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Mineral Composition and Genetic Variability of Some Mediterranean Populations of the Cultivated Alfalfa (*Medicago sativa* L.) Supported by Morphological Markers

L. Touil, F. Guesmi, K. Farès, C. Zagrouba and A. Ferchichi
Institute of the Arids Areas, Médenine, Tunisia

Abstract: The objective of this study was to investigate the differentiation level among 35 populations in which 20 are locals originating from the Tunisian South and 15 introduced from Italy, Australy, France and Morocco with morphologicals traits and mineral composition. The tenors of sodium, potassium and phosphorus were determined. Diversity according to the mineral composition and morphologicals characters inter populations were analyzed by two statistical procedures, Hierarchical classification and Correspondence Factorial Analysis. Its conclude that the local's populations were adapted at worst conditions in South Tunisian.

Key words: *Medicago sativa*, mineral composition, morphological traits, diversity, hierarchical classification

INTRODUCTION

Alfalfa has been proven to be one of the most productive forage crops and also one of the most effective man-planted vegetations to conserve soil and water and to fix soil nitrogen. Its interest were: Forage very rich in proteins, its contribution of the fertility of the ground. The various possible uses of Lucerne forage are direct animal feeding and also industrial treatments: Dehydratation and now protein extraction, perhaps fiber extraction. The improvement of these characters is necessary for the feeding of highly productive animals. The *M. sativa* complex shows a large genetic variability due to both natural and human selection under various climates and locations. It's an autotetraploid, with 2n = 4x = 32 and allogame species. The genetic progress in this species is slow because of its autotetraploidy, allogamy synthetic structure of the varieties. This species is characterized by a great morphological and agronomic variability (Julier *et al*., 2000) adopted in the programs of genetic improvement and the development of the cultivars with a very significant output (Julier *et al*., 2000). Several researchers were discussed around taxonomic classification the alfalfa (*Medicago sativa*). Lesins and Lesins (1979) consider that the complex *Medicago sativa* gathers three pennies species: Under species sativa which are characterized by flowers violets with pods without spines, under species falcata which is characterized by yellow flowers with pods with spines and under species glomerata which is characterized by flowers violets and pods with épines. Le Medicago kind is well represented in Tunisia. It constitutes a genetic inheritance extrémement richeet divérsifié (Seklami and Hansen, 1990). Contrary to the annual alfalfas, the culture of the perennial alfalfa is not new in Tunisia. It is very old on the level of the oases of the country (Le Houérou, 1969). It is the fodder plant most employed in irrigation. Its culture in dryness is a recent practice going back only to one score of years (Le Houérou, 1965).

MATERIALS AND METHODS

Plant material: Thirty five populations of the cultivated alfalfa (*Medicago sativa* L.) were involved in the study, including 20 local originating in the Tunisian South and 15 introduced (Table 1).

This study was carried out in experiment field of Institute Arid Area of Medenine Tunisia. Seeds of different genotype were sowed in April 2005. The measurements were carried two month after this date. The collect of vegetable material was realised in July 2005. The young leaflet were extracted, dried and conserved at 40°C for other use.

Morphological traits: The study of morphological variability is carried using 9 quantitative descriptors chosen according to the list of descriptors IPGRI. These parameters can be divided into vegetative parameters such as the length of the central leaflet (LFC), the width of the central leaflet (lFC) and the leaf area (SFC), the No. of

Corresponding Author: Leila Touil, Institute of the Arids Areas, Médenine, Tunisia Tel: (216) 75 633 005 Fax: (216) 75 633 006

Table 1: List of different populations of cultivated alfalfa

Name	Origin	Code
Locals populations		
Kattana	Gabès (Tunisie)	P1
Chenchou	Gabès (Tunisie)	P2
Cheninni 1	Gabès (Tunisie)	P3
Cheninni 2	Gabès (Tunisie)	P4
Cheninni 3	Gabès (Tunisie)	P5
Teboulbou	Gabès (Tunisie)	P6
Metwia	Gabès (Tunisie)	P7
Ghannouch	Gabès (Tunisie)	P8
Zerkine	Gabès (Tunisie)	P9
Essdada	Tozeur (Tunisie)	P10
Bouhlel	Tozeur (Tunisie)	P11
Degach	Tozeur (Tunisie)	P12
Hamma jerid	Tozeur (Tunisie)	P13
Zaafarane	Kébili (Tunisie)	P14
Nouael	Kébili (Tunisie)	P15
Jerzinze	Kébili (Tunisie)	P16
El golaa	Kébili (Tunisie)	P17
Limaguess	Kébili (Tunisie)	P18
Douz	Kébili (Tunisie)	P19
Stiftimia	Kébili (Tunisie)	P20
Introduced populations		
Sardi	France	P21
Ecotiposiciliano	Italie	P22
ABT	Italie	P23
Ameristand	Italie	P24
Erfoud 1	Maroc	P25
Melissa	France	P26
Siriver	Italie	P27
Rich 2	Maroc	P28
Demnat 203	Maroc	P29
Tamantit	Italie	P30
Magali	France	P31
Prosemet	Italie	P32
Mamuntanas	Italie	P33
Cossouls	France	P34
Africaine	Australie	P35

