Adaptability and productivity of some warm-season pasture species in a Mediterranean environment

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Summary

Warm-season grasses and legumes have the potential to provide forage throughout the Mediterranean summer when there are high temperatures and low rainfall and when cool-season grasses become less productive. Twenty-nine non-native, warm-season pasture species (twenty-three grasses and six legumes) were assessed for their adaptability to the coastal plain of southern Italy in terms of their productivity and nutritional quality. The investigated species were compared with two reference species widely used in a Mediterranean environment: a grass (*Festuca arundinacea*) and a legume (*Medicago sativa*). The species differed in their phenological and biological characteristics, i.e. start of vegetative resumption, first flowering and cold resistance, from each other and from the control species. From the second year after establishment, warm-season perennial grasses had high dry-matter (DM) yields and, in many cases, a more than adequate nutritional quality. As for legumes, the control, *M. sativa* gave the best results in all the investigated characters. Among the grasses, seven species (*Chloris gayana*, *Eragrostis curvula*, *Panicum coloratum*, *Paspalum dilatatum*, *Pennisetum clandestinum*, *Sorghum almum*, *Sorghum* spp. hybrid) had DM yields greater than the control species and had their maximum growth during the hottest period of the year, when *F. arundinacea*, the control grass species, was dormant. *Eragrostis curvula* had the highest annual DM yield (21·1 t ha^{-1}) and *P. clandestinum* provided the best combination of agronomic and yield characteristics which were similar to those of *M. sativa*. The seven above-mentioned species have the potential to supply hay or grazing and contribute to broadening and stabilizing the forage production calendar in Mediterranean-type environments.

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Introduction

Species of pasture plants can be divided into tropical (or) C_4 species and temperate (or) C_3 species, depending upon their germination characteristics, temperature requirements for growth and photosynthetic pathway (Ludlow, 1985; Winslow *et al.*, 2003). Both types grow from the Equator to high latitudes, and their distribution and separation into warm-season and cool-season species is due mainly to the inability of temperate and tropical species to survive high and low temperature, respectively, and, to a lesser extent, to their different temperature optima for growth and photosynthesis.

According to Ludlow (1985), maximum growth rates of C_4 grasses are greater than those of C_3 grasses and C_3 legumes from both tropical and temperate areas; yields of C_4 grasses generally range from two to four times those of C_3 species. C_3 and C_4 grasses often differ in their nutritional quality and, in a Mediterranean environment, grow during different parts of the year: growth of cool-season species occurs mainly in the cooler months, spring and autumn while growth of warm-season species occurs mainly during the warmer months of the year. For both pasture types, therefore, growth is reduced by a shortage of the above-mentioned inputs and especially by temperature (Ludlow, 1985).

A Mediterranean climate, as defined by Aschmann (1973), covers areas where more than 0·65 of annual precipitation occurs between November and April in the northern hemisphere and where annual hours with temperatures lower than 0°C do not exceed 263 h. Using this definition, most of the coastal areas of the Mediterranean countries including southern Italy and the Italian islands are included. Those factors are among the major limiting factors to herbage production. Moreover, the uneven seasonal variation in herbage production is the major technical constraint to the profitability of different livestock systems. In these environments in Italy, rain-fed herbage production is characterized by marked seasonality in growth, which is concentrated mainly in the spring and, to a lesser extent, in the autumn (Rivoira, 1976; Corleto, 1985; Pardini *et al.*, 1987; Pazzi *et al.*, 1990; Basso *et al.*, 1992), whereas irrigated pastures produce higher yields and a longer growing period (Caliandro and De Caro, 1973; Caliandro *et al.*, 1983; Corleto, 1985; Rubino *et al.*, 1985; Tarantino, 1991). In Mediterranean environments and in southern Italy, in particular, alfalfa (*Medicago sativa* L.) is the most widely grown forage legume species. In addition to the agronomic and environmental value of forage legumes in general, the widespread use of alfalfa in particular is due to its high adaptability to climate conditions and potential yield and to its high nutritional value, especially when irrigation can be used to mitigate drought (Iannucci *et al.*, 2002; Cosentino *et al.*, 2003). Nevertheless, yield in summer of both cool-season grasses and autochthonous (or native) legumes is reduced when compared with the one obtainable in spring and, occasionally, in autumn because of reduced tolerance of autochthonous species to summer temperatures (Cereti and D'Antuono, 1991). Conversely, warm-season grasses can provide green forage for livestock throughout the hot and dry Mediterranean summer, when cool-season grasses become less productive (Madakadze *et al.*, 1998).

