

Seed yield components and yield per plant in populations of *Panicum coloratum* L. var. *makarikariensis* Goossens

Barrios, C.¹, L. Armando^{1,2}, G. Berone^{1,3} & A. Tomás¹. ¹INTA EEA Rafaela, Ruta 34 km 227 (2300). Rafaela, Santa Fe, Argentina. ²CONICET. ³Lehrstuhl für Grünlandlehre, Technische Universität München, Am Hochanger 1 D-85350 Freising-Weihenstephan, Germany.
E-mail: matomas@rafaela.inta.gov.ar

Abstract

Panicum coloratum L. var. *makarikariensis* Goossens (makarikari grass) is a warm-season perennial bunchgrass native to South Africa, adapted to subtropical, subhumid environments with heavy soils, that tolerates seasonal flooding and relatively long periods of drought. The objective of this study was to evaluate the extent and nature of variation in seed yield components in a germplasm collection with a limited genetic base. Research material included 5 populations coming from a wide range of soils and different management regimes in north-central Argentina. Number of seeds per panicle was determined using a seed trap in each of 10 individual plants per population. Mature and empty seeds were determined. Number of panicles per plant was counted at the end of the harvest period. Weight of 1000 mature seeds was estimated by averaging the weight of 3 samples of 100 seeds. Number of mature seeds per plant and yield (g) of seeds per plant were obtained by multiplication of the factors involved. Data was analyzed using ANOVA and population means were compared by LSD at the 0.05 level of significance. Correlations and path coefficient analysis were performed on the seed data. Populations differed markedly in seed yield per plant and the number of mature seeds per panicle. Minor differences were detected in seed weight and no difference was evident in number of panicles per plant. Therefore, the component most associated to yield per plant was the number of mature seeds per panicle. Further studies need to be performed to evaluate genetic variation and heritability of this trait to be included in a breeding program.

Introduction

Panicum coloratum L. is a warm-season cross-pollinated perennial bunchgrass native to South Africa that has been used around the world to improve pastures and in range revegetation (Lloyd 1981), given its wide adaptability and its ability to tolerate seasonal flooding in addition to long periods of drought (Tischler & Ocumpaugh 2004). It present there are two varieties: var. *coloratum* (kleingrass), extensively grown in Texas, was developed primarily for utilization as gamebirds, and var. *makarikariensis* Goossens (makarikari grass), utilized in Queensland, Australia, on heavy clay soils subjected to heavy grazing (Lloyd 1981; Tischler & Ocumpaugh 2004). In Argentina, *P. coloratum* has been introduced as a forage grass several times (Petruzzini *et al.* 2003) from different sources but its use has not been used extensively in the country. To increase the sowed area, production of good quality seed is crucial and therefore, a breeding program has been recently initiated at the National Institute of Agricultural Technology (INTA)

in Argentina focused on several aspects of seed production and seedling establishment. The program started with a small germplasm collection, consisting of accessions adapted to different areas and management regimes.

Seed yield is one of the characters commonly evaluated in breeding programs at the plant level and analyzed in terms of its components (Hearn & Holt 1969; Elgersma 1990; Diz *et al.* 1994): panicles per plant (number pan pl^{-1}) (number panicles plant^{-1} or no. panicles plant^{-1}), mature seeds per panicle (number seeds pan^{-1}) and weight of mature seed (g seed^{-1}). This study evaluated the extent and nature of variation in seed yield per plant and the associated components in the germplasm collection at INTA to be used in the breeding program. Specific objectives were i) assess variability in seed yield and seed yield components and ii) determine correlations among seed yield components and partition the correlation through path coefficient analysis to assess relative importance of direct and indirect effects.

