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Drought survival of some perennial grasses in Mediterranean rainfed conditions: Agronomic traits

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SUMMARY – A three-year experiment was carried out to evaluate perenniality and adaptive responses to drought of elite grass material from recent plant improvement work of *Dactylis glomerata*, *Festuca arundinacea* and *Phalaris aquatica* species, within the multi-site activity of the EU-PERMED project. The trial located in North Sardinia (Italy) on a calcareous sandy-loam soil was sown in October 2004 to compare 16 accessions. Measurements included: establishment, dry matter production, average row cover, sward senescence in late spring, plant and tiller density and phenology. Most cultivars established well. Plant density at establishment was higher in cocksfoots than fescues but from autumn 2005 tiller density was similar. Along the three years, fescues yielded significantly more than cocksfoots. Among *P. aquatica* accessions the cv. Partenope yielded almost 13 t/ha in the first year but did not survive summer drought. Plant re-establishment after summer drought was satisfactory for most accessions except *D. glomerata* cv. Porto. Results are encouraging, as several accessions combined a satisfactory yield potential with persistence under severe summer drought.

Keywords: Perennial grasses, perenniality, rainfed conditions, summer dormancy.

RESUME – *"Survie à la sécheresse de plusieurs graminées pérennes en conditions pluviales méditerranéennes : caractères agronomiques ". Une expérience de trois ans a été effectuée pour évaluer la pérennité et les réponses d'adaptation à la sécheresse du meilleur matériel des espèces de graminées* Dactylis glomerata*,* Festuca arundinacea *et* Phalaris aquatica *produites lors d'un récent travail d'amélioration de plantes, dans le cadre de l'activité multi-sites du projet EU-PERMED. Les parcelles d'essai conduites dans la Sardaigne du nord (Italie), sur un sol limo-sableux calcaire, ont été semées en octobre 2004 pour comparer 16 variétés et écotypes. Les mesures incluent : l'installation, la production de matière sèche, la couverture moyenne le long des lignes, la sénescence de la couverture végétale à la fin du printemps et la régénération automnale, la densité et la phénologie des plants. La plupart des cultivars se sont bien installés. La densité des plantes à l'établissement était plus élevée chez les dactyles que chez les fétuques mais à partir de l'automne 2005, la densité des rejets était similaire. Le long des trois années, les fétuques ont produit sensiblement plus que les dactyles. Parmi les écotypes de* P. aquatica*, le cultivar Partenope a produit presque 13 t ha^{-1}durant la première année mais n'a pas survécu à la sécheresse estivale. Le re-établissement après la sécheresse estivale était satisfaisant pour la plupart des écotypes à l'exception du cultivar Porto de* D. glomerata*. Les résultats sont encourageants car plusieurs écotypes ont montré un potentiel satisfaisant de rendement avec une bonne persistance dans des conditions de sécheresse estivale sévère.*

Mots-clés : *Graminées pérennes, pérennité, conditions sèches, dormance estivale.*

Introduction

Perennial forage species may represent a valuable alternative to annual forage crops, improving the environmental and economic sustainability of Mediterranean agro-pastoral farming systems. However, previous experience has pointed out the constraint of finding perennial grass seeds, able to overcome summer drought, in the seed market (Roggero *et al.*, 1990; Franca *et al.*, 1995). Summer dormancy, induced by photoperiod and temperatures, is a key-trait for drought avoidance, which improves plant persistence and allows the achievement of a range of agronomic and environmental goals (Volaire and Norton, 2006). A multi-site field experiment within the PERMED project (http://www.montpellier.inra.fr/permed) was established to evaluate élite grass material from recent plant improvement work and to define adaptive responses to drought in the field by the combined observations of agronomists and ecophysiologists. The present paper reports the agronomic results obtained in Sardinia.

