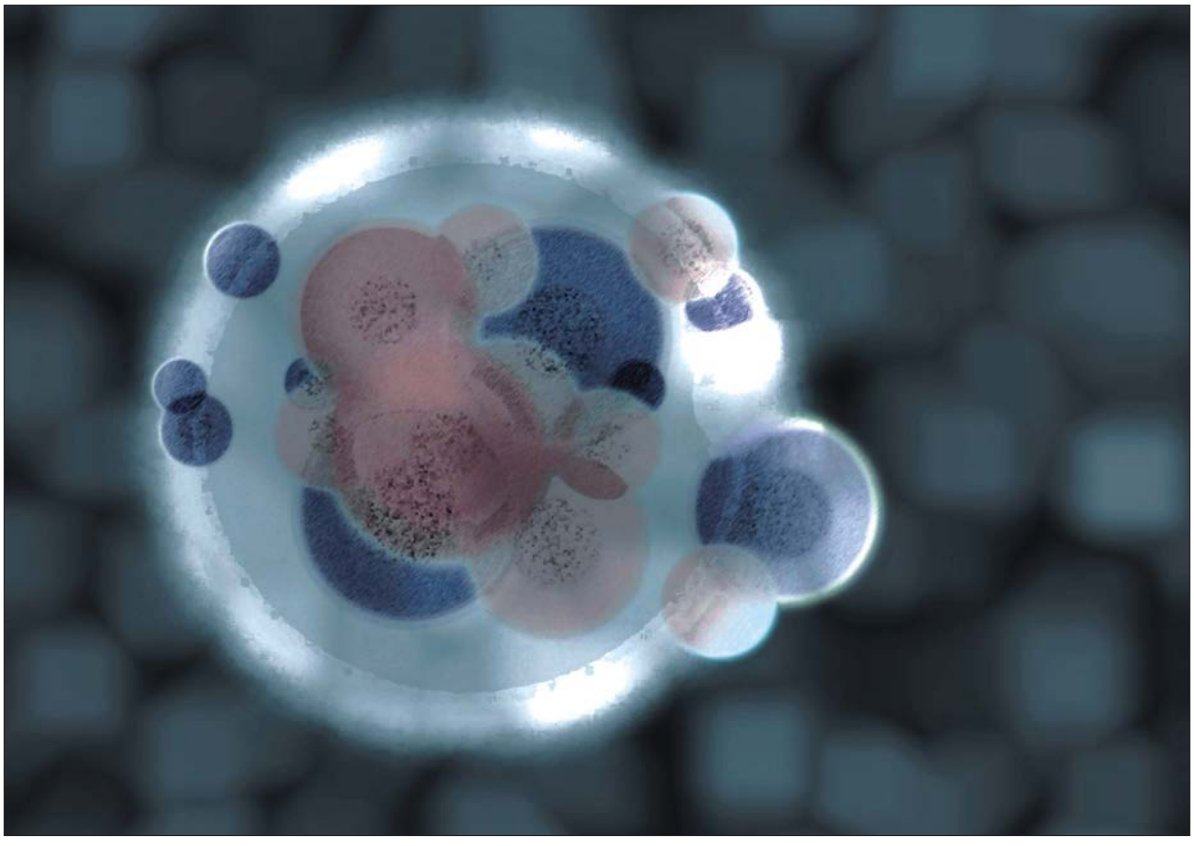

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Analysis of the Growth and the Chemical Composition within some Algerian Populations of Sulla

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Abstract: As part of the evaluation and the development of plant genetic resources of fodder and pastoral interest in Algeria, ten populations of sulla (*Sulla coronaria* (L.) Medik. Syn. *Hedysarum coronarium* L.) were subject to an assessment. The growth and the chemical composition of the populations were analyzed in this framework. The field trial is a randomized complete block design with four replications. Several parameters (seeds thousand weight, emergence of seedlings, number of plants per square meter, maximum height, maximum width, bloom, cutting date, green matter, dry matter, mineral matter, organic matter, crude fiber, fat, phosphorus, calcium, total nitrogen, Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), lignin, hemicellulose) have been determined. Two ecological factors (altitude, rainfall) were also taken into account. The variance analysis indicated a significant variation between the populations regarding eight variables linked to the growth and the chemical composition of the plant. Many significant relationships were also highlighted. The results of the correlation matrix indicated also that the total nitrogen content is negatively correlated with the number of plants per square meter and the final height. Overall, the results of principal component analysis showed a good distribution of variables, particularly, the final width, the hemicellulose and the NDF. The descriptive analysis signalized also the part of the altitude and the rainfall characterizing the natural habitats of the populations. This study permitted a better understanding of the nature of variation established within this species. Sulla can play a significant role in the socio-economic and environmental development of rural communities.

