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Adaptation, summer survival and autumn dormancy of lucerne cultivars in a south European Mediterranean region (Sardinia)

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SUMMARY – Some 16 lucerne cultivars of various geographic origins (Europe, north Africa, USA, Australia), including recent varieties as well as traditional cultivars, were evaluated in a rainfed environment of southern Sardinia (long-term annual rainfall: 382 mm) with the following objectives: (i) to compare adaptation and summer survival of different germplasm types and dormancy classes (ranging from moderate to non-dormant); and (ii) to define a genetic base for future breeding of drought-tolerant varieties targeted to south European Mediterranean environments. Results are provided for two-year dry matter yield, stand density after the second summer, autumn dormancy rating and phenology. These preliminary results suggest that drought-tolerant material may preferably be located in south European landraces which evolved under rainfed, drought-stressed environments, or in US or Australian varieties which were selected in stress conditions. North-African landraces, mostly evolved under irrigated conditions, tended to be less adapted to drought-stress conditions.

Key words: Alfalfa, drought tolerance, genetic resources, *Medicago sativa*, persistence.

RESUME –*"Adaptation, survie estivale et dormance automnale de cultivars de luzerne dans une région du sud de l'Europe méditerranéenne (Sardaigne)". Seize cultivars de luzerne de provenance géographique différente (Europe, Afrique du Nord, USA, Australie), comprenant soit des variétés récentes soit des cultivars traditionnels, ont été évalués dans un milieu pluvial de la Sardaigne méridionale (pluviosité moyenne : 382 mm) avec pour objectifs de : (i) comparer l'adaptation et la survie estivale de types différents de germoplasme et classes de dormance ; et (ii) définir une base génétique pour la future sélection de variétés tolérantes à la sécheresse, convenable aux milieux méditerranéens de l'Europe méridionale. On rapporte la production de matière sèche dans deux saisons, la densité de couverture après le deuxième été, la dormance automnale et la phénologie des cultivars. Ces résultats préliminaires suggèrent que le germoplasme tolérant à la sécheresse peut être identifié surtout dans des écotypes de l'Europe méridionale évolués dans des milieux secs en pluvial, ou des variétés américaines ou australiennes sélectionnées dans des conditions de stress. Les écotypes nord-africains, évolués généralement dans des conditions d'irrigation, tendraient à être moins adaptés aux conditions sèches*.

Mots-clés : *Luzerne, tolérance à la sécheresse, ressources génétiques,* Medicago sativa*, persistance.*

Introduction

Lucerne (*Medicago sativa* L.) is generally considered a crop able to endure drought, mostly owing to its ability to extract water from depth within the soil profile. Nonetheless, its growth is affected by water deficits in the upper soil layers, and irrigation is generally considered necessary in semi-arid environments to maintain stand density and ensure satisfactory yield. In Italy lucerne is the main forage crop and is grown on about 800,000 ha mostly located in north and central Italy, where summer drought is less severe and sometimes alleviated by irrigation.

The availability of water is an issue of growing concern in the Mediterranean area, also in relation to the predictions of an increasing incidence of drought determined by climate changes (Fischer *et al*., 2002). In a situation of competition with more profitable irrigated crops or non-agricultural utilisations of ever more limited water resources, a substantial reduction of water supply or the rainfed cropping is foreseeable for lucerne even under less favourable conditions. Moreover, an expansion of perennial forage species in semi-arid Mediterranean environments could allow to increase the forage production relative to annual species by profiting of an earlier crop growth at the onset of autumn rains.

It is therefore essential to enhance the ability of lucerne to respond adequately under rainfed cultivation in the presence of drought stress. However, most breeding of this species has been carried out in temperate regions and little work has been specifically devoted to stressful conditions. In the framework of a more general investigation of germplasm adaptation within the Mediterranean basin, the present study assessed the response of a set of cultivars of diversified geographic origin in a stressed environment of south Sardinia.

Materials and methods

The trial was carried out in Sanluri, a typical Mediterranean environment of south Sardinia with 382 mm long-term annual rainfall. The soil was a clay loam with pH of 8.0. The trial was sown on October 6, 2005 and included three French varieties, one variety and two ecotypes from Italy, four varieties from Australia or USA, and six ecotypes from Algeria, Morocco or Tunisia. The cultivars were sown at the seed rate of 25 kg/ha in plots of 6 m^2 (210 cm x 285 cm, with 10 rows 21 cm apart) according to a lattice block design with 4 replicates.