Materials and Methods

Seed yield components were evaluated in a germplasm collection established at INTA Rafaela Experiment Station ($31^{\circ}11'41''$ S; $61^{\circ}29'55''$ W) in October 2006. The collection includes 5 populations coming from a wide range of soils and precipitation in north-central Argentina: DF, UCB and MR from Córdoba, ER (and?) BR from Corrientes (Typic Haplustol, 600 mm annual precipitation in Córdoba, and Vertic Argiudol, 1500 mm of annual precipitation in Corrientes, respectively). Each population consists in 32 individual plants, at 0.60 m distance in a 8 x 4 matrix. Populations were planted apart to avoid cross pollination.

Estimates of seed yield components were obtained from 10 individual plants per population in the summer 2008-09. Number of panicles per plant (change $\text{n}^{\circ}\text{pan.pl}^{-1}$) was counted at the end of the harvest period. In order to prevent seed losses through shattering, a seed trap especially designed was used to collect all the seeds produced per panicle. The trap consisted in a cylindrical steel structure over a pole that was covered by a nylon stocking. Panicles were set into the trap when at least 2/3 of all florets had gone through anthesis to ensure out-crossing. Seeds were collected from the trap weekly, from 03/21/09 to 04/17/09, taken to the lab, counted, added up and weighted. The number of mature and empty seeds was determined in each panicle. Weight of 1000 seeds (change g.1000 seed^{-1}) was estimated by averaging the weight of 3 subsamples of 100 mature seeds per plant. Number of mature seeds per plant (change $\text{n}^{\circ}\text{seeds.pl}^{-1}$) and yield per plant (change g.pl^{-1}) of seeds per plant were obtained by multiplication of the factors involved. Separated ANOVAs were conducted to test for population differences for each trait measured. Comparisons of population means were conducted by LSD test at 0.05 level of significance? for traits that had significant variations among the populations. Correlation and path coefficient analyses were done by standard methods (Dewey & Lu 1958). The causal relationships for the path coefficient analysis involved the four seed yield components primarily measured as predictor (cause) variables and seed yield as the response (effect).