Materials and methods

The trial was located in North Sardinia (Italy) in the experimental station of Ottava (40°44' N, 8°32'

E; 80 m a.s.l.) on a calcareous type sandy-loam soil (pH = 7.7) about 80-90 cm deep. The average annual rainfall is 547 mm, distributed over an average of 80 rainy days. Mean annual temperature is 16.2℃ and the annual radiation sum is 191 Mj m^{-2}. The accessions compared belong to three grass species: (i) *Dactylis glomerata*: Currie, Delta-1, Jana, Kasbah, Medly, Ottava and Porto; (ii) *Festuca arundinacea*: Centurion, Fletcha, Fraydo, Lutine, Sisa, Tanit; and (iii) *Phalaris aquatica*: Australian, Partenope and Atlas. The field assigned to the trial was ploughed to a depth of about 30 cm and superficially tilled in October 2004. Fertilisation was carried out with 44 and 46 kg ha^{-1} of N and P respectively, incorporated in the soil with superficial tillage. Sixteen plots of 6 m^2 size (3 x 2 m), with no space between plots of the same block, with 4 replicates in a randomized complete block design, were sown on the 26^{th} of October 2004, followed by rolling. Plots were fertilised in autumn and spring of every year with 35 and 40 kg ha^{-1} of N, respectively. Weed control was carried out the first year only with 1 lt ha^{-1} of herbicide Joker (Dicamba), and in the second year by limited hand weeding. Australian and Grombalia (*F. arundinacea)* cultivars did not emerge in the first year and were resown the following autumn with new Australian and Atlas seeds, respectively. The cv. Partenope did not survive either the first or the second summer and was sown again in the second and third year. The cv. Lutine due to its low covering rate in the first year was oversown with new seeds in the gaps of the rows in October 2005. No irrigation was carried out.

Dry matter yield was estimated by regular mowing to *c.* 20 cm on a sample area of 3 m^2 per plot. Sward height was measured with the plate meter (Franca *et al.*, 1995). Plots were mowed at 5 cm above ground level. Visual assessment of average row cover (0-100%) was recorded monthly. Senescent biomass percentage on the total biomass in the plot was estimated through visual rating from late spring to early autumn. Plant density after establishment and tiller density after autumn re-growth and spring were recorded by counting the number of plants/tillers on four 25 cm long samples on 4 rows per plot. Heading percentage on total tillers was determined on 2 m of the outermost 2 rows left undisturbed (not mown). In the second and third year it was not possible to distinguish individual plants on the row, therefore heading was determined as a percentage of tiller number. Meteorological data were recorded daily by the on-site weather station (Table 1).

Table 1. Meteorological conditions during the three years of trial at Ottava research station

	35-year avg.	2004-2005	2005-2006	2006-2007
Rainfall September-March (mm)	490.0	471.4	469.8	389.8
Rainfall April-June (mm)	45.0	85.2	23	108
Rainfall July-August (mm)	12.0	10.2	6.0	18.0
Total rainfall (mm)	547.0	566.8	498.8	515.8
Mean of daily min. temp. Jan-Feb (℃)	6.1	5.2	5.1	8.3
Absolute min. temp. in winter (℃)	- 3.0	-1.0	-2.0	2.1
Mean of daily max. temp. July-Aug (℃)	29.6	30.9	30.4	29.4

Results and discussion

In the first year a good establishment was favoured by abundant autumn and early winter rainfalls, but total dry matter values were negatively affected by an early dry spring (Table 2). Satisfactory performances in the second and third year were reached, especially for fescues and to a lesser extent cocksfoots, confirming the results obtained by Bullitta *et al.* (1982). Very interesting performances were observed in terms of seasonal distribution of forage production. Fast autumn re-growth and high winter growth were recorded, for example by Tanit, Fletcha and Kasbah. This aspect is very important as forage availability from native pastures in these seasons is low and farmers are interested in reducing supplement use. Within cockfoots, the local Ottava ecotype showed increasing production values, despite slow initial establishment and lower overall density. Kasbah and Ottava, which in the first year yielded significantly less than other accessions, caught up in the second year: Kasbah due to a good autumn re-growth and winter production (October and January) and Ottava due to a good spring production (April). This pattern was confirmed during the third year. Among fescues, Lutine yielded the lowest over the three years, due to a low initial density, poor autumn re-growth and low winter production, though spring production was high. Fescues showed lower plant density than cocksfoots at establishment but greater tiller density at autumn re-growth (Table 3).

