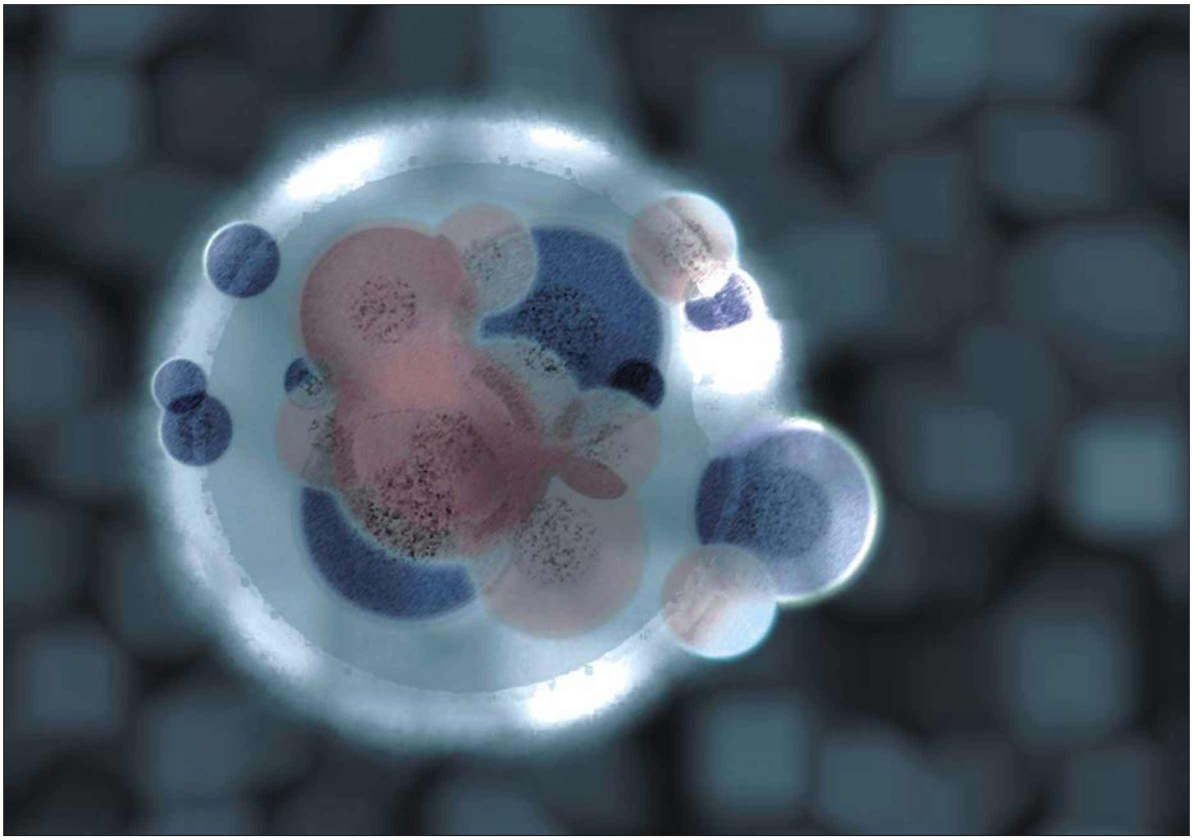

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Analysis of the Morpho-physiological Variation within Some Algerian Populations of Sulla (*Hedysarum coronarium* L., Fabaceae)

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Abstract: As a part of the characterization and the valorization of plant genetic resources of fodder and pastoral interest in Algeria, fourteen natural populations of *Hedysarum coronarium* L. were subjected to a morpho-physiological study. Ecological factors (altitude and rainfall) of the originating environment of the different populations were considered. Thirty four characteristics related to seed weight, seedling emergence, vegetative development, flowering and formation of fruiting heads were included in the study. The results indicate the existence of variability within the species and between the populations, especially for the rate of seedlings at the second simple leaf stage, the development of the height axis, the end of the bloom and the full fruiting heads characteristics which are significant. This would be linked to the ecological factors of the environment of origin, especially the altitude which would constitute the most important factor. The results of principal components analysis show off some important characteristics, particularly the numbers of leaves and ramifications per plant, which oppose themselves to certain characteristics linked to the breeding (flowering and formation of fruiting heads). *H. coronarium* L. should be developed, particularly in the isolated and disinherited areas, where they could adapt themselves with advantage.

Key words: Ecological factors, flowering, *Hedysarum coronarium*, seed weight, sulla, vegetative development

INTRODUCTION

Sulla (*Hedysarum coronarium* L.) is a short-lived, perennial legume originating from the Mediterranean where it is used widely for hay, silage and greenfeed (Whyte *et al*., 1953; In: Douglas, 1984; Kernick, 1978; In: Douglas, 1984). It is also an ornamental (Battandier and Trabut, 1902; Bonnier, 1934) and bees plant (Bonnier, 1934).

Meneghetti *et al*. (1997) specify that this member of the tribe Hedysareae is distributed in Spain, Algeria and southern Italy.

In Spain, the growth of sulla is restricted to Menorca Island, where it forms monophytic meadows and to the southern province of Cadiz, where it is mainly associated with other natural forage species (Rodriguez-Navarro *et al*., 1991).