primary branches (NBP) and the length of the plant (LP); morphological parameters in particular the No. of the flowers by plant (NFP) and No. it pods by plant (NGP) and finally certain parameters reflecting the fodder output which one can quote the dry weight of the stems (PST) and the dry weight of sheets (PSF).

The measurements are related to a cycle of development.

Mineral composition

Preparation of the extract vegetal

- Heat 1 g of powder at 500°C for 4 h
- Add 4 mL distilled water and 1 mL of hydrochloric acid
- Filter the mixture and to adjust with 100 mL by distilled water

This solution will constitute the basic extract for the analysis of sodium (Na^+), potassium (K^+) and phosphorus (P).

Sodium content and potassium: The contents of minerals are determined by photometer with flame. One prepares the standard solutions starting from solutions mothers, of concentration 1000 ppm.

Phosphorus content: The phosphorus content is determined by spectrophotometer. One prepares the standard solutions starting from a solution mother H_2PO_4.

RESULTS AND DISCUSSION

Morphological characteristics

Morphological parameters: The values of the descriptors studied for the various populations are shown in Table 2 which enables us to note that:

- The number of the primary branches (varies between 5 and 8) as well as the length of the plant (varies between 53 and 87 cm) do not show a variability between the local populations and those introduced:

Table 2: Quantitatively tested traits

Code	NBP	LP (cm)	LFCI (cm)	l FCI (cm)	SFCI (cm)	NI/P	NG/P	PSF	PST
P1	7	71	3.44	1.64	4.20	71	359	9.70	3.33
P2	6	76	3.27	1.17	3.83	56	48	4.30	2.50
P3	5	77	3.45	1.71	4.06	83	192	8.53	3.50
P4	5	87	3.30	1.50	3.53	87	356	14.03	4.23
P5	6	78	2.90	1.35	2.63	123	311	9.76	4.50
P6	8	76	3.03	1.42	3.06	111	455	11.00	3.20
P7	5	70	3.22	1.69	4.10	68	289	8.46	4.16
P8	6	74	2.96	1.33	2.73	60	109	6.83	3.00
P9	6	78	3.30	1.64	3.73	73	142	9.93	4.86
P10	7	74	2.90	1.70	3.50	85	256	9.36	4.53
P11	8	61	3.19	1.86	4.26	103	172	8.66	4.53
P12	6	69	2.95	1.81	3.83	109	346	8.50	3.33
P13	6	82	3.28	2.22	5.13	123	442	13.70	6.76
P14	8	72	2.60	1.57	3.00	206	545	15.90	4.36
P15	7	64	3.13	1.44	3.33	179	274	10.80	4.36
P16	8	69	2.78	1.38	2.90	103	250	9.83	6.00
P17	7	74	2.68	1.22	2.33	95	150	6.40	3.90
P18	7	73	3.23	1.44	3.20	65	331	9.80	2.26
P19	7	78	3.47	1.70	4.03	113	215	8.76	4.63
P20	6	70	3.50	1.51	3.63	89	205	6.86	2.93
P21	7	72	2.80	1.40	2.65	69	98	3.80	2.00
P22	8	71	3.35	1.50	3.93	31	63	4.33	2.30
P23	8	64	2.74	1.51	2.96	33	12	4.10	3.03
P24	7	59	3.05	1.30	2.73	46	31	4.50	2.56
P25	8	58	2.72	1.45	3.03	68	115	5.46	3.80
P26	7	63	3.07	1.30	2.80	28	25	3.83	2.62
P27	8	75	2.52	1.22	2.53	47	67	5.32	4.30
P28	8	55	2.91	1.39	2.80	39	16	2.86	1.80
P29	6	64	2.83	1.50	3.20	28	18	3.40	1.50
P30	7	53	2.54	1.12	2.06	38	54	3.06	1.90
P31	8	60	2.77	1.66	3.73	10	18	4.75	3.75
P32	7	69	3.27	1.28	3.40	36	18	4.00	2.40
P33	7	68	2.84	1.44	2.70	51	29	4.36	2.80
P34	9	73	2.90	1.34	3.16	41	32	4.18	2.84
P35	7	62	2.35	1.18	2.03	16	19	2.90	1.83