Key words: Bloom, chemical composition, fodder legume, *Hedysarum coronarium*, *Sulla coronaria*

INTRODUCTION

Sulla (*Hedysarum coronarium* L. syn. *Sulla coronaria* (L.) Medik.) (Choi and Ohashi, 2003) is a fodder legume from the western Mediterranean, where it is found on various types of soils (Issolah *et al*., 2012). This plant presents a significant vegetative growth up to three meters in some algerian populations (Issolah and Khalfallah, 2007).

The analysis of the chemical composition is the basis of assessment methods of the nutritive value of forages (Arab *et al*., 2009). It allows to quantify the nutrient contents and the anti-nutritional factors of the feed (Arab *et al*., 2009).

The information concerning the nutritive value of sulla regarding the environment is not sufficient in spite of the high quality and the productivity of this crop (Borreani *et al*., 2003; Moore *et al*., 2006).

This study is part of the assessment and development of species presenting a fodder and pastoral interest in Algeria. Its aim is to evaluate several parameters related to the growth and the chemical composition of ten algerian populations of sulla. It is also to analyze relationships that exist between these parameters at first and between these parameters and some ecological factors (altitude, rainfall) characterizing the natural habitats of the different populations. This work follows the complementary studies realized on spontaneous forage legumes (Issolah and Abdelguerfi, 1999; Issolah *et al*., 2006, 2011, 2012; Issolah and Khalfallah, 2007).

MATERIALS AND METHODS

Origin of material: Following a mission carried out by INRAA (National Institute of Agronomic Research of

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Table 1: Ecological characteristics of the natural habitats of ten algerian populations of *sulla* across the North Eastern Algeria (Issolah *et al*., 2012)

No. of population	Origin	Altitude (m)	Rainfall(mm)
1	Alger	310	746
2	Bejaia	05	964
3	Bejaia	05	705
4	Bejaia	10	705
5	Bejaia	485	935
6	Setif	1150	500
7	Setif	910	550
8	Guelma	500	650
9	Guelma	820	550
10	Tarf	65	750

Algeria), in 2008, across the North East of Algeria, several populations of sulla were collected (Issolah *et al*., 2012). Among these populations, ten have been the subject of an experiment in order to evaluate several parameters related to the growth and the chemical composition of the plant (Table 1).

Methods: For each population, 300 seeds m^{-2} (5 lines spaced by 25 cm at a rate of 60 seeds per line) were sown (09/12/2010) at the experimental station of INRAA (Baraki). A randomized complete block design with four replications was used. The texture of the soil was silty clayey. The pH was alkaline (8.17). The annual rainfall was 703.5 mm (2010/2011) and average temperatures of the year were respectively, 23.5°C (maxima average) and 14.2°C (minima average). The plot of land did not receive N-P-K fertilization before the sowing.

The considered parameters are the following: The thousand seed weight (TSW/g), the emergence of seedlings (SE/Number of days after the sowing), the No. of plants m^{-2} (NP), the maximum height reached by the population (MH:cm), the maximum width attained by the population (WM:cm), the date of appearance of the first inflorescences (1F/number of days after the sowing). Following the cut date (CD/number of days after the sowing) at the beginning of the bloom, several analyzes were performed in the laboratory through various techniques: weight of green matter (GM: g m^{-2}), weight of dry matter (DM:g), mineral matter (MM in %DM), organic matter (OM in %DM), crude fiber (CF in %DM) by Weende method, fat (F in %DM), phosphorus (P in %DM) by spectrophotometry, calcium (Ca in %DM) by titrimetric method, the total nitrogen (TN in %DM) by the Kjeldahl method (ISO, 2009), the acid detergent fiber (ADF in %DM), the neutral detergent fiber (NDF in %DM) and the lignin (LIG in %DM) (Van Soest *et al*., 1991).

The hemicellulose (Hcell in %DM) was deduced by the equation (NDF-ADF).

The thousand seed weight (TSW:g) was also determined before sowing and the green matter yield (GMY:kg ha^{-1}) was deduced for each population. The results are expressed in % of Dry Matter (DM) for the various parameters related to the chemical composition. The analyses of the laboratory were made in ITELV (Technical institute of livestock).

