Phyton (Horn, Austria)	**Vol. 39**	Fasc. 1	107–129	20. 8. 1999

Seed Germination in *Genisteae (Fabaceae)* from South-West Spain

By

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With 1 Figure

Received November 4, 1998

Accepted February 7, 1999

Key words: Dormancy, *Fabaceae*, *Genisteae*, hardseededness, Iberian Peninsula, seed germination.

Summary

LOPEZ J., DEVESA J. A., RUIZ T. & ORTEGA-OLIVENCIA A. 1999. Seed germination in *Genisteae (Fabaceae)* from South-West Spain. – Phyton (Horn, Austria) 39 (1): 107–129, 1 figure. – English with German summary.

The germination ability of 30 taxa of the tribe *Genisteae (Fabaceae)* from the Iberian Peninsula was studied, revealing the existence of hardseededness. Different methods were tested to evaluate their effectiveness as dormancy breaking agents. The influence of light on germination was also analyzed, as well as the temporal evolution of the germinative process over the experimental period. The study was carried out by subjecting the seeds to the action of two agents: sulphuric acid and boiling water. The former showed a high effectiveness for scarification in the subtribe *Genistinae*, and the latter in *Lupininae*. It was also demonstrated that with respect to the effect of light, in general terms, the *Genisteae* studied here were indifferent. In the course of the experimental period (30 days), two different germinative patterns could be distinguished: (a) one with a very rapid germination rate at the beginning of the process, which indicates a rapid imbibition phase, and (b) another with a delayed onset indicating a slower mode of imbibition.

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Zusammenfassung

LOPEZ J., DEVESA J. A., RUIZ T. & ORTEGA-OLIVENCIA A. 1999. Samenkeimung von *Genisteae (Fabaceae)* aus Südwestspanien. – Phyton (Horn, Austria) 39 (1): 107–129, 1 Abbildung. – Englisch mit deutscher Zusammenfassung.

Von 30 Taxa der Tribus *Genisteae (Fabaceae),* die von der Iberischen Halbinsel stammen und die Eigenschaft der Hartschaligkeit zeigen, wurde das Keimvermögen untersucht. Verschiedene Methoden wurden überprüft, um ihre Wirksamkeit als ruhebrechende Stoffe zu bestimmen. Der Einfluß von Licht auf die Keimung wurde ebenso untersucht wie die zeitliche Entwicklung von Keimungsprozessen während des Untersuchungszeitraumes. Die Untersuchung wurde so durchgeführt, daß die Samen dem Einfluß zweier Substanzen ausgesetzt wurden, Schwefelsäure und kochendem Wasser. Schwefelsäure war für das Durchlässigmachen bei der Subtribus *Genistinae* und kochendes Wasser bei *Lupininae* besonders wirksam. Es konnte auch gezeigt werden, daß in Hinsicht auf den Lichteffekt die untersuchten *Genisteae* sich indifferent verhielten. Im Verlauf des Untersuchungszeitraumes (30 Tage) konnten zwei verschiedene Keimmuster unterschieden werden: a) eines mit einer sehr raschen Keimrate zu Beginn, was auf eine rasche Wasseraufnahme hinweist und b) ein anderes mit einem verzögerten Anlauf, was auf einen langsameren Wasseraufnahmemechanismus hindeutet.

Introduction

The family *Fabaceae* comprises between 12 000 (CRONQUIST 1981) and 14 000 species (CREPET & TAYLOR 1985). Of these, 478 species and 21 genera belong to the tribe *Genisteae* (BISBY 1981), and with the exception of the genus *Hesperolaburnum*, all of them are represented in Europe (BISBY 1981). The centre of *Genisteae* diversification is probably situated in the Mediterranean Region (HOLUBOVÁ-KLÁSKOVÁ 1964), although there is a degree of representation in the tropics, South Africa, Australia, Madagascar, India, the Canary Islands, and for the genus *Lupinus* only, in America (POLHILL 1976).

Most *Leguminosae* seeds present physical dormancy, as a consequence of impermeability to water and gas due to the thickness and biochemical composition of their testa (RIGGIO BEVILACQUA & al. 1989, STEWART 1926). The internal degree of humidity of the seed is just the minimum necessary to preserve embryo viability (KELLY & al. 1992).

This phenomenon is not exclusive to this family (STONE & JUHREN 1951, THANOS & al. 1992), and is generally controlled by few genes (vide FORBES & WELLS 1968). It has been known since the age of Theophrastus (sec. TRAN & CAVANAGH 1984), although the first author to refer to seeds with this behaviour "hard seeds" was NOBBE in 1876. Hardseededness improves the survival of seeds in the soil, and by allowing germination to take place gradually (BURKART 1943) helps to avoid extinction of species (LECK & al. 1989).

Mechanical seed dormancy allows two broad groups of species to be distinguished: one with macrobiotic seeds (in the sense of BURKART 1943), which are able to maintain their viability over many years, and another with microbiotic seeds, able to germinate just after being released. According to GUPPY 1912 nearly 85 % of *Leguminosae* belong to the first group. Nonetheless, hardseededness varies inter- and intraspecifically, depending on the testa's degree of development and what impermeability strategies might have been generated (see KELLY & al. review, 1992), and on such other factors as the geographical location of the populations (e.g. in *Medicago sativa* L., vide ROLSTON 1978), the earliness of the seeds (DEXTER 1955), the ecological differences in relation to temperature and relative humidity (ROLSTON loc. cit.), the physico-chemical characteristics of the soil (e.g. *Trifolium incarnatum* L., JAMES & BANCROFT 1951), the action of the photoperiod (e.g. *Ononis sicula* GUSS.; GUTTERMAN & HEYDECKER 1973), and so forth.

The hardness of the seeds, which under natural conditions declines with time due to natural factors (TRAN & CAVANAGH 1984), can also be broken by a variety of methods (CAVAZZA 1951, QUINLIVAN 1971), all involving making microfissures in the testa (EWART 1908, HAGON 1971). Chemical solutions or enzymes may be used for this purpose (BRANT & al. 1971, HOPKINS 1923), as well as physical agents. Examples are: immersion in boiling water (DRAPER 1985), sulphuric acid (ORTEGA-OLIVENCIA & DEVESA 1997, RUIZ & DEVESA 1998, DEVESA & al. 1998) low temperatures or alternating low and high temperatures (BROWN & ESCOMBE 1897–1898); high pressures (BURKART 1943, DAVIES 1928a, b); percussion (HAMLY 1932); or abrasion (HUGHES 1915).

The current general agreement that most *Fabaceae* have hard seeds has arisen from the great number of studies on the topic. However, these studies have seldom dealt with wild shrubs or uncommercialized fodder herbs, despite the fact that they might be very interesting not only autoecologically, but also practically in terms of conservation of germ plasma in the soil bank.

With respect to *Genisteae*, available data on seed germinability are very limited. The focus has been on a few species of the following genera: *Spartium* (COMPTON 1912, VASSILCZENKO 1937); *Lupinus* (EVENARI 1949, GLADSTONES 1970, MORINAGA 1926a, b, PORSILD & al. 1967, PASCUAL 1986, QUINLIVAN 1961, 1966, 1968a, b, SERRATO-VALENTI & al. 1989, ZOHARY & HOPF 1993); *Argyrolobium* (e.g. *Argyrolobium zanonii* (TURRA) P. W. BALL; BUENDÍA & al. 1966); *Ulex* (ROLSTON 1978, PEREIRAS & al. 1985); *Adenocarpus* (ANGOSTO & MATILLA 1993, GONZÁLEZ & al. 1985); *Chamaecytisus* and *Teline* (GONZÁLEZ-ANDRÉS & ORTIZ 1996, PÉREZ DE PAZ & al. 1986); *Genista* (GONZÁLEZ-ANDRÉS & ORTIZ 1996, KINZEL 1926, sec. MAYER & POLJAKOFF-MAYBER 1989, MERLO & ALEMÁN 1996); *Cytisus* (ANGOSTO &

MATILLA 1993, BAKER 1989, GONZÁLEZ-ANDRÉS & ORTIZ 1996, KINZEL loc. cit.); *Cytisophyllum* (GÓNZÁLEZ-ANDRÉS & ORTIZ 1996).

