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SEED GERMINATION IN TWO DIFFERENT *HORDEUM MARITIMUM* WITH. AND *H. MURINUM* L. (GRAMINEAE) POPULATIONS

Riassunto - *La germinazione dei semi in due differenti popolazioni di Hordeum maritimum With. e H. murinum L. (Gramineae).* È stata analizzata l'evoluzione della germinazione in funzione della dormienza, della temperatura (10°, 20° e 30°C) e della post-maturazione nei primi 4 mesi, in cariossidi *di Hordeum maritimum* (alofita) e *H. murinum* (glicofita) provenienti da Patanella (Orbetello-GR), S. Piero a Grado (PI) e Galanchio (PI). Dai risultati ottenuti si evidenzia: un periodo di dormienza più lungo in *H. maritimum* rispetto ad *H. murinum,* a tutte le temperature; la durata della dormienza varia in entrambe le specie, in funzione della diversa provenienza dei semi; le elevate temperature agiscono da regolatore ecologico rallentando fortemente la germinazione.

Abstract - Evolution of *Hordeum maritimum* and *H. murinum* seed germination was studied in relation to dormancy, temperature and afterripening time. Caryopses used in this study were collected in Patanella (Orbetello - GR), S. Piero a Grado (PI) and Galanchio (PI). Results of pedological and climatic analysis of collection areas demonstrated different ecological requirements in the two *Hordeum* species. Germination was also found to present differences in behaviour between the two species. In particular, results showed that: 1. dormancy was much longer in *Hordeum maritimum* than in *H. murinum* at all temperatures; 2. high temperature (30°C) exercised prolonged inhibition of germination, apparently functioning as an ecological regulator of germination and of the dynamism of natural populations, 3. length of dormancy in the two *Hordeum* varieties was related to their different provenance sites.

Key words: *Hordeum maritimum, Hordeum murinum,* germination, afterripening, dormancy.

INTRODUCTION

Hordeum maritimum With. (= *H. marinum* Huds.) and *Hordeum*

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murinum L. (= *H. leporinum* Link) are annual self pollinating Gramineae with original distribution in Europe, Western Asia and North Africa.

Hordeum maritimum is common in saline habitats where it is associated with other halophile species. In various saline zones of Israel, for instance, *H. maritimum* is included in the Salicornietum herbaceae (ZOHARY, 1962). Present world distribution of this species includes Western Europe, North Africa and Macaronesia, the eastern Mediterranean coast, South-West Russia, Afghanistan, Pakhistan (BOTHMER et al., 1989). It is also found in the western USA (GLEASON, 1952). In Italy is found mainly in coastal zones (PARLATORE, 1848; FIORI, 1923); however it is also found in some inland sites with highly saline soils, as occurs for several other halophytes (ONNIS, 1964).

Hordeum murinum is common in waste lands and it belongs to the ruderal vegetation of many regions of the world. It is widespread throughout many parts of Europe and Africa (DAVISON, 1970, 1971). In Italy its distribution is very extensive, and it is frequently found in the coastal salt marsh, as for instance in Versilia and in the Orbetello Lagoon (Tuscany) (LOMBARDI, 1991). In addition, *H. murinum* is also found in the coastal areas of many Italian islands such as Lampedusa, Pantelleria, Giglio, Giannutri, Elba and Pianosa (PARLATORE, 1848; CARUEL, 1860).

In some cases *H. maritimum* (halophyte) and *H. murinum* (glycophyte) show overlapping distribution. This evidence, together with observations of the chemical and physical features of the soil where these species are found growing, provided the rationale for study of germination behaviour in presence of the more common salts (ONNIS and BELLETTATO, 1972; LOMBARDI, 1991).

In order to address these questions, thereby also contributing to better understanding of the ecophysiology of *Hordeum maritimum* and *H. murinum,* seed germination in the two species was analyzed in relation to duration of the afterripening period and ecological features of the collection sites. Research was carried out at three stations in Tuscany (Orbetello Lagoon-GR; S. Piero a Grado-PI; Galanchio-PI) where *Hordeum maritimum* and *H. murinum* grow and reproduce.

MATERIALS AND METHODS

A. *Germination*

Germination tests were performed using *Hordeum maritimum* and

H. murinum caryopses collected from plants belonging to 4 different populations:
1. two isolated but contiguous populations of *H. maritimum* and *H. murinum* (Patanella-western site of Orbetello Lagoon-GR);
2. one pure population of *H. maritimum* (Galanchio-PI);
3. one pure population of *H. murinum* (S. Piero a Grado-PI).

