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Fresnillo D.E.

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Ten years of ecological research on *Medicago minima* (L.) Bart.

D.E. Fresnillo Fedorenko
Facultad de Agronomía, Universidad Nacional del Sur y Centro de Recursos Naturales Renovables de la Zona Semiarida, Bahía Blanca, 8000, Argentina
Plant Science, The University of Western Australia and Centre for Legumes in Mediterranean Agriculture, Nedlands, 6009, Australia
Present address: Centre for Cropping Systems, Agriculture Western Australia, P.O. Box 483, Northam, W.A. 6401, Australia

SUMMARY – *Medicago minima* (L.) Bart. is one of the most widely distributed annual medics in both the Mediterranean basin and other semiarid temperate regions. This pasture legume is widely naturalised in Argentina and Australia and this paper discusses a series of ecological studies carried out between 1988-1999. Geographic distribution, morphology and phenology, seed dormancy, germination, seedling emergence and survival, responses to water stress and pasture production are addressed. Genetic variation is discussed in relation to the ability of the species to grow and cope with stresses encountered in a wide range of environments. These findings help explain why *M. minima* is so widespread and why it is a successful colonising species. A better knowledge of its ecophysiology has contributed to gain an understanding of the adaptative strategies of this species and to develop guidelines for its proper management in extensive production systems.

Key words: *Medicago minima*, distribution, adaptation, genetic variation.

***RESUME* –** *"Dix ans de recherche écologique sur* Medicago minima *(L.) Bart.".* Medicago minima *(L.) Bart. est une des luzernes annuelles les plus largement distribuées dans la région méditerranéenne et d'autres régions tempérées semi-arides. Cette légumineuse adaptée au pâturage est largement naturalisée en Argentine et en Australie. Cet article analyse une série d'études écologiques effectuées entre 1988-1999. La distribution géographique, la morphologie et la phénologie, la dormance des graines, leur germination, la levée et la survie des jeunes plantules, les réponses au stress de l'eau et la production de biomasse sont étudiées. La variation génétique est discutée en relation avec la capacité de l'espèce à se développer et faire face aux stress rencontrés dans une gamme d'environnements. Ces résultats expliquent pourquoi* M. minima *est une espèce colonisatrice très répandue. Une meilleure connaissance de son écophysiologie a permis de comprendre les stratégies de cette espèce et de développer des préconisations de gestion appropriées dans les systèmes de production étendus.*

Mots-clés : Medicago minima*, distribution, adaptation, variation génétique.*

Introduction

Medicago minima (L.) Bart. is a pasture legume native to the Mediterranean Basin and adjacent temperate regions, and is one of the most widely distributed annual medics in both its area of origin and other parts of the world with semiarid temperate climate.

The studies discussed in this paper were carried out in Argentina and Australia, two areas where this species has become naturalised. *M. minima* is widespread in El Calden District, a semiarid temperate region of 10 million ha in central Argentina. Beef cattle production is the main economic activity in dryland production systems. Rangelands in these systems are degraded as a result of overgrazing, drought and inadequate management, and show incipient or severe erosion. Plant communities are characterised by shrubs (e.g. *Prosopis caldenia* and *Larrea divaricata*), desirable native perennial grasses (e.g. *Stipa tenuis* and *Piptochaetium napostaense*) and annual herbs of which *M. minima* and *Erodium cicutarium* are the most conspicuous (Cabrera, 1976). *M. minima* is very palatable, has a high nutritive value (Cairnie and Monesiglio, 1967; Lutz and Graff, 1980) and is the main source of protein in the cattle diet during spring.

M. minima and *M. polymorpha* are the two most widespread annual medics in Australia and, together with other Mediterranean annual legumes (e.g. *M. truncatula*, *Trifolium subterraneum* and *T. glomeratum*), form the main legume components of southern Australian pastures. These species are of great importance to the grains and sheep industries because of their nitrogen-fixing capacity and their suitability for grazing. However, spiny species can also be costly to woolgrowers because they cause vegetable fault in wool (Crawford *et al.*, 1989).

The aim of this paper is to discuss a series of ecological studies that have contributed to our understanding of the factors responsible for the distribution and ecological success of *M. minima* in particular, and of Mediterranean legumes in general.

Ecological studies on *Medicago minima*

Geographic distribution

Soil factors are important in determining the distribution of *M. minima* and other annual legumes (e.g. Andrew and Hely, 1960; Robson, 1969). An ecogeographic survey in Western Australia showed that *M. minima* is present in soils that are finer-textured, higher in pH, and lower in available phosphorus than soils where it is absent (Fresnillo Fedorenko *et al.*, a, in press). In a third of the collection sites in Western Australia, *M. minima* is the only pasture legume present, but it is associated with *M. laciniata* in areas 260 mm annual rainfall and with *M. truncatula*, *M. polymorpha* and *M. littoralis* in areas between 300-325 mm. In contrast, in Argentina *M. minima* is the only pasture legume present in El Calden District characterised by soils containing a limestone horizon at <50 cm from the soil surface (Fresnillo Fedorenko *et al*., 1991). The greater ability of *M. minima* to utilise less soluble calcium phosphates or to absorb phosphate at high pH or at high calcium concentrations may explain both the adaptation of *M. minima* to these soils, and also differences in the distribution of annual medics (Robson, 1969). The absence of *M. minima* in areas of Western Australia with >325 mm annual rainfall is related to its low tolerance to soil acidity, or its lack of adaptation to soil salinity and waterlogging (e.g. Greenway and Andrew, 1962; Francis and Poole, 1973).

