Testing and understanding the adaptation patterns of alfalfa landraces and varieties across the Western Mediterranean basin

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Alfalfa can enhance the economic and environmental sustainability of crop-livestock systems in the western Mediterranean basin, but requires improved adaptation to stressful environments because of predicted shortage of irrigation water and climate change. The EU-funded project PERMED aimed to assist regional breeding programs in defining adaptation targets, genetic resources, adaptive traits and opportunities for international co-operation, by: i) assessing the adaptive responses of landraces from north Africa and Italy and varieties of various origin (France, Italy, Australia and USA) across 10 environments of Algeria, Tunisia, Morocco and Italy which were rainfed, irrigated with about 9-week water withholding in summer or, in one case, continuously irrigated (oasis management); ii) improving the understanding of useful adaptive traits, by physiological studies performed in artificial environments on a subset of cultivars with contrasting adaptation.
Three-year mean yield of agricultural environments was related ($P < 0.01$) to annual and spring-summer (April-September) water available. Total number of harvests (range: 9-23), soil salinity (range: 0.20-6.0 dS m^{-1} electrical conductivity), and spring-summer water available (range: 102-932 mm) were selected in this order as covariates ($P < 0.05$) in a factorial regression model which explained 50% of genotype × environment (GE) interaction variation. The Italian landrace Mamuntanas exhibited specific adaptation to severe drought. The Moroccan landrace Demnat 203 was specifically adapted to high number of harvests (partly reflecting frequent mowing). One variety selected for salt tolerance and one Moroccan landrace were specifically adapted to salt-prone soils. Environment classification based on GE effects indicated three groups which may be object of specific breeding: i) rainfed or irrigated environments with limited spring-summer water available (< 350 mm), nil/low soil salinity and moderate to low number of harvests; ii) salt-stress environments; iii) environments featuring many harvests.
Alfalfa cultivars with contrasting adaptation were evaluated in metal containers (55 cm × 12 cm × 75 cm deep) under different drought-stress levels. These environments could reproduce the cultivar adaptive responses across agricultural environments. The drought-tolerant response of Mamuntanas was associated with a conservative water strategy and with relatively high accumulation of water-soluble carbohydrates in taproot and crown under severe drought. The Moroccan landrace Demnat 203 exhibited greater root weight and tended towards higher concentration of soluble proteins in the storage organs.

Table 1. Plant survival after mild (M) and severe (S) drought stress, root dry weight before stress, water used between end of mild and of severe stress, and concentration in storage organs of soluble carbohydrates (WSC) after severe stress and soluble proteins before stress, in four alfalfa cultivars

Cultivar	Survival, M (%)	Survival, S (%)	Root weight (g/plot)	Water used (%)	WSC (mg/g)	Protein (mg/g)
Mamuntanas	93.4	67.0	8.9	1.5	192.5	14.5
SARDI 10	92.1	54.6	14.9	1.2	178.8	19.0
Prosementi	93.4	46.3	12.0	0.7	200.1	16.7
Demnat 203	90.5	45.2	16.4	0.5	169.5	19.1
ANOVA *P* level	NS	0.01	0.01	0.03	0.01	0.09