In Algeria, this species is very common in the Tell Constantinois and very scarcely found in the other regions, such like El-Kantara, Alger, Oran (Quezel and Santa, 1962). In many parts of Northeast Algeria, *H. coronarium* occurs together with other natural forage such as the genera *Trifolium*, *Medicago*, *Astragalus*, *Phalaris*, *Scorpiurus*, *Avena*, *Hedysarum*, *Lolium*, *Picris*, *Carthamus*, *Sonchus*, *Dactylis*, *Festuca*, *Hordeum*, *Leontodon*, *Lepturus*, *Lotus*, *Onobrychis* (Issolah *et al*., 2001).

Sulla is quite rich in terms of local varieties, especially in Italy (Villax, 1963). Spanish and Italian varieties are in general more sensitive to cold than those of the North Africa, However, a variety with white flowers was reported to be more rustic, but giving lower yield (Villax, 1963).

Several authors throughout the world indicated that *Hedysarum coronarium* L. is characterized by a stable chromosome number (2n = 16) whereas two chromosome numbers (2n = 16 and 2n = 18) were encountred in Algerian populations of this species (Issolah *et al*., 2006).

The area of cultivation of sulla includes Portugal, Spain, Morocco, Algeria, Tunisia, Egypt, Italy, former Yugoslavia and Greece (Flores *et al*., 1997). *Hedysarum coronarium* is an exotic legume to Australia (Casella *et al*., 1984). It was introduced into New Zealand

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in the early 1950s largely for use in soil conservation, but its potential as a forage was more fully realised in 1982 (Watson, 1982; In: Krishna *et al.*, 1990).

In the genus *Hedysarum*, little is known about the nature of genetic variability in diploid species (Baatout *et al.*, 1991a) and about the taxonomic relationships of the different taxa (Baatout *et al.*, 1991b).

The objective of this study is to understand the heriditary mechanism and quantify the genetic diversity available within Algerian populations of *Hedysarum coronarium* L. of diverse biogeographical origins using a number of morpho-physiological characteristics. This research follows previous studies conducted on fodder legumes species in Algeria (Issolah and Abdelguerfi, 1998, 1999a, 1999b, 2000, 2001, 2002, 2003; Issolah *et al.*, 1993, 2000, 2001, 2006; Issolah, 2006).

MATERIAL AND METHODS

Collecting missions were undertaken by the National Institute of Agronomic Research (INRAA) throughout the North-East of Algeria in 1998 (Issolah *et al.*, 2001). Several populations of *Hedysarum coronarium* L. were collected (Issolah *et al.*, 2006). Fourteen ones were subjected to a trial on two consecutive years (1999/2000 and 2000/2001) (Fig. 1).

The populations were sown (13/11/99) at the experimental station of Mehdi Boualem of Baraki (INRAA) at the altitude of 18.5 m, in a subhumid zone. The soil was clayey-mudy with pH of 8.12. The temperature was ranged from 10.9°C (m1) to 21.7°C (M1) for the first year (99/00) and from 11.7°C (m2) to 22.9°C (M2) for the second year (00/01). The annual rainfall was about 412 mm (99/00) and 408.1 mm (00/01), respectively.

After determinating the 1000 seed weight (WTS) of the populations, these are sowed on lines separated of 1.5 m, with 35 individuals per population. The individuals were separated between each others of 40 cm. We used a randomized complete block design with two replications. Thirty four characteristics were evaluated: 1000 seed weight (WTS); date of the emergence of the seedlings (DES); rate of seedlings at the first simple leaf stage (12/12/99: SL1, 22/12/99: SL2); rate of seedlings at the second simple leaf stage (27/12/99: SL3, 03/01/00: SL4, 09/01/00: SL5); rate of seedlings at the third simple leaf stage (17/01/00: SL6, 24/01/00: SL7, 01/02/00: SL8); Number of leaves (composed per three leaflets) per seedling (23/02/00: NL1, 06/03/00: NL2, 16/03/00: NL3); Number of leaflets per plant (26/03/00: NLP); Number of ramifications per plant (23/02/00: R1, 06/03/00: R2, 16/03/00: R3, 26/03/00: R4); winter development (31/03/00): height of axis (HA1) and width of axis (WA1); spring development (24/05/00): height of axis (HA2) and width of axis (WA2); autumnal development (10/01/01): height of axis (HA3) and width of axis (WA3); winter development

