Seed Quality of Windmillgrass Ecotypes in Two Locations of South Texas

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ABSTRACT

Hooded and shortspike windmillgrasses are native perennial grasses with potential for planting on highly erodible sites. However, both species display unfilled seed and seed dormancy resulting in poor seed quality. This study examines variations in filled seeds, viability, and germination response in windmillgrass ecotypes. Germination conditions were 12 hr dark, 68°F and 12 hr light, 86°F. Percent of seeds filled was superior (P<0.05) in Beeville with 21, 22, 24, and 29% compared to Kingsville with 5, 8, 12, and 15% for S-260, S-283, H-301, and H-313, respectively. No significant differences (P>0.05) in seed viability were found among production sites with values of 75, 64, 72, and 67% in Kingsville and 84, 70, 85, and 75% in Beeville for S-260, S-283, H-301, and H-313, respectively. The germination response was different (P<0.05) between production sites and species with germination in Beeville of 72 and 99% compared to Kingsville with 59 and 90% for shortspike and hooded windmillgrasses, respectively. Filled seed and germination in windmillgrass were better in Beeville than Kingsville. The seed viability of the filled seed of windmillgrass was not affected by production site.

KEY WORDS: Native grasses, percent seeds filled, seed viability, germination, *Chloris cucullata, Chloris subdolichostachya.*

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INTRODUCTION

The demand for native grass seed is increasing for use in revegetation, restoration, erosion control, landscaping, and other uses because of their low maintenance requirements and ecological adaptation (Stoner et al. 2004). Hooded windmillgrass (*Chloris cucullata* Bisch.) and shortspike windmillgrass (*C. subdolichostachya* Muell.) are warm-season, perennial grasses that are native throughout Texas, Oklahoma, New Mexico, and the Northeast portion of México (Hitchcock 1971; Hatch et al. 1999). Both grasses have potential for planting on highly erodible sites, especially for roadsides and on sites where introduced species have traditionally been planted for erosion control and other ground cover uses.

Hooded windmillgrass is a short, perennial bunchgrass with culms 6-24 inches tall that produces multiple seed crops allowing it to reseed itself and spread, whereas shortspike windmillgrass is a medium growth, strongly stoloniferous, perennial grass with culms 12-28 inches tall (Gould 1975; Correll and Johnston 1996). However, in Texas, availability and wide-scale use is limited by a number of factors including commercial seed availability and a lack of scientific information on seed production of these native species.

Furthermore, there are constraints for establishing these important native species from seed. The major challenges are that both species produce spikelets with unfilled seed and exhibit seed dormancy, resulting in very poor seed quality.

The primary biological purpose of seeds is to propagate the species by successfully completing germination and resuming plant growth (Baskin and Baskin 2000). Native species have innate mechanisms that regulate their potential for germination, often delaying or timing germination to coincide with optimal conditions for growth (USDA, NRCS 2004). Planting high quality seed is key to successful grass species establishment, but both biological and environmental factors can reduce seed quality (Boe 2003). Consequently, the site or perhaps more correctly the environmental characteristics of the site of seed production can be an important factor in the quality of seed produced.

The correct choice of location is a major requirement for the success of the seed production activity, mainly for specialized systems (Darris 2005). Harrison et al. (1996) stated that environmental and site conditions including geomorphology, slope, aspect, soil type, salinity, human impacts or management, seed sources, and existing vegetation determine how productive a plant species will be on a site. Coffin and Lauenroth (1992) found that differences in seed yield of blue grama (*Bouteloua gracilis* Lag. ex Steud) between range sites in north-central Colorado were greatly influenced by soil texture and animal grazing. For some grass species, temperature conditions during seed fill, oxygen conditions around the seed, and the location of seed production can promote the development of dormancy (Chapman 1996).

Kelly et al. (2000), mentioned that the dispersal unit in some grasses includes seed appendages integrated with the caryopsis (seed fill), and so the number of seeds filled by a grass plant can vary markedly according to species and site. Favorable temperature and/or precipitation levels in certain areas can promote greater photosynthate production resulting in above-average seed production in that year or in subsequent years (Veenendaal et al. 1996). Conversely, factors such as adverse temperature, humidity, or wind at the time of pollination or seed development can reduce flowering or seed fill and could negatively influence the seed quality (McKone 1990).