This article investigates the extent to which a range of summer-growing pasture species are capable of compensating for the constraints imposed by climate (high temperature and low precipitation) in order to ascertain their possible utilization in Mediterranean fodder systems. It reports the agronomic, production and feeding value traits for non-native, warm-season pastures species grown on the coastal plain of southern Italy with the aim of assessing their contribution to broadening and stabilizing the forage production calendar.

To meet the specific aims of the study, the term 'adaptability' has a more agronomic than ecological meaning and refers to the capacity of a species, under intensive management conditions of nutrient inputs and irrigation, to overcome the marked seasonality of climate, mainly resulting from temperature and precipitation.

Materials and methods

The experiment was carried out over a 4-year period (1995–1998) at the Experimental Teaching Centre 'E. Pantanelli' located in the area of Policoro (40°02′ N, 16°55′ E, 15 m above sea level) on a deep, alluvial, silty-clay soil of good structure and fertility. Its main chemical and physical characteristics are given in Table 1. Throughout the experiment, minimum and maximum temperatures and rainfall were recorded daily at the meteorological station of the experimental farm.

Table 1 Main chemical and physical soil characteristics of experimental site.

Soil characteristics	Value
Chemical characteristics	
Total nitrogen (‰)	1·67
Total P (ppm)	719
Assimilable P – Olsen's method – (ppm)	26·7
Exchangeable K – ammonium acetate method – (ppm)	227
Organic matter – Walkley Black method – (%)	3·64
Carbonates – as $CaCO_3$ – (%)	6·20
Reaction (pH in water)	7·72
Salinity (‰)	1·15
Particle size	
Coarse sand – 2> Ø >0·2 mm – (%)	0·58
Fine sand – 0·2> Ø >0·02 mm – (%)	39·20
Silt – 0·02> Ø >0·002 mm – (%)	37·40
Clay – Ø <0·002 mm – (%)	22·82
Hydrological constants	
Field capacity – measured in the field – (% dry weight)	31·5
Wilting point – −1·5 MPa – (% dry weight)	14·9
Bulk density (kg dm^{-3})	1·25

A randomized block design was applied, with three replicates and the area of the experimental plots was 6 m^2. Thirty-one species in total were tested, twenty-nine of which were warm-season species (twenty-three grasses and six legumes) and two control species, *Festuca arundinacea* and *M. sativa*; the majority of the species were perennial with only five being annual (*Cenchrus ciliaris*, *Cenchrus setigerus*, *Sorghum almum*, *Sorghum* spp. hybrid and *Dolichos lablab*). The list of the species and varieties used, some of which had been previously investigated by other authors (De Franchi *et al.*, 1995), is given in Table 2. Besides the aforementioned plots of 6 m^2, subjected to periodic biomass cutting and harvesting, smaller plots of 2 m^2, with two replications, were used in order to track the undisturbed development of the species and record their major phenological stages in the course of the 4 years of the experiment, with particular emphasis on flowering date, and seed formation and dispersion.

Plants were sown, in 30-cm spaced rows, with a seed density of 25 kg ha^{-1} for species having a 1000 seed weight lower than 1 g and of 40 kg ha^{-1} for the other species on 17 July 1995. The soil was ploughed to a depth of 45 cm in winter of the previous year, fertilized with 150 kg ha^{-1} of P_2O_5 and 80 kg ha^{-1} of N, well harrowed on the soil surface and irrigated a few days prior to sowing. Species that failed to survive through the winter, were resown in the late spring of the following year. In addition, the seeds of four genotypes

Table 2 List of the species and cultivars used in the experiment. Mean height and major phenological stages are also described.

