United States Department of Agriculture

FINAL STUDY REPORT
East Texas Plant Materials Center
Nacogdoches, Texas

Screening Switchgrass Germplasm from Southeastern Texas for Forage and Biofuel Potential

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ABSTRACT

Switchgrass evaluation at the East Texas Plant Materials Center, Nacogdoches, Texas

An assembly of switchgrass, *Panicum virgatum* L., ecotypes collected in east Texas was compared to existing cultivars released from the USDA NRCS Plant Materials Program. Nineteen lines were compared to four cultivar level switchgrass releases and one unreleased line, 9062821 Kemper County, MS, from the Coffeeville Plant Materials Center in Mississippi. The USDA NRCS cultivars and unreleased line represented upland and lowland switchgrass types used for comparison to identify accessions with excellent biomass production and improved forage characteristics. Accession 21 showed promise with biomass production similar to ‘Alamo’ switchgrass and significantly improved forage qualities. Accessions, 2 and 3, were also identified for high biomass production.

INTRODUCTION

Switchgrass is a native, warm season, perennial, bunch grass with attributes that make it valuable for conservation plantings, livestock forage, and biomass energy production (Vogel 1996, Ball et al., 2002). ‘Alamo’ and ‘Kanlow’ are two varieties cooperatively released through the USDA Natural Resources Conservation Service (NRCS) Plant Materials Program have sparked recent interest for cellulosic ethanol production due to their biomass production. ‘Alamo’ and ‘Kanlow’, both lowland types, are capable of producing yields in excess of 12 tons per acre in the southern U.S. with a single harvest in late fall following a spring application of

100 lb/N/acre (McLaughlin et al. 1999; McLaughlin and Kszos, 2005). However, lignification reduces forage digestibility (Moore and Mott, 1973; Cowling, 1975, Jung and Vogel, 1986) and animal performance (Duble et al., 1971).

Visual comparison of leaf morphology within the study with accession 21 on the front right having longer, less erect leaves with greater width that its neighbor on the left

The USDA NRCS East Texas Plant Materials Center (ETPMC), working with the Native Prairie Association of Texas (NPAT), developed a seed increase field of locally adapted switchgrass ecotypes for prairie restoration work in areas where genetic purity was a concern or using only local ecotypes was permitted. There were noticeable differences in ecotypes within the collection with several plants exhibiting superior vigorous, rapid growth and other desirable attributes. These individuals were identified for evaluation in a common nursery. Therefore, the objective of this study was to compare the biomass production and forage quality of switchgrass ecotypes from the NPAT material to commercially available cultivars and sources for biomass production and forage quality.

MATERIALS AND METHODS

Nineteen plants exhibiting favorable regrowth following prescribe burn, strong vigor, disease resistance, and other attributes, were visually selected from the NPAT seed increase fields at the ETPMC near Nacogdoches, TX. The selected material was dug from the field and divided into four clonal plugs containing 20 stems each. Plugs consisting of 20 stems of ‘Kanlow’, ‘Alamo’, ‘Blackwell’, ‘Cave-in-Rock’, and selection 9062821 from the Jamie L. Whitten Plant Materials Center, Coffeeville, MS served as comparison controls. The five controls represented upland and lowland switchgrass types (Table 1) and brought the total to 24 plots per replication. Each clone was assigned a number (1-24) to identify them in the evaluation nursery. Clonal plugs were planted on four foot centers in a randomized complete block design with each clone representing a replication (four replications). A boarder row was planted around the study perimeter to mitigate edge effects.

Each ecotype and control was measured for height annually by measuring the absolute plant height in each plot after seed set. Disease resistance and tiller density were rated annually with 1 = best and 9 = worst. Spread is the distance the plants spread from their original crown and determined by measuring the plants’ width in a north and south, and east and west directions. Dry biomass yield per plot was recorded in 2009 and 2014 at the boot stage. Plants were cut to a height of 10 inches. A representative sample was collected from the harvest for percent moisture. Leaf length, leaf width, stem diameter, and leaves per stem measurements were recorded once during the study when the plants reached the boot stage. These measurements consisted of 10 random samples from each plot in replications 1 and 2, and were taken during the second year of the study, 2009 only. Forage quality estimates of percent acid detergent fiber (ADF) and percent protein were determined by sampling forage from replications, 2, 3, and 4, in 2009 and 2010, when plants reached boot stage. Samples were harvested by cutting 15 stems in each plot approximately 10 inches above the ground, drying them at 60^oC overnight in a forage dryer, and grinding them in a Wiley Mill to pass a 1 mm screen.