Chambers (1989) found that viable seed production of species such as Idaho fescue (*Festuca idahoensis* Elmer), tufted hairgrass (*Deschampsia cespitosa* [L.] Beauv.), and alpine reedgrass (*Calamagostris purpurascens* R. Br.) vary both temporally and spatially, and that production of viable seed and seed fill is dependent upon the production site and the growing conditions for the production season.

Objectives of this study were to determine variations in seed fill, seed viability, and germination response in windmillgrass ecotypes as related to differences in production site.

MATERIAL AND METHODS

Hooded and shortspike windmillgrass seeds were collected by hand in 2003 from field plots located at Texas Agricultural Experiment Station in Beeville, TX and at Kika de la Garza Plant Materials Center at Kingsville, TX.

The Experiment Station at Beeville (28°27' N, 97°42' W; 256 ft elevation) is located in south Texas in the Rio Grande plain physiographic region. In winter the average temperature is 54°F, whereas in summer it is 84°F. Total annual precipitation is approximately 30 inches of this,19 inches, or 63%, usually falls during April through September, which includes the growing season for most warm season perennial grasses. Average relative humidity in mid-afternoon is about 60 percent. Terrain is level to gently rolling slopes. Many of the soils under forage-livestock production in this region are shallow and calcareous. The soils at the research site are Weesatche sandy clay loam (Fine-loamy, mixed, hyperthermic, Typic Argiustolls). This series is characterized as deep, well-drained loamy soil, with medium surface runoff, moderate permeability, and low water holding capacity (USDA, SCS 1981).

The Kika de la Garza Plant Materials Center (PMC) (27° 33’ N, 97° 52’ W; 53 ft elevation) is located just outside of Kingsville, TX. In winter, the average temperature is 68°F, whereas in summer it is 84°F. Mean annual rainfall is 28 inches. Long term rainfall are well distributed in the growing season of warm season grasses. September is the wettest month with 6 inches, whereas March is the driest month with 0.9 inches. Humidity is high during most of the year because the prevailing southeasterly winds bring in moist air from the Gulf of Mexico with an average of 60% at 6 a. m., 56% at noon, and 60% at 6 p. m. Topography of the PMC is flat. Soils at the PMC are classified as fine, mixed, hyperthermic Vertic Calciustolls (Raymondville clay loam) and moderately crumbly, Calcareous Grumosols (Victoria clay). Raymondville clay loam soils are characterized as moderately well drained, slow surface runoff, low permeability, and the available water holding capacity is moderate (USDA, SCS 1982). Victoria clay soils are dark, calcareous, crumbly soils that are called blackland which crack when they dry, and when wet, they swell and take in water slowly (USDA, SCS 1992).

Studied windmillgrass ecotypes were: shortspike 9085260 (S-260), shortspike 9085283 (S-283), hooded 9085301(H-301), and hooded 9085313 (H-313). Three replications of 100 seeds of each ecotype were used for determining percent of seeds filled. Each seed was checked by hand to determine if it contained a well-developed caryopsis.

Viability of seeds from each ecotype of the different collection sites was evaluated using 1% aqueous solution of tetrazolium (2, 3, 5-triphenyl tetrazolium chloride). Three replications of 100 filled seeds were soaked in distilled water for 18 h, subsequently, the lemma and palea were removed and the caryopsis was bisected longitudinally with a razor blade to expose the main structures of the embryo. As per the Grabe methodology (Grabe 1970), half of each caryopsis was immersed in the tetrazolium solution. After 3 h of dark incubation at 86°F, caryopsis with completely stained embryos were scored as viable (AOSA, 1970).