Species	Cultivar	Height (cm)‡	Start of spring regrowth†	First flowering†
Grasses				
Andropogon gerardii	Cimarron	23·4 e	Mid-April	Late August
Andropogon gerardii	Kaw	37·0 d	Mid-April	Late August
Bothriochloa insculpta	Hatch	36·2 d	(1)	Mid-August
Bothriochloa pertusa	Keppel	16·9 e	(1)	(2)
Bouteloua curtipendula	El Reno	27·2 e	Early April	Mid-June
Buchloë dactyloides		15·9 e	Mid-April	Mid-May
Cenchrus ciliaris	Gayndah	36·0 d	(1)	Late August
Cenchrus setigerus	Biloela	51·2 c	(1)	Mid-August
Chloris gayana	Callide	55·7 b	(1)	Late August
Chloris gayana	Pioneer	48·3 c	Late April	Early June
Eragrostis curvula	Ermelo	45·3 c	Early April	Early May
Festuca arundinacea	Penna	33·4 d	Early February	Mid-April
Panicum coloratum	Bambatsii	54·1 b	Mid-April	Mid-June
Panicum maximum	Gatton	52·7 b	Mid-April	Late June
Panicum virgatum	Blackwell	38·9 d	Early April	Early September
Paspalum dilatatum		43·6 c	Early April	Mid-June
Pennisetum clandestinum		32·5 d	Mid-April	(2)
Setaria sphacelata	Narok	66·5 b	(1)	(2)
Setaria sphacelata	Solander	63·7 b	Early May	Mid-June
Sorghastrum nutans	Cheyenne	28·7 e	Early April	Early September
Sorghum almum		80·6 a	Mid-April	Mid-June
Sorghum spp. hybrid	Silk	85·3 a	Mid-April	Mid-June
Sporobolus airoides		–	(1)	(2)
Urochloa mosambiciensis	Nixon	52·6 b	(1)	Late June
Legumes				
Desmodium intortum	Greenleaf	35·8 d	Mid-May	(2)
Dolichos lablab	Highworth	56·9 b	(1)	Mid-October
Lotononis bainesii	Miles	16·4 e	Early April	Late April
Medicago sativa	Garisenda	57·2 b	Early March	Late April
Neonotonia glycine	Cooper	37·7 d	(1)	(2)
Neonotonia glycine	Tinaroo	30·5 d	(1)	(2)
Stylosanthes guyanensis	Oxley	16·0 e	(1)	Early September

Mean values in the same column followed by the same letter are not different for $P \leq 0{\cdot}01$ (method of Calinski and Corsten, 1985).
†Early = 1–10 d of a month; mid = 11–20 d of a month; late = 21 d to end of a month.
‡Average of all measurements performed on mowed plots.
(1) Not survived the winter.
(2) Phase not reached.

were not available throughout the experiment; consequently, *Setaria spacelata* cv. Narok, *Sporobolus airoides* and *Neonotonia glycine* cv. Cooper were present only in 1995, *Chloris gayana* cv. Callide in 1995 and 1996 and *D. lablab* (used to substitute for *N. glycine* cv. Cooper) in 1996 and 1997.

In the course of the 4 years, weeding of the plots containing all the species was performed in late winter; furthermore, the plots were manually weeded, if necessary, just before cutting to prevent any impact on the dry-matter (DM) yield not attributable to the species. A sprinkler irrigation of about 400 m^3 ha^{-1} after each cutting, except for the last cut of each year, was applied; 50 kg ha^{-1} of N after each cutting was supplied only to grasses.

Mowing was always performed on the entire plot but an area of 2·5 m^2 was used for the measurement of the harvested biomass, in order to determine its dry weight. Harvesting was performed by cutting the plants to 5 cm above the soil surface. During the first experimental year (1995), to ensure the establishment of the plants at a satisfactory density, a harvest was performed only after flowering for those genotypes that had reached that stage. A final harvest was performed for all the genotypes at the end of October to evaluate biomass production at the end of the growing season and to have all the genotypes under the same conditions at the beginning of the subsequent winter period. In the subsequent years, cutting was performed every 28 d, following the method described by Corrall and Fenlon (1978) which aimed to simulate grazing; only those genotypes that each time exhibited enough vegetation to justify cutting were actually harvested.

The following measurements were made: survival of a plant species over the winter, date of flowering, pasture height before cutting, herbage mass of DM and nutritional value [crude protein (CP), crude lipid (CL), crude fibre (CF) and ash concentrations], the latter referring to samples collected in the summer of 1996. Plants height was considered as the maximum plant height on ten plants for each plot. The DM content of the harvested forage was determined by drying to constant weight at 75°C in a forced-draught oven. CP, CL, CF and ash concentrations were measured according to AOAC (1984).