Seeds were collected at maturity in June 1990 and stored in darkness at ambient temperature (18°-21°C). After 15 days and every subsequent 15 days up to 120 days of afterripening, seeds of the different populations were placed in 9 cm Petri dishes on Whatman n. 2 filter paper moistened with 6 ml of deionized water. Germination tests were carried out in darkness and at the constant temperatures of 10°, 20° and 30°C. For each test 135 caryopses of *H. maritimum* and 135 caryopses of *H. murinum* were used (3 replications for each species, with 15 seeds per replication at each temperature). Seed germination was checked daily with the microscope for 10 days. Seeds were considered to have germinated with emergence of the radicle.

B. *Chemical features of the soil*

In different months of the year, depending on seasonal changes and the plant life cycle, soil samples were collected at a depth of 30 cm, in the three provenance sites of the different populations. Samples were analyzed following the methods of the "Società Italiana Scienza del Suolo" (1985). In particular, pH, salinity (g/Kg) and Cl content (meq/100g) were recorded.

RESULTS

A. *Germination*

Percent results (= germination capacity) of the germination tests, are shown in tables 1 and 2.

1. Orbetello *(Hordeum maritimum* and *H. murinum* - Table 1)

10°C - Germination of *H. maritimum* caryopses was almost absent until after 60 days of afterripening, at 72 h culture, exceeding 50% (84%) only after 105 days, at 72 h culture. 100% germination was observed after 105 days, at 96 h culture (Table 1). *H. murinum* germination at 24 h culture was never over 30%, while at 72 h germinated seeds exceeded 50% as early as after 30 days of afterripening (64%).

TAB. 1 - Germination percentage (mean ± SE) of *Hordeum maritimum* (Mar) and *H. murinum* (Mur) seeds collected in the Patanella station (Orbetello Lagoon - GR) and placed in darkness for 10 days at different temperatures (T) in different afterripening times (AR).

AR (days)	T (°C)	Germination percentage after 1 day		2 days		3 days		4 days		7 days		10 days	
		Mar	Mur	Mar	Mur	Mar	Mur	Mar	Mur	Mar	Mur	Mar	Mur
15	10	0	0	2 ± 2.0	0	2 ± 2.0	7 ± 3.8	4 ± 2.2	7 ± 3.8	11 ± 5.9	17 ± 2.2	13 ± 5.9	24 ± 5.9
	20	0	0	0	2 ± 2.0	0	2 ± 2.0	0	2 ± 2.0	0	7 ± 3.8	2 ± 2.0	7 ± 3.8
	30	0	0	0	0	0	0	0	2 ± 2.0	0	2 ± 2.0	0	2 ± 2.0
30	10	0	11 ± 0.0	0	15 ± 4.4	2 ± 2.0	64 ± 4.4	11 ± 5.9	78 ± 2.2	24 ± 2.2	89 ± 5.9	47 ± 6.7	100 ± 0.0
	20	0	11 ± 8.0	0	15 ± 9.0	0	27 ± 3.8	2 ± 2.0	55 ± 5.8	9 ± 2.2	57 ± 4.4	13 ± 3.8	60 ± 3.8
	30	0	9 ± 2.2	0	13 ± 3.8	0	13 ± 3.8	9 ± 4.4	22 ± 2.2	9 ± 4.4	33 ± 2.2	20 ± 3.8	40 ± 6.7
45	10	0	15 ± 5.8	0	55 ± 9.6	0	86 ± 3.8	9 ± 4.4	95 ± 4.4	44 ± 2.2	95 ± 4.4	67 ± 3.8	100 ± 0.0
	20	0	47 ± 3.8	0	58 ± 5.9	0	69 ± 2.2	4 ± 2.2	78 ± 2.2	4 ± 2.2	98 ± 2.0	20 ± 3.8	98 ± 2.0
	30	0	20 ± 6.6	0	24 ± 5.9	0	24 ± 5.9	2 ± 2.0	31 ± 4.4	2 ± 2.0	33 ± 3.8	13 ± 3.8	38 ± 5.9
60	10	0	2 ± 2.2	0	84 ± 5.9	7 ± 3.8	100 ± 0.0	44 ± 2.2	—	80 ± 3.8	—	89 ± 4.4	—
	20	0	47 ± 5.8	0	53 ± 5.9	2 ± 2.0	64 ± 5.9	13 ± 3.8	82 ± 2.2	24 ± 4.4	87 ± 0.0	44 ± 9.6	93 ± 3.8
	30	0	11 ± 5.9	2 ± 2.0	24 ± 5.9	9 ± 4.4	24 ± 5.9	9 ± 4.4	27 ± 6.6	9 ± 4.4	29 ± 5.8	11 ± 4.4	36 ± 5.8
90	10	0	16 ± 4.4	0	87 ± 3.8	27 ± 3.8	100 ± 0.0	33 ± 2.2	—	78 ± 4.4	—	89 ± 4.4	—
	20	0	53 ± 3.8	2 ± 2.0	64 ± 4.4	9 ± 2.2	89 ± 3.8	20 ± 2.2	95 ± 4.4	69 ± 2.2	95 ± 4.4	87 ± 3.8	100 ± 0.0
	30	0	15 ± 3.8	2 ± 2.0	24 ± 3.8	2 ± 2.0	29 ± 2.2	9 ± 4.4	33 ± 0.0	11 ± 5.9	33 ± 0.0	11 ± 5.9	53 ± 5.9
105	10	0	29 ± 5.9	29 ± 5.9	100 ± 0.0	84 ± 2.2	—	100 ± 0.0	—	—	—	—	—
	20	4 ± 2.2	100 ± 0.0	20 ± 3.8	—	29 ± 2.2	—	62 ± 2.2	—	95 ± 2.2	—	100 ± 0.0	—
	30	0	47 ± 7.7	0	53 ± 5.8	0	53 ± 5.8	11 ± 2.2	58 ± 6.6	20 ± 3.8	58 ± 6.6	24 ± 5.9	69 ± 8.0
120	10	0	27 ± 3.8	51 ± 0.0	100 ± 0.0	89 ± 4.4	—	100 ± 0.0	—	—	—	—	—
	20	2 ± 2.0	100 ± 0.0	15 ± 3.8	—	64 ± 0.0	—	100 ± 0.0	—	—	—	—	—
	30	0	53 ± 0.0	2 ± 2.0	53 ± 0.0	2 ± 2.0	58 ± 5.8	20 ± 0.0	58 ± 5.8	20 ± 0.0	62 ± 2.2	24 ± 2.2	62 ±2.2

