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Ecotypic differentiation of *Medicago polymorpha* in Sardinia and Chile

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SUMMARY – Burr medic (*Medicago polymorpha* L.) is commonly found in Sardinia and in Chile throughout a wide range of Mediterranean type climates. In Sardinia it is part of the native flora at altitudes ranging between 0 and 1000 m a.s.l., with annual rainfall ranging between 500 and 1100 mm. In Chile, burr medic is naturalized and distributed in a north-south gradient of approximately 1000 km, where annual rainfall ranges between 100 mm (in the north) and 1300 mm (in the south). Ecophysiological studies on populations of *M. polymorpha* collected in these two countries revealed some common but also different trends of adaptation to a temperature-humidity gradient. Days to first flower and total dry matter were positively correlated with precipitation of the collection site (PP) in Chile but not in Sardinia. The percentage of hard seeds was negatively correlated with PP in both regions. The ecological and agronomic implications of these results are discussed.

Key words: Burr medic, native flora, ecophysiological studies, hard seed.

RESUME – *"Différenciation écotypique de la luzerne annuelle* Medicago polymorpha *L. en Sardaigne et au Chili". La luzerne annuelle* Medicago polymorpha *L. se trouve communément en Sardaigne et au Chili sous une gamme considérable de conditions climatiques de type méditerranéen. En Sardaigne elle appartient à la flore autochtone dans des régions situées entre 0 et 1000 m d'altitude avec une pluviométrie annuelle de 500 à 1100 mm. Au Chili, cette luzerne est naturalisée et se distribue le long d'un gradient de près de 1000 km, qui va des franges de désert, au nord (100 mm de précipitations annuelles) jusqu'à la zone humide au centre-sud (1300 mm de précipitations annuelles). Des études écophysiologiques réalisées sur des populations de* M. polymorpha *collectées dans les deux pays ont révélé des tendances communes et contrastées d'adaptation à un gradient de température et d'humidité. Le nombre de jours à la première floraison et la biomasse sèche totale furent positivement corrélés à la précipitation annuelle (PP) du site de collection au Chili mais pas en Sardaigne. Le pourcentage de graines dures fut négativement corrélé à PP dans les deux pays. Les implications écologiques et agronomiques des résultats sont discutées.*

Mots-clés : *Luzerne annuelle, flore autochtone, études écophysiologiques, graine dure.*

Introduction

Burr medic (*Medicago polymorpha*) is one of the most widespread, polymorphic annual legumes of Mediterranean origin. In Sardinia, Italy, it is part of the native flora, and its distribution includes a wide range of environments, ranging between 0 and 1000 m a.s.l., with annual rainfall ranging between 500 and 1100 mm (Porqueddu *et al*., 1992; Loi *et al*., 1995). In central Chile, it is abundantly naturalized along a 1000 km long environmental gradient, from an arid zone (29ºS) where annual rainfall is 100 mm to a perhumid one (38ºS) where annual rainfall is 1300 mm (Del Pozo *et al*., 1989; Ovalle *et al*., 1997).

Comparative studies of its ecotypic differentiation patterns along these two gradients should be useful in elucidating the evolutionary forces that work along environmental gradients, and also to efforts in selecting legumes for improving pastures and fallow fields in Mediterranean climate areas. In this paper we compared some bio-agronomic traits of *M. polymorpha* accessions from Sardinia and central Chile, in relation to a temperature-humidity gradient of the site of origin.

