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Research Note

Improving Germination in Windmillgrass Ecotypes

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Abstract

Hooded windmillgrass (*Chloris cucullata* Bisch.) and shortspike windmillgrass (*C. subdolichostachya* Muell.) are native perennial grasses with potential for planting on highly erodible sites and on sites where introduced species are not desired. However, in both species, seeds are dormant resulting in poor germination. The objectives of this study were to evaluate effects of lemma and palea removal and caryopsis scarification on seed germination of 8 outstanding ecotypes selected in previous studies for survival and growth characteristics. Seed treatments were 1) whole seed, 2) naked caryopsis, 3) scarified naked caryopsis (30 s), 4) scarified naked caryopsis (50 s), and 5) scarified naked caryopsis (60 s). Germination conditions were 12 h dark 20°C and 12 h light 30°C. Seed lot viability varied from 55% to 62% for shortspike windmillgrass ecotypes and from 71% to 78% for hooded windmillgrass ecotypes. Initial germination index (MIR_{10}) of naked caryopsis for shortspike windmillgrass ecotypes ranged from 16.3 to 21.6, compared to range from 0.2 to 0.6 to whole seed; whereas hooded windmillgrass ecotypes MIR_{10} ranged from 30.6 to 33.0 to naked caryopsis, compared to range from 5.8 to 8.0 to whole seed. The greatest total germination ($P < 0.05$) was obtained with naked caryopsis for all ecotypes and the scarification treatments did not have a positive effect on this parameter. As scarification time increased the total germination decreased. Lemma and palea removal improved ($P < 0.05$) total germination for all studied ecotypes.

Resumen

Hooded windmillgrass (*Chloris cucullata* Bisch.) y shortspike windmillgrass (*C. subdolichostachya* Muell.) son pastos nativos con alto potencial para establecerse en sitios altamente degradados y/o en áreas donde las especies introducidas son no deseadas. No obstante, en ambas especies la semilla presenta dormancia ocasionando pobres resultados en germinación. Los objetivos de este estudio fueron evaluar los efectos de remoción de la lemma y palea, y escarificación del cariopsis sobre la germinación de semillas en 8 ecotipos previamente seleccionados por características de sobrevivencia y crecimiento. Los tratamientos a la semilla fueron 1) semilla completa, 2) cariopsis desnudo, 3) cariopsis desnudo escarificado (30 s), 4) cariopsis desnudo escarificado (50 s), y 5) cariopsis desnudo escarificado (60 s). Las condiciones de germinación fueron 12 h obscuridad 20°C y 12 h luz 30°C. La viabilidad de las semillas varió de 55% a 62% para los ecotipos de shortspike y de 71% a 78% para los ecotipos de hooded. El índice de germinación inicial (MIR_{10}) de cariopsis desnudo para los ecotipos de shortspike varió de 16.3 a 21.6 comparado con un rango de 0.2 a 0.6 en semilla semilla completa; mientras que en ecotipos de hooded windmillgrass el MIR_{10} vario de 30.6 a 33.0 en cariopsis desnudo comparado con un rango de 5.8 a 8.0 en semilla completa. La mayor germinación total ($P < 0.05$) fue obtenida con cariopsis desnudo en todos los ecotipos y los tratamientos de escarificación no tuvieron efecto positivo sobre este parámetro. Conforme el tiempo de escarificación incremento, la germinación total disminuyó. La remoción de lemma y palea mejoró ($P < 0.05$) la germinación total en todos los ecotipos estudiados.

Key Words: Native grasses, dormancy, caryopsis, scarification, *Chloris cucullata*, *Chloris subdolichostachya*

INTRODUCTION

Hooded windmillgrass (*Chloris cucullata* Bisch.) and shortspike windmillgrass (*C. subdolichostachya* Muell.), are warm-season perennial grasses (Gould 1975; Hatch et al., 1999). They can be found in prairies on sandy or gravelly soils, and occasionally on clayey soils (Correll and Johnston 1996). These species are native throughout Texas, Oklahoma, New Mexico (Hitchcock 1971), and northeastern Mexico (Gould 1975). In Texas, hooded and shortspike windmillgrasses are more abundant in the Rio Grande Plains, although they can be found throughout most of the state (USDA, NRCS 2005).