In the present work, we have studied the germination ability of 30 *Genisteae* from the Iberian Peninsula (see studied material), where the tribe includes 16 genera and 80 species, many with infraspecific taxa. Our aim was to: (a) verify the existence of hardseededness; (b) test various treatments for effectiveness; (c) investigate the influence of light on the germinative process of the taxa studied.

Materials and Methods

Germinability test

For the germination studies the seeds were collected from natural populations (see studied material), between 1991 and 1993, and a random sample of seeds from the same year was utilized for each taxon. The seeds were stored and properly labelled in paper bags, after impurities, contaminant elements, and any malformed, and thus inviable, seeds were removed. The bags were maintained at the laboratory room temperature (20 ± 10 °C), in darkness, until the performance of the experiments during the autumn season of each year.

One population of each taxon was studied (three in the case of *Adenocarpus complicatus* subsp. *anisochilus* (BOISS.) FRANCO), and 30 seeds were selected randomly for each of the four scarification agent tests, and for both of the two control situations (light and darkness). Germination experiments were performed in an incubator chamber (RI-50-555, REVCO), placing the seeds in Petri dishes on layers of filter papers moistened with distilled water, at a constant temperature of 20 °C, an 8 hour photoperiod of cold white light and a relative humidity of 40–60 %. The experimental period lasted 30 days, because those seeds unable to germinate in a humid medium at a temperature of 15 °C (QUINLIVAN 1968a) in 10 days can be considered "hard seeds". Each day, those seeds with an emerged radicle of 1 mm (germinated seeds) were counted and removed from the Petri dishes.

Control seedlots were kept without any treatment, and the rest of the seedlots were subjected to two scarifying agents: boiling water, and 96% concentrated sulphuric acid, the latter being allowed to act for 60 and 90 minutes. In all the cases germination was tested in both darkness and the forementioned light conditions. Mechanical scarification methods (punction, abrasion, etc.) were rejected due to the smallness of the seeds or the risk of damage.

For each taxon, 240 seeds were used distributed into eight lots, to be given the following treatments:

B1. Scarification by immersion in boiling water for one minute, and germination under the forementioned light conditions.

B2. The same as B1, but in darkness.

C1. Control (unscarified) seedlot, germinated under the forementioned light conditions.

C2. Control (unscarified) seedlot, germinated in darkness.

S1. Scarification by a 60 minute period of immersion in sulphuric acid and germination under the forementioned light conditions.

S2. The same as S1, but in darkness.

S3. Scarification by a 90 minute period of immersion in sulphuric acid and germination under the forementioned light conditions.

S4. The same as S3, but in darkness.

As exceptions, in the cases of *Genista florida* L. and *Cytisus striatus* (HILL) ROTHM., due to the low germination percentages obtained with these treatments, the following ones were also tested:

B3. Scarification by immersion in boiling water for two minutes and germination under the forementioned light conditions.

B4. The same as B3 but in darkness.

S5. Scarification by a 120 minute period of immersion in sulphuric acid and germination under the forementioned light conditions.

S6. The same as S5, but in darkness.

Parameters analyzed

Firstly, for each taxon the number of germinated seeds was determined, and the respective percentages of germination obtained. The germinative capability (germinability) was ranked as a function of these percentages using the scale of JURADO & WESTOBY 1992, modified as follows: null (0% of germinated seeds), low (1–29%), moderate (30–69%), high (70–99%), and maximum (100%).

Secondly, the value of the vigour (V) of each seedlot was calculated as a measure of the germination rate, because the values of this index reflect the germinative capability of the seeds per unit time (see BRADBEER 1988). The formula used was: $V = (a/1 + b/2 + c/3 + d/4 + \ldots + x/n) \times 100 / S$, where a, b, c, . . ., respectively represent the number of seeds which germinated after 1, 2, 3 . . . days of imbibition, x is the number for day n and S the total number of seeds sown. The range of the V values is from 0 to 100 (maximum rate). The rates were categorized according to the following scale:

Very fast	$33.33 \leq V \leq 100$
Fast	$11.11 \leq V < 33.33$
Medium	$5.0 \leq V < 11.11$
Slow	$0.0 < V < 5.0$
Null	$0.0 = V$

Hence, a very fast rate means a hypothetically complete germination in the first 3 days of the experiment, a fast rate, in the 10 first days, medium, in the first 20 days, slow, over the entire experimental period (30 days), and null, no rate data due to a complete lack of germination.

In the present work, these five categories are represented by numbers: 0= Null; 1= Slow; 2= Medium; 3= Fast; and 4= Very fast.

The V parameter is very important from the practical point of view, because it carries more information than the simple percentages relative to the real possibilities of the seedlings establishing themselves in the soil (MAYER & POLJAKOFF-MAYBER 1989).

Statistical analysis

Germination data were analyzed by the application of chi-squared tests, in order to evaluate the existence, if any, of statistically significant differences between pairs of treatments over the experimental period. This analysis was made by the

Table 1.

Percentage germination (%) and vigour (V) of seeds after different experimental treatments in *Genisteae*: control (C1 and C2); boiling for 1 minute (B1 and B2) and scarification with sulphuric acid for 60 minutes (S1 and S2) and for 90 minutes (S3 and S4). C1, B1, S1 and S3 are seeds tested under cold white light and C2, B2, S2 and S4 under dark conditions.

