Piptatherum miliaceum (L.) Coss: A Mediterranean Native Perennial Grass with Potential Use for Bioenergy

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Piptatherum miliaceum (L.) Coss: a Mediterranean native perennial grass with potential use for bioenergy

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Introduction

In Mediterranean regions, the development of a bioenergy sector is restricted by the scarce availability of species and varieties suitable to cultivation in rainfed environments, where summer drought affects plant survival (Scordia *et al*., 2014). Native perennial grasses that survive summer drought in a dormant or semi-dormant state may represent potential bioenergy crops. Nevertheless, the native germplasm of Mediterranean perennial grasses is unexplored for bioenergy production, except for giant reed, and little investigated also for other uses, as forage production. Smilo grass (*Piptatherum miliaceum* (L.) Coss) is a native species growing in marginal environments and it is palatable up to flowering stage. Its high aboveground biomass production suggests the alternative use as bioenergy plant when its palatability decreases. The aim of this study was to evaluate the degree of variability in dry matter yield, biomass partitioning among organs and feedstock quality for bioenergy uses in Sardinian native smilo grass populations.

Materials and Methods

The field experiment was carried out at the experimental station of CNR (40°45’12” N, 8°25’17” E; 27 m a.s.l.), in Sardinia (Italy), from 2012 to 2014. The climate of the area is typically Mediterranean with mild winter, characterized by a long-term average annual rainfall of 554 mm prevailingly distributed in autumn and winter months, and a mean annual air temperature of 16.2 °C. The soil was sandy-clay-loam, alkaline, with a low nitrogen content (<1‰).

Seeds of smilo grass were collected in July 2010 from wild populations growing in 10 sites differing for micro-environmental conditions. Seeds were sown in plastic trays under a cold polycarbonate-covered tunnel and seedlings were maintained in optimal water conditions for about 16 weeks, together with seeds of tall fescue (*Festuca arundinacea* Schreb.) *cv* Flecha (FA) chosen as test species. In April 2012, plants were transplanted to a spaced-plant field nursery, arranged in a completely randomized design with three replicates. Each replicated plot contained 8 plants spaced 0.5 x 0.5 m. An emergency irrigation (50 mm) was provided just after transplanting to help root development. No fertilizers were applied after transplant. Weeds were controlled mechanically.

Annual aboveground dry matter yield (DMY) was estimated in July 2013 and 2014, on individual plant basis, as average of dry weight of 6 plants per block (18 plants per population).

Biomass partitioning among tillers, leaves and panicles was estimated at the end of each growing season on 150 reproductive tillers per accessions (50 tillers per plot). Each biomass component was weighted and then oven-dried at 60 °C up to constant weight and then dry weight rate (%) was calculated. An amount of DM of each component was ground and stored for biomass quality analysis.

Dry milled subsamples of each biomass component were analyzed for their calorific value and the carbon, hydrogen, nitrogen, sulphur and chlorine contents, according to the Technical Specification UNI CEN/TS (2005).

The variability in biomass production and biomass quality traits was investigated through a two-way fixed model of analysis of variance (ANOVA) with “Accession” (A) and “Block” (B) as fixed effects. Fisher's least significant difference (*LSD*) method was used for comparing means in the ANOVA. All ANOVAs were performed using Stat graphics Centurion XVI.

Results and Discussion

In the first growing season (from September 2012 to August 2013), total rainfall was 718 mm, concentrated in winter and spring. In the subsequent growing season, a better seasonal distribution but a lower amount of rain was registered (626 mm). In both growing seasons total rainfall were higher than long-term average. Mean temperatures never dropped below the average monthly value of 7 °C (February 2013) and did not differ from long-term values, except in late spring 2012.
The percentages of biomass partitioning for tillers, leaves and panicles showed significant interaction accession (A) x year (Y). Conversely, no interaction A x Y was found for DMY values, that are shown as averaged values in Table 1. The high

yielding populations of smilo grass PM05 and PM06 significantly differed in DMY from several of the remaining populations and out-yielded FA (+60%). Moreover, a substantial variability for biomass partitioning was found between growing seasons and across populations and species. In 2014, biomass partitioning in tillers was higher than in 2013 in all smilo grass populations and in the test species (on average, 63.5 vs 50%).

Table 1: Plant aboveground dry matter production and its partitioning into components of ten smilo grass populations and tall fescue. PM indicates collected populations of *P. miliaceum* and FA the test species *F. arundinacea* var Flecha.