The data obtained (40 for each variable/17 variables) have undergone statistical treatments (ANOVA). The groups of means were obtained with Tukey method. Then, the correlations (matrix of correlations) were analyzed between all variables and two ecological factors (altitude (ALT) and Rainfall (R)) of the natural habitats of the populations (10 means for each variable/21 variables). For a better visualization of relations between the populations and the different variables (19), the Principal Component Analysis (PCA) was used. Statistical treatments were performed using the softwares Minitab Inc. (2003) and XLSTAT (1995-2004).

RESULTS

Variance analysis: The analysis of variance (ANOVA) applied to 17 variables indicated a significant probability in 08 ones (Table 2). The phosphorus was not considered in the statistical analyzes because of the laboratory analysis which indicated a trace amount in all the populations. The most representative variables (0.000***) correspond, respectively, to the growth (No. of plant m^{-2}, maximum height, cutting date) and the chemical composition (Neutral Detergent Fiber (NDF) and hemicellulose). In the second position (0.002**) intervenes the maximum width of plants (WM) whereas the Acid Detergent Fiber (ADF) and the weight of the green matter (GM) occupy the last position (respectively, 0.013* and 0.027*). For the others variables, the probability is not significant.

Regarding the results of descriptive statistics applied to the Thousand Seeds Weight (TSW) and the yield of green matter (GMY) of sulla, a variation between the populations was indicated. The thousand seed weight reached a mean value of 4.556 g and the deduced mean value of green matter yield attained a quantity of 4661. 37 kg ha^{-1} (4,6 tons) (Table 3).

Matrix of correlations: This analysis was applied to all the variables (21) exception made for the phosphorus (trace amount). The main identified relationships (significant probability) are as follows (Table 4).

The populations with a high final height are characterized by a high No. of plants m^{-2} (0.001***). The populations which have a late beginning of the bloom (cutting date) are also late for the emergence of seedlings (0.032*) and the appearance of the first inflorescences (0.004**). The populations with a good performance of green matter yield also have a high

Table 2: Results of univariate analysis (ANOVA) of growth and chemical composition (% DM) parameters within some algerian populations of *sulla*

Parameters	Min	Max	Mean	F observed	Probability
SE (days)	12.0	17.0	14.50	1.45	0.218
NP	16.2	92.3	53.10	6.20	0.000***
WM (cm)	17.7	75.5	43.27	4.16	0.002**
HM (cm)	11.3	48.3	20.82	5.91	0.000***
1F (days)	122.8	143.5	130.40	1.48	0.208
CD (days)	128.5	176.3	141.60	9.06	0.000***
GM (g m^{-2})	184.5	882.4	466.19	2.61	0.027*
MM (%DM)	13.0	18.8	14.82	1.08	0.410
OM (%DM)	81.2	87.0	85.17	1.08	0.410
TN (%DM)	6.8	9.9	8.03	1.97	0.085
CF (%DM)	8.9	15.7	11.44	2.09	0.069
F (%DM)	1.2	1.9	1.38	1.12	0.383
Ca (%DM)	1.4	2.8	1.96	1.94	0.090
ADF (%DM)	19.5	28.4	24.62	3.01	0.013*
NDF (%DM)	34.5	49.1	41.25	8.99	0.000***
LIG (%DM)	16.4	20.4	18.15	0.47	0.881
Hcell (%DM)	6.6	29.6	15.94	7.38	0.000***

Min: Mean of a population, Max: Mean of a population, Mean: Mean of the species, Probability (signification): *5%; **1%; ***0.1 %, SE: Emergence of seedlings; NP: No. of plants m^{-2}; HM: Maximum height, WM: Maximum width, 1F: Date of appearance of the first inflorescences, CD: Cut date, GM: Weight of green matter m^{-2}; MM: Mineral matter, OM: Organic matter, CF: Crude fiber, F: Fat, Ca: Calcium, TN: Total nitrogen, ADF: Acid detergent fiber, NDF: Neutral detergent fiber, LIG: Lignin, Hcell: Hemicellulose

Table 3: Variation of some yield components in algerian populations of sulla (descriptive statistics)

Parameters	Minimum	Maximum	Mean	Standard deviation	Coefficient of variation (%)
TSW (g)	3.810	5.370	4.556	0.488	10.71
GMY (kg ha^{-1})	1845.300	8224.300	4661.370	2093.400	44.91