	C1		C2		B1		B2		S1		S2		S3		S4	
TAXON	%	V	%	V	%	V	%	V	%	V	%	V	%	V	%	V
GENISTA																
G. tridentata	13.33	0.76	10.00	0.42	33.33	1.80	3.33	0.19	43.33	3.78	20.00	1.75	43.33	4.34	50.00	2.59
G. polyanthos subsp. *hystrix*	16.66	0.97	0.00	0.00	10.00	0.70	6.66	0.43	63.33	6.24	66.66	9.74	76.66	8.48	73.33	10.52
G. triacanthos	3.33	0.37	13.33	1.32	66.66	4.37	70.00	4.88	43.33	4.87	63.33	9.03	6.66	0.63	10.00	0.92
G. hirsuta	3.33	0.55	3.33	0.11	73.33	3.39	33.33	1.38	96.66	8.51	96.66	7.55	96.66	13.42	86.66	16.45
G. anglica	6.66	0.45	3.33	0.12	33.33	3.27	10.00	0.42	66.66	11.93	33.33	3.27	76.66	12.96	56.66	8.13
G. falcata	6.66	0.46	0.00	0.00	6.66	0.38	0.00	0.00	56.66	5.24	26.66	3.47	93.33	10.46	86.66	10.18
G. umbellata	3.33	0.22	6.66	0.84	30.00	3.75	16.66	3.00	53.33	3.44	80.00	27.65	66.66	18.44	83.33	28.96
G. cinerascens	3.33	0.20	3.33	0.33	43.33	4.28	33.33	4.01	76.66	10.46	83.33	10.22	66.66	9.95	80.00	12.22
G. florida	0.00	0.00	0.00	0.00	6.66	0.38	13.33	0.71	46.66	2.75	43.33	2.91	73.33	3.26	50.00	3.21
RETAMA																
R. sphaerocarpa	0.00	0.00	0.00	0.00	40.00	3.62	46.66	3.84	96.66	8.86	100.00	10.90	100.00	10.45	96.66	10.37
SPARTIUM																
S. junceum	50.00	2.54	63.33	3.55	86.66	6.32	86.66	9.27	100.00	7.72	96.66	25.92	93.33	18.55	100.00	21.80
ECHINOSPARTUM																
E. barnadesii subsp. *dorsisericeum*	0.00	0.00	0.00	0.00	30.00	2.26	3.33	0.11	46.66	4.42	40.00	3.80	66.66	5.46	56.66	6.03
ULEX																
U. minor	6.66	0.31	10.00	0.91	73.33	2.93	36.66	1.52	36.66	2.09	46.66	3.88	36.66	2.39	36.66	1.55
U. eriocladus	10.00	0.56	6.66	0.26	93.33	7.35	70.00	5.86	90.00	7.47	20.00	2.16	6.66	0.71	43.33	5.24
CYTISUS																
C. multiflorus	0.00	0.00	3.33	0.17	93.33	7.17	100.00	6.61	63.33	7.13	73.33	8.37	36.66	2.63	26.66	2.95
C. balansae subsp. *europaeus*	10.00	1.70	0.00	0.00	43.33	3.81	40.00	3.34	33.33	2.26	73.33	9.75	40.00	3.94	83.33	5.16
C. arboreus subsp. *baeticus*	20.00	2.47	20.00	1.87	76.66	7.45	80.00	10.38	26.66	3.84	23.33	2.43	40.00	6.64	23.33	2.84
C. striatus	0.00	0.00	0.00	0.00	46.66	2.51	90.00	4.46	16.66	0.95	6.66	0.83	0.00	0.00	10.00	0.73
C. scoparius	13.33	0.47	3.33	0.17	93.33	6.86	100.00	5.95	50.00	4.87	96.66	13.27	3.33	0.25	3.33	0.16
ADENOCARPUS																
A. complicatus subsp. *complicatus*	3.33	0.22	3.33	0.66	96.66	7.03	93.33	6.34	80.00	22.41	76.66	20.89	83.33	27.72	83.33	27.36
A. complicatus subsp. *anisochilus*																
UNEX 17038	6.66	0.67	0.00	0.00	83.33	9.54	86.66	4.27	93.33	21.23	90.00	22.23	100.00	22.65	100.00	23.60
UNEX 17106	3.33	0.55	3.33	0.11	83.33	5.83	56.66	4.77	96.66	22.85	96.66	27.02	96.66	22.40	100.00	28.58
UNEX 17110	0.00	0.00	3.33	0.12	83.33	5.70	83.33	4.38	66.66	15.24	66.66	9.70	80.00	16.52	66.66	13.98
A. telonensis	6.66	0.32	10.00	0.91	13.33	0.74	66.66	3.06	33.33	5.06	6.66	1.07	53.33	6.88	70.00	14.27
A. hispanicus subsp. *gredensis*	0.00	0.00	0.00	0.00	26.66	1.36	30.00	1.33	43.33	4.14	23.33	3.24	36.66	4.50	43.33	6.25
A. hispanicus subsp. *argyrophyllus*	3.33	0.30	6.66	0.60	96.66	7.60	96.66	7.19	36.66	5.42	60.00	7.03	70.00	10.24	60.00	12.08
ARGYROLOBIUM																
A. zanonii	0.00	0.00	0.00	0.00	96.66	18.85	100.00	28.47	100.00	29.53	100.00	17.85	100.00	13.65	100.00	19.16
LUPINUS																
L. luteus	100.00	28.48	93.33	17.64	100.00	27.61	100.00	36.19	96.66	25.91	96.66	25.39	100.00	25.27	100.00	26.79
L. albus	100.00	13.92	100.00	14.62	100.00	16.46	100.00	15.05	100.00	21.25	100.00	22.50	100.00	19.53	100.00	33.95
L. angustifolius	0.00	0.00	3.33	0.12	10.00	1.67	20.00	3.77	6.66	0.54	13.33	0.94	43.33	3.13	36.66	2.75
L. hispanicus var. *bicolor*	0.00	0.00	3.33	0.83	100.00	24.61	100.00	24.74	10.00	2.70	6.66	2.03	66.66	14.38	73.33	14.90
L. micranthus	10.00	3.88	3.33	0.30	70.00	12.53	63.33	13.94	26.66	5.06	36.66	6.55	60.00	9.19	66.66	7.47

construction of 2×2 contingency tables from the total germination data obtained at 10, 20 and 30 days in each experiment. The pairs of treatments compared were (data available upon request):

* C1/B1, C1/B3, C1/S1, C1/S3, C1/S5, C2/B2, C2/B4, C2/S2, C2/S4, C2/S6. Scarification treatments versus control lots, under the same light conditions, in order to test the action of the scarifying agents.

* C1/C2, B1/B2, B3/B4, S1/S2, S3/S4, S5/S6. Scarification treatments and control lots, under different light conditions (light/dark), in order to study the action of the light.

* B1/B3, B2/B4, S1/S3, S3/S5, S1/S5, S2/S4, S4/S6, S2/S6. Different duration times of scarification treatments, under the same light conditions, in order to test the importance of the length of time in the action of the scarifying agents.

* B1/S1, B1/S3, B1/S5, B2/S2, B2/S4, B2/S6, B3/S1, B3/S3, B3/S5, B4/S2, B4/S4, B4/S6. Different scarification treatments, under the same light conditions, in order to compare their effectiveness.

Germination curves

Cumulative germination curves relative to the total number of sown seeds were plotted. This type of graphical representation is well-suited to assessing differences between treatments and taxa, facilitating the display of the evolution of the germinative process over the experimental period (THOMSON & EL-KASSABY 1993).

Results and Discussion

The results yield information about the following aspects: a straightforward quantitative evaluation of the germination of the taxa studied, according to the different treatments (expressed as germination percentages); the germinative success of the seeds of the taxa studied (expressed through the Vigour parameter); the efficacy of the scarifying agents according to the applied statistical analysis; and finally, the pattern of the germinative process, derived from the study of the corresponding curves.

These results are compiled in the following tables and figures:

Tables 1 and 2 give the values of the percentages of germination and the Vigour obtained with control and treated seedlots, respectively.

Table 3 shows the statistical significance levels found when comparing the germination of the control and the sulphuric acid scarified seedlots

Table 2.

Percentage germination (%) and vigour (V) for additional treatments made for *Genista florida* and *Cytisus striatus*: boiling for 2 minutes (B3, B4); scarification with sulphuric acid for 120 minutes (S5, S6). B3 and S5 are seeds tested under cold white light and B4 and S6 under dark conditions.

	B3		B4		S5		S6	
TAXON	%	V	%	V	%	V	%	V
Genista florida	16.66	0.75	16.66	0.74	86.66	4.71	76.66	7.77
Cytisus striatus	86.66	5.21	100.00	6.99	0.00	0.00	0.00	0

Table 3.

Significance of the differences (chi-squared test) in germination after 10, 20 and 30 days between different treatments and the same light conditions in *Genisteae*: PART A, seeds scarified with sulphuric acid for 60 and 90 minutes (S1, S2, S3 and S4) and control seeds (C1 and C2); PART B, seeds scarified with sulphuric acid for 60 and 90 minutes (S1, S2, S3 and S4). S1, C1, S3 are seeds tested under cold white light and S2, C2, S4 under dark conditions. –, not significant; ** $P < 0.01$; *** $P < 0.001$; d, days.