Samples were sent to the agronomy lab at Stephen F. Austin State University, Nacogdoches, Texas to determine acid detergent fiber (ADF), and crude protein (CP). Percent total digestible nutrients (TDN) was estimated using (73.5 + (0.62 * %CP) – (0.71 * %ADF). Crude protein was estimated by multiplying percent nitrogen by 6.25. Acid detergent fiber was determined using the Van Soest detergent method described by ANKOM Technology (1998). Percent N was determined with a combustion procedure using a vario MACRO elemental analyzer (Elementar Analyse Systems GmbH, 2007). When data were normally disturbed and variances equal, an analysis of variance was used to determine differences in plant growth characteristic and forage quality. Significant means were separated using the least significant difference test and Tukey’s HSD at the 5% level of probability.

RESULTS AND DISCUSSION

There was a 98% survival rate on the transplanted material in 2008. After two years most plots had obtained the maximum sized allowed by the plant spacing and required tillage to keep them separated. Dry biomass yields ranged from 6.1 to 12.4 (Figure 1). Eleven accessions produced greater dry matter yields than Alamo, the recommended cultivar for conservation plantings in east Texas. Accession 2 produced the highest dry matter yield which was 50% greater than ‘Cave-in-Rock’; 42% greater than ‘Blackwell’; 32% greater than Kanlow, and 23% greater than Alamo. Accession 9062821 from Mississippi produced greater yields than the other control at 10.6 pounds per plot.

Forage quality estimated of percent ADF, TDN and CP at the boot stage for switchgrass accessions are shown in Table 2. Acid detergent fiber ranged from 41 to 53%, TDN from 40-47%, and CP from 5-8%. There were significantly differences among accessions for TDN and CP but the magnitude of the differences were small. Accessions 21 had the highest TDN (49%) and Kanlow and 9062821 the highest CP (8%). Douglas et al. (1995) reported a higher TDN (57%) and CP (10%) for upland switchgrass ecotypes and Blackwell harvested at the boot stage in Mississippi. In comparison to bermudagrass (*Cynodon dactylon*), the primary perennial forage in the southeastern U.S., ‘Coastal’ harvested at 4 to 6 week intervals was higher in forage quality (Ball et al., 2002) than any of the switchgrass accessions harvested at the boot stage. Accession 9, 14, 15, 18, 21, and 24 met the TDN and CP requirements for a dry, pregnant beef cow (National Research Council, 1986). Accession 21 showed significantly increased forage characteristics compared to the other accessions with the lowest ADF and consequently the highest TDN (49%). It also ranked high in protein (7%).

A high leaf to stem ratio is a desirable attribute for forages and affects diet selection and forage intake of grazing livestock. Stem and leaf morphological characteristics at the boot stage, and plant height at maturity, are presented in Table 3. There were several accessions with similar number of leaves per stem and ranged from 5.3 to 7.9. Accession 14 had the highest number of leaves per stem and significantly more compared to Cave-in-Rock, Blackwell, and accessions 20 and 21.

Smaller stems are desirable forage characteristic because small size stem cure more easily than larger stems, allowing the cut hay less exposure time to the elements prior to baling. There were significant difference in stem diameter of the switchgrass accessions, ranging from 3.90 to 6.98 mm. Cave-in-Rock and Blackwell had the smallest stem diameters which is characteristic of upland types in the Southern Plains (Eberhart and Newell, 1958). Also exhibiting similar stem size are accessions 2 and 5. Larger stemmed accessions are better suited for conservation buffers for soil erosion control where the size and density of stems are critical in dispersing concentrated flow (Dewald et al., 1996).

Leaf length varied among accessions with the average length approximately 24 inches. Accessions 7 and 14 had significantly longer leaves than Cave-in-Rock and 9062821. Plant height ranged from 50 to 78 inches at maturity. Blackwell and Cave-in-Rock, and accessions 1, 2, 9, 11, 2, 21, 23, and 24 were significantly smaller in stature than Alamo, the tallest plant in the nursery. Accessions 6, 7, 13, 14 and Kanlow were similar in height to Alamo.