After 30 days and at 10 days of culture, germination capacity reached the highest value (100%).

20°C - *H. maritimum* seeds presented low germination capacity values at 72 h culture until after 90 days. Values exceeded 50% at 72 h after 120 days (64%), but remained low until 60 days of afterripening. 100% germination was not reached until after 105 days. *H. murinum* caryopses showed 58% germination after 45 days of afterripening and at 48 h. After 105 days and at 24h the highest value (100%) was reached. Germination capacity at 240 h of culture showed very low values after 15 days of afterripening (7%) but reached 98% as early as the 45th. day.

30°C - *H. maritimum* germination was absent after 15 days of afterripening and presented very low values until 120 days (24% at 240 h) (Table 1).

H. murinum seeds never reached 100% germination (62% at 240 h after 4 months). However, germinated seeds exceeded 50% after 90 days at 240 h.

2. Galanchio *(Hordeum maritimum* - Table 2)

10°C - At 24 h *H. maritimum* germination capacity values were low for all tests. The highest value, 7%, was observed after 60 days of afterripening. After 105 days, caryopses reached 84% germination at 48 h.

Germination capacity reached 50% at 72 h of culture between 45 and 60 days. 100% germination was observed after 90 days of afterripening at 96 h.

20°C - Germination percentage of *H. maritimum* seeds at 24 h was 0% until after 60 days (20%) and exceeded 50% only after 120 days of afterripening. At 72 h this value was reached between 90 and 105 days. Seeds achieved 100% germination at 168 h after 105 days.

30°C - Germination capacity was never above 29% in all treatments. This value was recorded after 105 days of afterripening at 240 h.

3. S. Piero a Grado *(Hordeum murinum* - Table 2)

10°C - Germination percentage of *Hordeum murinum* at 24 h of culture was not above 20% in any test. At 48 h germination capacity reached 73% as early as the 45th. day of afterripening. At 72 h seeds achieved 58% germination after 30 days. The highest germination capacity value (100%) was observed at 240 h of culture after 45 days of afterripening and subsequently with increasingly shorter periods of culture (at 72 h after 105 days)

20°C - At 24 h culture *H. murinum* presented 87% germination as early as the 60th. day of afterripening. At 48 h and after no more than 45 days, germination already reached 80%.

TAB. 2 - Germination percentage (mean ± SE) of *Hordeum maritimum* (Mar) and *H. murinum* (Mur) seeds collected respectively in S. Piero a Grado station (PI) and Galanchio (PI) and placed in darkness for 10 days at different temperatures (T) and in different afterripening times (AR).

