Variation in seed shattering in a germplasm collection of *Panicum coloratum* L. var. *makarikariensis* Goossens

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Abstract

Panicum coloratum L. var. *makarikariensis* Goossens (makarikari grass) is a warm-season perennial forage, to be potentially used in Argentine in sites characterized by heavy soils with highly variable climate, with successive alternate periods of drought and flooding. Before its use is generalized in the country, some issues related to difficulties in seed production of adequate amount and quality should be addressed. Phenotypic variability in seed retention reported in *P. coloratum* var. *coloratum* has raised the possibility of genetic improvement in the species. The aim of this work was to evaluate seed shattering variability in a makarikari grass collection located at INTA Rafaela Experiment Station, consisting of 5 populations collected at different sites, that serves as base of a breeding program started in 2006.

Seed shattering was evaluated using a seed trap in 10 plants per population. Panicles were set into the trap at the peak of anthesis. Seeds were collected weekly in a paper bag, taken to the lab and counted. Seed retention was calculated at each harvest date, as the ratio of the number seeds retained per panicle over the total number of seeds produced. Trap setting was performed in the summer of 3 consecutive years (2007-2008 and 2009). Data of wind intensity and rainfall were gathered for those years. Results showed that populations differed markedly in the dynamics of seed production and shattering. In 2007, peak of anthesis occurred sequentially among populations. Seed shattering took place in a similar fashion. In the following years, anthesis and shattering were synchronized among populations. The variability in SR among years found in this study suggested a large environmental component in this character in makarikari grass indicating that genetic improvement may be slow. Further studies are needed to help elucidate specific mechanisms for resistance to shattering in makarikari grass.

Introduction

Panicum coloratum L. var. *makarikariensis* Goossens (makarikari grass) is a warm-season perennial grass, to be potentially used as forage in rangelands of Central Northern Santa Fe (Argentine). The site is characterized by heavy soils with highly variable climate, resulting in a succession of drought and flooding periods. The makarikari grass is naturally adapted to black, cracking clay soils in sub-humid environments (Lloyd 1981). Inflorescence development is indeterminate and seed maturation is nonuniform within the same panicle. Seed shatters readily at maturity or earlier if weather conditions are severe (Tischler & Ocumpaugh 2004). Seed shattering and non-uniformity of seed ripening have been considered major limitations to consistent seed production because yield can be dramatically reduced if harvests are delayed for any reason, but seed quality can be compromised if harvested before physiological maturity (Roe 1972). Issues related to seed production should be addressed before promoting its utilization in the region. Fortunately, phenotypic variability in seed retention in some accession of *P. coloratum* var. *coloratum* has been previously reported, suggesting the possibility of genetic improvement in the species (Young 1986; Young 1991).

The present study was initiated to assess seed shattering variability in a germplasm collection in Argentina to evaluate the possibility of undertaking an efficient program of selection and breeding to develop a shattering resistant material.

Materials and Methods

Seed shattering dynamics were evaluated in a germplasm collection established at INTA (National Institute of Agricultural Technology) Rafaela Experiment Station (31°11’41’’ S; 61°29’55’’ W) in October 2006. The collection included 5 populations coming from a wide range of soils, precipitation and different management regimes in north- central Argentina. Three populations were collected in Córdoba (Typic Haplustol, 600 mm annual precipitation): DF was under grazing of cattle and goats; UCB and MR were not grazed. The other two populations (ER and BR) were from Corrientes (Vertic Argiudol, 1500 mm annual precipitation, grazed by beef cattle). Populations consisting in 32 individual plants planted spaced at 0.6 m distance, were widely separated from each other to prevent cross pollination.

A seed trap especially designed was used to collect all the seeds produced per panicle. The trap consisted of a cylindrical steel structure over a pole and covered by a nylon stocking. Panicles were set into the trap at the peak of anthesis, when at least 2/3 of all florets had gone through anthesis. Ten plants per populations were evaluated. Trap setting was performed in 3 consecutive summers (2006-07, 20007-08 and 2008-09, hereafter 2007-2008 and 2009, respectively). In 2007, traps’ setting up was performed on 03/6 in DF, 03/15 in UCB, 03/20 in ER and BR. A strong rainfall event the last week of March 2007 delayed trap setting in MR until 04/04 (Figure 1). Date of anthesis was uniform among populations in 2008 and 2009; therefore all traps were set on 02/04/08 and on 02/27/09. The seeds trapped in the nylon-stocking as they ripened, were collected weekly in a paper bag, taken to the lab and counted for seed shattering evaluation. In 2007, seed collection started on 03/15 in DF, on 03/21 in UCB, on 04/04 in BR and ER and on 04/11 in MR. Seed collection commenced 02/19 for all populations in 2008 and on 03/10 in 2009. Consequently, seeds were collected at 8 successive dates in 2007, 5 dates in 2008 and 9 in 2009. The samples were hand-cleaned, seeds were separated from remaining glumes and only mature seeds were counted. At the last harvest, panicles were cut, taken to the lab and the threshed seeds were counted and added up to get the total number of seeds per panicle.