The germination test was conducted on naked caryopsis. Naked caryopses were extracted by hand rubbing seed on a rubber-corrugated mat with a rubber block to remove the lemma and palea from whole seeds. Later, a South Dakota Seed Blower was used to separate the bare caryopsis from the chaff. Plastic boxes of 5 x 5 x 1.4 inches, with tight fitting lids were used to germinate the seeds. The substrate for each container was one sheet of K-24 Kimpack 14 ply cellulose paper and one of blue paper (both are from Anchor paper Co. St. Paul, Minn.). The kimpack blotter designed to be very absorbent and maintain moisture for the seeds. Blue paper improved the contrast with seeds to facilitate counting the seedlings resulting in more reliable counts (Schleicher & Schuel 2002). Seeds were moistened with distilled water. Each box, containing one hundred randomly selected caryopsis, and was considered as an experimental unit. Three replicates per ecotype from each production site were used in the study. Germination conditions were 12 hr dark 68°F and 12 hr light 86°F. Germination counts were made every day for 28 d. Seeds were considered germinated if both the radicle and coleoptile exceeded the seed in length and the seedling was normal according to the seedling evaluation criteria of the AOSA for comparable grasses (AOSA, 1992). Seedlings were removed as they were counted.

Data were analyzed using a randomized complete block design with a three-way factorial arrangement of treatments with three replicates (Snedecor and Cochran 1980). Factors evaluated were two sites, two species, and two ecotypes. Seed fill, viability and germination data were subjected to analysis of variance using the general linear model (GLM) procedure of the Statistical Analysis System (SAS Inst., Cary, NC, 2000). Percent germination values were adjusted for the percent of live seed in each ecotype. An arcsine transformation was used on percent germination data before analyses.

RESULTS

Temperatures were similar over the months of the experiment on both sites, except for a sudden drop in temperature in September and October at the Beeville site (Figure 1). Even though the amount of annual rainfall was similar, the distribution of rainfall differed markedly between sites (Figure 2). Total precipitation during the growing season (May-Sep) was 19.6 and 18.1 inches for the Kingsville and Beeville sites, respectively. The rainfall amount (6.8 inches) during July at Beeville produced an increase in plant growth, resulting in increased seed head emergence. At Kingsville, rainfall (10.5 inches) occurred after the growing season with no effect on plant growth. During most of the period of seed head formation and emergence the rainfall was only 3.7 inches and suppressed plant growth. Relative humidity during the growing season averaged 70% in Beeville compared to 60% registered in Kingsville. Average wind speed during the pollen dispersal period (May-Jul) was 16.6 miles/h at Beeville compared to 25.6 miles/h at Kingsville.

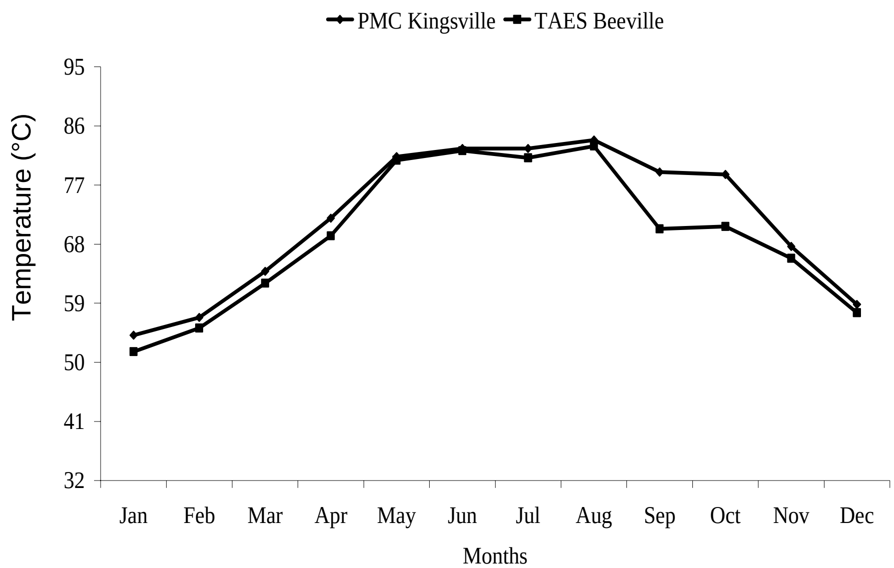

Figure 1. Mean monthly temperature comparison between PMC Kingsville versus TAES

No (P>0.05) interactions among treatments were found for fraction of seed fill. Production site, species, and ecotypes were different (P<0.05) in percent of seed fill. The Beeville location was higher (P<0.05) with 21, 22, 24, and 29% compared to Kingsville with 5, 8, 12, and 15% for S-260, S-283, H-301, and H-313, respectively (Figure 3).