Both grasses appear to have potential for planting on highly erodible sites and on sites where introduced species are not desired. However, these native species display high dormancy, resulting in poor germination. Structures encompassing the embryo, the physiological state the embryo itself, or combination of these factors often contribute to seed dormancy (Kelly et al. 1992).

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The influence of encompassing structures (palea and lemma) on germination and dormancy has been studied in several warm-season grasses. Hand removal of the entire lemma and palea was sufficient to increase germination from 0% to 88% in fall panicum (*Panicum dichotomiflorum* Michx.) seed (Brecke and Duke 1980). Fulbright and Flenniken (1988) stated that dormancy in *Paspalum plicatulum* Michx. seed apparently results from physiological mechanisms and mechanical or permeability restrictions imposed by the lemma and palea. Removing the lemma and palea in 25 species that normally exhibited a high degree of dormancy improved germination from 54% to 100% on average (Simpson 1990). Tian et al. (2002) reported that while the cupule (including lemma and palea) contributes to the dormancy of *Tripsacum dactyloides*, the pericarp and/or testa are the main factors restricting germination of this species.

The objectives of this study were to evaluate effects of lemma and palea removal and scarification treatments on germination of several ecotypes of hooded and shortspike windmillgrasses.

MATERIALS AND METHODS

Hooded and shortspike windmillgrasses seeds were collected by hand in June of 2003 from field plots located at Texas A&M Agricultural Experiment Station in Beeville, Texas (28°27′N, 97°42′W; 78 m elevation). Seed was stored at 10°C and 50% relative humidity before the test. Germination tests were performed in October of 2003 at the Kika de la Garza Plant Materials Center at Texas A&M University-Kingsville.

We studied 8 outstanding ecotypes of windmillgrass selected in previous studies for survival and growth characteristics. Shortspike windmillgrass ecotypes were: 9085260 (S-260), 9085262 (S-262), 9085283 (S-283), and 9085289 (S-289), and hooded windmillgrass ecotypes were: 9085300 (H-300), 9085301 (H-301), 9085313 (H-313), and 9085316 (H-316). Seed treatments were: 1) whole seed, 2) naked caryopsis, 3) scarified naked caryopsis (30 s), 4) scarified naked caryopsis (50 s), and 5) scarified naked caryopsis (60 s). For the "whole seed" treatment, each seed was checked to determine if it contained a well-developed caryopsis. For the "naked caryopsis" treatment, the lemma and palea were removed from whole seeds rubbing on a rubber-corrugated mat with a rubber block by hand. Later, a South Dakota Seed Blower was used to separate the bare caryopsis from the chaff. Scarification of naked caryopsis was accomplished with a Forsberg tabletop sand-paper scarifier. Box containers of 13 × 13 × 3.5 cm, with tight fitting lids were used to germinate the seeds. The substrate for each container was two sheets of K-24 Kimpack 14 ply cellulose paper and one of blue paper (both are from Anchor Paper Co., St. Paul, MN). The seeds were moistened with distilled water. Each box, containing 100 randomly selected whole seeds or caryopsis, was considered as an experimental unit and 3 replications per treatment were used in the study. Germination conditions were 12-hour dark 20°C and 12-hour light 30°C based on results reported by Fulbright et al. (1983), Schrauf et al. (1995), and Roundy and Biedenbender (1996). Germination counts were made every day for 28 days. 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.

Initial germination was estimated using the Maguire Index Rate (Maguire 1962), a time weighted cumulative germination index, calculated as the sum of the percentage of seeds germinating on each day divided by the number of days since the germination test began. The index was used in our experiment only until the 10th day (MIR_{10}) as our assays focused on early germination, and Maguire's formula is weighted in favor of initial germination (Brown and Mayer 1986). In addition, total germination was determined at the 28th day of the germination test on the basis of the percent live seed in each ecotype:

$$\begin{array}{l}\text{\% germination}\\ \text{adjusted for live seed}\end{array} = \frac{\text{\% germination} \times 100}{\text{\% live seed}} \quad [1]$$

Percent live seed in each ecotype was determined 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 hours of dark incubation at 30°C, caryopsis with completely stained embryos were scored as viable (AOSA 1970).