		PART A				PART B				PART A				PART B	
TAXON	d	S1/C1	S2/C2	S3/C1	S4/C2	S1/S3	S2/S4	TAXON	d	S1/C1	S2/C2	S3/C1	S4/C2	S1/S3	S2/S4
GENISTA								*C. arboreus*	10	–	–	**	–	–	–
G. tridentata	10	**	–	***	–	–	–	subsp. *baeticus*	20	–	–	**	–	–	–
	20	***	**	**	–	–	–		30	–	–	–	–	–	–
	30	***	–	***	***	–	**								
								C. striatus	10	–	–	–	–	–	–
G. polyanthos	10	**	***	***	***	***	–		20	–	–	–	–	–	–
subsp. *hystrix*	20	***	***	***	***	–	–		30	**	–	–	–	**	–
	30	***	***	***	***	–	–								
								C. scoparius	10	***	***	–	–	***	***
G. triacanthos	10	**	***	–	–	**	***		20	***	***	–	–	***	***
	20	***	***	–	–	***	***		30	***	***	–	–	***	***
	30	***	***	–	–	***	***								
								ADENOCARPUS							
G. hirsuta	10	**	–	***	***	***	***	*A. complicatus*	10	***	***	***	***	–	–
	20	***	***	***	***	–	–	subsp. *complicatus*	20	***	***	***	***	–	–
	30	***	***	***	***	–	–		30	***	***	***	***	–	–
G. anglica	10	***	–	***	***	–	**	*A. complicatus*							
	20	***	**	***	***	–	**	subsp. *anisochilus*							
	30	***	***	***	***	–	–	UNEX 17038	10	***	***	***	***	–	–
									20	***	***	***	***	–	–
G. falcata	10	**	**	***	***	***	***		30	***	***	***	***	–	–
	20	***	***	***	***	***	***								
	30	***	***	***	***	***	***	UNEX 17106	10	***	***	***	***	–	–
									20	***	***	***	***	–	–
G. umbellata	10	–	***	***	***	***	–		30	***	***	***	***	–	–
	20	***	***	***	***	**	–								
	30	***	***	***	***	–	–	UNEX 17110	10	***	***	***	***	–	–
									20	***	***	***	***	–	–
G. cinerascens	10	***	***	***	***	–	–		30	***	***	***	***	–	–
	20	***	***	***	***	–	–								
	30	***	***	***	***	–	–	*A. telonensis*	10	***	–	***	***	–	***
									20	***	–	***	***	–	***
G. florida	10	–	–	–	–	–	–		30	***	–	***	***	–	***
	20	–	**	–	***	–	–								
	30	***	***	***	***	**	–	*A. hispanicus*	10	***	**	**	***	–	–
								subsp. *gredensis*	20	***	***	***	***	–	–
RETAMA									30	***	***	***	***	–	–
R. sphaerocarpa	10	***	***	***	***	**	–								
	20	***	***	***	***	–	–	*A. hispanicus*	10	***	**	***	***	**	**
	30	***	***	***	***	–	–	subsp. *argyrophyllus*	20	***	***	***	***	***	–
									30	***	***	***	***	***	–
SPARTIUM															
S. junceum	10	–	***	***	***	***	–	*ARGYROLOBIUM*							
	20	***	***	***	***	–	–	*A. zanonii*	10	***	***	***	***	–	–
	30	***	***	***	***	–	–		20	***	***	***	***	–	–
									30	***	***	***	***	–	–
ECHINOSPARTUM															
E. barnadesii	10	–	**	–	–	–	–	*LUPINUS*							
subsp. *dorsisericeum*	20	***	***	***	***	–	–	*L. luteus*	10	**	–	***	–	–	–
	30	***	***	***	***	–	–		20	–	–	–	–	–	–
									30	–	–	–	–	–	–
ULEX															
U. minor	10	–	–	–	–	–	**	*L. albus*	10	–	–	–	–	–	–
	20	–	***	**	–	–	***		20	–	–	–	–	–	–
	30	***	***	***	**	–	–		30	–	–	–	–	–	–
U. eriocladus	10	***	–	–	***	**	**	*L. angustifolius*	10	–	–	–	**	–	–
	20	***	***	–	***	***	–		20	–	–	***	***	***	**
	30	***	–	–	***	***	–		30	–	–	***	***	***	**
CYTISUS								*L. hispanicus*	10	–	–	***	***	***	***
C. multiflorus	10	***	***	**	**	–	***	var. *bicolor*	20	–	–	***	***	***	***
	20	***	***	***	**	–	***		30	–	–	***	***	***	***
	30	***	***	***	**	**	***								
								L. micranthus	10	–	**	***	***	**	***
C. balansae	10	–	***	–	–	**	***		20	–	**	***	***	**	***
subsp. *europaeus*	20	**	***	**	***	–	–		30	–	***	***	***	***	**
	30	**	***	***	***	–	–								

Table 4.

Significance of the differences (chi-squared test) in germination after 10, 20 and 30 days between different treatments and the same light conditions in *Genisteae*: PART C, seeds scarified by boiling for 1 minute (B1, B2) and control seeds (C1, C2); PART D, seeds scarified by boiling (B1, B2) and seeds scarified with sulphuric acid for 60 and 90 minutes (S1, S2, S3 and S4). B1, C1, S1, S3 are seeds tested under cold white light and B2, C2, S2, S4 under dark conditions. –, not significant; ** $P < 0.01$; *** $P < 0.001$; d, days.

		PART C		PART D			
TAXON	d	B1/C1	B2/C2	B1/S1	B1/S3	B2/S2	B2/S4
GENISTA							
G. tridentata	10	-	-	**	***	-	-
	20	-	-	-	-	-	-
	30	-	-	-	-	**	***
G. polyanthos	10	-	-	-	***	***	***
subsp. *hystrix*	20	-	-	***	***	***	***
	30	-	-	***	***	***	***
G. triacanthos	10	-	-	**	-	***	-
	20	***	***	-	***	-	***
	30	***	***	-	***	-	***
G. hirsuta	10	-	-	***	***	-	***
	20	-	-	***	***	***	***
	30	***	***	**	**	***	***
G. anglica	10	**	-	-	***	-	***
	20	**	-	**	**	**	***
	30	***	-	***	***	**	***
G. falcata	10	-	-	**	***	**	***
	20	-	-	***	***	***	***
	30	-	-	***	***	***	***
G. umbellata	10	***	-	***	***	***	***
	20	***	-	-	***	***	***
	30	***	-	-	***	***	***
G. cinerascens	10	***	**	-	***	-	***
	20	***	***	-	-	***	***
	30	***	***	***	-	***	***
G. florida	10	-	-	-	-	-	-
	20	-	-	-	-	-	**
	30	-	**	***	***	***	***
RETAMA							
R. sphaerocarpa	10	***	**	-	***	***	***
	20	***	***	***	***	***	***
	30	***	***	***	***	***	***
SPARTIUM							
S. junceum	10	-	***	-	***	***	***
	20	***	***	-	-	**	***
	30	***	**	**	-	-	**
ECHINOSPARTUM							
E. barnadesii	10	-	-	-	-	**	-
subsp. *dorsisericeum*	20	***	-	-	***	***	***
	30	***	-	-	***	***	***
ULEX							
U. minor	10	-	-	-	-	-	-
	20	**	-	-	-	***	-
	30	***	**	***	***	-	-
U. eriocladus	10	***	***	-	**	-	-
	20	***	***	**	***	**	-
	30	***	***	-	***	***	**
CYTISUS							
C. multiflorus	10	***	***	-	-	-	-
	20	***	***	***	***	-	***
	30	***	***	***	***	***	***
C. balansae	10	-	**	-	-	***	**
subsp. *europaeus*	20	***	***	-	-	**	***
	30	***	***	-	-	***	***

		PART C		PART D			
TAXON	d	B1/C1	B2/C2	B1/S1	B1/S3	B2/S2	B2/S4
C. arboreus	10	**	***	-	-	***	***
subsp. *baeticus*	20	***	***	***	***	***	***
	30	***	***	***	***	***	***
C. striatus	10	-	-	-	-	-	-
	20	**	***	-	**	**	-
	30	***	***	**	***	***	***
C. scoparius	10	**	***	-	**	***	***
	20	***	**	***	***	***	**
	30	***	***	***	***	-	***
ADENOCARPUS							
A. complicatus	10	***	-	***	***	***	***
subsp. *complicatus*	20	***	***	-	-	-	-
	30	***	***	**	-	-	-
A. complicatus							
subsp. *anisochilus*							
UNEX 17038	10	***	-	***	***	***	***
	20	***	***	-	**	***	***
	30	***	***	-	**	-	**
UNEX 17106	10	-	-	***	***	***	***
	20	***	***	***	***	***	***
	30	***	***	-	-	***	***
UNEX 17110	10	-	-	***	***	***	***
	20	***	***	-	**	-	**
	30	***	***	-	-	-	-
A. telonensis	10	-	-	***	***	-	***
	20	-	-	-	***	-	***
	30	-	***	-	***	***	-
A. hispanicus	10	-	-	***	**	**	***
subsp. *gredensis*	20	-	**	**	-	-	-
	30	***	***	-	-	-	-
A. hispanicus	10	***	**	-	**	-	***
subsp. *argyrophyllus*	20	***	***	***	-	***	***
	30	***	***	***	***	***	***
ARGYROLOBIUM							
A. zanonii	10	***	***	-	-	-	-
	20	***	***	-	-	-	-
	30	***	***	-	-	-	-
LUPINUS							
L. luteus	10	**	**	-	-	-	-
	20	-	-	-	-	-	-
	30	-	-	-	-	-	-
L. albus	10	-	-	-	-	-	-
	20	-	-	-	-	-	-
	30	-	-	-	-	-	-
L. angustifolius	10	-	***	-	-	**	-
	20	-	***	-	***	**	-
	30	-	**	-	***	-	-
L. hispanicus	10	***	***	***	***	***	***
var. *bicolor*	20	***	***	***	***	***	***
	30	***	***	***	***	***	***
L. micranthus	10	**	***	-	-	**	-
	20	***	***	-	-	***	-
	30	***	***	***	-	**	-

Table 5.