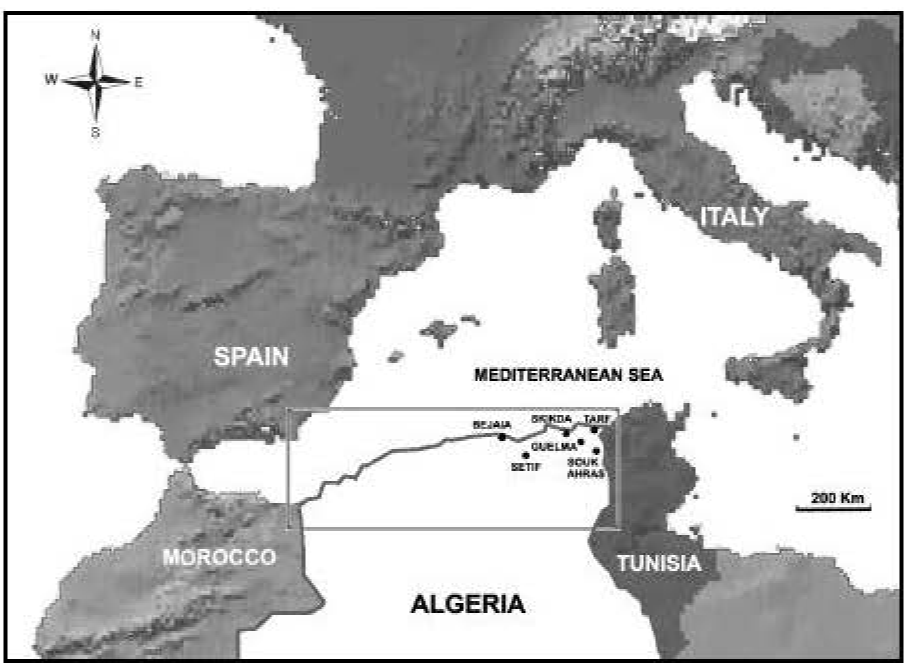

Fig. 1: Origin areas of fourteen natural populations of *Hedysarum coronarium* L. in Algeria. A) Bejaia; B) Setif; C) Skikda; D) Guelma; E) Tarf; F) Souk Ahras (Issolah *et al.*, 2006)

Table 1: Ecological characteristics of the originating environment of fourteen natural populations of *Hedysarum coronarium* L. in Algeria (Issolah *et al*., 2006 completed)

No. of populations	Origin area	Altitude (m)	Rainfall (mm)
2/98	Bejaia	1	964
4/98	Bejaia	3	800
6/98	Bejaia	250	800
8/98	Setif	740	564
10/98	Setif	830	564
12/98	Setif	960	665
13/98	Setif	1030	600
16/98	Guelma	120	700
18/98	Guelma	250	800
20/98	Guelma	400	558
22/98	Guelma	500	600
24/98	Skikda	270	600
26/98	Souk Ahras	840	700
28/98	Tarf	5	700

(28/03/01): height of axis (HA4) and width of axis (WA4); flower bud (FB); first inflorescence (FI); full Bloom (FB1); end of the bloom (EB); duration of the bloom (DB); number of inflorescences per plant (NFP); appearence of the first fruiting head (FH1); full formation of fruiting heads (FH).

The notations concerning the vegetative development were made periodically, at precise dates during the two years (99/00 and 00/01). The notations concerning the bloom and the fruiting heads were made by regular passages (2-3 days), during the first year. In this case, the indicated values are expressed in the number of days after sowing.

The considered characteristics made the subject of statistics treatments (statistical parameters, variance analysis, matrix of correlations, linear regression analysis, principal component analysis) through Statistica (1997), Excel (2000) and Stat-itcf (1988) computer programs. Certain ecological factors such as the rainfall (ANRH, 1993) and the altitude of the natural habitat have been considered (Issolah *et al*., 2006) (Table 1).

RESULTS AND DISCUSSION

Statistical parameters: Results of statistical parameters of the 1000 seed weight (mother seeds) of the populations, indicate the performance of the population 13/98. As a matter of fact, this one presents the heaviest seeds (6.27 g) whereas the population 28/98 is characterised by the lightest ones (3.89 g). The mean value of the species is 5.02 g. The standard deviation and the coefficient of variation are, respectively 0.6328 and 12.60. Our results correspond to the finding of Villax (1963) who says that the 1000 seed weight in *Hedysarum coronarium* L. is 5-6 g.

The study of the average weight of one seed within eight species of the genus *Hedysarum* in Algeria (Abdelguerfi-Berrekia, 1985) showed that *H. naudinianum* presents the heaviest seeds (17.2 mg). Next come those of *H. glomeratum* (8.9 mg), *H. spinosissimum* (8.0 mg), *H. pallidum* (7.8 mg), *H. aculeolatum* (7.2 mg), *H. flexuosum* (5.9 mg), *H. carnosum* (5.1 mg) and finally *H. coronarium* (4.9 mg). In the same genus, the mean weight of a seed is comprised between 17.2 and 4.9 mg (Abdelguerfi-Berrekia, 1985). The weight of 1000 seeds (5.3 g) within *Hedysarum confertum* Desf., which is present in the matorral areas of southeast Spain (Rios *et al*., 1991), reaveled itself near to that of *H. coronarium.*

Thus, within the genus *Hedysarum*, *H. coronarium* is met among the species with light seeds.

Variance analysis: The results of variance analysis permitted to show variability within *Hedysarum coronarium* L. (Table 2).

Thus, out of thirty three analysed characteristics, four are significant: the rate of seedlings at the second simple leaf stage (SL3***), the development of the height of axis (OA2**), the end of the bloom (EB*) and the full formation of fruiting heads (FH*).

The population 4/98 was accurately distinguished in regard to important development of the axis height (HA2; HA3), the late appearence of the Flower Bud (FB), the First Inflorescence (FI), the Full Bloom (FB), the end of the bloom (EB), the high number of inflorescence per plant (NFP), the late appearence of the first fruiting head (FH1) and the full formation of Fruiting Heads (FH).

Except the existing variability, we note the importance of the vegetative development of the populations which attains a mean of 222.5 cm (PA4). It can go up to 304 cm in population 18/98. Thus, the covering of the soil revealed itself very interesting in this species.