Accession 21 exhibited a trend for greater dry matter yield when compared to ‘Alamo’ and ‘Kanlow’ (Figure 1), but was significantly shorter in stature than ‘Alamo’ and ‘Kanlow’; one of the shortest accessions in the study (Table 3). It also had the highest tiller density (figure 2), and lowest spread (Figure 3). Indicating that while it did not occupy as much space as other accessions, the space that it did occupy was densely packed with stems. This characteristic is desirable for erosion control in concentrated flow areas along field borders or vegetative barriers. Accession 21 also had a perfect disease rating throughout the course of the study (Figure 4). The environmental factors in east Texas are favorable for fungal pathogens such as the *Puccini* sp. that create rust on Indiangrass and easterngama grass. These fungal pathogens often result in decrease vigor and plant health. When combined with other stress factors they can even result in stand loss (Handley et al 1990; Staples 2000). Significant differences were found for leaf width and length where accession 21 ranked among the highest mean groups for these characteristics (Table 3). Those two factors combined with its tiller density could help attribute to good dry matter yields while being shorter, with less spread than other accessions. There were also significant differences for the number of leaves per stem and stem diameter where accessions 21 ranked as average or slightly below (Table 3).

Accession 3 ranked the highest in dry matter yield/plant, greater than ‘Alamo’ and ‘Kanlow’ (Figure 1). It was also in one of the highest mean categories for height and stem diameter (Table 3). Accession 3 produced the highest ADF. A high ADF is desirable for residue used in different combustion system to generate energy. These traits indicate potential for creating a release with superior biofuel qualities and should be investigated further. Accession 2 was noteworthy as well with the highest dry matter yield in the study Figure1.

CONCLUSION

19 switchgrass accessions were compared to 4 cultivar level releases and one pre varietal line developed through the USDA NRCS Plant Materials Program. The plants were evaluated for dry biomass yield, forage quality, spread, disease resistance, tiller density, height, and related morphological characteristics such as stem diameter, number of leaves per stem, leaf length, and leaf width. Accession 21 ranked highest in forage quality and showed a trend for higher biomass yields when compared to existing cultivars used for biomass production. It shows promise as a dual purpose plant release for forage and biofuel purposes. Due to its smaller stature, accession 21 should be typed genetically to determine if it is an upland or lowland type. Accessions 2 and 3 exhibited excellent biomass production and should be evaluated further to determine their potential as a biomass specific release. The ETPMC is currently evaluating existing switchgrass cultivars from the south eastern United States for adaptability to east Texas to determine their potential for use in conservation practices in east Texas. Germplasm from accessions 2, 3, and 21 will be stored at the ETPMC for future use in release development.

Table 1: Plant Materials Program Switchgrass Cultivar PI Numbers, Origins, and Identification USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar/Source	Type	Acc. Study#	Origin	Releasing PMC
Kanlow	Lowland	16	Hughes County, OK	Manhattan, KS
Alamo	Lowland	19	Live Oak County, TX	Knox City, TX
9062821	Lowland	18	Kemper County, MS	Coffeeville, MS
Blackwell	Upland	17	Kay County, OK	Manhattan, KS
Cave-in-Rock	Upland	15	Hardin County, IL	Elsberry, MO