AR (days)	T (°C)	Germination percentage after days: 1		2		3		4		7		10	
		Mar	Mur	Mar	Mur	Mar	Mur	Mar	Mur	Mar	Mur	Mar	Mur
15	10	0	0	0	0	4 ± 4.0	22 ± 2.2	15 ± 4.4	31 ± 5.9	18 ± 3.8	38 ± 5.9	49 ± 6.6	60 ± 3.8
	20	0	0	0	2 ± 2.0	0	4 ± 0.0	0	7 ± 3.8	2 ± 2.0	13 ± 3.8	9 ± 2.2	29 ± 8.0
	30	0	0	0	0	0	0	0	2 ± 2.0	0	4 ± 4.4	2 ± 2.0	4 ± 4.0
30	10	0	0	9 ± 5.9	27 ± 3.8	20 ± 6.7	58 ± 4.4	62 ± 5.9	96 ± 2.2	67 ± 6.6	100 ± 0.0	98 ± 2.0	—
	20	0	15± 9.6	0	24 ± 8.9	0	53 ± 5.9	0	53 ± 5.9	7 ± 3.8	56 ± 4.4	11 ± 2.2	87 ± 6.6
	30	0	0	0	0	0	0	13 ± 3.8	11 ± 2.2	18 ± 2.2	13 ± 3.8	20 ± 0.0	18 ± 5.9
45	10	2 ± 2.0	20 ± 3.8	13 ± 3.8	73 ± 3.8	44 ± 5.9	91 ± 4.4	78 ± 2.2	95 ± 2.2	80 ± 3.8	95 ± 2.2	80 ± 3.8	100 ± 0.0
	20	0	42 ± 5.9	7 ± 0.0	80 ± 3.8	9 ± 2.2	89 ± 2.2	11 ± 3.8	89 ± 2.2	27 ± 4.4	89 ± 2.2	47 ± 3.8	91 ± 2.2
	30	0	7 ± 3.8	0	7 ± 3.8	4 ± 2.2	7 ± 3.8	4 ± 2.2	7 ± 3.8	4 ± 2.2	7 ± 3.8	7 ± 0.0	7 ± 3.8
60	10	7 ± 3.8	13 ± 3.8	27 ± 3.8	73 ± 3.8	78 ± 4.4	98 ± 0.0	91 ± 5.8	100 ± 0.0	93 ± 3.8	—	95 ± 4.4	—
	20	20 ± 3.8	87 ± 3.8	20 ± 3.8	89 ± 4.4	20 ± 3.8	95 ± 2.2	24 ± 2.2	95 ± 2.2	33 ± 3.8	98 ± 2.0	53 ± 3.8	100 ± 0.0
	30	9 ± 2.2	11 ± 4.4	9 ± 2.2	11 ± 4.4	9 ± 2.2	11 ± 4.4	11 ± 2.2	15 ± 5.8	20 ± 3.8	15 ± 5.8	22 ± 2.2	15 ± 5.8
90	10	7 ± 0.0	4 ± 4.0	27 ± 3.8	47 ± 3.8	75 ± 4.4	95 ± 2.2	100 ± 0.0	100 ± 0.0	—	—	—	—
	20	4 ± 0.0	91 ± 2.2	22 ± 3.8	98 ± 2.0	40 ± 4.4	100 ± 0.0	78 ± 2.2	—	82 ± 2.2	—	95 ± 4.4	—
	30	0	18 ± 4.4	0	18 ± 4.4	2 ± 2.0	18 ± 4.4	9 ± 2.2	20 ± 3.8	15 ± 2.2	22 ± 2.2	15 ± 2.2	22 ± 2.2
105	10	4 ± 2.2	2 ± 2.0	84 ± 2.2	95 ± 4.4	100 ± 0.0	100 ± 0.0	—	—	—	—	—	—
	20	4 ± 2.2	87 ± 1.2	22 ± 4.4	100 ± 0.0	80 ± 6.6	—	95 ± 2.2	—	100 ± 0.0	—	—	—
	30	20 ± 3.8	93 ± 6.6	20 ± 3.8	100 ± 0.0	22 ± 2.2	—	29 ± 2.2	—	29 ± 2.2	—	29 ± 2.2	—
120	10	0	7 ± 3.8	69 ± 0.0	98 ± 2.0	91 ± 2.2	100 ± 0.0	95 ± 3.8	—	100 ± 0.0	—	—	—
	20	51 ± 0.0	89 ± 4.4	71 ± 0.0	100 ± 0.0	78 ± 0.0	—	100 ± 0.0	—	—	—	—	—
	30	27 ± 2.2	95 ± 3.8	27 ± 2.2	100 ± 0.0	27 ± 2.2	—	27 ± 2.2	—	27 ± 2.2	—	27 ± 2.2	—

At 72 h, germinated seeds exceeded 50% after 30 days of afterripening. The highest value of germination capacity (100%) was recorded for the first time after 60 days and at 240 h culture.

30°C - Germination of *H. murinum* seeds at 24h of culture did not reach 50% until after 105 days (93%). Germination values were low in all tests during the first 3 months of afterripening (15-22% at 10 days of culture). It was only after 105 days of afterripening that seeds achieved 100% germination, at 48 h culture.

B. *Chemical features of the soil*

Results obtained by analysis of the soil samples collected at different times of the plant life cycles from the three *Hordeum maritimum* and H. *murinum* sites are shown in tables 3 and 4.

1. Orbetello (Table 3)

The soil in which the H. *maritimum* population was found presented highest salinity values in May (3 g/Kg) and the lowest in March (0.56 g/Kg). Cl-content (meq/100g) reached values between 1.12 and 0.65 meq/100g. Soil salinity in the *H. murinum* area reached 1.35 g/Kg in May.