Significance of the differences (chi-squared test) in germination after 10, 20 and 30 days for control seeds C1 vs C2 (C1/C2) and for seeds with different scarified treatments (boiling B1/B2; sulphuric acid for 60 minutes S1/S2; sulphuric acid for 90 minutes S3/S4) in *Genisteae*. C1, B1, S1, S3 are seeds tested under cold white light and C2, B2, S2, S4 under dark conditions. –, not significant; **, $P < 0.01$; *** $P < 0.001$; d, days. Parentheses refer to dark conditions, causing greater germination.

TAXON	d	C1/C2	B1/B2	S1/S2	S3/S4
GENISTA					
G. tridentata	10	-	-	-	**
	20	-	-	-	**
	30	-	***	-	-
G. polyanthos	10	-	-	(***)	-
subsp. *hystrix*	20	**	-	-	-
	30	**	-	-	-
G. triacanthos	10	-	-	(**)	-
	20	-	-	-	-
	30	-	-	-	-
G. hirsuta	10	-	-	-	-
	20	-	-	-	**
	30	-	***	-	-
G. anglica	10	-	***	***	-
	20	-	***	***	-
	30	-	**	***	-
G. falcata	10	-	-	-	-
	20	-	-	**	-
	30	-	-	**	-
G. umbellata	10	-	-	(***)	-
	20	-	-	(***)	-
	30	-	-	(**)	-
G. cinerascens	10	-	-	-	-
	20	-	-	-	-
	30	-	-	-	-
G. florida	10	-	-	-	-
	20	-	-	-	-
	30	-	-	-	-
RETAMA					
R. sphaerocarpa	10	-	-	(***)	-
	20	-	-	-	-
	30	-	-	-	-
SPARTIUM					
S. junceum	10	-	(**)	(***)	-
	20	-	-	-	-
	30	-	-	-	-
ECHINOSPARTUM					
E. barnadesii	10	-	-	-	-
subsp. *dorsisericeum*	20	-	***	-	-
	30	-	***	-	-
ULEX					
U. minor	10	-	-	-	-
	20	-	**	(**)	-
	30	-	***	-	-
U. eriocladus	10	-	-	-	(***)
	20	-	-	***	(***)
	30	-	**	***	(***)
CYTISUS					
C. multiflorus	10	-	-	-	-
	20	-	***	-	-
	30	-	-	-	-
C. balansae	10	-	-	(***)	**
subsp. *europaeus*	20	-	-	(***)	(***)
	30	-	-	(***)	(***)

TAXON	d	C1/C2	B1/B2	S1/S2	S3/S4
C. arboreus	10	-	(**)	-	-
subsp. *baeticus*	20	-	-	-	-
	30	-	-	-	-
C. striatus	10	-	-	-	-
	20	-	-	-	-
	30	-	(**)	-	-
C. scoparius	10	-	-	(***)	-
	20	-	***	(***)	-
	30	-	-	(***)	-
ADENOCARPUS					
A. complicatus	10	-	**	-	-
subsp. *complicatus*	20	-	-	-	-
	30	-	-	-	-
A. complicatus					
subsp. *anisochilus*					
UNEX 17038	10	-	***	-	-
	20	-	***	-	-
	30	-	-	-	-
UNEX 17106	10	-	-	-	-
	20	-	-	-	-
	30	-	**	-	-
UNEX 17110	10	-	-	-	-
	20	-	-	-	-
	30	-	-	-	-
A. telonensis	10	-	-	**	-
	20	-	-	**	-
	30	-	(***)	***	-
A. hispanicus	10	-	-	-	-
subsp. *gredensis*	20	-	-	-	-
	30	-	-	-	-
A. hispanicus	10	-	-	-	-
subsp. *argyrophyllus*	20	-	-	-	-
	30	-	-	-	-
ARGYROLOBIUM					
A. zanonii	10	-	-	-	-
	20	-	-	-	-
	30	-	-	-	-
LUPINUS					
L. luteus	10	-	-	-	-
	20	-	-	-	-
	30	-	-	-	-
L. albus	10	-	-	-	-
	20	-	-	-	-
	30	-	-	-	-
L. angustifolius	10	-	-	-	-
	20	-	-	-	-
	30	-	-	-	-
L. hispanicus	10	-	-	-	-
var. *bicolor*	20	-	-	-	-
	30	-	-	-	-
L. micranthus	10	-	-	-	-
	20	-	-	-	-
	30	-	-	-	-

Table 6.

Significance of the differences (chi-squared test) in germination after 10, 20 and 30 days for different treatments in *Genisteae:* PART A, seeds scarified with sulphuric acid for 120 minutes (S5, S6) and control seeds (C1, C2); PART B, seeds scarified with sulphuric acid under the same light conditions (S1/S5, S3/S5, S2/S6, S4/S6); PART C, seeds scarified by boiling for 2 minutes (B3, B4) and control seeds (C1, C2); PART D, seeds scarified by boiling (for 1 minute – B1, B2 – and for 2 minutes – B3, B4) and seeds scarified with sulphuric acid (for 60 minutes – S1, S2 – for 90 minutes – S3, S4 – and for 120 minutes – S5, S6) under the same light conditions; PART E, seeds scarified by boiling for different times (B1/B3, B2/B4); PART F, seeds scarified by boiling (B3/B4); seeds scarified with sulphuric acid for 120 minutes (S5–S6). C1, B1, B3, S1, S3, S5 are seeds tested under white cold light and C2, B2, B4, S2, S4, S6 under dark conditions. –, not significant; ** $P < 0.01$; *** $P < 0.001$; d, days. Parentheses refers to dark conditions.

		PART A		PART B				PART C		PART D								PART E		PART F	
TAXON	d	S5/C1	S6/C2	S1/S5	S3/S5	S2/S6	S4/S6	B3/C1	B4/C2	B1/S5	B3/S1	B3/S3	B3/S5	B2/S6	B4/S2	B4/S4	B4/S6	B1/B3	B2/B4	B3/B4	S5/S6
Genista florida	10	-	***	-	-	**	***	-	-	-	-	-	-	***	-	-	***	-	-	-	**
	20	***	***	***	***	***	***	-	-	***	-	-	***	***	**	***	***	-	-	-	***
	30	***	***	***	-	***	**	**	**	***	**	***	***	***	**	***	***	-	-	-	-
Cytisus striatus	10	-	-	-	-	-	-	-	**	-	-	-	-	-	-	**	**	-	-	-	-
	20	-	-	-	-	-	-	***	***	**	***	***	***	***	***	***	***	**	***	(***)	-
	30	-	-	**	-	-	-	***	***	***	***	***	***	***	***	***	***	***	-	(**)	-

(Part A), and when comparing these scarifying treatments under identical light conditions (Part B).

Table 4 shows the statistical significance levels found when comparing the germination of the control and the boiling water scarified seedlots (Part C), and when comparing these scarifying treatments (Part D).

Table 5 shows the statistical significance levels found when comparing the results of the germination of the control and each of the scarified seedlots under different light conditions.

Table 6 shows the statistical significance levels found when comparing the germination of the control and the special scarified seedlots (see Materials and Methods) of *Genista florida* and *Cytisus striatus*, and the comparison of the special treatments with each other.

Figures 1a–d show the two kinds of curves resulting from plotting the germination data.