Data were analyzed using a randomized complete block design with 3 replicates (Snedecor and Cochran 1980). Analysis of variance was performed using the general linear model (GLM) procedure of the Statistical Analysis System (SAS Institute, Cary, NC, 2000). Means were separated using Duncan's Multiple Range Test ($P < 0.05$).

RESULTS

Seed lot viability, as determined by tetrazolium analysis, varied from 55% to 62% for shortspike windmillgrass ecotypes and from 71% to 78% for hooded windmillgrass ecotypes (Table 1). Lemma and palea removal improved ($P < 0.05$) total germination for all studied ecotypes with a range of 55% to 72% for shortspike windmillgrass ecotypes and from 95% to 100% obtained with hooded windmillgrass ecotypes, compared to a range from 1% to 4% and from 30% to 40% for whole seeds in shortspike and hooded windmillgrass ecotypes, respectively (Table 1).

Removing the lemma and palea improved total germination ($P < 0.05$) for all ecotypes studied with increases of 56, 52, 70, 59, 60, 59, 70, and 58% for S-260, S-262, S-283, S-289, H-300, H-301, H-313, and H-316, respectively (Table 1).

Initial germination (MIR_{10}) of naked caryopsis was greater ($P < 0.05$) than for whole seed for all ecotypes studied. The MIR_{10} for naked caryopsis ranged from 16.3 to 21.6 for shortspike windmillgrass ecotypes, compared to a range from 0.2 to 0.6 for whole seed; whereas for hooded windmillgrasses the MIR_{10} for naked caryopsis ranged from 30.6 to 33.0, compared to a range from 5.8 to 8.0 for whole seed (Table 1).

Table 1. Seed viability, total and initial germination of windmillgrass seed ecotypes for whole seed and naked caryopsis.[1]

		Total Germination (%)		Initial Germination (MIR_{10})	
Ecotype	Seed viability %	Whole seed	Naked Caryopsis	Whole seed	Naked Caryopsis
Shortspike-260	62 ± 1.3	4 ± 1.7 b	60 ± 2.5 a	0.6 ± 0.9 b	18.4 ± 1.6 a
Shortspike-262	55 ± 3.2	3 ± 2.2 b	55 ± 3.1 a	0.4 ± 1.4 b	16.3 ± 2.0 a
Shortspike-283	56 ± 2.6	2 ± 1.9 b	72 ± 2.8 a	0.3 ± 1.6 b	21.6 ± 1.7 a
Shortspike-289	55 ± 2.9	1 ± 1.0 b	60 ± 1.9 a	0.2 ± 1.3 b	18.2 ± 1.2 a
Hooded-300	75 ± 1.6	4 ± 1.4 b	98.7 ± 1.3 a	8.0 ± 1.0 b	32.7 ± 1.4 a
Hooded-301	78 ± 2.2	3 ± 2.3 b	95 ± 2.0 a	6.3 ± 1.7 b	30.6 ± 1.8 a
Hooded-313	76 ± 1.4	3 ± 1.8 b	98.4 ± 1.6 a	5.8 ± 1.5 b	33.0 ± 1.3 a
Hooded-316	71 ± 2.0	3 ± 2.1 b	96 ± 1.3 a	7.1 ± 1.2 b	31.4 ± 1.5 a

[1]Values within a row followed by different letters are significantly different ($P < 0.05$). (Mean ± SE).

Table 2. Total seed germination response of windmillgrass ecotypes under different caryopsis scarification time treatments.[1]

		Caryopsis scarification treatments %		
Ecotypes	Naked caryopsis %	30 seconds	50 seconds	60 seconds
S-260	60 ± 1.1 a	48 ± 2.4 b	38 ± 3.2 bc	28 ± 3.8 c
S-262	55 ± 1.2 a	42 ± 3.3 b	33 ± 3.6 bc	25 ± 3.2 c
S-283	72 ± 1.8 a	55 ± 2.7 b	46 ± 3.8 c	33 ± 3.1 d
S-289	60 ± 1.4 a	51 ± 3.1 b	23 ± 3.9 c	16 ± 3.4 d
H-300	99.4 ± 0.6 a	84 ± 2.9 b	72 ± 3.6 c	56 ± 3.5 d
H-301	95 ± 1.6 a	82 ± 2.6 b	69 ± 3.1 c	53 ± 2.9 d
H-313	99.6 ± 0.4 a	83 ± 3.4 b	70 ± 3.8 c	55 ± 3.6 d
H-316	96 ± 1.5 a	82 ± 2.1 b	66 ± 3.5 c	51 ± 3.8 d

[1]Values within rows followed by different letters are significantly different ($P < 0.05$). (Mean ± SE).