Materials and methods

In Sardinia, seeds collected in 1989 at 35 sites along an altitudinal gradient extending from sea level to 1000 m a.s.l., with annual rainfall ranging between 500 and 1100 mm, were sown for evaluation at the

Bonassai Research Station of Istituto Zootecnico e Caseario per la Sardegna (40ºN; 80 m a.s.l. and 550 mm of annual rainfall) in November 1990. The soil is calcareous alluvium with pH = 7.5. Accessions were sown in 4.5 m^2 plots in a randomized block design with three replicates. Seed were inoculated with rizhobia isolated from a local population of *M. polymorpha* and sown at a rate of 15 kg/ha. Plots were fertilized with 100 kg/ha^{-1} P_2O_5 before sowing. Dry matter production was estimated by mowing to c. 8 cm, simulating grazing conditions, using quadrants of 0.75 m^2 and seed yield by taking two subsamples of 25 25 cm per plot. Phenological observations were taken twice a week to determine the number of days from emergence to first flower. The percentage of hard seeds was determined on 45 pods placed in petri dishes in the field for four months in summer. Number of seeds per pod and 1000-seed weight were also recorded.

In Chile, seeds collected in December 1988 at 33 sites along a N-S gradient extending from the arid zone (100 mm of annual rainfall) near La Serena (29ºS), to a perhumid zone (1300 mm of annual rainfall) near Temuco (38ºS), were sown for evaluation on May 22, 1990. Each seed lot was inoculated with a selected rhizobial strain (Herrera *et al*., 1996), and then sown in raised beds with granitic soil (pH = 5.8), at the INIA Research Station at Cauquenes (35º58'S, 72º17'W; 177 m a.s.l. and 690 mm of annual rainfall). Two lines of 1.1 m were sown for each accession, with 44 plants per line. A mixture of P_2O_5 (100 kg/ha), S (44 kg/ha) and $CaCO_3$ (2000 kg/ha) was applied to the soil before sowing. Phenological observations were taken every two days on 25 plants per accession to determine days from emergence to first flower. Dry matter production and seed yield was determined by harvesting the whole microplot. Number of seeds per pod and 1000-seed weight were also recorded. For the determination of the percentage of hard seeds, 100 pods of each accession were placed on the soil surface in December 1990. After four months (April 1991) pods were placed in petri dishes at 20ºC to evaluate seed germination. All characters were related with mean annual rainfall of the site of collection.

Results

Onset of flowering ranged from 128 to 138 days and from 78 to 124 days in the Sardinian and Chilean collection, respectively (Fig. 1). A strong positive correlation was found between days from emergence to first flower and mean annual rainfall of the site of collection (PP) in the Chilean accessions but not in the Sardinian ones (Table 1).