2. S. Piero a Grado (Table 4)

Salinity was 0.36 and 0.49 g/Kg in May and December respectively. The highest value recorded for Cl- concentration was 0.6 meq/100g (December).

3. Galanchio (Table 4)

In May and December, soil salinity was between 5.66 and 2.15 g/Kg. In September and April, values were respectively 24.3 and 4.7 g/Kg. Cl-values ranged from 1.77 meq/100g in December to 30 meq/100g in September.

TAB. 3 - Chemical features of the soil of Patanella station (Orbetello - GR).
Mar = *Hordeum maritimum*; Mur = *H. murinum*; *sal* = salinity (g/Kg), *Cl* = clorure content (meq/100g)

Parameter	October		March		May	
	Mur	Mar	Mur	Mar	Mur	Mar
pH	7.72	8.22	8.27	8.42	7.79	7.74
sal.	0.87	2.74	0.56	1.56	1.35	3.00
Cl	0.47	0.65	0.32	0.35	0.32	1.12

TAB. 4 - Chemical features of S. Piero a Grado (PI) (Mur) and Galanchio (PI) (Mar) soil (see Table 3).

Parameter	September		December		April		May	
	Mur	Mar	Mur	Mar	Mur	Mar	Mur	Mar
pH	—	8.10	8.20	8.56	—	8.73	7.74	7.23
sal.	—	24.30	0.49	2.15	—	4.70	0.36	5.66
Cl	—	30.00	0.60	1.77	—	3.00	0.30	7.00

C. *Climate*

Climatic data from the texts published by the Hydrographic Service of the Ministry of Public Works were collected. Data referred to the Pisa stations (43°42' Lat. N) and Orbetello (42°27' Lat. N), and included the monthly average of minimum and maximum temperatures, rainfall in mm and number of rainy days per month (Table 5).

TAB. 5 - Montly average of the minimum (min) and maximum (max) temperature, mm of rain (mm) and number of the rainy days (rd). The data are relative to period 1925/1950.

		Months						
Station		Gen.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Pisa	max	10.9	12.7	15.7	19.1	22.8	26.9	29.6
	min	2.6	3.2	5.8	8.2	11.9	15.3	17.7
	mm	101	76	89	75	83	47	24
	rd	9	8	8	8	8	4	3
Orbetello	max	11.7	12.7	14.6	17.1	20.5	24.8	27.8
	min	4.6	5.6	7.5	10.1	13.4	17.3	19.8
	mm	80	64	59	44	36	18	7
	rd	8	6	6	6	5	2	1

		Ago.	Sep.	Oct.	Nov.	Dec.	Annual
Pisa	max	30.1	26.8	21.7	16.3	11.8	20.4
	min	17.5	15.2	11.2	7.5	3.5	10.0
	mm	21	83	152	142	101	994
	rd	3	6	10	12	10	89
Orbetello	max	27.7	25.8	21.4	17.3	13.2	19.5
	min	19.5	17.9	13.7	9.8	6.0	12.1
	mm	21	53	96	105	89	672
	rd	2	4	7	8	9	64

DISCUSSION

Germination tests were planned on the basis of climatic features recorded for the caryopses provenance sites. Analysis of temperature data shows that between June and October (duration of the experimental tests), mean values ranged between 30° and 11.2°C for the Pisa stations (S. Piero a Grado and Galanchio) and between 27.7° and 13.7°C for the Orbetello station (Patanella) (Table 5). To take these variations in temperature into account, germination tests were carried out at different afterripening times and at the constant temperatures of 10, 20 and 30°C.

Results confirmed the existence of differences in behaviour between *Hordeum maritimum* and *H. murinum,* as previously observed at 20°C by ONNIS and BELLETTATO (1972) for seeds collected at the S. Forzorio station (Sardinia). Other studies have shown that such differences are particularly noticeable as regards "relative dormancy" (BELDEROK, 1961) and "residual dormancy" (MELETTI 1968, ONNIS, 1984).

Differences detected in the present study were even greater when germination behaviour at the extreme temperatures of 10° and 30°C was analyzed. In these cases, as also at 20°C, germination of *H. maritimum* caryopses was much slower in comparison to *H. murinum,* and relative dormancy took much longer to break. At 30°C, for example, at 72 h of culture, *H. maritimum* seed germination capacity never reached 50%, while the glycophyte *H. murinum* exceeded this value after 100 days of afterripening (Figure 1).