- The length of central leaflet varies between 2.6 and 3.45 cm, that of the width lie between 1.17 and 2.22 cm and the leaf area vary between 2.03 and 5.15
- The number of inflorescences (ranging between 10 and 200) as well as the number of the pods (located between 16 and 545) are very significant at the local and weak populations with means at the introduced populations
- The dry weight of the sheets (which varies between 3 and 14 g) as that of the stems (which is located between 2 and 6 g) is shown more interesting at the local populations than that introduced

Hierarchical classification by combining all the parameters: The various studied populations are arranged in 4 groups by combining the vegetative and reproductive parameters (Fig. 1).

Group 1 (G1): With poor yield. It includes the total of introduced populations Magali, African, Ameristand 801S, Mamuntanas, Cossouls, Melissa, Demnat 203, ABT, Prosementi, Rich2, Ecisilia, Siriver, Tamantit, Sardi and Erfoud1; Some local's populations: Chenchou, Ghannouch, Chenenni1, Stiftimia, Douz, Zerkine, Elgolaa and Bouhlel. The characteristics of this group are: the central leaflet is characterized by a fairly significant length from 2.35 to 3.5 cm, an average width of 1.12 to 2.53 cm and a surface fairly significant ranging between 2.03 and 3.93 cm^2; an average height (53 to 77 cm); a number of the inflorescences (10 to 56) and pods (varying from 12 to 67) weak; a dry weight of the stems (between 1.5 and 3.75 g), that of the sheets (2.9 with 5.32 g) weak.

Group 2 (G2): It includes some local's populations: Essdada, Jersine, Metwia, Kattana, Chenenni 2, Limaguess, Chenenni 3, Dgach and Nouael. The characteristics of this group are: a height is very significant (64 with 87 cm); LE central leaflet is characterized by a significant length ranging between 2.8 and 3.5 cm, an also significant width from 1.4 to 1.8 cm and a significant surface located between 2.7 and 4.2 cm^2; a number of the inflorescences (65 to 179) and pods (250

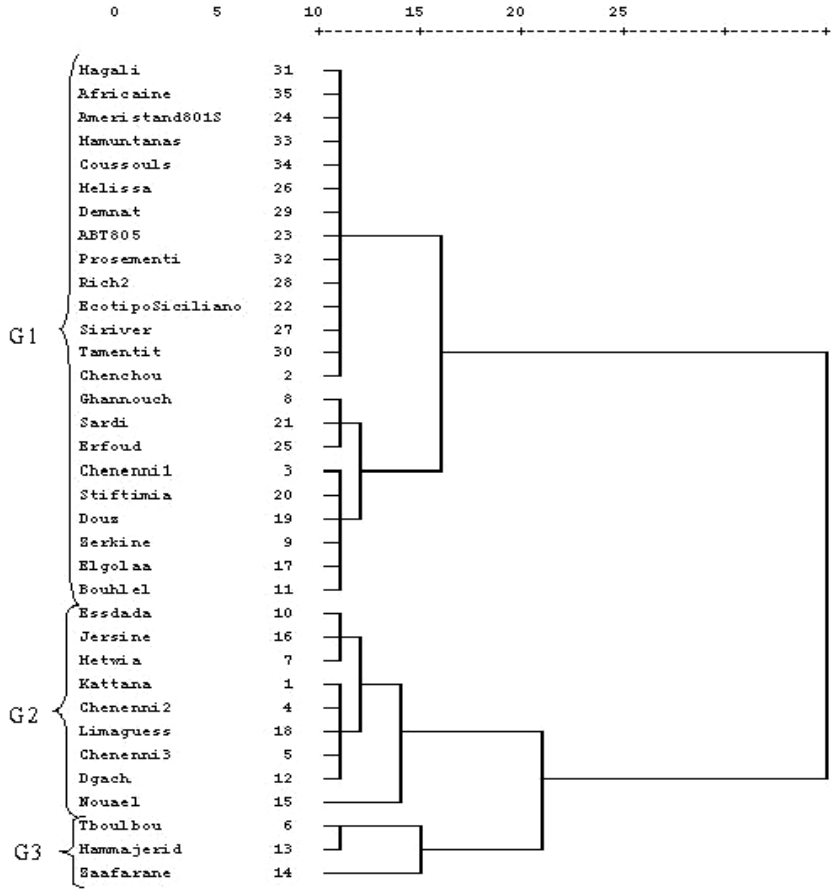

Fig. 1: Hierarchical classification of different populations based on morphologicals traits

and 359) significant; a dry weight of the stems (2.26 with 4.36 g), that of the sheets (8.5 and 14 g) significant.