Seed retention (SR) was calculated at each harvest date, as the ratio of the number seeds retained per panicle over the total number of seeds produced by each panicle. In addition, data of wind intensity and rainfall were gathered for those years. Statistical analysis of SR data was performed using Mixed Model procedure of SAS® using the compound symmetry covariance structure. For the purpose of comparisons only 5 harvesting dates per year were considered. Main effects and the interactions of year, population and date of harvest were made by using analysis of variance. Mean comparisons were made using LSD. The significance level for all comparisons was $P<0.05$.

Results

Total precipitation during the growing season (November to April) for the 2006-07, 2007-08 and 2008-09 were 1224.9 mm, 495.9 mm and 579.5 mm, respectively. The 70-yr average precipitation for the site over the same period is 707 mm. Storms with copious rainfall events and wind velocities over 10 $km.h^{-1}$ were frequent in the summer of 2007. Lower precipitation and less intense winds characterized the summer of 2008 and 2009, compared to 2007 (Figure 1).

Results of ANOVA are shown in table 1. Interactions were all significant, and then factors were analyzed separately. Populations differed markedly in the dynamics of seed production and shattering (Figure 1). In 2007, the first cycle after plants were transplanted from their original site, peak of anthesis occurred earlier in DF, one week later in UCB, then in BR and ER and finally in MR. Populations DF was also the first to start shattering seeds in 2007. Populations UCB and BR were intermediate while ER and MR retained the seeds until April. A massive seed falling (peak shattering) in DF and UCB was associated to a big storm by the end of March On the contrary, anthesis and shattering were synchronized among populations in 2008 and 2009. Strong surface winds and rainfall could be associated to a notorious seed falling event (peak shattering) in all 5 populations in 2008. Winds were constant though calmer than before during the summer of 2009, nonetheless seed shattering was concentrated the first week of April.

Table 1. Analysis of variance for seed retention percentage for 5 populations of makarikari grass evaluated 3 successive years at 5 consecutive harvesting dates in Rafaela, Santa Fe, Argentina.

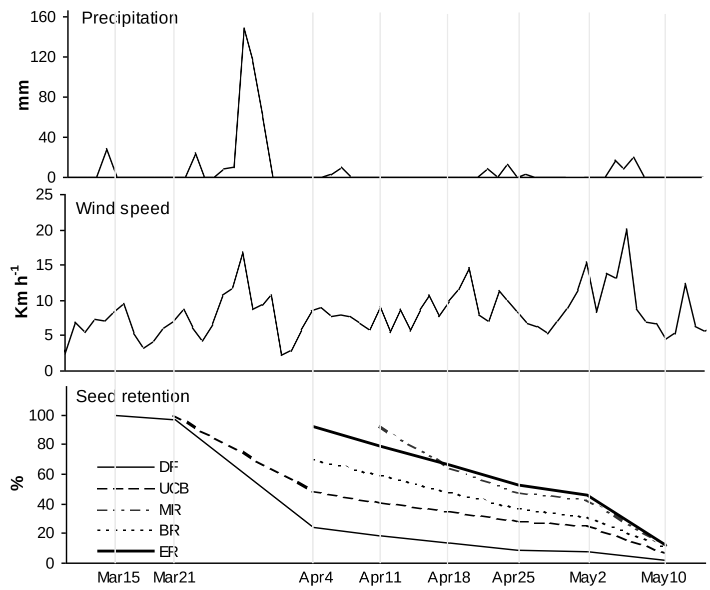
Source	**df**	**F- value**
Population (P)	4	7.3***
Year (Y)	2	65.5***
Harvest date (D)	4	726.8***
P x Y	8	31.6***
P x D	16	4.1***
Y x D	8	24.5***
P x Y x D	32	3.2***

*** Significant at the 0.001 level.

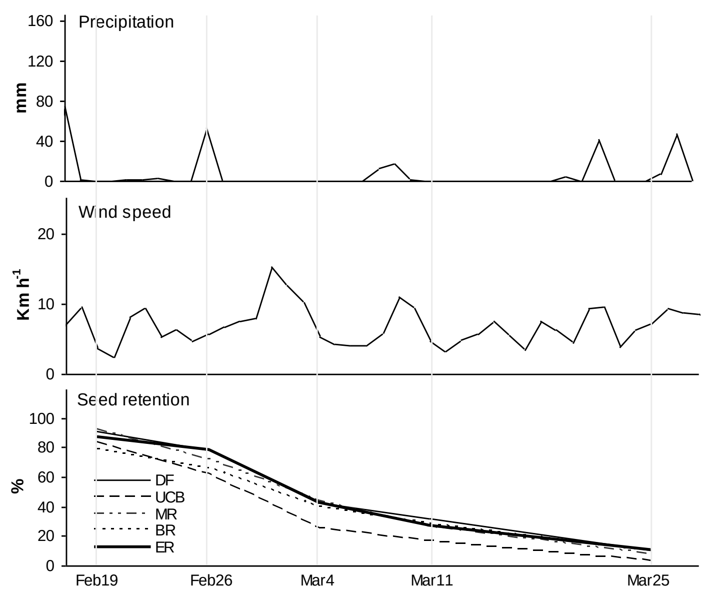
Mean seed retention percentages (SR) per population per year are shown in table 2. Within populations, mean SR percentage was significantly different among years ($p<0.001$). Populations ER and MR showed the best SR performance in 2007 while DF and UCB highest retention was in 2009. Seed retention was comparable in 2007 and 2009 for BR population. The worst retention performance for BR, ER, MR and UCB were in 2008 while DF retained the least in 2007. Within years, differences in mean SR among populations were highly significant in 2007 ($p<0.001$); the highest SR were observed in MR and ER, BR and UCB were intermediate and DF was the one with the least retention. Differences in SR were less pronounced in 2008 ($p<0.05$) and populations showed comparable performance in 2009 ($p=0.28$).