Results

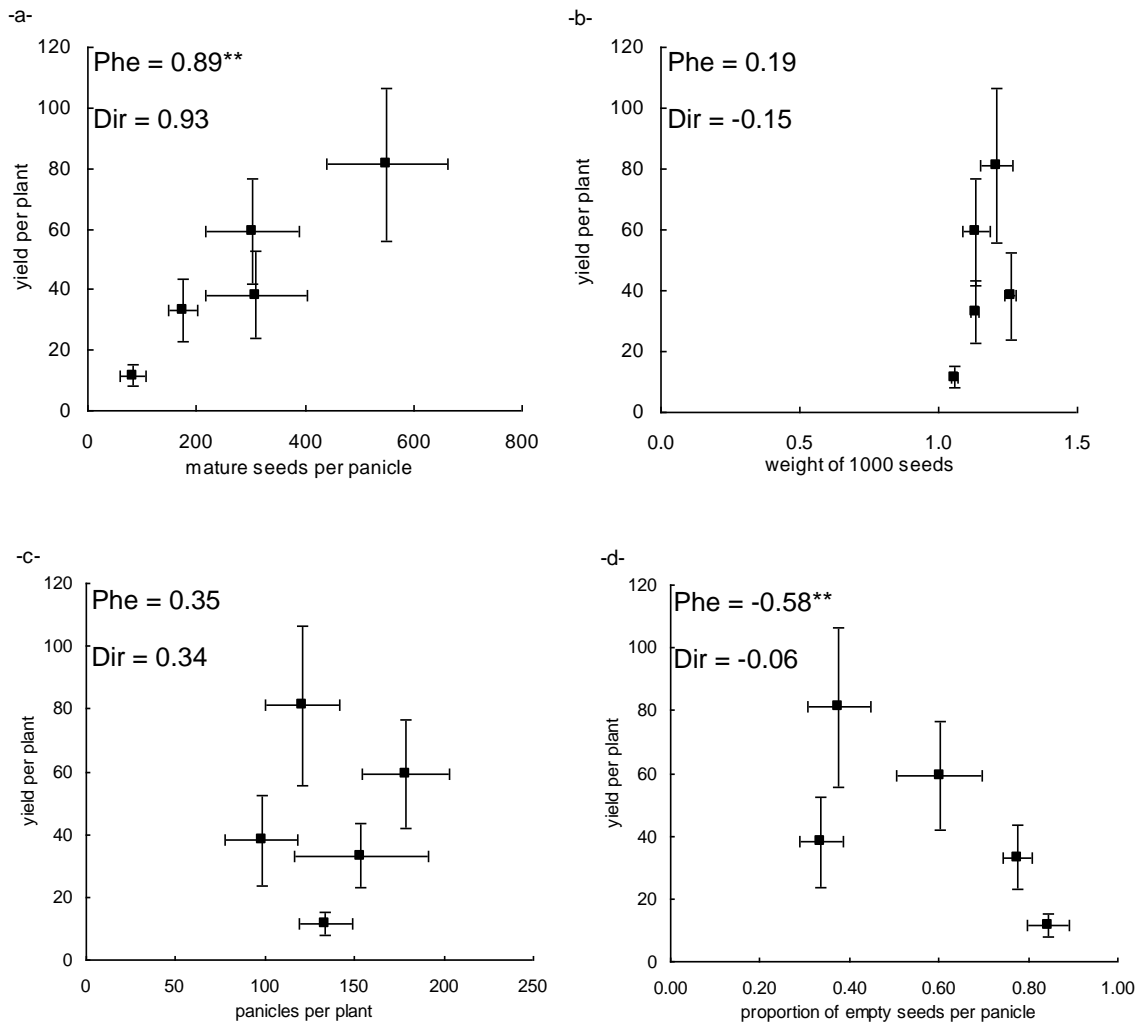
Variation among populations was detected in seed yield per plant, with ER the highest, BR and MR the lowest and DF and UCB intermediate (Table 1). Interestingly, in terms of the components of yield, while a similar ranking was detected for number of mature seed per panicle, variation in the weight of the seed was only slightly significant and no differences among populations were detected in the number of panicles per plant (Table 1). These findings suggest that variation of yield per plant was mainly associated with variation in number of mature seed per inflorescence.

Table 1. Means of yield per plant (change g.pl⁻¹), mature seeds per inflorescence (change seeds.pan⁻¹), 1000 seeds weight (change g.1000 seed⁻¹) and number of inflorescences per plant (change pan.pl⁻¹), in 5 populations of *Panicum coloratum* var. *makarikariensis* at Rafaela, Argentina in 2009.

Population	Yield per plant	Mature seeds per panicle	1000 seeds weight	Panicles per plant
DF	50 ^b	398 ^b	1.278 ^a	98 ^a
ER	86 ^a	572 ^a	1.226 ^{ab}	123 ^a
BR	22 ^c	161 ^c	1.058 ^d	129 ^a
UCB	54 ^b	321 ^b	1.162 ^{bc}	144 ^a
MR	27 ^c	161 ^c	1.131 ^c	152 ^a

Values followed by a common letter within a column are not significantly different as indicated by LSD test at $p = 0.05$

Figure 1. Relationships between yield per plant (change g.pl^{-1}) and (a) mature seeds per panicle (change seeds.pan^{-1}), (b) weight of 1000 seeds (change g.1000 seed^{-1}), (c) number of panicles per plant (change pan.pl^{-1}), and (d) proportion of empty seeds, in 5 populations of *Panicum coloratum* var. *makarikariensis* at Rafaela, Argentina in 2009. Phe = total phenotypic correlation coefficient; Dir = direct effect.