Data and statistical analysis

The harvest dates were slightly different for each species, according to their growth rate and phenological development during the growing season, but were also slightly different in the successive years of the experiment. In order to allow a comparison between species and years, the harvest dates were combined into four periods. The first period (P1) contained all the harvests from the start of growth in the spring until 10 May and roughly corresponds to spring, when the cool-season grasses are vegetative; the second period (P2) contained harvests from 11 May to 15 June and approximately corresponds to the period when the performance of cool-season grasses declines; the third period (P3) contained harvests made from 16 June to 31 August, and corresponds to when the cool-season grasses are dormant; and the fourth period (P4) contained those harvests from 1 September until the end of the growing season when the cool-season grasses start to regrow.

All the obtained data were submitted to an analysis of variance. Plant height and nutritional value variables were analysed as a randomized block design. Yield of DM was analysed as a 'split-strip-plot' analysis design (Steel and Torrie, 1980; Gomez and Gomez, 1984) with the genotypes being the main plots, the harvests within and between years as sub-plots, both virtually positioned by 'strips'.

Comparison between the means was made as proposed by Calinski and Corsten (1985) to form groups that were not superimposed. Such a procedure is less reliable than the more common multiple comparison procedures between means, but is applied in exploratory analyses in order to select special sets of treatments through clear and unambiguous criteria (Acutis and Lotito, 1995).

Results

Meteorological data

The monthly mean maximum and minimum temperatures and the sum of monthly precipitation for the years of the experiment and for the long-term average (1959–1998) are given in Table 3. In the 4 years of the experiment, maximum temperatures were generally lower than the long-term average, whereas minimum temperatures showed no strong deviation from the long-term average. Temperatures below 0°C were infrequent and reached minimum values of −2·5°C in February 1996, this being the coldest year, whereas the highest daily maximum values, ranging from 35 to 36°C, were those in summer 1998.

Rainfall varied greatly between years, both in quantity and distribution. In 1995, the period of the growing season had less rainfall than average but with a rainfall distribution – adequate amounts in August and September – which favoured crop establishment. The wettest year was in 1996 which had a greater than average autumn and winter rainfall. In 1997, total rainfall was not different from the long-term average, although the seasonal distribution was a relatively dry period (until mid-August) followed by a rather rainy one favoured growth but delayed the last two harvests of the year. Finally, in 1998, total rainfall was lower than average but evenly distributed through the year.

Establishment and dry-matter yield

Twelve species did not survive the winter in 1995 (Table 2); the remaining species showed resumption of vegetative growth in April, except for the control species and *Lotononis bainesii* which resumed growth earlier and *Setaria sphacelata* cv. Solander and *Desmodium intortum* which resumed growth later. The appearance of early flowers was never observed for six species (Table 2) and it was rather variable for the remaining ones in the period from mid-April to mid-October.

The average vegetation height (Table 2) of the species harvested at least once ranged between 83 cm (the mean value for the two sorghum species, with upright habit and of rapid growth) and 20 cm, the average height for those species with a creeping habit (*Bothriochloa pertusa*, *Buchloe dactyloides*, *L. bainesii*), of low vigour (*Andropogon gerardii* cv. Cimarron, *Stylosanthes guyanensis*), or of constitutionally small-size (*Bouteloua curtipendula*, *Sorghastrum nutans*).

Table 3 Monthly average maximum (T_{max}) and minimum (T_{min}) temperatures (°C) and cumulative rainfall (mm, rain) in the four years of the experiment and in the period from 1959–1998.