Matrix of correlations: The matrix of correlations has emphasized very numerous relationships between the morpho-physiological characteristics taken into consideration. The main existing relationships are synthesized as follows (Table 3).

The populations presenting a high 1000 seed weight (WTS), are precocious in terms of first fruiting head appearance.

The populations which seedlings rate at first simple leaf stage (SL1) is high, present also a high rate of seedlings at the second (SL4) and third (SL8) simple leaf stage, a weak development of height axis at the end of winter season (WA1) and during spring period (WA2).

The populations that ensure a good soil re-covering (WA2), present a weak rate of seedlings at the first and second simple leaf stage (SL1; SL4), a high Number of leaflets per plant (NLP), a high number of ramifications per

Table 2: Results of the variance analysis within fourteen Algerian populations of *Hedysarum coronarium* L.

Characteristic		Min	Max	Mean	Fobserved	Probability	Significance
DES	(days)	14.62	19.84	17.72	2.39	0.0647	NS
SL1	(%)	9.00	66.00	35.00	1.17	0.3932	NS
SL2	(%)	64.00	94.00	78.43	0.67	0.7583	NS
SL3	(%)	3.00	38.00	18.64	7.39	0.0006	S***
SL4	(%)	28.00	79.50	56.39	2.15	0.0901	NS
SL5	(%)	40.50	88.00	76.68	1.89	0.1314	NS
SL6	(%)	3.00	25.50	9.50	0.93	0.5490	NS
SL7	(%)	11.50	53.50	30.07	1.44	0.2587	NS
SL8	(%)	39.00	74.50	61.43	0.80	0.6501	NS
NL1		1.10	2.54	1.56	0.61	0.8118	NS
NL2		1.55	4.47	2.45	0.78	0.6674	NS
NL3		2.47	5.73	3.84	0.83	0.6268	NS
NLP		14.43	62.00	28.76	1.28	0.3304	NS
R1		3.61	5.48	4.21	0.87	0.5945	NS
R2		4.11	6.79	4.86	1.08	0.4488	NS
R3		4.61	8.49	6.12	0.72	0.7221	NS
R4		3.91	12.46	6.84	1.27	0.3360	NS
HA1	(cm)	2.09	3.97	2.94	1.37	0.2910	NS
WA1	(cm)	8.48	18.73	12.96	1.27	0.3366	NS
HA2	(cm)	3.85	10.39	7.26	5.18	0.0030	S**
WA2	(cm)	28.44	80.10	57.04	1.25	0.3457	NS
HA3	(cm)	11.83	26.05	17.55	1.02	0.4884	NS
WA3	(cm)	63.59	86.33	74.07	2.54	0.0526	NS
HA4	(cm)	44.50	138.50	74.64	0.92	0.5615	NS
WA4	(cm)	149.50	304.00	222.50	1.74	0.1652	NS
FB	(days)	146.40	169.33	156.70	1.85	0.1399	NS
FI	(days)	162.35	178.00	170.63	1.91	0.1286	NS
FB1	(days)	171.52	183.63	176.96	0.87	0.6002	NS
EB	(days)	187.67	206.45	195.20	2.86	0.0347	S*
DB	(days)	21.41	30.50	25.63	2.06	0.1023	NS
NFP		16.63	67.28	37.18	1.12	0.4218	NS
FH1	(days)	175.60	190.01	182.07	1.62	0.1965	NS
FH	(days)	187.42	204.88	194.12	3.06	0.0270	S*

Min: Mean of a population with the lowest value; Max: Mean of a population with the highest value; Mean: Mean of the species. Signification: *5%; **1%; ***0.1%

Table 3: Relations between the morpho-physiological characteristics in fourteen (14) Algerian populations of *Hedysarum coronarium* L.