Germination values:
Generalities

When comparing the germination percentages obtained for the control and the differently treated seedlots (Tables 1–2), one sees firstly clear evi-

Table 7.

Assigned values to different germination velocities for every taxon and treatments (control: C1 and C2; boiling: B1, B2, B3 and B4; scarification with sulphuric acid: for 60 minutes (S1, S2); for 90 minutes (S3, S4) and for 120 minutes (S5, S6) according to the vigour (V) in *Genisteae*. 0: null; 1: slow; 2: medium; 3: quick; 4: rushy. C1, B1, B3, S1, S3, S5 are seeds tested under white cold light and C2, B2, B4, S2, S4, S6 under dark conditions.

TAXON	C1	C2	B1	B2	S1	S2	S3	S4	B3	B4	S5	S6
GENISTA												
G. tridentata	1	1	1	1	1	1	1	1				
G. polyanthos subsp. *hystrix*	1	0	1	1	2	2	2	2				
G. triacanthos	1	1	1	1	1	2	1	1				
G. hirsuta	1	1	1	1	2	2	3	3				
G. anglica	1	1	1	1	3	1	3	2				
G. falcata	1	1	1	0	2	1	3	2				
G. umbellata	1	1	1	1	1	3	3	3				
G. cinerascens	1	1	1	1	2	2	2	3				
G. florida	0	0	1	1	1	1	1	1	1	1	1	2
RETAMA												
R. sphaerocarpa	0	0	1	1	2	2	2	2				
SPARTIUM												
S. junceum	1	1	2	2	2	3	3	3				
ECHINOSPARTUM												
E. barnadesii subsp. *dorsisericeum*	0	0	1	1	1	1	2	2				
ULEX												
U. minor	1	1	1	1	1	1	1	1				
U. eriocladus	1	1	2	2	2	1	1	2				
CYTISUS												
C. multiflorus	0	1	2	2	2	2	1	1				
C. balansae subsp. *europaeus*	1	0	1	1	1	2	1	2				
C. arboreus subsp. *baeticus*	1	1	2	2	1	1	2	1				
C. striatus	0	0	1	1	1	1	0	1	2	2	0	0
C. scoparius	1	1	2	2	1	3	1	1				
ADENOCARPUS												
A. complicatus subsp. *complicatus*	1	1	2	2	3	3	3	3				
A. complicatus subsp. *anisochilus*												
UNEX 17038	1	0	2	1	3	3	3	3				
UNEX 17106	1	1	2	1	3	3	3	3				
UNEX 17110	0	1	2	1	3	2	3	3				
A. telonensis	1	1	1	1	2	1	2	3				
A. hispanicus subsp. *gredensis*	0	0	1	1	1	1	1	2				
A. hispanicus subsp. *argyrophyllus*	1	1	2	2	2	2	2	3				
ARGYROLOBIUM												
A. zanonii	0	0	3	3	3	3	3	3				
LUPINUS												
L. luteus	3	3	3	4	3	3	3	3				
L. albus	3	3	3	3	3	3	3	4				
L. angustifolius	0	1	1	1	1	1	1	1				
L. hispanicus var. *bicolor*	0	1	3	3	1	1	3	3				
L. micranthus	1	1	3	3	2	2	2	2				

Table 8.

Summary of the different taxa studied according to the vigour (V) in *Genisteae*. TR stands for the different treatments (scarification with sulphuric acid for 60 minutes – S1, S2 –, for 90 minutes – S3, S4 – and for 120 minutes – S6; B2, B4 scarification by boiling for 1 minute and for 2 minutes respectively). The rate and the model of germination curve (G) are indicated. Bold typed treatments indicate germination percentages above 70%. Underlined treatments indicate germination percentages equal to 100%. Listed curves are: Exp., exponential; Sig., sigmoidal; (o), oscillating; (a), ascendent; (s) simple. S1, S3, B2 are seeds tested under cold white light and S2, S4, S6, B4 under dark conditions.

TAXON	TR	Rate	G
GENISTA			
G. tridentata	S3	Slow	Sig. (o)
G. polyanthos subsp. *hystrix*	**S4**	Medium	Exp. (o)
G. triacanthos	S2	Medium	Sig. (o)
G. hirsuta	**S4**	Fast	Sig. (s)
G. anglica	**S3**	Fast	Sig. (a)
G. falcata	**S3**	Medium	Sig. (o)
G. umbellata	**S4**	Fast	Exp.
G. cinerascens	**S4**	Medium	Sig. (o)
G. florida	**S6**	Medium	Sig. (o)
RETAMA			
R. sphaerocarpa	**S2**	Fast	Sig. (o)
SPARTIUM			
S. junceum	**S2**	Fast	Exp. (o)
ECHINOSPARTUM			
E. barnadesii subsp. *dorsisericeum*	S4	Medium	Sig. (s)
ULEX			
U. minor	**S2**	Slow	Sig. (s)
U. eriocladus	**S1**	Medium	Sig. (o)
CYTISUS			
C. multiflorus	**S2**	Medium	Sig. (o)
C. balansae subsp. *europaeus*	**S2**	Medium	Sig. (o)
C. arboreus subsp. *baeticus*	**B2**	Medium	Sig. (o)
C. striatus	**B4**	Medium	Sig. (o)
C. scoparius	**S2**	Fast	Exp.
ADENOCARPUS			
A. complicatus subsp. *complicatus*	**S3**	Fast	Exp.
A. complicatus subsp. *anisochilus*			
UNEX 17038	**S4**	Fast	Sig. (a)
UNEX 17106	**S4**	Fast	Exp.
UNEX 17110	**S3**	Fast	Sig. (s)
A. telonensis	**S4**	Fast	Exp.
A. hispanicus subsp. *gredensis*	**S4**	Medium	Sig. (a)
A. hispanicus subsp. *argyrophyllus*	**S4**	Medium	Sig. (s)
ARGYROLOBIUM			
A. zanonii	**S1**	Fast	Sig. (s)
LUPINUS			
L. luteus		No dormancy	
L. albus		No dormancy	
L. angustifolius	B2	Slow	Sig. (s)
L. hispanicus var. *bicolor*	**B2**	Fast	Sig. (s)
L. micranthus	B2	Fast	Exp. (o)

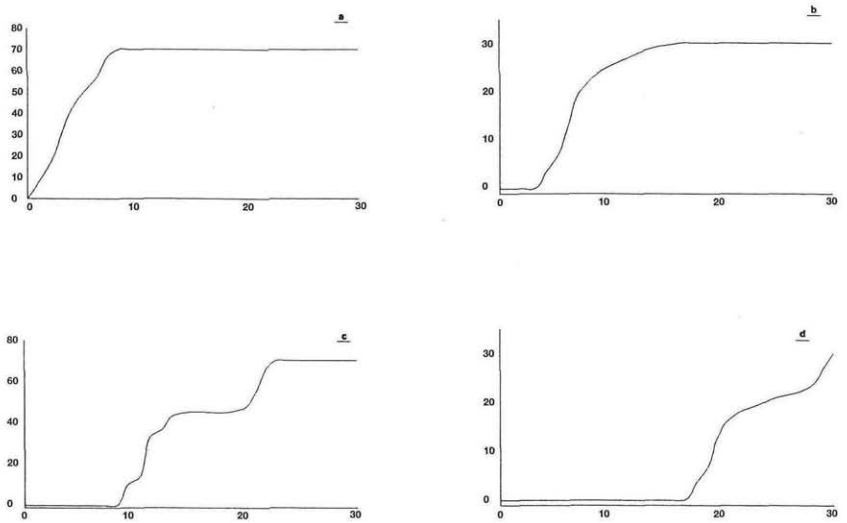

Fig. 1. a: Germination curve of *Adenocarpus telonensis*. Along the abscissa are days elapsed after treatment; along the ordinate are cumulative germination percentages. b: Germination curve of *Genista umbellata*. Along the abscissa are days elapsed after treatment; along the ordinate are cumulative germination percentages. c: Germination curve of *Genista triacanthos*. Along the abscissa are days elapsed after treatment; along the ordinate are cumulative germination percentages. d: Germination curve of *Adenocarpus hispanicus* subsp. *gredensis*. Along the abscissa are days elapsed after treatment; along the ordinate are cumulative germination percentages.

dence of hardseededness in the tribe *Genisteae*. This behaviour, so widespread in the *Leguminosae* (see QUINLIVAN 1971, and references in ROLSTON 1978), was not observed in the material studied of *Spartium junceum* L. (the germinabilities ranged between 50 and 63.33%; Table 1) or *Lupinus luteus* L. and *Lupinus albus* L. (which even reached a germinability of 100%; Table 1). The former could well be due to a naturalized origin of the material studied, since this species is commonly used as an ornamental near buildings, roads and paths (DEVESA 1995). The two *Lupinus* species are cultivated quite frequently in our region. In general, hardness of the seeds is common in the wild species of this genus (CROCKER 1916). Furthermore, some of them are known to have an extraordinary capability of maintaining their germinative power over long periods of time: 500 years (FORD-LLOYD & JACKSON 1986) or even more (*Lupinus arcticus* WATS.; PORSILD & al. 1967).