Table 2. Dry matter yield (t ha^{-1}) and least significant difference (P<0.05) for each cut and year totals

Species	Accession	May 05	Oct 05	Jan 06	Apr 06	Oct 06	Jan 07	Mar 07	May 07	Year I	Year II	Year III
D. glomerata	Jana	2.3	2.2	0.5	2.2	1.0	1.4	0.7	1.9	2.3	4.8	5.0
	Medly	2.4	1.5	0.6	2.9	0.2	1.0	1.2	1.3	2.4	5.0	3.8
	Kasbah	1.5	1.8	1.2	2.1	1.1	1.9	0.7	0.6	1.5	5.2	4.4
	Delta-1	2.6	2.3	0.6	2.4	1.0	1.1	0.9	1.9	2.6	5.3	4.9
	Currie	2.1	2.2	0.4	1.9	1.0	1.1	0.6	2.2	2.1	4.5	4.9
	Porto	2.4	0.5	0.4	1.5	0.1	0.5	0.5	1.7	2.4	2.4	2.7
	Ottava	1.8	1.7	0.5	2.7	1.0	1.3	1.0	2.3	1.8	4.9	5.5
F. arundinacea	Tanit	3.7	3.2	2.0	2.9	1.9	1.4	1.3	1.6	3.7	8.2	6.2
	Sisa	3.2	2.6	1.7	3.9	1.7	1.1	1.1	2.1	3.2	8.3	6.0
	Centurion	3.1	2.5	2.1	3.5	1.5	2.4	1.4	1.2	3.1	8.1	6.5
	Fletcha	3.9	3.4	2.6	3.3	2.1	2.4	1.1	1.3	3.9	9.3	6.9
	Lutine	1.9	1.7	1.6	3.8	1.2	1.1	1.2	2.1	1.9	7.1	5.6
	Fraydo	3.9	2.8	2.3	3.8	1.2	2.8	1.4	0.8	3.9	8.9	6.2
P. aquatica	Atlas(*)	-	-	-	1.2	0.4	1.8	0.8	1.1	-	1.2	4.1
	Australian(*)	-	-	-	0.8	0.4	2.3	0.8	1.1	-	0.8	4.6
	Partenope(**)	12.8	-	-	2.2	-	1.3	1.0	1.3	12.8	2.2	3.7
	LSD	*1.0*	*0.6*	*0.4*	*0.6*	*0.6*	*0.5*	*0.3*	*0.5*	*1.1*	*1.0*	*0.9*
Cocksfoot		2.2	1.7	0.6	2.2	0.8	1.2	0.8	1.7	2.2	4.6	4.4
Fescues		3.3	2.7	2.1	3.6	1.6	1.8	1.2	1.5	3.3	8.3	6.2
P. aquatica		11.8	-	-	1.4	0.4	2.0	0.8	1.1	12.8	1.4	4.3

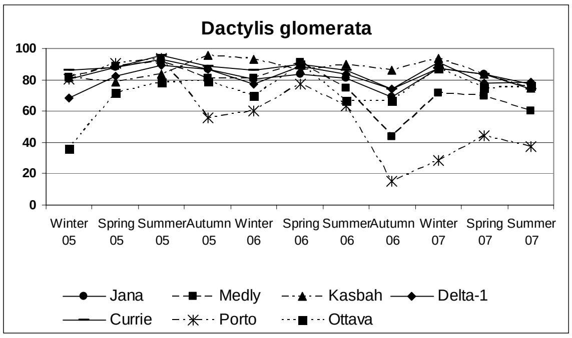
(*) DMY of Apr 2006 also includes a 2nd harvest in May of 0.3 t ha^{-1}.
(**) DMY of May 2005 also includes a 2nd harvest in July of 1.0 t ha^{-1} and DMY of Apr 2006 also includes a 2nd harvest in May of 1.1 t ha^{-1}.