Group 3 (G3): It includes 3 local populations: Tboulbou, Hamma Jerid and Zaafarane. The characteristics of this group are summarized as follows: a significant height (72 with 82 cm); the central leaflet is characterized by a significant length ranging between 2.6 and 3.3 cm, its width are also significant and vary from 1.42 to 2.22 cm and its surface significant is located between 3 and 5.13 cm^2; a number of the inflorescences (111 to 206) and that of the pods (442 to 545) very significant; a dry weight of the stems (3.2 and 6.75 g), that of the sheets (11 and 15.9 g) very significant.

Analyze factorial in principal components (ACP): The factorial analysis in principal components is a procedure making it possible to measure the performance of the various parameters. The percentage of inertia of various axes is shown in Table 3.

Table 3: Inertia percentage

Axes	F_1	F_2	F_3
Valeur propre	4.71	1.65	1.06
Variance	52.35	18.28	11.73
Cumulé (%)	52.35	70.63	82.63

The selected plan is formed by the two axes F_1 and F_2 which provide 71% of total information (Fig. 2).

Populations: Zaafarane, Teboulbou, Hamma Jerid, Nouael, Chenenni 2, Chenenni 3, are correlated with the positive part of F_2 axis. This group is characterized thus, by a significant length of plant, length of central leaflet, surfaces central leaflet and dry weight of stems; an average No. of primary branches; width of central leaflet means; very high numbers of inflorescences and pods by plant.

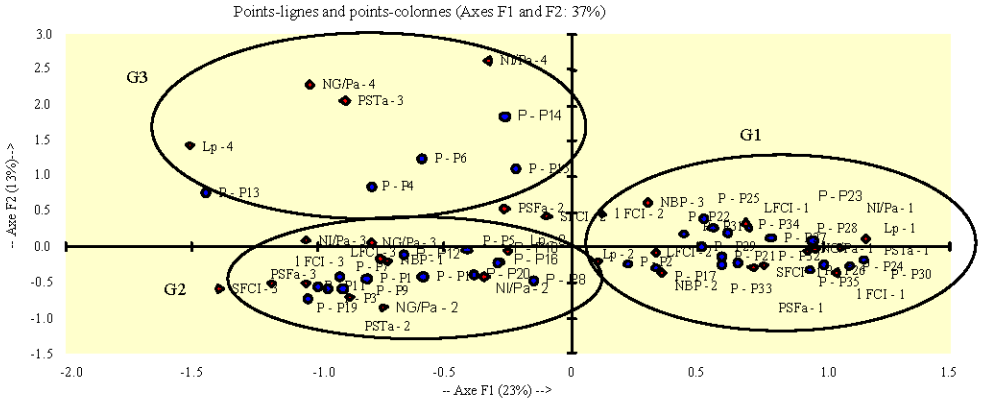

Fig. 2: Superposition of different populations and the quantitative traits with the two axis F1 et F2; P-P1: Kattana; P-P2: Chenchou; P-P3: Cheninni 1; P-P4: Cheninni 2; P-P5: Cheninni 3; P-P6: Teboulbou; P-P7: Metwia; P-P8: Ghannouch; P-P9: Zerkine; P-P10: Essdada; P-P11: Bouhlel; P-P12: Degach; P-P13: Hamma jerid; P-P14: Zaafarane; P-P15: Nouael; P-P16: Jerzinze; P-P17: El golaa; P-P18: Limaguess; P-P19: Douz; P-P20: Stiftimia; P-P21: Sardi; P-P22: Ecotiposiciliano; P-P23: ABT; P-P24: Ameristand; P-P25: Erfoud 1; P-P26: Melissa; P-P27: Siriver; P-P28: Rich 2; P-P29: Demnat 203; PP-30: Tamantit; P-P31: Magali; P-P32: Magali; P-P33: Mamuntanas; P-P34: Cossouls; P-P35: Africaine; NG/P: Number of Pods by Plants; PST: Dry weight of stems; PSF: Dry weight of sheets; LP: Length of plant; NI/P: No. of inflorescence by plant; SFC: Area of central leaflet; LFC: Length of central leaflet; lFC: Width of central leaflet

The populations Dgach, Kattana, Bouhlel, Essdada, Chenenni 1, Douz, Stiftimia, Chenenni 3, Ghannouch, Jersine and Limaguess are concentrated of the negative part of F1 axis. This group is characterized by: Significant length of the plant and length of central leaflet; a lower No. of primary branches; a high No. inflorescences and pods by plant.