Minimum: Value reached by a population, Maximum: Value reached by a population, Mean: Mean value of the species, TSW: Thousand seed weight, GMY: Green matter yield

Table 4: Relations between the parameters linked to the growth, the chemical composition and the ecological factors of the natural habitat in some algerian populations of *sulla*

Parameters	TSW	SE	NP	HM	1F	CD	GM	GMY	MM	OM
HM	-0.130	-0.280	0.872	-	-0.191	-0.484	0.473	0.473	-0.403	0.403
	0.719	0.434	0.001***		0.597	0.156	0.168	0.168	0.249	0.248
CD	0.183	0.677	-0.618	-0.484	0.816	-	-0.346	-0.346	0.241	-0.235
	0.614	0.032*	0.057	0.156	0.004**		0.327	0.327	0.502	0.513
GM	0.573	-0.441	0.637	0.473	-0.076	-0.346	-	1.000	-0.349	0.350
	0.084	0.202	0.048*	0.168	0.835	0.327		0.000***	0.323	0.322
GMY	0.573	-0.441	0.637	0.473	-0.076	-0.346	1.000	-	-0.349	0.350
	0.084	0.202	0.048*	0.168	0.835	0.327	0.000***		0.324	0.322
OM	0.471	-0.368	0.438	0.403	-0.325	-0.235	0.350	0.350	-1.000	-
	0.169	0.295	0.205	0.248	0.359	0.513	0.322	0.322	0.000***	
F	0.458	-0.048	0.070	-0.170	-0.062	-0.039	0.638	0.638	-0.076	0.074
	0.183	0.896	0.848	0.639	0.865	0.914	0.047*	0.047	0.834	0.839
Ca	-0.306	0.012	0.280	0.381	0.358	-0.151	0.158	0.158	0.387	-0.381
	0.390	0.974	0.433	0.278	0.310	0.678	0.664	0.664	0.269	0.277
TN	0.021	0.392	-0.753	-0.639	0.088	0.392	-0.151	-0.151	0.385	-0.393
	0.955	0.263	0.012*	0.047*	0.810	0.263	0.677	0.677	0.272	0.261
ADF	-0.173	0.756	-0.558	-0.333	0.203	0.431	-0.564	-0.564	-0.039	0.036
	0.633	0.011*	0.094	0.347	0.573	0.214	0.089	0.089	0.915	0.920
NDF	0.253	-0.625	0.599	0.472	-0.715	-0.700	0.304	0.304	-0.676	0.673
	0.480	0.053	0.067	0.168	0.020*	0.024*	0.393	0.393	0.032*	0.033*
Hcell	0.207	-0.773	0.622	0.466	-0.758	-0.701	0.387	0.387	-0.611	0.606
	0.565	0.009	0.055	0.174	0.011*	0.024*	0.269	0.269	0.061	0.063
R	0.328	0.152	-0.074	0.039	0.130	0.196	0.136	0.135	-0.387	0.389
	0.355	0.676	0.838	0.916	0.721	0.587	0.709	0.709	0.270	0.267
ALT	0.082	-0.087	-0.371	-0.537	-0.134	-0.086	-0.107	-0.107	0.249	-0.253
	0.822	0.812	0.291	0.109	0.711	0.814	0.768	0.768	0.487	0.480

Content of cell: Pearson correlation, Probability (signification): *5, **1 and ***0.1%, TSW: Thousand seed weight, SE: Emergence of seedlings, NP: No. of plants m^{-2}, HM: Maximum height, 1F: Date of appearance of the first inflorescences, CD: Cut date, GM: Weight of green matter, MM: Mineral matter, OM: Organic matter, F: Fat, Ca: Calcium, TN: Total nitrogen, ADF: Acid detergent fiber, NDF: Neutral detergent fiber, LIG: Lignin, Hcell: Hemicellulose, ALT: Altitude, R: Rainfall

No. of plants m^{-2} (0.048*). The populations with a high content of organic matter, have a low mineral matter content (0,000***). The populations with a high fat content also have a high green matter yield (0.047*). The populations with a high total nitrogen content, have a weak No. of plants m^{-2} (0.012*) and a weak final height (0.047*). The populations with a high content of ADF are late for the emergence of seedlings (0.011*). The

populations with a high NDF content are characterized by an early appearance of the first inflorescences (0.020*), an early date of the beginning of the bloom (cutting date) (0.024*) and have a low mineral matter content (0.032*) and a high content of organic matter (0.033*). The populations with a high content of hemicellulose, present an early appearance of the first inflorescences (0.011*) and an early beginning of the bloom (cutting date) (0.024*).