	1995			1996			1997			1998			1959–1998		
	T_{max}	T_{min}	Rain	T_{max}	T_{min}	Rain	T_{max}	T_{min}	Rain	T_{max}	T_{min}	Rain	T_{max}	T_{min}	Rain
January				12·6	5·7	166	12·6	5·2	72	12·7	4·0	71	12·6	3·7	65
February				10·2	3·2	113	13·9	3·6	3	15·0	4·5	23	13·3	4·1	52
March				13·0	4·8	95	16·6	5·6	23	13·5	3·7	93	15·6	5·9	59
April				17·1	7·2	37	15·2	4·0	25	18·3	8·0	10	18·6	8·2	34
May				22·4	13·4	30	23·9	13·2	1	21·9	12·7	26	23·2	12·6	30
June				27·1	17·4	1	26·7	17·3	13	28·2	17·1	0	27·6	16·5	18
July	30·7	20·8	1	29·1	18·2	7	29·8	18·9	5	31·5	19·8	6	31·0	19·1	16
August	28·2	19·4	72	29·5	19·6	29	28·7	19·1	52	30·9	21·8	22	31·0	19·2	22
September	24·7	16·1	46	23·4	15·0	46	25·8	16·6	103	25·1	16·8	11	27·4	16·4	39
October	22·5	12·7	4	19·7	12·1	113	20·4	11·8	152	22·2	12·7	36	22·5	12·6	65
November	15·4	6·7	65	17·5	8·7	40	16·7	9·9	106				17·3	8·1	79
December	14·7	7·9	45	13·5	6·0	71	13·3	5·2	19				13·8	5·1	78
Average or total													21·2	11·0	557
Deviation from the 1959–1998 period	−1·1	+0·5	−66	−1·6	0	+191	−0·9	−0·1	+17	−0·4	+0·3	−102			

The mean annual DM yields for higher yielding species (*C. gayana* cv. Pioneer, *Eragrostis curvula*, *Panicum coloratum*, *Paspalum dilatatum*, *Pennisetum clandestinum*, *S. almum*, *Sorghum* spp. hybrid) showed values ranging from 16·4 to 21·1 t ha^{-1}, these being on average 0·30 higher than the control (Table 4). Moreover, on average, the above species gave 0·50 of their production in mid-summer (P3), which corresponds to the 'summer slump' (maximum vegetative decline) period of *F. arundinacea*.

Annual species, re-sown early in June every year, were characterized by rather late and not very high yields. Due to its very slow growth, *A. gerardii* cv. Cimarron was not harvested in the first year; *S. sphacelata* cv. Narok and *Neotonia glycine* cv. Cooper produced 6·1 and 3·6 t ha^{-1} DM, respectively, in 1995; *S. guyanensis* always had a very low plant density with stunted and chlorotic plants; it was harvested only in 1997 with a production of 1·1 t ha^{-1} DM; *N. glycine* cv. Tinaroo produced no growth in the fourth year.

The investigated species differed in the DM content; *B. curtipendula* and *B. dactyloides* showed rather high values, on average close to 0·41, whereas *S. sphacelata* cv. Solander and *P. clandestinum* exhibited the lowest value, on average equal to 0·20 (data not shown).

Crude protein concentration (Table 5) was, as expected, higher for legumes than for grasses. Among the former, *L. bainesii* had the highest CP concentration, whereas *S. sphacelata* cv. Solander, *P. clandestinum* and *C. gayana* cv. Callide has the highest concentrations among the latter. *Pennisetum clandestinum* and *M. sativa* yielded the highest amount of CP in the 4-year period with 12·4 and 11·2 t ha^{-1} respectively (data not shown). *Setaria sphacelata* cv. Solander had the highest CL concentration followed by five other grasses, all of them having values greater than 20 g kg^{-1} DM. Ash concentration (Table 5) was on average higher in grasses than in legumes, with values greater than 120 g kg^{-1} DM for *Urochloa mosambiciensis*, *C. ciliaris* and *C. gayana* cv. Callide, whereas the lowest values were observed for *E. curvula*, *S. nutans*, *B. dactyloides* and *Panicum virgatum*. Finally, the CF concentration (Table 5), which had an average value of 290 g kg^{-1} DM across all the investigated species, showed lower values for *P. clandestinum* and *L. bainesii*. The CF concentration was high for *M. sativa* and low for *F. arundinacea*, *S. sphacelata* cv. Solander and the two species (*B. curtipendula*, *B. dactyloides*) that exhibited the highest DM content.