It is significant that above all at 10°C and 20°C, *H. murinum* presented much more rapid germination within the first 72 h as compared to *H. maritimum.* Moreover, above all at 10°C, *H. murinum* presented higher germination capacity during the 10 day-test (Fig. 2 and 3). This observation could explain shoot germination in the glycophile species following late summer - early autumn rain, even when rainfall is only light and accompanied by a drop in temperature. This behaviour is in fact known for other Gramineae, such as some cultivated species of *Triticum* or *Hordeum,* and it could be the consequence of break of dormancy (residual and/or relative) due to the decrease in temperature (MUNERATI, 1920; MELETTI and FLORIS, 1988). However, humidity also plays an important role, since even minimum rainfall can be sufficient for germination (BASKIN and BASKIN, 1979; ONNIS et al., 1979; BOCCHERI, 1986; SALIM, 1989).

It is clear that in some cases where *H. murinum* grows on saline

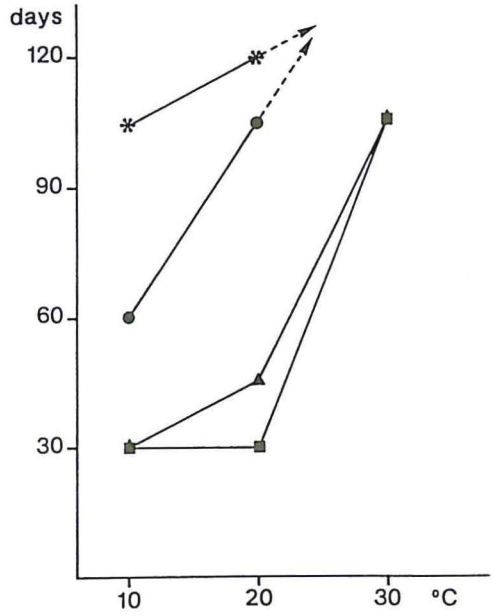

Fig. 1 - Afterripening days to reach 50% of germination at 72 h of culture for the two different seeds population of *H. maritimum* (—*— Patanella, —●— Galanchio) and *H. murinum* (—▲— Patanella, —■— S. Piero), at different temperature (°C).

soil where salinity reaches high levels in summer, the behaviour of this species during the summer months may lead to the death of young plants and consequently, of the species.

The more prolonged residual dormancy in *H. maritimum* (Figure 1) could be a strategy to delay germination, thereby providing seeds with optimal humidity and salinity. This mechanism would assure adequate conditions for survival of the species, above all in special environments such as salt zones (STEFANI and ONNIS, 1983; FENNER, 1985). The presence of low germination energy above all at the highest temperatures was shown previously, for other halophytes, such as *Hordeum jubatum,* but it does not seem to be a limiting factor for diffusion of the species (BADGER and UNGAR, 1989).

The ecological significance of seed dormancy in the two *Hordeum* species may be linked to the environmental features of the provenance sites. It is known that environmental conditions affect seed ripening, and in particular that such conditions subsequently play a role not only in regulating germination but also in influencing plant development (LONA, 1947; MELETTI, 1968). Results obtained in the present research demonstrated that at all temperatures, seeds collected from