The total germination of naked caryopsis was superior ($P < 0.05$) to scarification treatments in all studied ecotypes. The scarification treatments did not have a positive effect on total germination, as scarification time increased the total germination decreased (Table 2), which suggests that scarification may have damaged the seed.

DISCUSSION

The beneficial effects of lemma and palea removal on total germination obtained in this study agree with the findings of several studies where the removal of lemma and palea increase germination rate dramatically in several grass species (Brecke and Duke 1980; Simpson 1990). Additionally, Matus-Cádiz and Hucl (2005) working with annual canarygrass (*Phalaris canariensis* L.) demonstrated that whole seed had a greater dormancy displaying 10% germination compared with 95% germination obtained with naked caryopsis.

In our study hooded windmillgrass had a greater MIR_{10} and total germination than shortspike windmillgrass. However, this study should be repeated including more seedlots from different sources in order to characterize the seed germination at species level. Although the windmillgrass dispersal unit is integrated by seed appendages along with the caryopsis these results may be used to calculate bulk seeding rates, as well as to understand why certain hooded windmillgrass ecotypes, such as H-300, H-301, H-313, and H-316 are more easily established than some shortspike windmillgrass ecotypes, such as S-260, S-262, S-283, and S-289. Differences in dormancy breaking and germination responses of windmillgrass seed ecotypes may help determine which ecotype we may need to plant depending on available soil moisture and other climatic conditions. Baskin et al. (1999) reported similar observations in *Leptochloa panicea* Michx. ssp. *mucronata* compared to *L. panicoides* Presl., and *L. fusca* Lam. showing the importance of knowing the differences in dormancy breaking and germination responses of seeds of *Leptochloa* species to define the wide range of habitats for each species as affected by soil moisture conditions.

The lemma and palea are the main factors restricting germination of hooded windmillgrass seeds, whereas in shortspike windmillgrass seeds, the dormancy apparently results from permeability restrictions caused by the lemma and palea as well as physiological mechanisms. Further research will be necessary to determine the exact mechanism(s). Similar results were found by Lodge (2004) working on phalarisgrass (*Phalaris aquatica* L.) and wallabygrass (*Austrodanthonia bipartite* Link.) where dormancy on freshly harvested seeds of phalaris was mainly associated with the structures surrounding the caryopsis (7.7% germination for freshly harvested seeds compared to 79.5% one month after harvest), and wallabygrass dormancy was related to physiological dormancy of the caryopsis.

The high total germination showed by naked caryopsis of all studied ecotypes compared to scarification treatments, and the declining trend observed as scarification time increased on total germination indicates that scarification is unlikely to have a positive impact on caryopsis germination in windmillgrass ecotypes. Mechanical scarification of naked caryopsis tends to decrease total germination in both hooded and shortspike windmillgrass ecotypes.

Dormancy is an adaptation that enables plants to survive during adverse conditions (Bewley 1997). According to our results the lemma and palea appeared to be a major cause of dormancy and they are the main factors restricting germination of hooded and shortspike windmillgrass seeds. Shortspike windmillgrass seeds have a more complex dormancy that was not eliminated by any treatment imposed. More research is needed to identify other techniques to overcome the seed dormancy in shortspike windmillgrass since an average of 39% of seeds did not germinate after palea and lemma removal.

MANAGEMENT IMPLICATIONS

Lemma and palea removal improved seed germination in hooded and shortspike windmillgrasses seed, suggesting that the commercial seed industry should manage naked caryopsis to increase the possibility of successful establishment of these native species. Shortspike windmillgrass may be used in drier environments where moisture conditions may be unpredictable and some seed dormancy may be desirable to increase the possibility of a successful establishment when moisture conditions are favorable. Hooded windmillgrass may be more suitable where adequate soil moisture is generally available.

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