Through this analysis, the ecological factors (altitude, rainfall) of the natural habitats of the populations don't seem to have an impact on the parameters linked to the growth and the chemical composition of the plants.

Principal component analysis: The principal component analysis covered ten populations and 19 variables. The plan 1-2 extracted 53.69% of the information.

According to the decreasing contribution of the variables (%), the most important variables appear as follows through, the axes 1 and 2 (Fig. 1)

ALT > WM > R > Hcell > NDF > NP > SE > HM > CD > 1F>MM>OM>CF>GM>TN>ADF>Ca>LIG>F

Overall, the results showed a good distribution of variables across 1 and 2 axes (Fig. 1) and the important contribution of a number of parameters, particularly the final width, the hemicellulose and NDF contents. Concerning the ecological factors, they are well represented, with a greater contribution of the altitude, compared to the rainfall.

The dispersion of populations and variables showed that axis 1 is the axis of the architecture (height), the bloom and the chemical composition. The axis 2 is the axis of the architecture (width/ground cover) and the ecological parameters (Fig. 2).

The axis 1 is positively represented by five variables (NP, HM, OM, NDF, Hcell) and a group (A) of three populations (3, 4 and 7). Overall, this first group of populations is more efficient concerning the No. of plants m^{-2}, the organic matter and presents a higher content of NDF and Hcell. Negatively, the axis 1 is represented by six variables (SE, 1F, DC, MM, TN, ADF) and a second group (B) consisting of three populations (1, 8, 10). These ones are generally later for the emergence of seedlings and the bloom and richer in mineral matter, total nitrogen and ADF compared to the populations of the group A (Fig. 2).

The axis 2 is positively represented by two variables (HM and ALT) and a group (C) of two populations

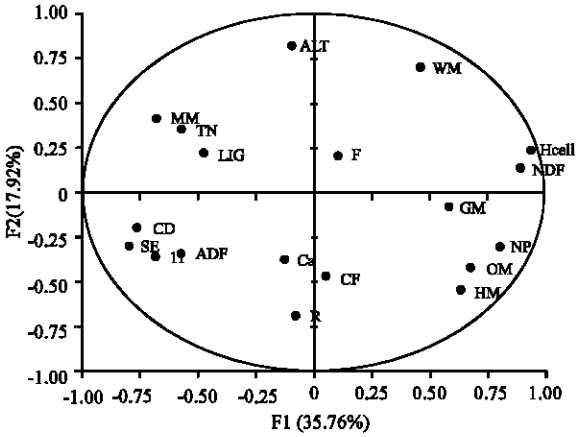

Fig. 1: Circle of correlations (variables) of the principal component analysis in algerian populations of sulla, SE: Emergence of seedlings, NP: No. of plants m^{-2}, HM: Maximum height, WM: Maximum width, 1F: Date of appearance of the first inflorescences, CD: Cut date, GM: Weight of green matter, MM: Mineral matter, OM: Organic matter, CF: Crude fiber, F: Fat, Ca: Calcium, TN: Total nitrogen, Hcell: Hemicellulose, ADF: Acid detergent fiber, NDF: Neutral detergent fiber, LIG: Lignin, ALT: Altitude, R: Rainfall

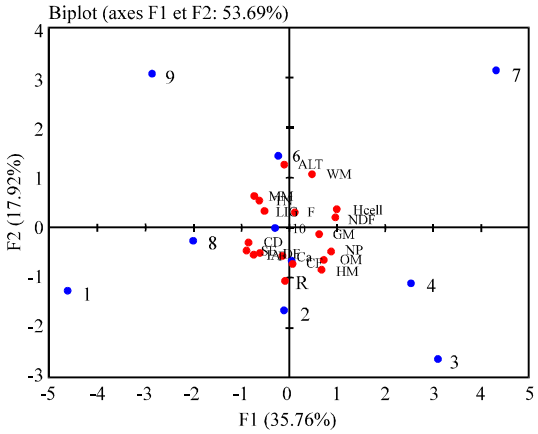

Fig. 2: Dispersion of individuals (populations) of the principal component analysis in algerian populations of sulla, Groupe A (populations 3, 4, 7); Group B (populations 1, 8, 10); Group C (populations 9, 6) and Group D (populations 2, 5)

(9 and 6). These populations coming from the high altitude areas are characterized by a weak height. Negatively, the axis 2 is represented by only one variable (R) and a group (D) of two populations (2, 5) (Fig. 2).