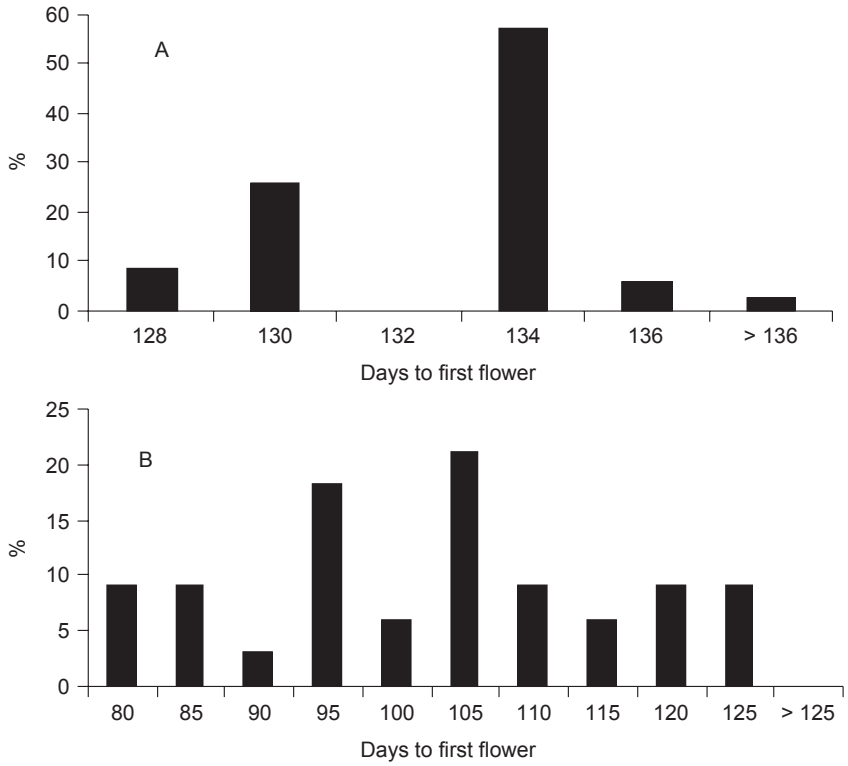

Fig. 1. Histogram of frequency for days to first flower of accessions of burr medic collected in Sardinia (A) and in Chile (B).

Total dry matter production increased and seed yield/total dry matter decreased as PP increased in the Chilean collection, but no correlation was found in the Sardinian collection; seed yield was not correlated with PP in both regions (Table 1).

Number of seeds per pod decreased, as PP increased in Sardinia but not in Chile. Hardseededness at the end of summer was high in all accessions ranging from 69 to 99% in Sardinia and from 76 to 99% in Chile. There was a negative correlation between the percentage of hard seeds and PP in both regions (Table 1).

Table 1. Correlation coefficients between mean annual rainfall of the collection site and agronomic characters of various accessions of *Medicago polymorpha* collected in Sardinia and Chile

Character	Sardinia	Chile
Days to first flower	NS	0.90**
Total dry matter	NS	0.41*
Seed yield	NS	NS
Seed yield/total dry matter	NS	-0.78**
No. seeds per pod	-0.42**	NS
1000-seed weight	NS	NS
Hardseededness	-0.59**	-0.39*
No. of accessions	35	33

*Significant at 0.05 probability level, **significant at 0.01 probability level.

Discussion

In Sardinia the aridity gradient associated to an altitudinal transect did not lead to a wide phenological differentiation among accessions of *M. polymorpha*. This contrasts to what was found by Piano *et al*. (1996), in accessions and pure lines of subterranean clover collected also in Sardinia, where flowering time was positively correlated with altitude and mean annual rainfall of the collection site. In Chile, a clear phenological differentiation exists among accessions of *M. polymorpha*, where early flowering accessions are found at the northern and drier end of the gradient, whereas later flowering accessions are found at the southern and wetter environments.

The different pattern of phenological differentiation observed in the Sardinian and Chilean populations of *M. polymorpha*, can be explained by: (i) in Chile the differences in the length of the growing period along the N-S gradient are larger than in the altitudinal gradient of Sardinia, despite there being clear differences in PP among sites; (ii) as a result, the variability in flowering time among Sardinian accessions of *M. polymorpha* was much lower than the variability among Chilean accessions of *M. polymorpha*; (iii) interchange of seeds between populations along the altitudinal gradient due to transhumance of sheep flocks carrying pods; and (iv) differences in flowering time within populations, as was found in subterranean clover (Piano *et al*., 1996), could mask "small" differences between populations, when phenological observations are taken in dense and cut plots, as was the case in the Sardinian experiment.

The increase in total dry matter production and the decrease in seed yield/total dry matter with increasing PP in the Chilean collection, could be the result of a terminal water stress during seed growth at Cauquenes, that was probably more severe in late flowering accessions.

In both regions, accessions with spineless pods or with very short stiff spines and with higher percentage of hard seeds prevailed in the drier environments (Porqueddu *et al*., 1996; Del Pozo *et al*., 2001), i.e. at low altitude in Sardinia, and at the northern end of the gradient in Chile. By contrast, spiny accessions are more common and even exclusive (in the case of Chile) in more humid environments, like high altitudes in Sardinia and south of Chile. According to Loi *et al*. (1995), spineless accessions or with short spines correspond to var. *polymorpha* and the spiny accessions correspond to var. *vulgaris*, and they seem to have different distributions along the aridity gradient. The presence of some spiny pods accessions at low altitude in Sardinia could be the result of the transhumance of sheep flock occurred until recent times.

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