No interaction (P>0.05) among production site X species X ecotypes was detected in seed viability with values of 79, 67, 78, and 71% for S-260, S-283, H-301, and H-313, respectively. No response (P>0.05) to main effects was found for seed viability.

No interaction (P>0.05) among production site X species X ecotypes was detected in seed viability with values of 79, 67, 78, and 71% for S-260, S-283, H-301, and H-313, respectively. No response (P>0.05) to main effects was found for seed viability.

No (P>0.05) interactions among treatments were found for seed germination. A location effect (P<0.05) was observed, where the two species performed consistently in the two locations with values in the Beeville location of 72 and 99% compared to the Kingsville location with 59 and 90% for shortspike and hooded windmillgrasses, respectively (Figure 4).

Table 1. Mean monthly temperature and total monthly rainfall for 2003 at PMC

	PMC Kingsville		TAES Beeville	
Month	Temperature °C	Rainfall (mm)	Temperature °C	Rainfall (mm)
Jan	12.3	25.50	10.9	58.3
Feb	13.8	33.50	12.9	76.0
Mar	17.7	32.25	16.7	57.0
Apr	22.2	3.00	20.7	5.5
May	27.4	0.25	27.1	1.0
Jun	28.1	81.25	27.9	82.5
Jul	28.1	107.00	27.3	173.8
Aug	28.8	41.25	28.3	12.5
Sep	26.1	268.30	21.3	190.3
Oct	25.9	89.50	21.5	92.7
Nov	19.8	21.50	18.8	33.3
Dec	14.9	14.25	14.2	12.3
Average	22.1		20.6	
Total		717.55		795.05

The influence of production site on percent of seeds filled observed in this study agreed with the findings of several studies where environmental factors such as soil types, temperature, precipitation, humidity, and wind at the time of seed development can impact seed fill in one area. McKone 1990 working with snow tussock-grass (*Chionochloa pallens* Zotov) found that seed fill was different in dark gray loamy sand soil compared to olive yellow gravelly sand soil with values of 76% and 21%, respectively. In another study, Coffin and Lauenroth (1992) demonstrated that soil texture had a significant effect on seed fill of blue grama (*Bouteloua gracilis* Lag. ex Steud), where coarse-textured soil produced the higher seed fill value with 82% compared to 52% obtained on fine-textured soil. Based on our results, soil type, wind, relative humidity and precipitation pattern were the main factors responsible for the differences in seed fill in windmillgrass ecotypes. Seed fill in windmillgrasses was higher in Beeville than Kingsville. This difference between production sites may suggest a greater stress was imposed by lower precipitation during seed development at the Kingsville site. In addition to dry spring weather in Kingsville, high drying winds may have further stressed the plants at Kingsville. Beeville received adequate precipitation, and experienced high relative humidity and low wind resulting in less stressful conditions for plant growth and seed production.

