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Germination trials of annual autochthonous leguminous species of interest for planting as herbaceous cover in olive groves

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ABSTRACT

The germination of five species of annual native leguminous plants (*Astragalus hamosus* L., *Medicago minima* (L.) L., *Medicago orbicularis* (L.) Bartal, *Medicago polymorpha* L., and *Scorpiurus muricatus* L.), present spontaneously in the ground cover of olive groves, was tested under experimental garden conditions using different scarification and planting depth treatments. Surface and deep planting were carried out after submitting seeds to different treatments: mechanical scarification (MS) with sandpaper, chemical scarification consisting of immersion in sulphuric acid for five (S_5) or ten (S_10) minutes and non-scarified seeds (Con). Germination success was calculated by analysing (i) the final germination and (ii) the pattern of germination that occurred during the 27 months that the study lasted. The most effective method for interrupting the dormancy of all the species (except *M. polymorpha*) was surface seeding with MS. Unlike the other treatments, in which there were germination peaks in each successive autumn, manually scarified seeds only germinated in the first autumn after sowing, and only within 10 days in the case of surface planting and within 20 days in deep-sown seeds. The speed and abundant germination obtained after manual scarification indicates that the dormancy of the tested species is a product of the hardseededness of the seed coat. Chemical scarification only managed to break down the tough seed cover in the case of deep-sown *M. orbicularis*.

1. Introduction

Most of the world's olive groves are found in the Mediterranean region. In total, there are 2.5 million ha of olive groves in Spain, of which 60% are in Andalusia (S Spain). About 60% of Spanish olive cultivation is carried out in adverse locations (Repullo-Ruibérriz, 2014). Factors such as the low percentage of this woody crop in open plantations, the situation of many olive groves on steep hillsides and the use of inappropriate practices in the control of spontaneous herbaceous plants all favour high rates of soil erosion (Gómez et al., 2009; Schoorl and Veldkamp, 2001) that are currently way above sustainable thresholds (Montgomery, 2007). Furthermore, the continuous use of herbicides for more than 50 years has provoked a loss of seed banks in spontaneous pastures and soil compaction, which in turn has led to lower resilience and an increase in the amount and speed of water run-off (Gómez et al., 1999; Lindstrom and Onstad, 1984).

In integrated production and ecological olive groves plant cover is encouraged and conserved via mechanical cutting and/or grazing (see Torres et al., 2013a for a revision of the techniques used to manage plant cover in ecological olive groves). Recent studies have shown that the use of plant cover (1) reduces the loss of soil compared to other techniques that opt for bare soil all-year round (Bruggeman et al., 2005; Francia et al., 2006; Gómez et al., 2004, 2009), (2) increases the soil's organic matter content and lessens the loss of organic carbon and nitrogen, available K and the phosphorous associated with water-born sediments (García-Ruiz et al., 2012; Gómez et al., 2009; Repullo-Ruibérriz, 2014), (3) improves notably the capacity for water infiltration (Simoes et al., 2014) and (4) halts the contamination of the surface water by synthetic chemical herbicides and fertilizers (Rodríguez-Lizana et al., 2007).

Numerous trials have been conducted involving the planting of ground cover with species of interest as forage crops such as grasses (Castro, 1994) and legumes (Hall et al., 1993; Repullo-Ruibérriz, 2014), or with species such as crucifers that help control *Verticillium dahliae* (Alcántara et al., 2009, 2011). Nevertheless, few farmers opt to plant herbaceous ground cover. In part, this reticence is due to the inherent problems with the planting and tending of ground cover, i.e. seed selection, the choice of method and timing of controls, and the need to reseed in many of species that are used. Recent studies with other types of crops have shown

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that the use of fodder grass species as monospecific ground cover improves soils but also implies an increase in the use of nitrogen-based fertilizers if crop yields are to be maintained (Alvarez and Steinbach, 2009).

The maintenance and conservation of spontaneous plant cover in olive groves is a potentially good alternative to the use of fodder species. Spontaneous cover has great specific diversity. Numerous adventitious species belonging mainly to the botanical families *Fabaceae*,*Poaceae*, *Asteraceae* and *Brassicaceae* (Foráster, 2010; García-Fuentes and Cano, 1998) have been described as growing in olive groves. Recent studies have demonstrated that the use of plants of these families reduces both erosion and the loss of organic carbon in soils in olive groves (Repullo-Ruibérriz et al., 2014). Most spontaneous leguminous species in olive groves have high seed production (Conway et al., 2001; Zoghlami and Zouaghi, 2003), are prostrate (Meloni et al., 2000), are adaptable to a wide range of environmental conditions (Chebouti and Abdelguerfi, 1999; Ehrman and Cocks, 1990), are able to improve soil quality by fixing atmospheric nitrogen (Faria et al., 1989), have high protein contents, and are high-quality forage for cattle (Derkaoui et al., 1993; Evers, 2011; Licitra et al., 1997; Zhu et al., 1996). Leguminous species are thus ideal for restoring plant cover (Meloni et al., 2000), for conserving and improving degraded soils in olive groves, and for diversifying exploitations by permitting the introduction of cattle (Torres et al., 2013b). The seeds of leguminous plants are characterised by having impermeable coats (Lodge, 1996; Souza and Marcos-Filho, 2001), which play an important role in germination patterns under natural conditions since they ensure that seed germination only occurs at optimum moments for seedling growth (Lodge and Whalley, 2002). This mechanism, which guarantees the perpetuation and regeneration of natural pastures, is determinant when high germination success rates over a short period of time are sought (Argel and Paton, 1999).