Genetic diversity

Morphological characteristics of 35 strains of *M. minima* collected in Western Australia, Argentina and the Mediterranean indicated that there is great within-species genetic diversity (Fresnillo Fedorenko *et al.*, b, in press). In contrast, genetic variation is very small (95% similarity) in Western Australian strains (260-325 mm), which were most similar to a Libyan strain (125 mm annual rainfall), and most different from an Argentinean (340 mm). The latter was most similar to a Sardinian strain (600 mm rainfall). In the Argentinean strain only, morphological differences suggested that there is within-population genetic variation, but further studies are needed to confirm this hypothesis.

Phenology of *M. minima* has been studied in Argentina (Fresnillo Fedorenko *et al.*, 1996), and in Australia including Western Australian, Argentinean and Mediterranean strains (Fresnillo Fedorenko *et al.*, b, in press). In general, seedling emergence of *M. minima* occurs during autumn (May) after the first significant rainfall event. Vegetative development continues during winter and early spring, and reproductive stages are initiated by mid-spring. Pod maturation occurs during mid to late spring. At the end of the season, plants desiccate rapidly as result of high temperatures (>35ºC). Plants survive the dry summer as seed.

Variation in plant traits and its correlation to annual rainfall in the area of origin suggests that ecotypic differentiation has occurred in populations of *M. minima* (Fresnillo Fedorenko *et al.*, b, in press). In strains adapted to low rainfall environments, plants are smaller, flower earlier, mature faster, produce less seed, have a higher harvest index, and have a shorter growth cycle compared with strains adapted to wetter environments. However, in this study there was no evidence of the correlation seed:pod ratio and rainfall observed by Ehrman and Cocks (1990).

Seed dormancy, germination and seedling survival

The role of seed dormancy is to prevent germination until this and seedling survival are favoured by environmental conditions. Softening of *M. minima* seeds occurs mostly in autumn and genetic differences exist in seed softening patterns of strains from Western Australia, the Mediterranean basin and Argentina (Fresnillo Fedorenko *et al.*, d, in press). The data support Taylor's temperature driven 2-stage model of seed softening (Taylor, 1981). Mediterranean and Argentinean strains (except Libya) soften earlier than Western Australian strains. This suggests that they would not persist under Western Australian conditions because of susceptibility to germination after early rains. In addition, variation in the within-year softening patterns in relation with the temperature regimes in the areas where two strains where collected, suggests that ecotypic differentiation has occurred in naturalised Western Australian populations.

M. minima shows rapid germination and emergence after the first autumn rainfall. This adaptive strategy has been extensively studied in plants of desert ecosystems (Beatley, 1969; Westoby, 1979). *M. minima* produces several cohorts early during the growing season. Seedling emergence has been twice (6250 plants/m^2) in areas with bare soil patches (continuous grazing) compared with areas of good herbaceous cover (6 years ungrazed) (Fresnillo Fedorenko *et al.*, 1993). Plant mortality for the first cohort was 15% in the grazed and 1% in the ungrazed areas. Seedlings emerged later in the season showed higher mortality. Successful emergence and seedling survival under contrasting vegetation covers suggests that *M. minima* will survive under changes in rangeland management. This is, when grazing pressure ceases in heavily grazed sites, the legume will very likely not be eliminated.

Response to water stress

Periods of water stress are common in the environments where *M. minima* grows. The ability of this legume to survive under water stress at different stages of the growth cycle and set seed also helps explain its success in a wide range of environments. Studies using single plants showed that repeated drying cycles between 7-35 days markedly reduced shoot and root growth (Fresnillo Fedorenko *et al.*, 1995). In addition, water stress reduces shoot more than root production and stimulates a larger allocation of dry matter to reproductive structures in *M. minima* (Peláez *et al.*, 1995; Busso *et al.*, 1998).

Studies in swards with contrasting seeding densities (5-150 kg/ha) demonstrated that plant density and water stress significantly influence growth patterns and seed yield of *M. minima* (Fresnillo Fedorenko *et al.*, c, in press). At high density, total growth, seed yield and individual plant weight are less than at low density. Also high-density populations allocate a lower proportion of dry matter to reproductive organs compared with low-density populations. Dry matter allocation to reproductive organs is higher in irrigated compared with rainfed swards. These results may be explained in terms of competition for water.

Pasture production

In central Argentina *M. minima* is recognised for making a significant contribution to cattle diet during late winter and spring (Fresnillo Fedorenko *et al.*, 1991). Dry matter production in spring was nearly 3 t/ha and represented more than 60% of the total aboveground production of the herbaceous layer in a year with 430 mm rainfall. Forage production of annuals will vary significantly among years with different precipitation. However, a shallow root system in *M. minima* very likely allows this species to take advantage of small rainfall events contributing to its survival and production when growing in association with native perennial grasses (Fresnillo Fedorenko *et al.*, 1992).

Conclusions

One limiting factor in animal production on rangelands is the poverty of legume species for complementing animal diets. The existence of *M. minima* in extensive areas changes this situation at least during part of the year. A better knowledge of its ecophysiology and genetic diversity has contributed to gain an understanding of the adaptative strategies of this species and to develop guidelines for its proper management.

Further research should seek the inclusion of *M. minima* in conventional plant breeding programs or more advanced biotechnological manipulations in trying to obtain a domesticated legume for semiarid regions.

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