For the remaining taxa, there was either no germination at all, or, in the best of cases, it reached values never higher than 20% (e.g. *Cytisus ar-*

boreus subsp. *baeticus* (WEEB) MAIRE; Table 1). These may be considered normal levels of germination in the context of this family, as such levels had been found before, in some members of the tribe (< 10–20% in *Argyrolobium zanonii*, BUENDÍA & al. 1966), in most cases being related to testa thickness, as has been experimentally demonstrated with *Lupinus* material by different workers (FORBES & WELLS 1968, GLADSTONES 1970, QUINLIVAN 1961, 1966, 1968a, b, SERRATO-VALENTI & al. 1989, TRAN & CAVANAGH 1984).

In general terms, when scarifying agents were applied, the germination percentages were improved for nearly all of the taxa (Tables 1 and 2), thus confirming both the need for scarifying in order to break dormancy, and the efficacy of the method employed. These methods emulate under laboratory conditions the natural degrading action of the soil's microbial flora, or of the fires that sometimes take place over the soils (ROLSTON 1978). The low levels of germinability found by GONZÁLEZ & al. 1985 in the *Adenocarpus complicatus* (L.) GAY subsp. *complicatus* material collected in Galicia (Spain) after sulphuric scarification treatments, can only be explained (in the light of our experimental results) by the short time they allowed the acid to act (10 minutes) and its concentration (50%).

Sulphuric acid treatment

In general terms, the scarifying efficacy of the sulphuric acid was higher in *Genistinae* than in *Lupininae* (see Tables 1–2 and Part A of the Tables 3 and 6), although in the latter two patterns could be distinguished, one for the cultivated species (*Lupinus luteus* and *L. albus*), with high or maximum germinability whether they were scarified or not, and another for the wild species (*Lupinus angustifolius* L., *Lupinus micranthus* GUSS. and *Lupinus hispanicus* var. *bicolor* MERINO), which germinated with more difficulty than the *Genistinae*, after the chemical scarification.

With respect to the length of time of sulphuric acid action, in general terms, for the cultivated *Lupininae*, scarcely any differences in germination were found. The opposite was the case for the wild *Lupininae* and the *Genistinae* (see Tables 1–2, and Part B of Tables 3 and 6). This is indirect evidence for a generally higher degree of hardseedeness, being higher in the case of the wild *Lupininae* (Tables 1 and 3).

A longer time of sulphuric acid action (e.g. 120 minutes, ANGOSTO & MATILLA 1993) may sometimes even be advisable, as was found in the case of *Genista florida* (Tables 1–2 and Part B of Table 6). In other cases, shorter times were preferable, e.g. for *Genista triacanthos* BROT. and *Cytisus scoparius* (L.) LINK (Tables 1 and Part B of Table 3), where the 60-minute treatment produced a better effect than the 90-minute one. Nevertheless, we have to be cautions in interpreting some of the data (e.g. the cases of *Adenocarpus telonensis* (LOISEL.) DC. or *Cytisus striatus*), because as JOR-

GENSEN & al. 1992 indicated, germination results in laboratory experiments may be liable not only to random variations, but also influenced by other factors, such as loss of viability of the embryos or the action of fungi.

Boiling water treatment

Immersion in boiling water was found to be a good scarifying procedure (Tables 1–2, and Part C of Tables 4 and 6), as various authors had already pointed out (CAVAZZA 1951, DRAPER 1985). Its action on the *Genistinae* seeds was significant in 62.96% of the cases listed in Table 4, Part C, and even more so in the wild *Lupininae* (83.33%), the exception being *Lupinus angustifolius* (Table 1).

The degree of effectiveness was lower, however, when the whole set of data from the subtribe *Lupininae* was considered (56.66%), due to the cultivated origin of some of the studied species.

In the case of the *Genistinae*, *Genista tridentata* L., *Genista polyanthos* subsp. *hystrix* (LANGE) FRANCO and *Genista falcata* Brot. did not show any response to the boiling water action at all; in *G. florida* and *Adenocarpus telonensis* germination was improved by darkness, while avoidance of darkness improved germination in *Genista anglica* L., *Genista umbellata* (L'HÉR.) POIR. and *Echinospartum barnadesii* subsp. *dorsisericeum* G. LÓPEZ. For the rest of the taxa of the subtribe, the hydrolytic action was effective in all cases, improving germinability from null or low levels to moderate, high or even 100%, both in light and in darkness.

In the special treatments carried out with seeds of *Genista florida* and *Cytisus striatus* (Table 2), the results showed an identical pattern for the two species (Table 6, Part C). There seemed to be less importance in the length of immersion time (Table 6, Part E), though the limited data mean that this is only a tentative conclusion.

Boiling water versus sulphuric acid treatment

Comparison of the sulphuric acid and boiling water treatments showed significant differences in germination in 57.55% of the cases listed in Tables 1 and 4, Part D. These differences can be imputed to the chemical nature of the testa, and its resistance to degradation. Similarly, significant differences were also found between sulphuric acid treatment and mechanical scarification (see GONZÁLEZ & al. 1985, PÉREZ DE PAZ & al. 1986), most often with better results for the latter due to its power to abrade the testa, as long as the embryo is not damaged. Even so, different taxa showed different responses. Thus, for the subtribe *Lupininae*, excepting the species with a cultivated origin (where no differences were found between treatments), different sensitivities of the testa to the scarifying agents were observed, which very often depended on the light conditions (excepting *Lupinus hispanicus* var. *bicolor*, which showed no light dependency).

For the subtribe *Genistinae*, the results (Tables 1–2 and Part D of Tables 4 and 6) followed a similar pattern. In the genera *Genista*, *Retama*, *Spartium* and *Echinospartum*, the most suitable scarifying treatment seemed to be with acid, whereas in the rest (*Ulex*, *Cytisus*, *Adenocarpus* and *Argyrolobium*), the boiling water treatment was found to be as good as or better than acid.

Influence of light

With respect to the effect of light, which is well-known in the genus *Ononis* (*O. sicula*, GUTTERMAN & HEYDECKER 1973), no statistically significant differences were found in most of the present experiments (Tables 1, 2, 5 and 6 -Part F), especially for the unscarified seedlots (97.91% with no significant difference), where the hardseededness interferes strongly with the results. In the case of the subtribe *Lupininae*, there were no differences at all (Table 5). Similar results were found in *Adenocarpus* by GONZÁLEZ & al. 1985. Therefore, although it is common for the seeds of wild and cultivated species of other families to be photoblastic (BRADBEER 1988, MAYER & POLJAKOFF-MAYBER 1989, VANDER VEEN 1970), especially under certain particular environmental conditions (VANDER VEEN 1970, VOGEL 1980), in general terms, the seeds of the *Genisteae* studied here can be assumed not to be photoblastic.

Nevertheless, slightly different germination responses could be appreciated when comparing results from experiments carried out under different light conditions (Tables 1, 2, 5 and 6 -Part F), particularly in the case of some of the *Genistinae* (in all the species of *Genista* studied except *Genista cinerascens* LANGE; in *Retama*, *Spartium*, *Echinospartum* and *Ulex*; in some *Adenocarpus* and in the genus *Cytisus*). These differences were not always observable by the end of the experiments, although they had appeared at some time during the experimental period. There seems to be a notably curious behaviour of the seeds of *Genista umbellata* in just one the treatments (sulphuric acid for 60 minutes), which germinate better in darkness (Table 5).