Forage dry matter yield was assessed on a plot area of 3 m^2 over 15 harvests (March 23, May 19, June 15, August 8, October 17 and November 13 in 2006; March 15, April 23, June 5, June 25, July 17, August 9, August 31, September 25 and October 24 in 2007). An indication of cultivar persistence was provided by percent of lucerne row cover at the end of the second summer, averaging the visual assessments carried out on the regrowths of the twelfth and thirteenth harvests. Flowering was recorded in the first spring as the number of days from January 1 to 50% flowering. Dormancy class was estimated according to the NAAIC standard method (Teuber *et al*., 1998), by: (i) measuring plant height about 30 days after the last autumn harvest; (ii) estimating the linear regression of dormancy class as a function of plant height for some cultivars of known dormancy class; and (iii) exploiting the regression to estimate the dormancy class of all materials (including the reference cultivars). Plant height was assessed by averaging the observations in autumn 2006 and 2007, reporting the estimated dormancy to the nearest 0.5 class.

An ANOVA was performed for each trait, separating the top- and bottom-ranking cultivar means according to the LSD at $P < 0.05$. Trait relationships were investigated by simple correlation analysis. All statistical analyses were performed by CROPSTAT software (IRRI, 2007).

Results

The first evaluation season (September 2005-August 2006) was rather stressful, with a total rainfall of 403 mm close to the long term (382 mm) and a severe drought in spring associated with fairly high temperatures (Table 1). The second season (September 2006-August 2007) was favourable (565 mm overall) but had a dry summer (Table 1). No cold stress occurred in either season (Table 1).

Table 1. Main climatic variables in the evaluation seasons

Climatic variable	2005-06	2006-07
Rainfall September-March (mm)	334	412
Rainfall April-June (mm)	14	151
Rainfall July-August (mm)	55	2
Mean of daily min. temp. January-February (°C)	3.8	7.8
Absolute min. temp. in winter (°C)	1.0	0.5
No. of frost days	0	0
Mean of daily max. temp. May-June (°C)	28.7	26.3
Mean of daily max. temp. July-August (°C)	33.0	29.7

The top-yielding set of cultivars over the two seasons included the Italian ecotypes (Mamuntanas, which originated in Sardinia, and the Sicilian ecotype), the foreign varieties SARDI 10, Ameristand 801S and Melissa, and the Italian variety Prosementi (Table 2). Tamantit, which had a poorer initial establishment compared with the other cultivars (data not reported), and Africaine, were the lowest-yielding populations. The cultivar persistence at the end of the second summer reflected largely the response for forage yield, but most north-African cultivars (Rich 2, Demnat 203, Gabès 2355 and Africaine) and Coussouls did not differ ($P < 0.05$) from the most-persistent material (Table 2).

Table 2. Two-year forage dry matter yield, persistence as row cover percent at the end of the second summer, flowering date and autumn dormancy estimated from late autumn plant height of the evaluated lucerne cultivars

Cultivar	Origin	Forage yield (t/ha)	Persistence (%)	Flowering (dd from Jan. 1)	Plant height (cm)	Estimated dormancy class	Reported dormancy class
Mamuntanas	Italy	14.20 [a]	32.8 [a]	126	17.5	7	—
Sicilian ecotype	Italy	13.27 [a]	35.9 [a]	122 [b]	16.4	6.5	—
SARDI 10	Australia	12.91 [a]	28.4 [a]	125	23.7	10	10
Ameristand 801S	USA	12.54 [a]	29.9 [a]	125	21.7	9	8
Prosementi	Italy	12.19 [a]	34.7 [a]	126	14.7 [b]	6	6
Melissa	France	12.13 [a]	27.4 [a]	126	21.8	9	—
Demnat 203	Morocco	11.98	29.2 [a]	130 [a]	27.9 [a]	11.5	—
Siriver	Australia	11.95	22.8	124 [b]	21.5	9	9
Erfoud 1	Morocco	11.29	26.4	124 [b]	22.1	9	—
Gabès 2355	Tunisia	10.91	28.5 [a]	132 [a]	23.8	10	—
Rich 2	Morocco	10.79	31.6 [a]	126	19.3	8	—
ABT 805	USA	10.75	26.1	126	17.9	7.5	8
Magali	France	10.55	26.9	124 [b]	14.4 [b]	6	6.5
Coussouls	France	10.45	29.5 [a]	125	13.1 [b]	5.5	4.5
Africaine	Tunisia	6.47 [b]	28.2 [a]	125	13.4 [b]	5.5	—
Tamantit	Algeria	4.83 [b]	9.1 [b]	121 [b]	21.9	9	—

[a]Not different from top-ranking mean according to LSD ($P < 0.05$).
[b]Not different from bottom-ranking mean according to LSD ($P < 0.05$).