In all plant restoration programmes it is important to examine closely all components of the production chain, that is, the potential and efficiency of seed production, the obtaining, management and storage of seeds, germination and plant production capacity, and the establishment of plants in the field (Prieto and López, 2006). Numerous studies exist that have attempted to identify pre-germination techniques or treatments that break dormancy and stimulate seed germination in annual leguminous plants. Scarification is one of the most commonly used pre-germination treatments (Can et al., 2009; Martin and De la cuadra, 2004; Patanè and Gresta, 2006; Uzun and Aydin, 2004; Wang and Grusak, 2005) but its effectiveness depends on the genus, species and type of treatment employed (Demir and Ermis, 2004; Kimura and Islam, 2012). Most of these studies have been carried out under laboratory conditions and use the germination capacity achieved by the end of the study as an index for evaluating the success of germination under different pre-germination treatments. Nevertheless, if the conclusions drawn from germination trials with leguminous species are to be put into practice in restoration plans or used to improve soil cover in olive groves, it is necessary to undertake account field studies that analyze germination success in terms of both germination capacity and the time needed for germination to occur (McNair et al., 2012).

This study describes the germination under experimental garden conditions of five species of annual leguminous species that commonly occur in olive groves. The objectives of the study were: (1) to analyse the accumulated germination percentage, (2) identify the germination curves throughout the study and (3) evaluate the differences in germination patterns under different pre-germination treatments.

2. Material and methods

In 2012 mature pods of five annual leguminous species that act as ground cover in olive groves were collected: *Astragalus hamosus*L. (*A. hamosus*), *Medicago minima* (L.) L. (*M. minima*), *Medicago orbicularis* (L.) Bartal (*M. orbicularis*), *Medicago polymorpha* L. (*M. polymorpha*) and *Scorpiurus muricatus* L. (*S. muricatus*). Pods were gathered in ecological olive groves in the county of Sierra Mágina (Jaén), which has average annual precipitation of 400 mm and a precipitation regime characterized by severe summer drought and a concentration of precipitation in autumn (Estación Agroclimática de Mancha Real, X:447571; Y:4196710). Pods were separated by species and conserved under laboratory conditions until the beginning of autumn, when their seeds were manually separated from the pods and planted in experimental garden conditions under different pre-germination treatments and at different depths.

Four pre-germination treatments (Treat) and two planting depths (Depth) were tested. The treatments were as follows: mechanical scarification using a medium-grain sandpaper (MS), two chemical scarifications consisting of immersion in 95% sulphuric acid for five (S_5) and ten (S_10) minutes and a control in which seeds were not treated in any way (Con). There were two planting depths: surface (S) and buried (B). burial depth was three times the average seed size, varying between 0.6 and 1 cm (depending on species). The burial depth (<1 cm) was optimal for

Table 1
Results of the generalized mixed linear models testing all fixed effects (treatments (Treat), Planting depth (Depth) and the interaction Treat × Depth) and the decomposition of the interaction effect between treatments and planting depth on the final germination for five species of annual native plants. F statistics are used for fixed effects. Significance of effects is indicated as *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. The treatments were as follows: mechanical scarification (MS), five minutes in sulphuric acid (S-5), ten minutes in sulphuric acid (S-10) and control (Con). The seed planting depths were: on the surface (S) and burial (B).

	A. hamosus			*M. minima*			*M. orbicularis*			*M. polymorpha*			*S. muricatus*		
	DF	F	p	DF	F	p	DF	F	p	DF	F	p	DF	F	p
Treatment	3;792	51.66	***	3;792	26.67	***	3;800	48.68	***	7;856	1.42		7;792	12.677	***
Depth	1;792	9.31	***	1;792	0.02		1;800	13.26	***	7;856	16.01	***	7;792	3.31	
Treat × Depth	3;792	7.68	***	3;792	5.14	**	3;800	11.84	***	7;856	0.69		7;792	2.89	*
Variation in final germination percentage of different planting depths for each treatment															
MS	1;792	7.80	**	1;792	107.49	***	1;800	12.89	***	1;856	7.8	**	1;792	1.91	
S_5	1;792	11.11	**	1;792	0.77		1;800	5.17	*	1;856	6.71	*	1;792	6.41	*
S_10	1;792	14.49	***	1;792	7.79	**	1;800	10.09	**	1;856	3.99	*	1;792	0.568	
Con	1;792	9.72	**	1;792	4.06	*	1;800	35.42	***	1;856	0.74		1;792	1.81	
Variation in final germination percentage of different treatments for each planting depth															
B	3;792	42.565	***	3;792	11.46	***	3;800	64.21	***	3;856	0.74		3;792	3.08	*
S	3;792	468.5	***	3;792	48.2	***	3;800	234.89	***	3;856	1.46		3;792	12.66	***