Characteristics	WTS	SL1	R1	HA1	WA1	WA2	HA4	FB	FI	EB	NFP	FH1	FH
WTS	1.00	0.03	-0.07	0.50	0.20	0.23	0.23	-0.44	-0.51	-0.40	-0.15	-0.54*	-0.39
SL1	0.03	1.00	-0.01	-0.21	-0.66*	-0.66*	-0.30	-0.15	0.02	-0.19	-0.31	-0.23	-0.32
SL3	0.21	0.38	0.37	0.18	-0.07	-0.45	-0.28	-0.57*	-0.41	-0.69*	-0.58*	-0.64*	-0.75*
SL4	-0.04	0.58*	0.29	-0.21	-0.47	-0.65*	-0.39	-0.51	-0.14	-0.44	-0.51	-0.40	-0.60*
SL5	-0.16	0.46	0.35	-0.66*	-0.41	-0.31	-0.01	-0.24	0.11	0.01	0.09	0.05	-0.11
SL7	0.08	0.36	0.41	0.26	-0.06	-0.39	-0.27	-0.51	-0.44	-0.43	-0.49	-0.64*	-0.74*
SL8	-0.08	0.68*	0.46	-0.46	-0.38	-0.38	-0.12	-0.19	-0.02	-0.07	0.05	-0.16	-0.23
NL1	0.15	0.01	0.82*	-0.12	0.47	0.25	0.15	-0.70*	-0.74*	-0.53	0.25	-0.62*	-0.58*
NL3	-0.13	-0.40	0.65*	-0.34	0.44	0.40	0.15	-0.28	-0.300	0.00	0.47	-0.12	-0.08
NLP	0.09	-0.47	0.81*	-0.11	0.79*	0.64*	0.32	-0.51	-0.61*	-0.27	0.56*	-0.36	-0.24
R1	-0.07	-0.01	1.00	-0.25	0.48	0.22	0.14	-0.54*	-0.58*	-0.45	0.40	-0.47	-0.41
R2	-0.07	-0.30	0.90*	-0.18	0.69*	0.55*	0.29	-0.46	-0.54*	-0.22	0.58*	-0.33	-0.24
R3	-0.20	-0.32	0.72*	-0.30	0.56*	0.37	0.16	-0.42	-0.43	-0.23	0.41	-0.20	-0.23
R4	0.12	-0.46	-0.81*	-0.11	0.81*	0.68*	0.41	-0.46	-0.60*	-0.25	0.60*	-0.33	-0.21
WA1	0.20	-0.66*	0.48	0.29	1.00	0.82*	0.48	-0.29	-0.55*	-0.25	0.49	-0.24	-0.10
HA2	0.11	-0.43	0.05	-0.05	0.58*	0.74*	0.72*	0.28	0.02	0.36	0.67*	0.36	0.41
WA2	0.23	-0.66*	0.22	0.19	0.82*	1.00	0.63*	-0.02	-0.20	0.19	0.71*	0.10	0.27
WA3	0.46	-0.48	-0.31	0.64*	0.25	0.26	-0.15	-0.10	-0.03	-0.16	-0.30	-0.16	-0.00
HA4	0.23	-0.30	0.14	-0.01	0.48	0.63*	1.00	0.20	-0.05	0.22	0.50	0.23	0.19
FB	-0.44	-0.15	-0.54*	-0.30	-0.29	-0.02	0.20	1.00	0.84*	0.85*	0.20	0.87*	0.85*
FI	-0.51	0.02	-0.58*	-0.36	-0.55*	-0.20	-0.05	0.84*	1.00	0.82*	0.03	0.89*	0.80*
FB1	-0.48	-0.34	-0.45	-0.27	-0.16	-0.06	0.09	0.86*	0.81*	0.67*	0.05	0.83*	0.77*
EB	-0.40	-0.19	-0.40	-0.46	-0.25	0.19	0.22	0.85*	0.82*	1.00	0.48	0.89*	0.93*
DB	0.03	-0.27	0.28	-0.23	0.33	0.50	0.10	0.08	-0.13	0.37	0.65*	0.03	0.28
NFP	-0.15	-0.31	0.40	-0.46	0.49	0.71*	0.50	0.20	0.03	0.48	1.00	0.36	0.53
FH1	-0.54*	-0.23	-0.47	-0.47	-0.24	0.10	0.23	0.87*	0.89*	0.89*	0.36	1.00	0.92*
FH	-0.39	-0.32	-0.41	-0.41	-0.10	0.27	0.19	0.85*	0.80*	0.93*	0.53	0.92*	1.00

Signification (*): $p<0.05$

plant (R2; R4), a good initial development in width and height (WA1; HA2), a good final development in height (HA4) and a high number of inflorescences per plant (NFP).

The precocious populations in terms of flower bud appearance, present a high seedlings rate at the second simple leaf stage (SL3), a high number of leaves per seedling (NL1) and a high number of ramifications (R1). They are precocious in regard of appearance of first inflorescence, full bloom, ending bloom, the appearance of first fruiting head and full formation of fruiting heads.

Linear regression analysis: In order to visualize better the relations established between certain morpho-physiological characteristics and some ecological factors (altitude and rainfall) of originating environment of the populations in *H. coronarium*, we had recourse to regression (Fig. 2 A-F).

The linear model (Fig. 2A) explains at 39.9% the positive correlation between the 1000 seed weight and the altitude of the environment where the populations are originated; this correlation appears significant (y = 0.0011x + 4.5309; R^2 = 0.399*) and at 39.03% (Fig. 2B) the negative correlation between the percentage of seedlings at the second simple leave stage and the rainfall of originating environment of populations (y = 0.0655x + 63.606; R^2 = 0.3903*).

It shows at 34.83% (Fig. 2C) the negative correlation between the end of the bloom and the altitude that appears significant (y = -0.0081x+198.78; R^2 = 0.3483*) and

