been stratified to prolong stratification and prevent it from drying out before it germinates?
6. How do GA treatments effect germination and emergence?
7. How does standard hay cutting and baling equipment work on eastern gamagrass managed for biomass?

CONCLUSIONS

Eastern gamagrass has many desirable characteristics that warrant further investigation as a biofuel crop in the southern states. Such traits include but are not limited to is its perenniating ability, adaptation to soils and climate of the Southeast, high yield potential, non invasiveness, seed propagation, and adaptation to conventional row crop equipment used by many farmers in the southeastern states. However, before eastern gamagrass can be recommended for biomass production several questions concerning management for optimum production and establishment will need to be answered.

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