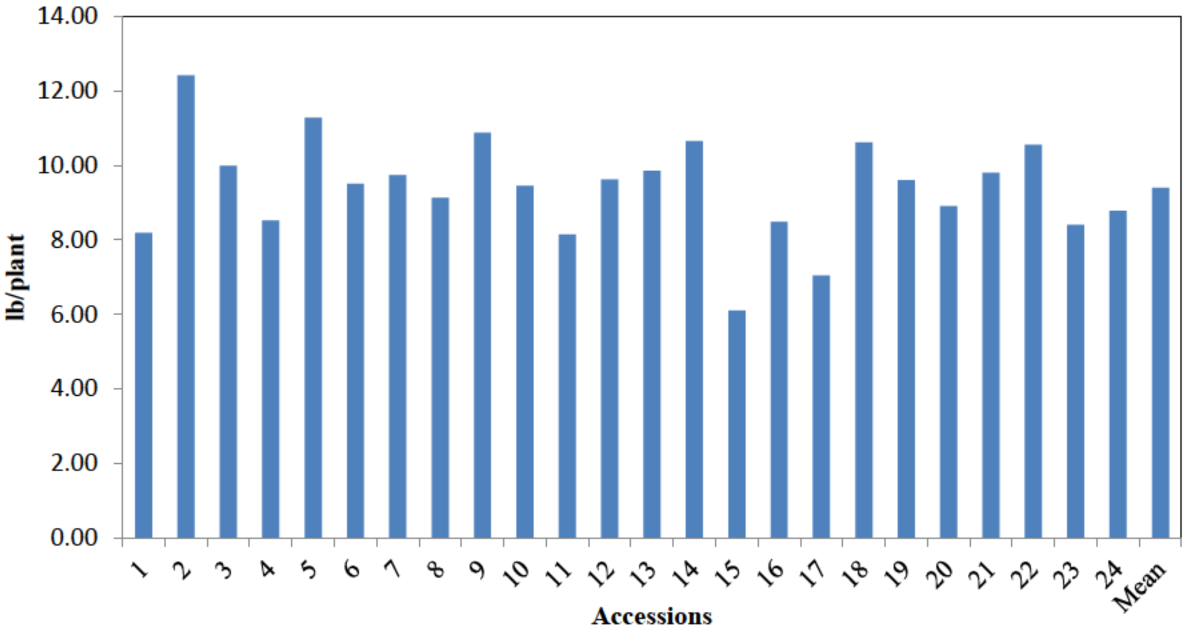

Figure 1. 2009-2013 mean switchgrass yield per plot USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Table 2: Forage quality estimates of cultivar and ecotypes harvested at the boot stage in 2009 USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Accession Number	ADF[1/]	TDN[1/]	CP[2/]
	------------------------%----------------------		
1	49	42	6
2	49	42	7
3	53	40	5
4	49	43	7
5	49	42	7
6	45	45	5
7	45	46	6
8	46	45	6
9	43	47	5
10	43	47	7
11	46	45	7
12	47	44	7
13	47	44	6
14	46	45	7
15	45	47	8
16	48	43	6
17	47	44	8
18	44	47	7
19	44	46	6
20	46	45	6
21	41	49	7
22	47	44	7
23	47	44	7
24	46	45	7
Mean	46	45	6
LSD$_{(0.05)}$[3/]	3	2	1

1/ Acid detergent fiber

2/ Total digestible nutrients, %TDN = (73.5 + (0.62 * %CP) – (0.71 * %ADF)

3/ Least significant difference at P<0.05.

Table 3: Stem and leaf characteristics at boot stage and plant height at maturity of switchgrass USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Accession	Leaves per Stem	Stem Diameter	Leaf Width	Leaf Length	Height
		----------------mm--------------		-----------------in------------------	
1	6.47 ABC[1/]	6.23 ABC	18.50 ABCD	24.47 AB	62.63 CDEFG
2	6.64 ABC	4.91 DE	16.32 CDEFG	21.38 AB	63.13 CDEFG
3	7.13 ABC	6.23 ABC	18.87 ABC	24.33 AB	69.38 ABCD
4	6.40 ABC	6.23 ABC	20.01 AB	24.35 AB	67.50 ABCDE
5	6.93 ABC	4.98 DE	18.10 ABCDE	25.64 AB	68.63 ABCDE
6	7.02 ABC	6.22 ABC	16.63 BCDEF	22.50 AB	70.13 ABCD
7	7.20 ABC	6.07 BCD	19.08 ABC	28.33 A	71.75 ABCD
8	6.19 ABC	5.82 BCD	18.00 ABCDE	22.70 AB	68.97 ABCDE
9	7.40 AB	5.77 BCD	17.57 ABCDEF	25.36 AB	63.50 CDEFG
10	7.00 ABC	6.50 ABC	17.94 ABCDE	26.43 AB	68.13 ABCDE
11	6.53 ABC	6.98 AB	18.90 ABC	23.58 AB	63.25 CDEFG
12	6.93 ABC	6.25 ABC	16.58 BCDEF	25.49 AB	69.13 ABCD
13	7.48 AB	5.94 BCD	20.41 A	22.21 AB	71.13 ABCD
14	7.95 A	6.54 ABC	17.57 ABCDEF	28.94 A	73.75 ABC
15	5.33 C	3.90 F	11.31 G	20.12 B	52.13 FG
16	7.17 ABC	5.98 BCD	17.69 ABCDE	25.08 AB	71.50 ABCD
17	5.47 BC	4.35 EF	13.72 EFG	21.06 AB	50.00 G
18	5.95 ABC	5.69 CD	14.94 DEFG	19.85 B	77.25 AB
19	6.40 ABC	6.53 ABC	17.68 ABCDE	21.20 AB	78.00 A
20	5.68 BC	6.17 ABC	19.97 AB	25.05 AB	61.38 DEFG
21	5.43 BC	5.55 CD	20.41 A	25.89 AB	53.81 EFG
22	6.91 ABC	5.94 BCD	13.41 FG	25.71 AB	72.00 ABCD
23	6.67 ABC	6.77 ABC	18.96 ABC	24.88 AB	65.63 BCDEF
24	6.87 ABC	5.83 BCD	17.40 ABCDEF	21.45 AB	65.25 CDEF
Mean	6.63	5.94	17.5	23.99	66.6

1/ Means in columns followed by same letter are not significantly according to Tukey’s HSD at P<0.05 level.