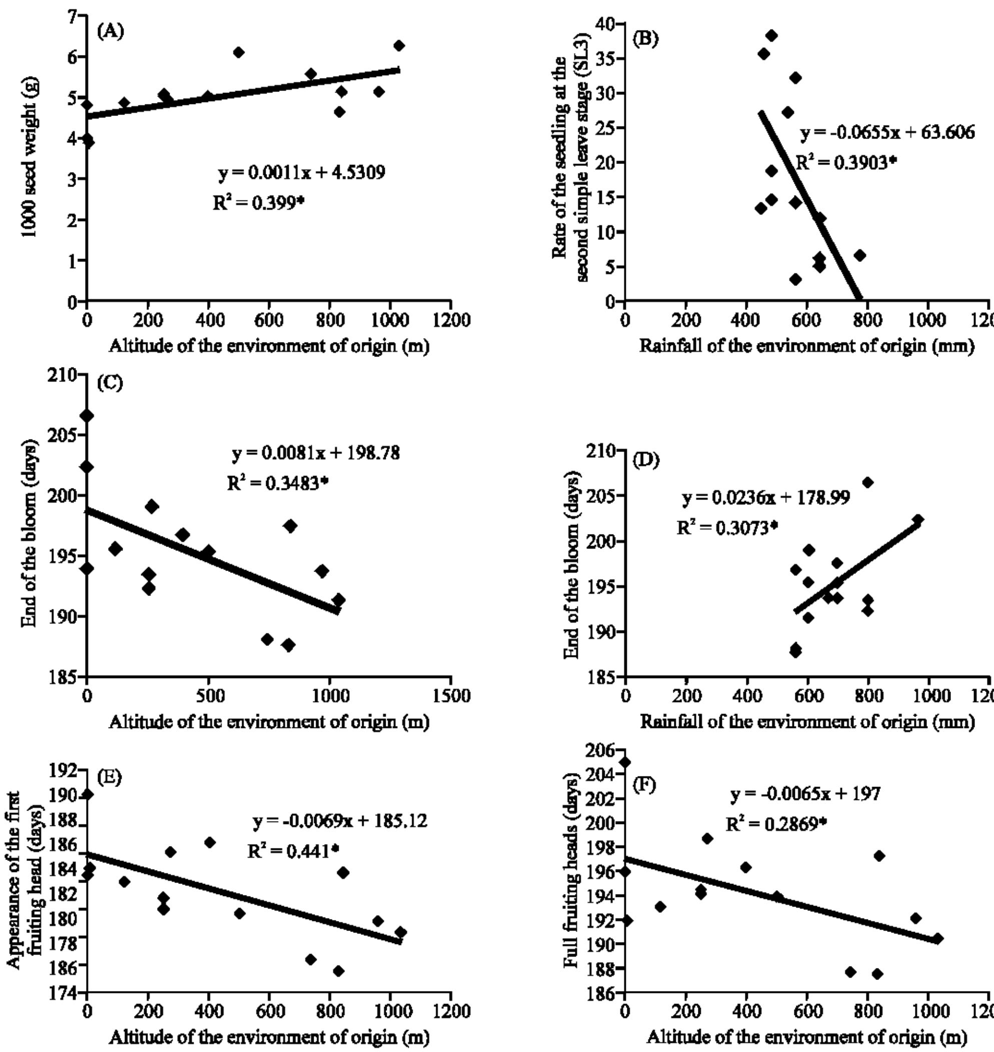

Fig. 2: Linear regression analysis of morpho-physiological characteristics related to ecological factors (altitude, rainfall) of originating environment of *H. coronarium* populations. A- WTS x altitude, B- Rate of seedlings (second simple leave stage) x rainfall, C- End of the bloom x altitude, D- End of the bloom x rainfall, E- Appearance of the first fruiting heads x altitude, F- Full fruiting heads x altitude

at 30.73% (Fig. 2D) the positive correlation between the end of the bloom and the rainfall of the origin site (y = 0.0236 + 178.99; R^2 = 0.3073*).

The linear model (Fig. 2/E) explains at 44.1% the negative correlation which exist between the appearance of the first fruiting head and the altitude of origin site (y = -0.0069x + 185.12; R^2 = 0.441*) and at 28.69% (Fig. 2F) the negative correlation between the full formation of fruiting heads and the altitude of the environment of origin (y = -0.0065 + 197; R^2 = 0.2869*).

We note that the altitude intervenes on four characteristics (weight of seeds, end of the bloom, appearance of the first fruiting head, full fruiting heads) whereas the rainfall intervenes only on two characteristics (rate of the seedlings at the second simple leave, end of the bloom). We signalize that only one characteristic (end of the bloom) is influenced by both of the altitude and the rainfall. The altitude would constitute the most important ecological factor for its influence on the morpho-physiological variation of the populations within *H. coronarium.*

Our results show that the populations which present the highest thousand seed weight are originating from the high altitude areas whereas a previous work (Abdelguerfi-Berrekia, 1985) conducted on Algerian populations of the genus *Hedysarum* showed that it was not possible to establish clear links between characteristics related to fruiting heads, seeds and origin environment. By another way, Abdelguerfi (2001) indicated, in 17 Algerian populations of *H. coronarium*, that the factors of the environment of origin don't seem to have an effect on the weight of one hundred joints, the thousand seed weight and the ratio seeds/pods. Nevertheless, the same author signalizes, in *H. spinosissimum* subsp. *capitatum*, that the weight of seeds seems to increase with the altitude.

Berrekia and Abdelguerfi (1988) indicate for *H. coronarium* that the Algerian populations of the sub-humid level are frequently more precocious than those of the humid level. Our present work shows off the importance of the height of the axis (HA2), which the variation revealed itself highly significant, without establishing links with the factors of the origin environment. Nevertheless, a previous study conducted on twenty Algerian populations of *H. coronarium* indicate that the populations which presented a weak final development of height come from the high altitude areas (Issolah *et al*., 2001).

In Italy, Sarno *et al*. (1978) have also shown the influence of high elevation on the diversification of morphological types within *H. coronarium*.