Genetic variation for flowering date was fairly limited, with 12 cultivars attaining 50% blossom within 124 and 126 days from January 1. The Algerian ecotype Tamantit and the Sicilian ecotype tended to greater earliness, whereas the north-African ecotypes Gabès 2355 and Demnat 203 were the latest-flowering (Table 2).

As expected, the variation was larger for autumn dormancy. Reported and estimated values of cultivars with known dormancy class were very close or coincident, with the exception of Ameristand 801S and Coussouls (both having one-unit higher estimated autumn activity) (Table 2). North-African ecotypes showed negligible or absent dormancy (class ≥ 8), with the notable exception of Africaine whose dormancy was comparable with that of European cultivars selected in temperate regions, such as Magali (selected in western France) and Prosementi (selected in northern Italy). One of the three Moroccan ecotypes, namely Demnat 203, displayed an autumn activity level at the limit of the standard scale (so far having 11 as the highest class level: Teuber *et al.*, 1998). The two Italian ecotypes originated in Mediterranean regions were little dormant, whereas the French variety Melissa was non-dormant (Table 2).

Forage yield was highly correlated with persistence at the end of the second summer (Table 3). There was a slight trend towards correlation of lower autumn dormancy with later flowering ($P < 0.12$).

Table 3. Simple correlation coefficients among two-year forage dry matter yield, persistence at the end of the second summer, flowering date and estimated autumn dormancy

Variable	Persistence	Flowering	Dormancy class
Forage yield	0.72 **	0.27 ns	0.15 ns
Persistence	–	0.34 ns	-0.30 ns
Flowering		–	0.41 ns

**$P < 0.01$; ns: $P > 0.05$.

Discussion

These preliminary results suggest that more productive material for moderately drought-stressed Mediterranean environments may preferably be located in south-European landraces which evolved in semi-arid, rainfed environments, such as Mamuntanas and the Sicilian ecotype, or in US or Australian varieties which were selected in stress conditions, such as SARDI 10 and Ameristand 801S. North-African landraces, which mostly evolved under irrigated conditions, tended to be less productive, although they were not significantly inferior in terms of persistence. The Italian variety Prosementi, selected in northern Italy under rainfed conditions, was locally well-adapted in accordance with its known wide adaptation to Italian environments (Annicchiarico, 1992) and its somewhat better response to conditions of moderate drought stress relative to other varieties selected in the same region (Annicchiarico, 2007). The only well-performing French variety was Melissa, characterised by unusually low autumn dormancy relative to other south-European material.

The two varieties selected for grazing tolerance, namely ABT 805 and Coussouls, were not among the best-yielding cultivars, just like Siriver, which was selected mainly for aphid tolerance in a fairly high-rainfall area (Canberra) of Australia. While the poor yield response of Tamantit may partly be accounted for by its poor emergence (apparently in coincidence with high incidence of seed-borne diseases: data not reported), the low yield of Africaine and its dormant habit relative to the other north-African ecotypes were unexpected and rise the doubt that the sown seed was not true-to-type of the original Tunisian ecotype. This may have been caused by the widespread introduction into Tunisian seed markets of low-cost, possibly poorly-adapted foreign germplasm of lucerne (M. Mezni, pers. comm.).

The generally good agreement between estimated and reported dormancy class of the reference cultivars confirm the reliability of the estimated values. The slight inconsistency observed for two cultivars may be due to genotype × environment interaction effects, which are known to occur for this character (Teuber *et al*., 1998). The lack of linear correlation between adaptation and dormancy level of the materials is not surprising, when considering that the local ecotype (Mamuntanas) possessed an intermediate dormancy level of 7, attained by evolutionary adaptation to winter low temperatures which are intermediate between those of north Africa (whose typical ecotypes were non-dormant) and of temperate Europe (whose varieties were moderately dormant).

The high correlation between forage yield and persistence at the end of the second summer of the cultivars suggests that the yield responses in the third evaluation season and their indications on adaptive responses will not differ substantially from those currently observed. However, at least one more year of evaluation is needed to obtain reliable information on cultivar persistence in the long term (four or five years).

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