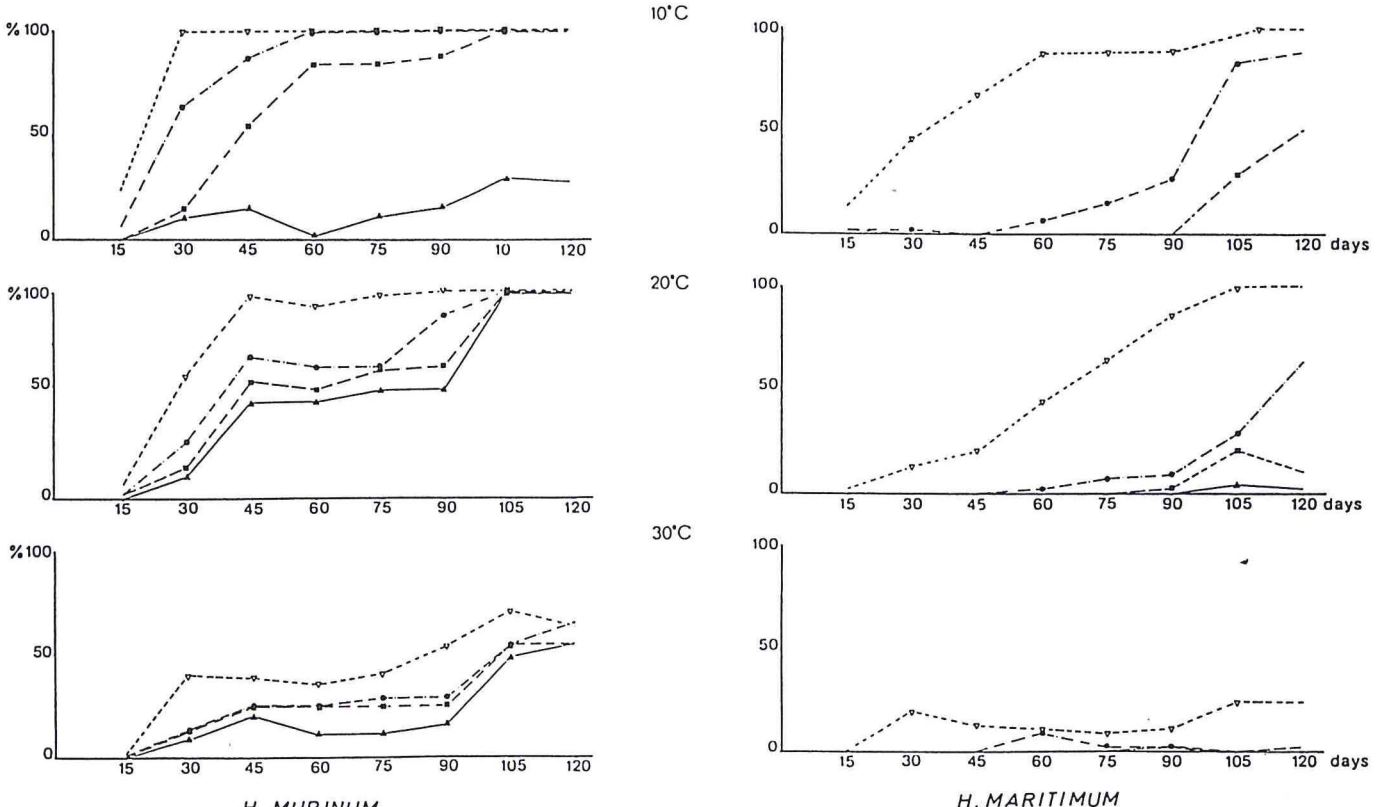

Fig. 2 - Germination (%) at 24 (▲——▲), 48 (■——■), 72 (●——●) and 240 h (▽- - - -▽) of culture in deionized water at different temperature and different afterripening time (15-120 days), in seeds of *H. maritimum* and *H. marinum* collected from the Patanella population.