In Algeria, Abdelguerfi (2001) indicated that in *Hedysarum coronarium*, the stand type and the development of the orthotropic axis seem to be influenced by high elevation. High-altitude populations have a prostrate stand whereas low-altitude ones have an erected stand. In some species of the genus *Hedysarum*, some populations were subject to a strong selection pressure from the originating environment and formation of ecotypes seems evident (Abdelguerfi, 2001). In our case, there are not relations between the number of ramifications and the ecological factors (altitude, rainfall) of the originating environment of populations.

Principal component analysis: The analysis of the principal components turns on fourteen populations and thirty three characteristics. The altitude and the rainfall are used as supplementary variables. The plan 1-2 extracts 55.2% from information.

According to the decreasing quality of the representation (Table 4), the most important variables appear as follows: NLP > R2 > R4 > R1 > NL1 > NL2 > R3 > NFP > FI > FH > SL4 > WA2 > SL3 > NL3 > FB > HA2. These sixteen variables have a quality = 52.40%. Six others variables are included between 40.64 and 49.29% and eleven show a rate = 33%.

Globally, the results highlighted the good distribution of the variables through two axis (Fig. 3) and the importance of a certain number of characteristics, in particular the number of leaves and ramifications per plant which are distinguished clearly and are opposed to certain characteristics related to the bloom and the breeding (formation of fruiting heads).

Axis 1 is an axis of precocity and of architecture; the earliest populations with flowering are located on the right and latest ones are on the left.

Axis 2 is an axis of production.

The analysis of the Fig. 3, which represents the dispersion of the populations in the plan of components 1 and 2, shows that populations of the group C (originated from the area of Setif) and those of the group B (originated from the area of Guelma) are stretched along axis 1. Certain individuals are early, others are late. They are heterogeneous populations showing great morphophysiological variation.

The populations of group A (coming from the area of Bejaia) are spread out along the positive part of axis 2. They are especially characterized by a good production of inflorescences.

The cloud of the populations of the group B overlaps with group A, which indicates the existence of individuals or morphologically similar populations.

The population 24/98 (Skikda) with late flowering, is opposed to axis 1 at population 10 (Setif) early and having

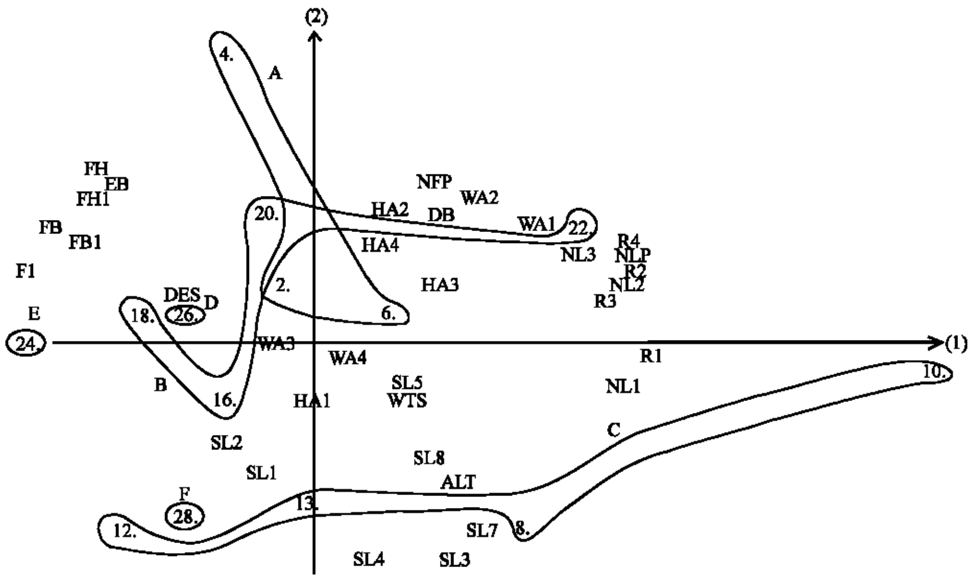

Fig. 3: Distribution of Algerian populations of *H. coronarium* in the plan engendered by the first 2 axis of the principal components. Group A: populations No. 2/98, 4/98, 6/98; Group B: populations No. 16/98, 18/98, 20/98, 22/98; Group C: populations No. 8/98, 10/98, 12/98, 13/98; Group D: population No. 26/98; Group E: population No. 24/98; Group F: population No. 28/98

a high number of leaves (composed per three leaflets) per seedling, a high number of leaflets and ramifications per plant.

Axis 2 opposes the population 4 (Bejaia), characterized by a good spring vegetative development of the height and width axis, a high number of inflorescences per plant and a full late formation of fruiting heads with populations 12/98, 13/98, 8/98 (setif) and 28 (Tarf) presenting the inverse characteristics and with the populations 16/98, 18/98, 20/98, 22/98 (Guelma) having intermediate characteristics.

This analysis highlights the existence of great morpho-physiological variation between the populations coming from the same area, particularly from setif and intraspecific for the characteristics of precocity and production in *Hedysarum coronarium* L. species.