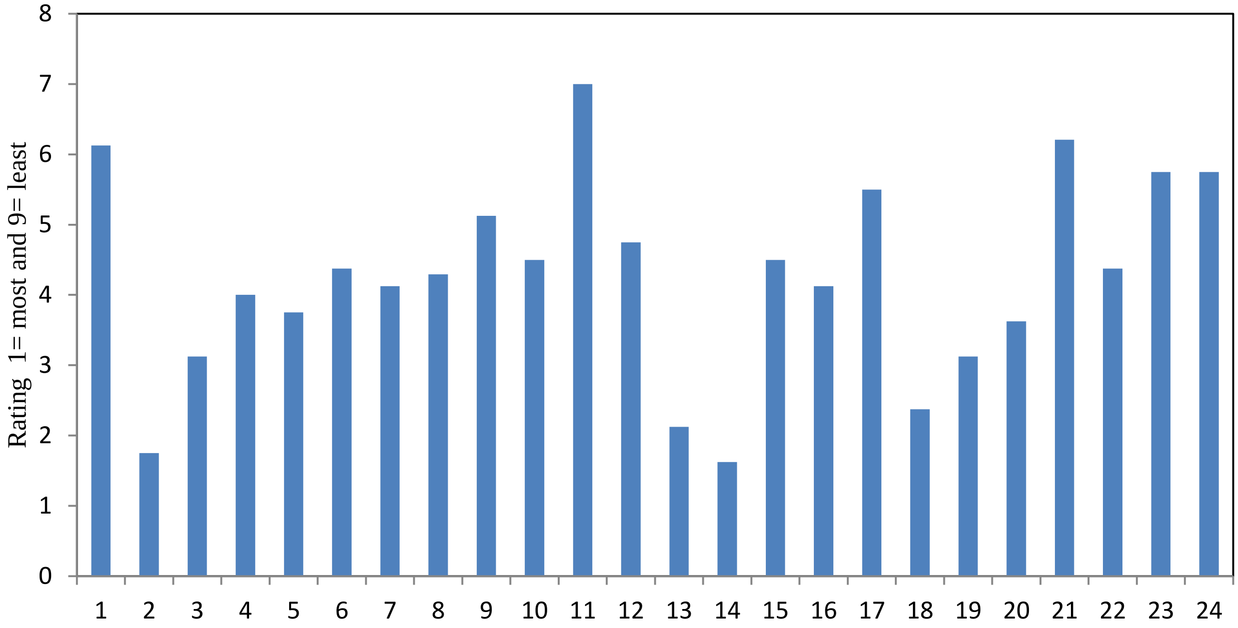

Figure 2. Mean tiller density rating of switchgrass, USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX 2009-2014.