Table 3. Plant density at establishment (Feb 2005) and tiller density thereafter (no. per m^2)

Species	Accession	Feb-05	Oct-05	Apr-06	Nov-06	Apr-07
D. glomerata	Jana	497	1709	3040	960	1506
	Medly	598	1557	2076	717	1081
	Kasbah	590	1831	2156	1970	1250
	Delta-1	373	1616	2644	1030	1241
	Currie	740	1716	2654	1070	1516
	Porto	792	587	2253	210	658
	Ottava	192	1137	2431	1217	1387
F. arundinacea	Tanit	328	1959	3391	1330	1428
	Sisa	115	1939	2973	1393	1150
	Centurion	360	2710	3685	1383	1300
	Fletcha	295	2146	2991	1497	1150
	Lutine	77	1326	2409	923	877
	Fraydo	400	1853	2502	1240	951
	LSD (P<0.05)	*111*	*564*	*938*	*448*	*332*
Cocksfoots		540	1450	2465	1025	1235
Fescues		249	1995	2912	1140	1055

Lutine, Sisa and Ottava showed the poorest establishment values. Tiller number generally increased from October 2005 to April 2006 for all accessions. In autumn 2006, Kasbah showed the highest density value, while Porto significantly reduced tiller density.

Porto and to a lesser extent Medly within cocksfoots, and Lutine and to a lesser extent Fraydo within fescues, also showed the lowest row cover in the third spring. Seasonal average patterns of row covering rate were strictly related to tiller densities (Fig. 1).



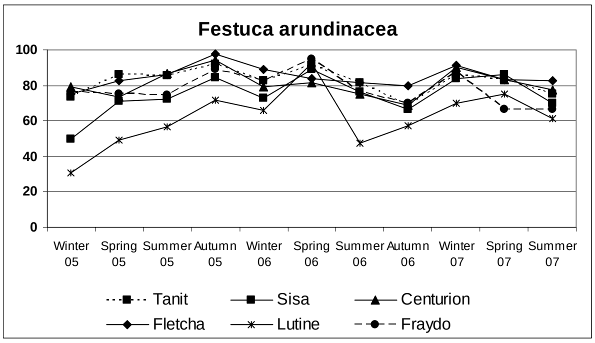


Fig. 1. Average row cover (%) for the two main groups of species along the three years.

Fescues showed lower heading percentages than cocksfoots, due to a higher overall tiller number. Among cocksfoots, Porto confirmed to be the most late-heading one while the most early-maturing accession was Kasbah. The highest heading values were reached by Ottava, Porto and Kasbah (between 30% and 40% of heading). Heading percent was strongly and inversely related to tiller number: accessions with high tiller densities (Jana, Tanit and Centurion) had lower heading percentages, whereas accessions with low tiller densities (e.g. Porto and Lutine) had higher heading percentages.

P. aquatica accessions, especially Partenope, were the first accessions to enter the leaf senescence stage, from late May / beginning of June, followed by the cocksfoot Kasbah. In July all cocksfoots reached 90%-100% of dry tissues, whereas fescues senesced later and to a lesser extent than cocksfoots (max 90-95% in July). Among cocksfoots the greenest accession was Porto and among fescues Lutine and Sisa.

Conclusions

Site-specific results are encouraging as several accessions of fescues and cocksfoots associated satisfactory production levels with persistence (e.g. Fletcha). Some varieties gave a consistently good response in terms of fast autumn re-growth and winter production which is very important to mitigate seasonality of production in low-input grassland-based farming systems. Further responses are expected from the multi-site analysis of genotype x environment interactions, the correlation with plant eco-physiological results and forage quality analyses. Perennial grasses may represent a useful complement or an alternative to legume meadows, but varieties must be chosen in relation to specific farm organization needs.

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