Discussion

The aim of the experiment was to compare the performance of warm-season species and cultivars to be used as supplemental and/or alternative sources of herbage to traditional species of temperate environments. In the last decade, some tropical and steppe-type species have been introduced in southern Italy to compensate for scarce green herbage production in summer in that they are markedly warm-season and better adapted to conditions of water scarcity compared with more widespread autochthonous species (Pardini *et al.*, 1987; Corleto and Cazzato, 1990; Pazzi *et al.*, 1990; Piemontese *et al.*, 1994; De Franchi *et al.*,

Table 4 Dry-matter (DM) yields for the years 1995, 1996, 1997 and 1998 (number of harvests in parentheses for the latter 3 years), the DM yield and the proportion of the mean annual DM yield (Prop.) occurring in each of the four periods (P1 from regrowth to 10 May; P2 from 11 May to 15 June; P3 from 16 June to 31 August; P4 from 1 September to the end of the growing season) and mean annual DM yield.

	Dry matter yield (t ha^{-1})				P1		P2		P3		P4		Mean
	1995	1996	1997	1998	DM yield (t ha^{-1})	Prop.	DM yield (t ha^{-1})	Prop.	DM yield (t ha^{-1})	Prop.	DM yield (t ha^{-1})	Prop.	DM yield (t ha^{-1})
A. gerardii cv. Cimarron*	–	10·0 c (4)	7·9 c (4)	6·2 c (3)	–	–	6·7 c	0·28	15·2 c	0·63	2·2 d	0·09	6·0 c
A. gerardii cv. Kaw	1·7 b	16·8 b (5)	16·4 b (4)	15·7 b (4)	–	–	20·8 a	0·41	20·4 c	0·40	9·2 c	0·18	12·7 b
B. insculpta	8·1 a	8·4 c (1)	18·6 b (4)	18·7 a (4)	–	–	–	–	21·0 c	0·39	32·7 a	0·61	13·5 b
B. pertusa	8·8 a	5·6 c (1)	10·3 c (2)	10·1 c (2)	–	–	–	–	8·5 d	0·24	26·3 a	0·76	8·7 c
B. curtipendula	2·9 b	18·3 b (5)	15·6 b (5)	12·6 b (5)	–	–	16·8 b	0·34	19·6 c	0·40	13·0 c	0·26	12·4 b
B. dactyloides	1·4 b	19·5 b (5)	17·8 b (4)	16·8 b (6)	4·6 b	0·08	18·1 b	0·33	21·2 c	0·38	11·6 c	0·21	13·9 b
C. ciliaris	10·3 a	7·0 c (2)	17·2 b (4)	12·2 b (3)	–	–	–	–	25·4 b	0·54	21·4 b	0·46	11·7 b
C. setigerus	9·0 a	9·8 c (2)	19·3 b (4)	14·8 b (3)	–	–	–	–	30·5 b	0·58	22·5 b	0·42	13·2 b
(*C. gayana* cv. Callide)	8·2	6·3 (1)	–	–	–	–	–	–	–	–	14·5	1·00	–
C. gayana cv. Pioneer	6·5 b	26·1 a (5)	30·2 a (5)	13·3 b (5)	–	–	15·1 b	0·20	34·0 b	0·45	27·1 a	0·36	19·0 a
E. curvula	5·0 b	27·7 a (5)	30·7 a (5)	21·1 a (6)	5·3 b	0·06	28·9 a	0·34	33·0 b	0·39	17·3 b	0·21	21·1 a
F. arundinacea	2·7 b	20·2 b (6)	25·8 a (7)	10·6 c (7)	24·7 a	0·42	9·3 c	0·16	11·0 d	0·19	14·3 c	0·24	14·8 b
P. coloratum	7·8 a	17·9 b (4)	25·1 a (5)	16·2 b (5)	–	–	9·5 c	0·14	37·7 a	0·56	19·6 b	0·29	16·8 a
P. maximum	10·8 a	18·2 b (4)	19·4 b (5)	12·1 b (5)	–	–	5·7 c	0·09	27·2 b	0·45	27·6 a	0·46	15·1 b
P. virgatum	3·9 b	18·8 b (5)	13·0 c (4)	13·6 b (4)	–	–	22·7 a	0·46	17·4 c	0·35	9·2 c	0·19	12·3 b
P. dilatatum	2·6 b	26·3 a (5)	29·5 a (5)	24·4 a (5)	–	–	23·6 a	0·28	39·8 a	0·48	19·4 b	0·23	20·7 a
P. clandestinum	11·3 a	22·1 a (5)	28·2 a (5)	20·3 a (5)	–	–	13·5 b	0·17	36·1 a	0·44	32·2 a	0·39	20·5 a
S. sphacelata cv. Solander	8·4 a	13·8 c (3)	23·3 b (5)	5·1 c (2)	–	–	6·5 c	0·13	18·4 c	0·36	25·7 a	0·51	12·7 b
S. nutans	2·1 b	18·7 b (5)	13·4 c (4)	13·0 b (5)	–	–	18·7 b	0·40	19·0 c	0·40	9·5 c	0·20	11·8 b
S. almum	13·3 a	18·3 b (5)	27·3 a (5)	15·7 b (5)	–	–	17·6 b	0·24	43·7 a	0·59	13·1 c	0·18	18·7 a
S. spp. hybrid	11·7 a	16·1 b (4)	22·4 b (5)	15·3 b (5)	–	–	11·0 c	0·17	42·1 a	0·64	12·5 c	0·19	16·4 a
U. mosambiciensis	5·2 b	6·6 c (1)	10·7 c (2)	8·6 c (1)	–	–	–	–	–	–	31·1 a	1·00	7·8 c
D. intortum	5·2 b	8·8 c (2)	13·2 c (4)	7·0 c (4)	–	–	–	–	18·2 c	0·53	16·0 b	0·47	8·6 c
(*D. lablab*)	–	5·4 (1)	8·3 (2)	–	–	–	–	–	11·5	0·84	2·2	0·16	–
L. bainesii	–	8·5 c (4)	6·7 c (3)	6·7 c (3)	–	–	9·4 c	0·43	10·6 d	0·48	1·9 d	0·09	5·5 c
M. sativa	1·6 b	22·4 a (6)	27·5 a (6)	22·2 a (7)	15·6 a	0·21	16·6 b	0·22	32·1 b	0·44	9·4 c	0·13	18·4 a
N. glycine cv. Tinaroo	4·6 b	4·9 c (1)	6·6 c (4)	–	–	–	–	–	3·7 d	0·23	12·4 c	0·77	4·0 c