A previous cytogenetic study conducted on some of these populations revealed that the chromosomic variation ($x = 8$ and $x = 9$), established for the first time in *H. coronarium* L., would be linked to the ecological factors of the originating environment (Issolah *et al*., 2006). Throughout the length of the chromosomes and the diversity of heterochromatic bands, the Algerian populations would be richer in heterochromatin than Italian populations (Issolah *et al*., 2006). The environment of the origin of the populations would have an influence on the distribution of the heterochromatin in *Hedysarum coronarium* (Issolah *et al*., 2006).

In the same family (Fabaceae), the morphological variability observed in several Algerian species of the genus *Trifolium* (Issolah *et al*., 1993) is linked to certain ecological factors (altitude, rainfall, longitude, latitude) of the originating environment of the populations. (Issolah and Abdelguerfi 1998, 1999a, 2000, 2001, 2002; Issolah *et al*., 2000).

Issolah (1997) and Issolah and Abdelguerfi (1999b) determinated two chromosome numbers ($2n = 10$ and $2n = 12$) in Algerian populations of *Trifolium scabrum*. The population with $2n = 12$ is characterized by a high number of pods by fruiting head and a big size of fruiting heads. Besides, it comes from a marginal area with relatively low altitude and rainfall.

A study conducted on *Trifolium glomeratum* indicate that early-flowering lines were found in sites with dry, hot springs (short growing seasons), mid-season lines from cooler, moister areas, while the late-flowering lines came from areas with good spring rains and cold winters (Woodward and Morley, 1974).

According to Negri and Veronesi (1987), Italian populations of white clover coming from higher altitudes showed a low degree of spring regrowth and later bloom date.

In native white clover (*Trifolium repens*) populations in Nova Scotia, Fraser (1991) indicate that the variations in raceme number per plant appeared to be related to latitude of origin.

Table 4: Principal component analysis of the morpho-physiological study within fourteen Algerian populations of *Hedysarum coronarium* L.

	Principal components (Axis)			
	Axis 1 (31.0%)		Axis 2 (24.2%)	
Variables	Inertia	Percentage	Inertia	Percentage
WTS	0.1951	0.0381	-0.2316	0.0536
DES	-0.3063	0.0938	0.1427	0.0204
SL1	-0.1775	0.0315	-0.6786	0.4604
SL2	-0.2872	0.0825	-0.4239	0.1797
SL3	0.3619	0.1310	-0.7486	0.5605
SL4	0.1878	0.0353	-0.7767	0.6032
SL5	0.1629	0.0265	-0.2773	0.0769
SL7	0.4028	0.1623	-0.6732	0.4532
SL8	0.2473	0.0611	-0.3749	0.1405
NL1	0.8659	0.7498	-0.1290	0.0167
NL2	0.8595	0.7388	0.2295	0.0527
NL3	0.7333	0.5377	0.3260	0.1063
NLP	0.9171	0.8411	0.3407	0.1161
R1	0.8768	0.7687	-0.0163	0.0003
R2	0.9157	0.8386	0.2913	0.0849
R3	0.8108	0.6574	0.2111	0.0446
R4	0.9053	0.8195	0.3761	0.1415
HA1	-0.0089	0.0001	-0.2542	0.0646
WA1	0.6631	0.4397	0.4890	0.2391
HA2	0.1871	0.0350	0.7239	0.5240
WA2	0.4213	0.1775	0.7509	0.5638
HA3	0.3338	0.1114	0.3040	0.0924
WA3	-0.1326	0.0176	0.0209	0.0004
HA4	0.1757	0.0309	0.5035	0.2535
WA4	0.0633	0.0040	-0.0040	0.0000
FB	-0.7289	0.5313	0.5493	0.3018
FI	-0.7969	0.6351	0.3220	0.1037
FB1	-0.6502	0.4228	0.4771	0.2276
EB	-0.5299	0.2808	0.7021	0.4929
DB	0.3486	0.1215	0.5804	0.3368
NFP	0.3410	0.1163	0.8069	0.6512
FH1	-0.6322	0.3997	0.6375	0.4064
FH	-0.5511	0.3037	0.7784	0.6059
ALT	0.3244	0.1052	-0.4708	0.2217
R	-0.3334	0.1111	0.3269	0.1069

1st Column: co-ordinates on the principal axis, 2nd column: square cosinus (quality of the representation)

In *Trifolium subterraneum*, both morphological traits and early dry matter yield are influenced by the environment of origin of the Sicilian populations (Pecetti and Piano, 1993). In another study conducted on the same species, Piano *et al.* (1993) indicate that native populations have adjusted their adaptative characteristics to the climatic features of the sites where they naturally grow.

Thus, the relations seem to be established between some morpho-physiological characteristics and the originating environment of the populations within certain species of the *Fabaceae* family.

CONCLUSIONS

The analysis of the morpho-physiological variation of some natural populations of the species *Hedysarum coronarium* L. in Algeria has for principal objective the understanding of the hereditary mechanism and the diversity of the populations within this species. The existence of variability is clearly demonstrated throughout this study. The results showed the preponderant part of the altitude and the rainfall of the origin environment on a certain number of characteristics linked to the behaviour of the different populations. The established variability would contribute to widen the range of choice in spontaneous populations of *Hedysarum coronarium* L., particularly for the isolated and disinherited areas, where they could adapt themselves with advantage. More investigations will help us to understand the mechanism of evolution of these populations within the species *H. coronarium.*

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