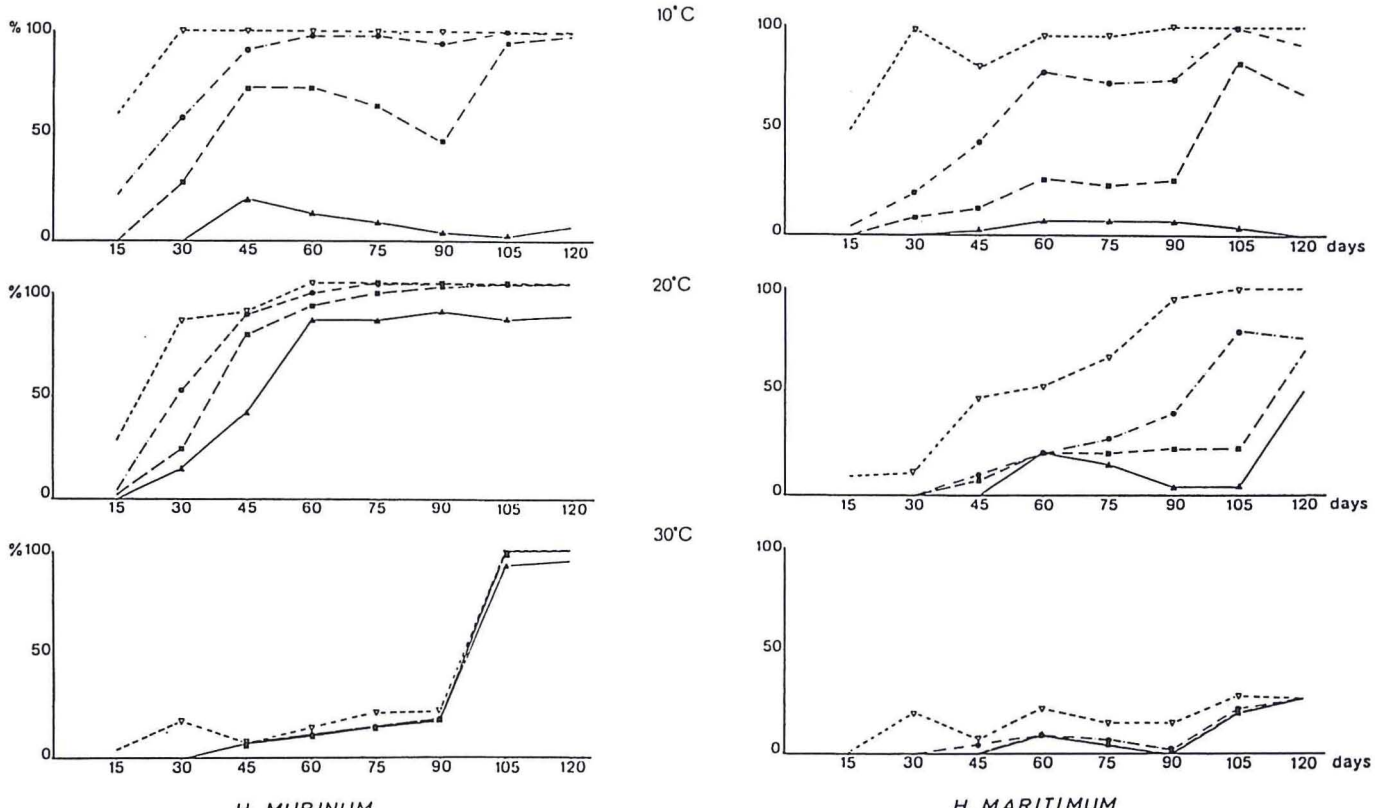

Fig. 3 - Germination (%) at 24 (▲——▲), 48 (■——■), 72 (●——●) and 240 h (▽- - - -▽) of culture in deionized water at different temperature and different afterripening time (days), in seeds of *H. maritimum* and *H. marinum* respectiovely of Galanchio and S. Piero a Grado populations.

contiguous but isolated populations of *H. maritimum* and *H. murinum* in the Patanella station (Orbetello Lagoon) presented longer dormancy and lower germination capacity values, compared to those collected in S. Piero a Grado and Galanchio. This could be due to adaptation to the different environmental conditions of the three stations.

From climatic data it can be observed that the Patanella station, although presenting moderately saline soil (Table 3), has a higher mean temperature and much more scanty rainfall. Consequently, less dilution of salts takes place in comparison with the Galanchio (Pisa) station. Since salinity at Galanchio is sometimes in excess of 1%, soil at the latter station, can be classified, on the basis of the more accepted classifications, as a true "saline soil" (WAISEL, 1972; BLUM, 1988).

The rainfall data of Patanella suggest that the more prolonged dormancy of caryopses collected at this station could therefore be related to the greater total water stress which the two species underwent, rather than merely to saline stress. In Galanchio, on the other hand, (Table 4) saline stress is the greatest limiting factor. Thus while in Patanella the highest salinity was 3 g/Kg, in Galanchio salinity reached 24 g/Kg (Tables 3 and 4). Soil conditions of the latter type could lead to death of glycophile species such as *Hordeum murinum.* Observations on the vegetation associated with *H. maritimum* in Galanchio showed that only very few species were present in this area, all of which were typical of saline soil, such as *Salicornia herbacea, Atriplex halimus, Plantago coronopus* and *Arthrocnemum glaucum.*

For the Patanella station it is important to notice that although the two *Hordeum* species grow in contiguous areas, the same differences in germination behavour were detected between them (longer relative and residual dormancy for the halophile species) as were observed for seeds at the two Pisa stations. Soil chemical analysis has shown that *H. maritimum* soil has higher salinity throughout the year compared with that in which *H. murinum is* found growing (Table 3). Furthermore, the vegetation growing in the low-lying areas of this station in association with the two species that form large carpets confirms the differences in salinity between the two soils. Close to the brackish flooding depressions one finds species such as *Arthrochnemum glaucum, Atriplex halimus, Limonium serotinum, Salicornia herbacea, Sueda maritima.* On the other hand, in areas with decreasing salinity one may find species such as *Agropyron repens, Agrostis stolonifera, Briza media, Briza minor, Juncus acutus, Juncus bufonius, Lagurus ovatus, Plantago coronopus* and *Puccinellia festucaeformis.*

A different phytocenose with H. *murinum* as prevailing species is

observed near the area occupied by *H. maritimum*. Some species that are associated with the glycophyte *H. murinum* are *Bellis perennis, Festuca pratensis, Lotus tenuis, Melilotus officinalis, Polypogon monspeliensis, Rumex sempervirens* and *Trifolium repens*.

The determining factor would appear to be represented by the different Cl- content observed in soil, above all in Spring and Summer, when plants are at a delicate stage of their life (reproduction, production and fruit ripening). It is in this period that Cl-content exercises a determining influence on species fertility (ONNIS and BELLETTATO, 1971; LOMBARDI, 1991). From these observations it becomes clear that differences in soil Cl-content despite apparently homogeneous environments (note that the two *Hordeum* stations are included in the same Orbetello Lagoon area) are of great importance for separation of *H. maritimum* and *H. murinum* populations and classification of different ecological groups. In the case of Patanella, *Hordeum maritimum,* together with *Plantago coronopus,* can be characterized as belonging to the "ecological group", in which it can be seen as an indicator species typical of soil where salinity of the horizon at a depth of 30-70 cm is >20 g/Kg and <40 g/Kg. Such soils are hardly ever subject to flooding, and in summer the groundwater lies at 120-160 cm. This situation was also observed in the Camargue Lagoon (CORRE, 1975).

On the basis of the above considerations on germination behaviour in seeds collected from different sites, it should become possible in the future to distinguish different ecotypes, whose biology is related to the environmental conditions that have accompanied the development of the two species.

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