The species in parentheses were not subject to statistical analysis.

In a column values followed by the same letter are not different for $P \leq 0{\cdot}01$ (method of Calinski and Corsten, 1985).

*Full names of species are given in Table 2.

Table 5 Chemical composition of herbage of the species collected in summer 1996.

	Crude protein ($g\ kg^{-1}$ DM)	Crude lipid ($g\ kg^{-1}$ DM)	Ash ($g\ kg^{-1}$ DM)	Crude fibre ($g\ kg^{-1}$ DM)
A. gerardii cv. Cimarron*	102 f	19 c	76 d	297 c
A. gerardii cv. Kaw	85 g	23 b	76 d	293 c
B. insculpta	111 e	21 c	108 b	332 a
B. pertusa	119 e	20 c	112 b	293 c
B. curtipendula	86 g	20 c	77 d	273 d
B. dactyloides	86 g	19 c	70 e	266 d
C. ciliaris	120 e	18 d	123 a	309 b
C. setigerus	114 e	23 b	108 b	314 b
C. gayana cv. Callide	140 c	20 c	123 a	296 c
C. gayana cv. Pioneer	131 d	19 c	100 c	284 c
E. curvula	96 f	15 e	63 e	313 b
F. arundinacea	127 d	13 e	78 d	259 d
P. coloratum	114 e	22 b	102 c	293 c
P. maximum	130 d	19 c	105 b	314 b
P. virgatum	82 g	23 b	70 e	303 b
P. dilatatum	113 e	22 b	86 d	297 c
P. clandestinum	152 c	19 c	112 b	229 e
S. sphacelata cv. Solander	163 b	27 a	105 b	271 d
S. nutans	82 g	17 d	71 e	306 b
S. almum	121 e	20 c	82 d	260 d
S. spp. hybrid	112 e	17 d	79 d	299 b
U. mosambiciensis	132 d	20 c	130 a	305 b
D. intortum	160 b	21 c	90 d	304 b
D. lablab	160 b	20 c	108 b	296 c
L. bainesii	179 a	16 e	96 c	239 e
M. sativa	152 c	19 c	89 d	301 b
N. glycine cv. Tinaroo	149 c	17 d	105 b	301 b

Values in a column followed by the same letter are not different for $P \leq 0{\cdot}01$ (method of Calinski and Corsten, 1985).
*Full names of species are given in Table 2.