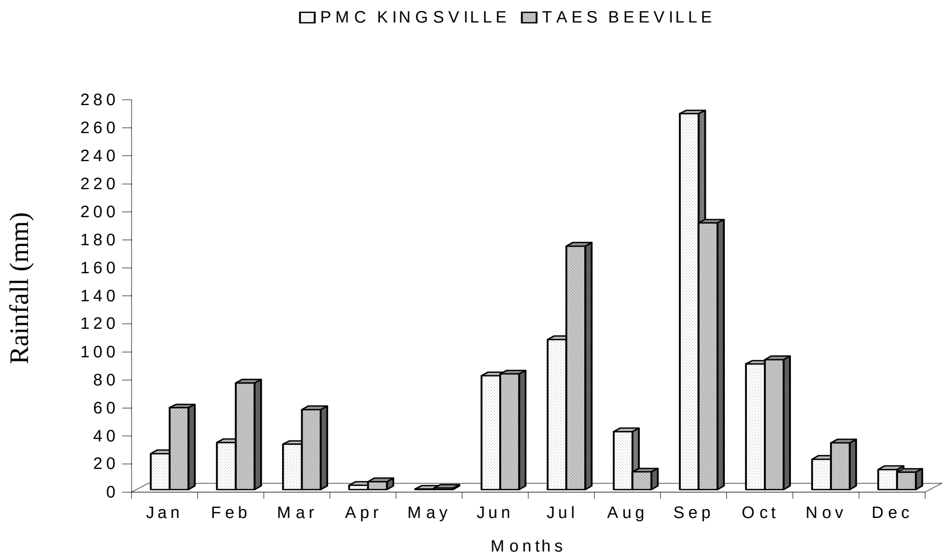

Figure 2. Rainfall comparison between PMC Kingsville versus TAES Beeville over the period of study (2003).

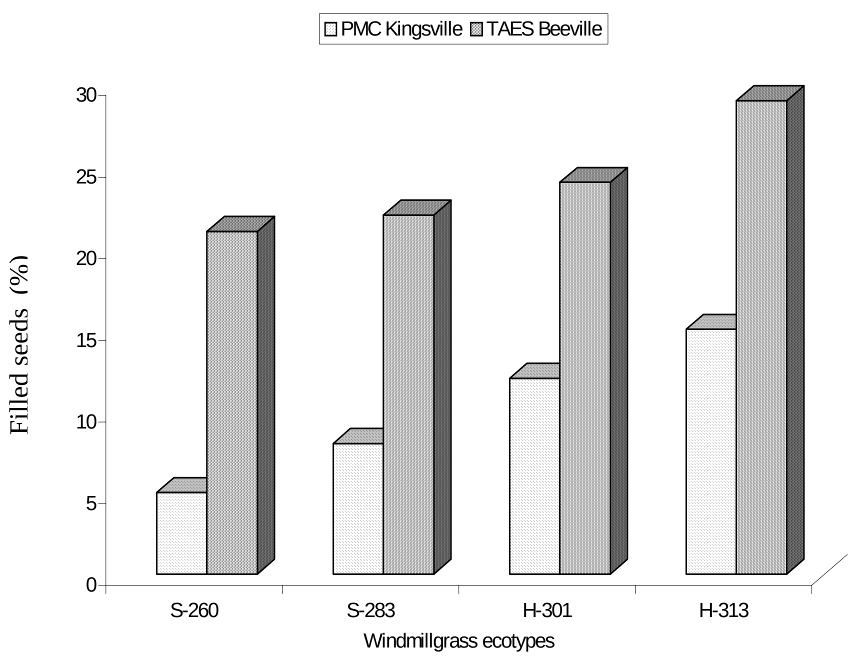

Figure 3. Production site effects on seed-fill of windmillgrass ecotypes

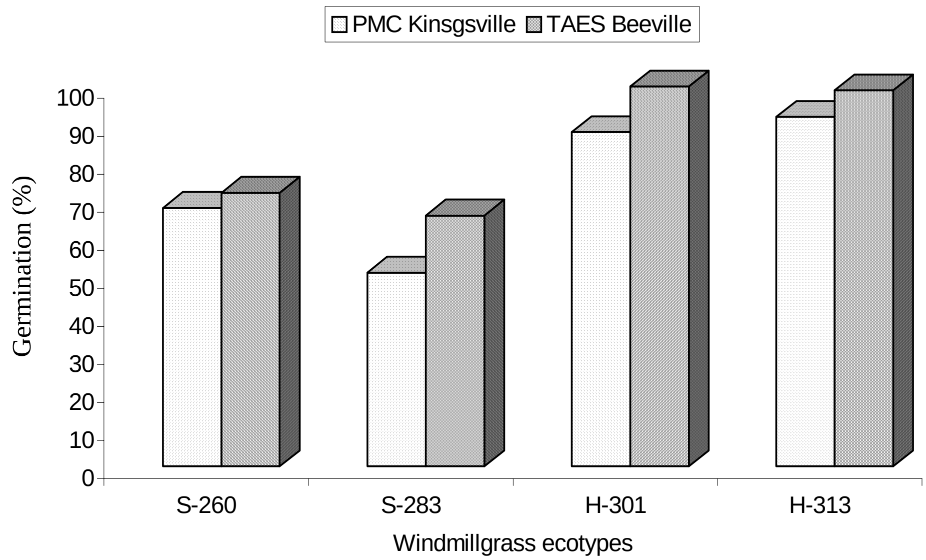

Figure 4. Production site effects on seed germination of windmillgrass ecotypes during 2003.