Correlations were partitioned into direct and indirect effects through path coefficient analysis. Number of mature seeds per panicle had the greatest positive effect on seed yield per plant (Fig. 1a) while weight of 1000 seeds and number of inflorescences per plant were negligible (Fig 1b, 1c), and the proportion of empty seeds per panicle was negative but not significant. The indirect effects were not significant ($P > 0.10$) for all variables analysed. The ranking of populations in the total number of seeds produced per panicle (Table 2) (the original text is fine) was different than the ranking of population for the number of mature seeds produced per panicle (Table 1), which means that populations showed differences in the proportion of empty (immature) seeds produced (Table 2, Fig. 1d).

Table 2. Means of total seeds per panicle (change seeds.pan⁻¹) and proportion of empty seeds, in 5 populations of *Panicum coloratum* var. *makarikariensis* at Rafaela, Argentina in 2009.

Population	Total seeds per panicle	Proportion of empty seeds
DF	568 ^c	0.32 ^c
ER	981 ^a	0.38 ^c
BR	784 ^{abc}	0.80 ^a
UCB	718 ^{bc}	0.56 ^b
MR	765 ^{abc}	0.78 ^a

Values followed by a common letter within a column are not significantly different as indicated by LSD test at $p = 0.05$

Discussion

Results from this study showed that there were marked differences in quantitative seed production traits among populations of makarikari grass. Variation in seed yield among cultivars have been reported in many forage grasses (Voltas *et al.* 1999; Lemke *et al.* 2003; Herrera-C *et al.* 2008). In this study, differences were not apparently related to the site where the populations were collected as populations from the same origin showed differential seed production (i.e. ER and BR were both collected in Corrientes).

Yield per plant was strongly and positively associated to the number of mature seeds per panicle (Fig. 1a), in agreement with previous reports for this and other species (Lloyd 1981; Diz *et al.* 1994; Wu *et al.* 2008). The lack of relationships between the seed weight and yield per plant found in makarikari grass (Fig. 1b), agree with the notion that seed size (weight) is a more conservative, highly-heritable character than seed number (Sadras & Denison 2009). However a significant positive genotypic correlation of both components, seed weight and seed number, was observed for *Pennisetum* sp. (Diz *et al.* 1994).

Our results showed that for populations of *P. coloratum* var. *makarikariensis*, the number of panicles per plant was not correlated to the seed yield per plant (Fig. 1c), contrasting with previous work in bermudagrass (Wu *et al.* 2008), that showed a large effect of panicle number on the seed yield per plant. Interestingly, this work showed that the number of total seeds per panicle was quite similar between populations (Table 2), implying that genesis of reproductive structures (flowers) was similar between populations. However, the number of mature seeds per panicle was different populations (Table 1), which cause a negative relationship between the proportion of empty seeds and the seed yield (Fig. 1d). The relatively high proportion of immature seeds in some populations could be due to unsuccessful fertilization and/or seed abortion. In addition, a source (photosynthesis) limitation due to nutritional and water deficits, during the period of fertilization of flowers may not be expected because plants were grown with high availability of water and nutrients, and all populations flowered and filled their seeds in a same time frame (January to April 2009). Hence, proportion of empty seeds seemed to be quite variable and characteristic of each population. In perennial grasses, unlike cereals, the vegetative

sinks (e.g. daughter tillers) are an active system of nutrient demand during the reproductive stage, being stem a specially important sink (Ryle 1970; Ryle & Powell 1972). In this study, populations BR and MR had more empty seeds, also were more leafiness and stoloniferous than the other populations (personal observation, A. Tomás) suggesting they might provide a greater proportion of assimilates to the vegetative parts than the other populations studied. Otherwise, the high proportion of empty seeds in MR and BR might be associated to a high number of sterile florets. In addition, the number of sterile florets was shown to be variable within and between species in several forage grasses (Elgersma 1990; Makela & Kousa 2009).

In conclusion, the variability observed among populations in seed production per plant associated to variability in the mature seeds per panicle and the proportion of empty seeds per panicle, suggests that these traits might be suitable to be utilized in a breeding program to improve the seed production in *P. coloratum* var. *makarikariensis*. However, further studies are needed to calculate estimates of the heritable genetic variation

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