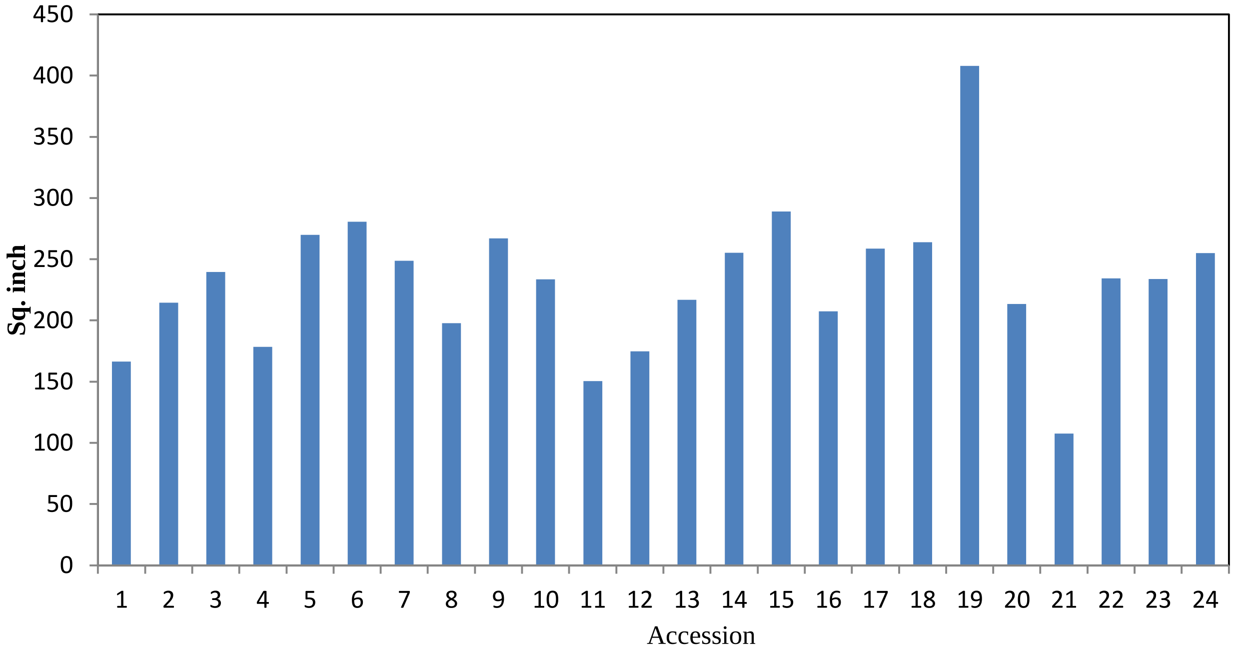

Figure 3. Mean spread of switchgrass from the original crown USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX 2009-2014

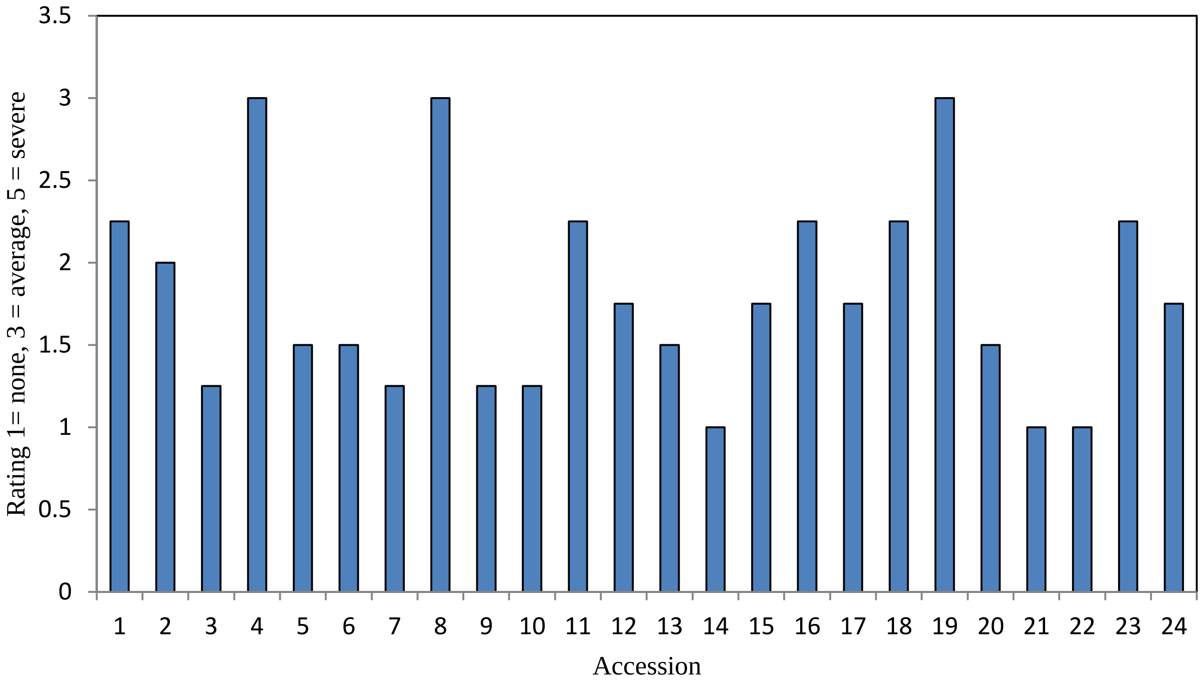

Figure 4. Mean disease rating of switchgrass, USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX 2009-2014

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