Figure 1. Seed retention (%) in populations of *Panicum coloratum* L. var. *makarikariensis*, rainfall (mm) and wind velocity at 2 m on the ground level (km h^{-1}), registered in the summer of a) 2007, b) 2008 and c) 2009. Seed collection dates are shown in the X axis.

a)



b)



c)

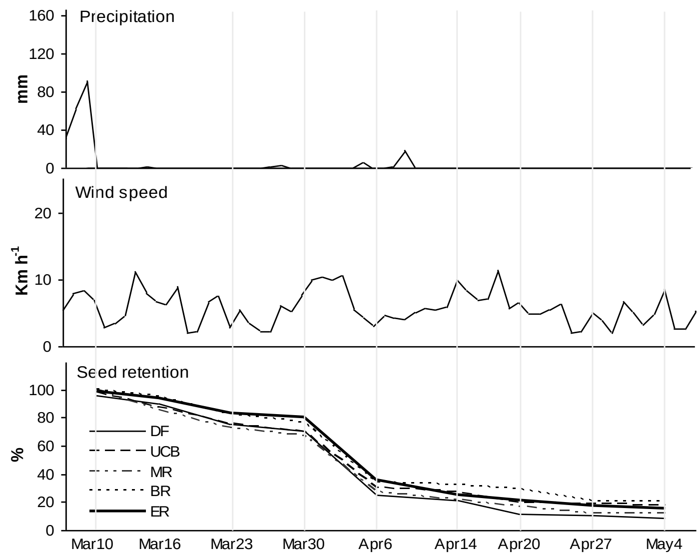


Table 2. Mean seed retention percentage and standard errors for 5 populations of makarikari grass evaluated 3 successive years at 5 consecutive harvesting dates in Rafaela, Santa Fe, Argentina.

Population	2007	2008	2009‡
MR	79.71 aA	47.87 cA	53.72 b
ER	77.79 aA	49.16 cA	63.54 b
BR	60.13 aB	44.72 bAB	61.23 a
UCB	51.57 bB	37.70 cB	59.12 a
DF	34.04 cC	48.33 bA	58.37 a

Within rows, different small letters indicate significant differences at 0.05 level.
Within columns, different cap letters indicate significant differences at 0.05 level.
‡ Population means were not significantly different in 2009 at 0.05 level.

Discussion

Results from this study showed that patterns of seed retention changes among populations and among years in a germplasm collection of makarikari grass growing in central-Argentina. Population ER from Corrientes exhibited the least shattering percentage in 2007 but, no differences in SR among populations were detected in 2009, even though a tendency was apparent. A delayed seed shattering in ER in 2007 could be related to a deferred anthesis associated to a differential origin. Floral transition may be affected by signals that feed into both environmental and endogenous (or autonomous) pathways (Colasanti & Coneva 2009) and it was reported that weather conditions during the previous season affected flowering capacity and seed yield in reed canarygrass (*Phalaris arundinacea* L.) (Sahramaa *et al.* 2004).

In this study, time elapsed since the peak anthesis to peak shattering was variable among years and populations. In 2007, time elapsed since the peak anthesis to peak shattering was shorter in

DF and longer in ER and MR. However, peak anthesis and seed shattering were synchronized among populations in 2008 and 2009. A substantial seed fall occurred 2 weeks after anthesis in 2008, and 4 weeks after anthesis in 2009. Optimal harvest time has been conveniently correlated to growing degree units after peak anthesis in several forage grasses (Berdahl & Frank 1998) but it was found to be variable between years in eastern gamagrass (*Tripsacum dactyloides* L.) (Lemke *et al.* 2003). Further studies need to be performed to find an indicator to help managers decide optimum harvest timing in makarikari grass.

Perspectives

The variability in SR among years found in this study suggested a large environmental component in this character in makarikari grass indicating that genetic improvement may be slow. However, results could be successful if selection for SR was performed on specific characters not related to environmental interactions, such as inflorescence structure and abscission of the glumes (Falcinelli *et al.* 1984; Whalley *et al.* 1990). Therefore, morphological and histological studies on inflorescence structure and seed abscission may be needed to help elucidate specific mechanisms for resistance to shattering in makarikari grass.

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