Populations	**Dry matter (g plant^{-1})**[a]	**Tillers (%)**		**Leaves (%)**		**Panicles (%)**	
		2013	**2014**	**2013**	**2014**	**2013**	**2014**
FA	652.0 a	53.3 e	62.4 ab	33.9 d	33.6 e	12.4 a	3.9 a
PM01	768.9 ab	49.7 a-d	62.0 ab	28.3 bc	16.0 a-d	25.9 bcd	22.0 c-g
PM02	977.9 bcd	52.4 de	60.5 a	27.1 abc	13.2 abc	23.2 b	26.3 fg
PM03	766.1 ab	51.5 b-e	70.7 c	26.7 abc	12.3 a	25.3 bcd	17.0 bc
PM04	783.4 ab	50.0 a-d	67.6 bc	29.4 c	15.0 a-d	24.4 bc	17.3 bc
PM05	1137.7 d	50.5 a-e	59.0 a	24.3 a	14.1 a-d	29.0 bcd	26.9 g
PM06	1089.5 cd	48.5 ab	62.0 ab	24.0 a	17.4 d	31.5 d	20.6 b-f
PM07	812.3 ab	48.7 abc	63.0 ab	25.8 abc	17.3 cd	29.7 bcd	19.7 bcd
PM08	867.9 abc	48.1 a	60.8 a	25.8 ab	14.3 a-d	30.4 cd	24.9 d-g
PM09	813.3 ab	51.4 b-e	68.0 bc	27.0 abc	17.8 d	25.2 bc	15.8 b
PM10	748.4 ab	49.3 a-d	61.0 a	26.5 abc	12.9 ab	28.2 bcd	26.0 efg

[a] *As average of 2013-2014. Means followed by the same letters within a column are not significantly different ($p \leq 0.05$)*

In 2013, tiller biomass rate was highest in tall fescue (53.3%) whereas in 2014, one smilo grass population only showed a significantly higher biomass accumulation in tillers than tall fescue (PM03). Similarly, tall fescue accumulated the highest amount of DM in leaves both in 2013 and in 2014 (about 34%). Both in 2013 and 2014, the contribution of panicles to dry biomass was markedly higher in smilo grass populations than in tall fescue. Finally, the calorific value reached on average 18.2 MJ kg^{-1} in tillers, a value slightly higher than in leaves and panicles (Table 2). The proximate analysis also showed differences among plant components. In particular, the ash content of leaves was about three times as higher than in tillers.

Table 2. Means and standard deviation (SD) for heating value, proximate and ultimate analysis in plant components of 10 smilo grass populations (% of dry weight).

Plant components	**Heating value (MJ kg^{-1})**	**Volatile matter (%)**	**Fixed carbon (%)**	**Ash content (%)**	**C (%)**	**H (%)**	**N (%)**	**S (%)**	**Cl (%)**	**O (%)**
Leaves										
Mean	16.3	75.7	13.8	11.5	48.5	6.2	1.7	1.0	1.2	43.6
SD	0.3	5.9	6.7	3.5	0.6	0.9	0.4	0.3	0.3	1.6
Tillers										
Mean	18.2	70.0	11.0	4.6	49.0	5.5	1.3	1.2	1.7	44.2
SD	0.9	4.7	0.8	1.1	1.6	0.7	0.3	0.5	0.2	1.8
Reproductive organs										
Mean	16.7	69.8	13.3	8.3	48.5	5.9	1.7	1.3	1.4	43.9
SD	0.7	6.4	4.0	2.5	1.3	0.9	0.7	0.5	0.4	1.7

The ultimate analysis indicated for smilo grass biomass contents of C, H, O and N typical for herbaceous fuels and quite similar to those reported for switch grass (David and Ragauskas, 2010). However, this outcome also revealed substantial higher contents of sulphur and chlorine, compared to switch grass. If confirmed, this indicate that smilo grass may be not suitable for direct combustion but for other bioenergy applications as biogas production or as cellulosic feedstock. Nonetheless, additional positive features of smilo grass need to be taken into account. In fact, the establishment and harvest of smilo grass can be performed with conventional farm machinery and the potential use as a dual purpose crop (bioenergy but also forage) may be more acceptable to farmers than the cultivation of rhizomatous species as giant reed or difficult-to-establish and exotic species as switch grass.

Conclusion

Two accessions of smilo grass (PM05 and PM06) exhibited a positive combination of high biomass yields (up to 1100 g $plant^{-1}$) and good calorific value (18.2 MJ kg^{-1} in tillers) and seem suitable for further studies aimed at exploiting native populations for bioenergy production under rainfed conditions and low inputs. Nonetheless, other accessions showed a better biomass partitioning in favour of tillers. The quality of biomass of smilo grass showed some critical aspects related to the high contents of chlorine and sulphur, especially in tillers (1.7% and 1.2%, respectively), and the high ash content. Nevertheless, the harvest of smilo grass in July can be seen as a favourable point for the implementation of a biomass chain involving other conventional species with different harvest times.

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