Finally, there was a notable tendency of some species of *Cytisus* to germinate better in darkness, in contradiction to the observation by KINZEL in 1926 (sec. MAYER & POLJAKOFF-MAYBER 1989) that the germinability of *Cytisus scoparius* was indifferent to the light conditions. In this particular case (species of *Cytisus*), this behaviour is coherent with myrmecochory, the seeds having a clearly developed vestigial aril, very rich in lipids, essential oils, and ant nutrients (BEATTIE 1985, BERG 1979). This ability to germinate under low light conditions is consistent by extension, with that of the seedlings of some *Genisteae* to grow under limited light sources (less than 10% of natural conditions in the case of *Cytisus scoparius*, WILLIAMS 1981).

Vigour (V)

The analysis of the values of the Vigour (Tables 1, 2, 7) showed that in most of the taxa studied (control seedlots) the germination rate was null or slow. The scarification treatments were totally ineffective in two cases (*Genista tridentata* and *Ulex minor* ROTH), minimally effective in another (the acceleration from null to slow levels in *Lupinus angustifolius*), but, most frequently (in 27 of the 30 taxa studied), accelerated the germination rate. In the last group, three different patterns could be distinguished (see Table 7): the first, those taxa that when scarified began to germinate at a medium rate (36.66% of the taxa studied); the second, those that did so at a fast rate (46.66%); and the last, the case of the cultivated *Lupininae*, *Lupinus luteus* and *L. albus*, which germinated at a very fast rate. However it should be borne in mind here that the control seedlots of these species also germinated rapidly.

The importance of the scarifying agent thus lies not just in the possibility that it gives for the germinability to be improved, but in how much it can accelerate the process. This has great importance on the seedling establishment phase (THOMSON & EL-KASSABY 1993). The results given in Table 7 show that the action of the boiling water was more advantageous in the germination rate of the *Lupininae* (66.66% of the taxa studied, except for the cultivated species, reached a fast rate) than in the *Genistinae* (where 36% reached medium or fast levels). Also, the action of the acid had a greater effect in *Genistinae* (88% of the taxa accelerated their rates to the medium or fast ranges) than in *Lupininae* (where, except for the cultivated species, 66.66% of the rest of the taxa did the same).

Germination curves

All germination curves followed a non-linear kinetic pattern, due to the absence of a constant factor actuating in a continual way (PEMBERTON & CLIFFORD 1994), as is habitual in normal germinative processes (BRADBEER 1988, MAYER & POLJAKOFF-MAYBER 1989). Two variants of this non-linearity could be distinguished: an exponential and a sigmoidal pattern. In the former, the germination rate is very rapid at the beginning of the process, and declines gradually to an asymptotic minimum value. The sigmoid model evidences a somewhat delayed initial imbibition phase, which is followed by a gradual increase in velocity that afterwards again decreases gradually to its asymptotic value. Of the cases studied, 14.59% belonged to the first pattern (e.g. *Adenocarpus telonensis*, Fig. 1a) and 66.95% to the second. In the latter, there were different variants of the general pattern (simple in 24.89%, e.g. *Genista umbellata*, Fig. 1b; oscillating in 34.76%, e.g. *G. triacanthos*, Fig. 1c; ascendent in 7.30%, e.g. *Adenocarpus hispanicus* subsp. *gredensis* RIVAS MART. & BELMONTE,

Fig. 1d). For the rest of the cases (18.46%), the plots were considered unrepresentative due to the scarce germination.

Finally, Table 8 summarizes the scarifying treatments that seemed to be best suited to the different taxa studied.

Acknowledgements

This research was supported by the "Dirección General de Investigación Científica y Técnica" (DGICYT, PB90-0670) of Spain and "Consejería de Educación y Juventud (Junta de Extremadura)-Fondo Social Europeo" (EIA94-13).

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Studied material. Vouchers in UNEX herbarium. BA, Badajoz province; CC, Cáceres province; SA, Salamanca province.

Subtribe *Genistinae*

GENISTA L. *G. tridentata* L. - CC: Valencia de Alcántara, Sierra Fría (UNEX 16799). *G. polyanthos* subsp. *hystrix* (LANGE) FRANCO – CC: Plasencia, road from Plasencia to Monfragüe, railway station (UNEX 17091). *G. triacanthos* BROT. – CC: road from Mérida to Cáceres, cross to Las Herrerías (UNEX 16839). *G. hirsuta* VAHL – BA: Segura de León (UNEX 16774). *G. anglica* L. – CC: Piornal (UNEX 17966). *G. falcata* BROT. – CC: Valencia de Alcántara, Sierra Fría (UNEX 17069). *G. umbellata* (L'HÉR.) POIR. – BA: Alburquerque, Arroyo Los Ruices (UNEX 17062). *G. cinerascens* LANGE – CC: Piornal, Sierra de Piornal (UNEX 17088). *G. florida* L. – CC: Villanueva de La Vera, Cascada del Diablo (UNEX 16899). *RETAMA* RAF. *R. sphaerocarpa* (L.) BOISS. – BA: Alburquerque, Puerto de los Conejeros (UNEX 17036). *SPARTIUM* L. *S. junceum* L. – BA: Castuera (UNEX 17684). *ECHINOSPARTUM* (SPACH) ROTHM. *E. barnadesii* subsp. *dorsisericeum* G. LÓPEZ. – SA: Peña de Francia (UNEX 17081). *ULEX* L. *U. minor* ROTH – CC: Valencia de Alcántara, Sierra Fría (UNEX 16996). *U. eriocladus* C. VICIOSO – BA: Higuera de Vargas, road from Higuera de Vargas to Jerez de los Caballeros (UNEX 17001). *CYTISUS* L. *C. multiflorus* (L'HÉR.) SWEET – BA: Cross road N-630 with the road to Carmonita (UNEX 16871). C. *balansae* subsp. *europaeus* (G. LÓPEZ & JARVIS) MUÑOZ GARM. – CC: between Tornavacas and Portilla de Jaranda (UNEX 17964). *C. arboreus* subsp. *baeticus* (WEBB) MAIRE – BA: Valle de Matamoros, Cerro San José (UNEX 16911). *C. striatus* (HILL) ROTHM. – CC: Cañamero (UNEX 16866). *C. scoparius* (L.) LINK – CC: Montánchez (UNEX 17977). *ADENOCARPUS* DC. *A. complicatus* (L.) GAY subsp. *complicatus* – CC: Montánchez (UNEX 17051). *A. complicatus* subsp. *anisochilus* (BOISS.) FRANCO – CC: Guadalupe (UNEX 17038). Cañamero (UNEX 17106). Jaraíz de la Vera, direction to Piornal (UNEX 17110). *A. telonensis* (LOISEL.) DC. – BA: Sierra de Siruela, next to the hermitage (UNEX 17049). *A. hispanicus* subsp. *gredensis* RIVAS MART. & BELMONTE – CC: La Garganta, between La Garganta and Candelario (UNEX 17043). *A. hispanicus* subsp. *argyrophyllus* (RIVAS GODAY) RIVAS GODAY – CC: Parque Natural de Monfragüe (UNEX 17041). *ARGYROLOBIUM* ECKL. & ZEYH. *A. zanonii* (TURRA) P. W. BALL – CC: Serrejón, La Oliva (UNEX 17075).

Subtribe *Lupininae*

LUPINUS L. *L. luteus* L. – BA: Puebla de Obando, Puerto del Zángano (UNEX 17011). *L. albus* L. – BA: Valdebótoa (UNEX 17961). *L. angustifolius* L. – BA: Castuera, between Castuera and Benquerencia (UNEX 17012). *L. hispanicus* var. *bicolor* MERINO – CC: Tornavacas (UNEX 16966). *L. micranthus* GUSS. – BA: Alburquerque (UNEX 17963).