DISCUSSION

Based on our results, soil type, wind, relative humidity and precipitation pattern were the main factors responsible for the differences in seed fill in windmillgrass ecotypes. Seed fill in windmillgrasses was higher in Beeville than Kingsville. This difference between production sites may suggest a greater stress was imposed by lower precipitation during seed development at the Kingsville site. In addition to dry spring weather in Kingsville, high drying winds may have further stressed the plants at Kingsville. Beeville received adequate precipitation, and experienced high relative humidity and low wind resulting in less stressful conditions for plant growth and seed production.

Another important issue to consider about seed fill differences between production sites is that wind pollination, or anemophily, is considered a primary pollen dispersal mechanism in many grasses (Lyons et al. 1989) and a numbers of factors, including wind, humidity, and temperature can affect pollen viability (Luna et al. 2001).

Desiccation may have contributed to the loss of windmillgrass pollen viability in Kingsville due to high temperature and high wind-speed. Conditions for pollen survival at Beeville were better during this same time period than at Kingsville, which may have contributed to the higher seed fill at Beeville than at Kingsville.

In a study conducted by Chambers (1989) the percent of seed fill of Idaho fescue (*Festuca idahoensis* Elmer) and tufted hairgrass (*Deschampsia cespitosa* [L.] Beauv.)

varied greatly in response to the timing and the amount precipitation on central and southern Rocky Mountains sites in Colorado. Both species exhibited the same pattern of seed fill, indicating poor seeds fill in central sites with 20 and 18% compared to southern sites with 72 and 63% for Idaho fescue and tufted hairgrass, respectively. Observed variation in seed fill was largely attributed to more water from the winter snow, causing dry soils during the growing season. In addition, Coffin and Lauenroth (1992) found that differences in seed fill of blue grama (*Bouteloua gracilis* Lag. ex. Steud.) were greatly influenced by soil texture and animal grazing in north-central Colorado. On locations protected from grazing, soil texture had effect on seed fill; the greatest seed fill was produced on the coarse-textured soil and the fewest on the fine-textured soil.

Seed viability in windmillgrasses ecotypes was not affected by production site, whereas seed germination was strongly affected by production site. Similar results were found by Hacker and Ratcliff (1989) working on fifteen accessions of buffelgrass (*Cenchrus ciliaris* L.), eight of near-equatorial and six of near-tropical origin with high (1200-1400 mm), medium (700-800 mm), low (400-500 mm), and very low rainfall (25-220 mm) sites. Seed viability tended to be similar (85%) in the sites and under all rainfall patterns. Seed germination was higher for near-equatorial (88%) than from near-tropical accessions (62%) and from high (79%) rather than for low (63%) rainfall areas. They suggested that buffelgrass accessions maintain seed viability and differ in seed germination attributes that may be adaptive to their climate of origin.

Minnick and Coffin (1999) studied effects of climate variables on spatial patterns in germination of *Bouteloua gracilis* (H. B. K.) Lag Ex Steud and *Bouteloua eriopoda* Torr. along a gradient from northern Colorado (40° 49’ N; 104° 46’ W) to southern New Mexico (31° 50’ N; 107° 39’ W). For *B. gracilis* they found that germination decreased from north to south along the climate gradient with values of 98% at Trinidad, CO (37° 15’ N) to 89% at Bosque, NM (33° 46’ N). In contrast, the percentage of germination of *B. eriopoda* increased from north to south with values of 34% at Limon, CO (39° 16’ N) to 78.5% at New Mexico State University, NM (32° 17’ N).

Low seed fill for the grass species in Kingsville coincided with low seed germination, indicating poor seed development at that site. This may be attributed to slower species phenological development at Kingsville compared to those growing on the Beeville site. Seed properties, including seed fill, viability, and germination can greatly affect the success of seed grass industry efforts. Production of filled seeds and viable seed of windmillgrass is not only variable among species, but also among ecotypes within any given site.

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