This descriptive analysis indicated also that the number of populations linked to the axis 1 is higher and the populations present, in general, a better quality of representation (square cosinus) than those corresponding to the axis 2 (Fig. 2).

DISCUSSION

In Algeria, the distribution of sulla is conditioned by the variation and the interaction of three ecological factors (edaphic, climatic, topographic) (Issolah *et al*., 2012). The altitude and the rainfall affect the physico-chemical properties of different soils on which sulla was met, with a more pronounced effect of the first factor (altitude), particularly on the physical parameters (Issolah *et al*., 2012).

Moreover, previous results showed that the altitude intervenes, more frequently than the rainfall, on some morpho-physiological characteristics of sulla (Issolah and Khalfallah, 2007). The algerian population of sulla which come from the high altitude areas, were characterized by a week vegetative development (Issolah *et al*., 2001).

According to Le Houerou (1979), the variation of forage quality is important between the populations of sulla.

The present study highlighted a significant variation between the populations regarding eight variables among which five are linked to the growth aspects (NP, WM, HM, DC, GM) and three are related to the chemical composition (NDF, ADF, Hcell) of the plant.

The results are, on average, relatively higher than those cited by some authors (Arab *et al*., 2009; Martiniello *et al*., 2000; Selmi *et al*., 2010) in terms of mineral matter and NDF contents. There are also relatively lower in the case of organic matter and the content of ADF. However, the parameter that has attracted the attention is the content of total nitrogen with 8.03% MS whereas it varies, on average, between 18.8 and 21.03% MS in those studies (Arab *et al*., 2009; Martiniello *et al*., 2000; Selmi *et al*., 2010).

Moreover, the results of the correlation matrix indicated that the total nitrogen content is negatively correlated with the No. of plants m^{-2} and the final height. In addition, the reduced total nitrogen content could be explained by the complete absence of fertilization in the plot of land reserved to this study. In this case, the atmospheric nitrogen fixed by the plant (legume/nodules) would be its main source of supply for nitrogen.

Concerning the thousand seed weight and the green matter yield, the results indicated a variation between the different populations without any links with the ecological factors (altitude, rainfall) of the natural habitats. A previous study conducted on fourteen algerian populations of sulla signalized a positive correlation (significant) between the thousand seed weight and the altitude of the environment of origin (Issolah and Khalfallah, 2007).

According to Arab *et al*. (2009), the fiber proportions of ADF and NDF of some studied forages are the indications of their nutritional value; when NDF fibers increase, the voluntary consumption of dry matter decreases; for ADF fibers, they are usually related to the digestibility and energy value of the feed; the more there are ADF fibers in the feed, the more the digestibility and the energy content are low (Arab *et al*., 2009).

Many relationships have also been highlighted between the growth parameters and the parameters related to the chemical composition of sulla.

The principal components analysis revealed the existence of some variation concerning the characteristics related to the vegetative growth, the bloom and the chemical composition of populations coming from different regions of the North East of Algeria. The variation exists also between populations originating from the same region of the country, particularly those of Guelma and, with a lesser extent, Bejaia. This analysis signalized also the part, respectively, of the altitude and the rainfall characterizing the natural habitats of the populations.

Through a study related to the nutritive value of sulla, Borreani *et al*. (2003) show the variation of crude protein concentration for the cultivars in two different Mediterranean sites.

This research work (growth and chemical composition) follows the previous studies (Issolah *et al*., 2006, 2011, 2012; Issolah and Khalfallah, 2007) conducted on different aspects (inventory of the natural forage associations, ecology, morpho-physiology, chromosomic variation) characterizing the populations of sulla coming from the different natural habitats of Algeria. This permits a better understanding of the nature of variation established within this species.

CONCLUSION

This study permitted to highlight the existence of variation between the different populations and to establish many relationships between the growth and the chemical composition parameters within sulla. This constitute a basis of assessment of nutritive value of this forage legume through the future use of livestock in order to determine the coefficient of digestibility, the most suitable, based on populations coming from different natural habitats. Moreover and because of the influence

of some ecological factors on the behaviour of sulla, a higher number of populations would give more information in this framework. It would allow to verify and confirm the existence or not of any relationship between the parameters related to the chemical composition and the different ecological factors. This research work would contribute to guide a future selection program suitable for the different agro-edapho- climatic conditions of each region.

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