1995; Gherbin and De Franchi, 1999; Maiorana *et al.*, 2002; Cassaniti *et al.*, 2003). Most of the species are perennials (with the efficient C_4 photosynthetic pathways) and are generally drought-resistant, winter-hardy and also adapted to sandy and lower fertility soils usually not used for cropping (Smith, 1986). Variation in heading or flowering date, growth habit, spring vigour and DM yield have been reported by other authors (Thomas and Sumberg, 1995; Campbell and Xia, 2002). The warm-season grasses evaluated in this experiment generally proved to have characteristics of adaptability to climate, yield and feeding value appropriate for use in livestock production systems in southern Italy.

Measurements showed that the investigated species differed considerably in both the timing of resumption of growth and the start of the reproductive stage. All the perennial genotypes were rather slow in establishing, with production being lower in the first year than in the subsequent years for grasses, whereas yields were always low for legumes, except for the control, *M. sativa*, because of difficulties in establishment, poor winter hardiness and limited vegetative vigour. The DM yields of *M. sativa* cv. Garisenda were similar to those observed previously.

Among grasses, over the 4-year period, seven species (*C. gayana* cv. Pioneer, *E. curvula*, *P. coloratum*, *P. dilatatum*, *P. clandestinum*, *S. almum*, *Sorghum* spp. hybrid) produced annual DM yields greater than the control species *F. arundinacea* cv. Penna, which had similar DM yields to that observed previously, with average values of 19·0 t ha^{-1} for the seven species and 14·8 t ha^{-1} for *F. arundinacea*. In particular, *E. curvula* had the highest DM yield in absolute value, equivalent to 21·1 t ha^{-1}. DM yields were predominantly distributed in summer, with 0·50 of the DM harvested between mid-June and late August, at the time when temperate grass species were not growing.

The DM yields of warm-season perennial grasses have the potential to supply hay or grazing for livestock in Mediterranean environments in summer when DM yields of cool-season species are less or none (Madakadze *et al.*, 1998; Gherbin and De Franchi, 1999; Maiorana *et al.*, 2002; Cassaniti *et al.*, 2003; Fike *et al.*, 2005). In relation to feeding value, many of the grasses had CP concentrations slightly lower than the legumes and not very high ash and CF concentrations.

In particular, among grass species, *P. clandestinum* proved to be better adapted than the other species and it stood out by its adaptability to soil conditions, high tiller density, regrowth capability, constant and high DM yields over the 4-year period, and high feeding value. *Medicago sativa* was by far the superior species among the investigated legumes and had similar characteristics to *P. clandestinum*. These two species also produced the highest amounts of CP per unit area.

Environmental issues associated with grassland ecosystems include the introduction of non-native species; they can exert a negative impact on native landscapes both locally and globally (Mack *et al.*, 2000). The abundance and survival of many native plant and animal species is thus threatened, contributing to a general loss of biodiversity. In a more general sense, this kind of risk is linked with the intensification of agricultural practices. Native pastures may not often match introduced pastures in terms of fodder production, but other important advantages are related to their protection (low input requirement, potential genetic recourses, soil protection, supporting endangered habitat, etc.). Those intensified forage systems are usually the dominant type of grassland in lowland regions, representing millions of hectares in Europe, and are frequently the main forage resources for grass-based farming systems (Plantureux *et al.*, 2005). Importance has to be assigned to two complementary strategies. The first one relates to the protection of residual natural pasture, mostly in marginal agricultural area subjected to abandonment; the second one pertains to the management of intensive forage systems, mainly in lowland areas, in order to effectively control non-native plants that are detrimental when they become invasive and spread rapidly.

Conclusions

The production data obtained showed that seven warm-season grasses species (*C. gayana* cv. Pioneer, *E. curvula*, *P. coloratum*, *P. dilatatum*, *P. clandestinum*, *S. almum*, *Sorghum* spp. hybrid) are attractive in that they have the potential to supply hay or grazing for livestock in Mediterranean environments in summer when the cool-season species, such as *F. arundinacea*, are less productive. Such species could be grown and integrated into livestock production systems in southern Italy, make a contribution to broadening and stabilizing the forage production calendar and thereby improve livestock production systems in Mediterranean-type environments.

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