Following populations: Sardi, Esicilia, ABT, Ameristand, Erfoud, Melissa, Siriver, Rich 2, Demnat 203, Tamentit, Magali, Prosemet, Mamuntanas, Cossouls, Africane, Chenchou and Elgolaa are concentrated to the positive part of the F_1. This group of populations is characterized by: low length of plant, low No. primary branches, No. inflorescences and pods by plant; low length and width of central leaflet; average surface central leaflet; low dry weight of the stems and the sheets.

Mineral composition

Sodic profile

Sodium contents: The sodium contents of the various populations are represented by Table 4 which shows that the sodium contents vary between 06 and 0.159%.

Hierarchical classification: The sodium contents are analyzed by the software SPSS which group all the

Table 4: Sodium percentage for the different populations of Lucerne

Population	Na^+ (%)
P1	0.102
P2	0.092
P3	0.061
P4	0.102
P5	0.123
P6	0.123
P7	0.113
P8	0.129
P9	0.123
P10	0.092
P11	0.0815
P12	0.113
P13	0.102
P14	0.092
P15	0.0815
P16	0.102
P17	0.139
P18	0.123
P19	0.129
P20	0.102
P21	0.129
P22	0.113
P23	0.123
P24	0.102
P25	0.113
P26	0.129
P27	0.123
P28	0.061
P29	0.123
P30	0.0815
P31	0.139
P32	0.102
P33	0.159
P34	0.113
P35	0.071

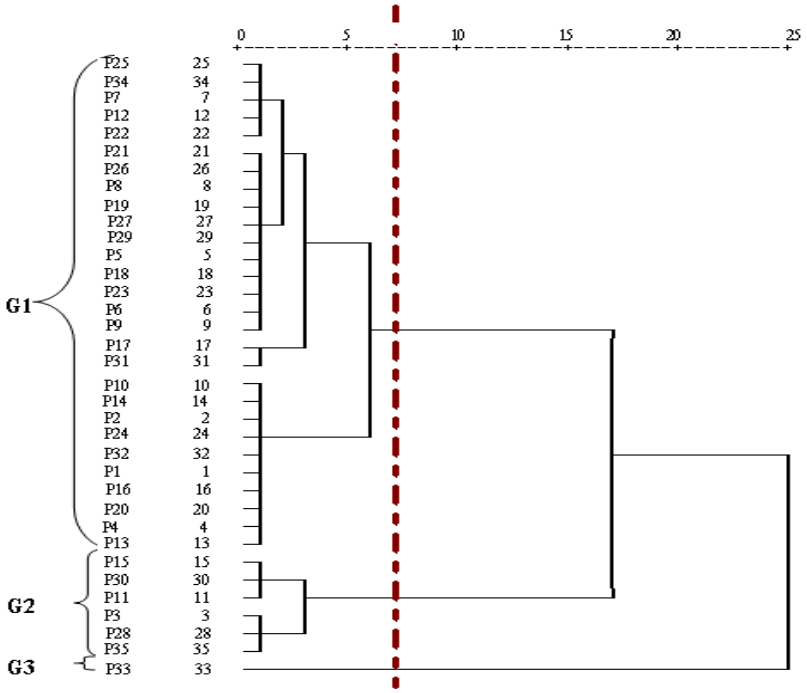

Fig. 3: Hierarchical classification with Na^+ composition

populations in 3 groups carried by the dendrogram from Fig. 3.

Group 1 (G1): Included: Erfoud, Cossouls, Metwia, Degach, EcotipoSiciliano, Sardi, Melissa, Ghannouch, Douz, Siriver, Demnat 203, Erfoud, Cossouls, Metwia, Essdada, Zaafarane, Kattana, Ameristand 801S, Prosementi, Jersine, Staftimia, Cheninni 2 and Hammajerid which are characterized by high percentages of sodium (ranging between 0.092 and 0.139%).

Group 2 (G2): Included populations: Chenenni1, Rich 2, African, Bouhlel, Nouael and Tamantit which are characterized by low contents (located between 0.061 to 0.08%).

Group 3 (G3): Included only one population, it is Mamuntanas which is characterized by content very high sodium (0.159%).

Potassic profile

Potassium contents: The potassium contents for the various populations are shown in Table 5, the potassium contents varied between 1.08 and 2.64%.

Table 5: Potassium percentage (%) for the different populations of Lucerne

Population	K^+ (%)
P1	1.32
P2	1.56
P3	1.68
P4	1.92
P5	2.04
P6	1.92
P7	2.16
P8	1.80
P9	2.52
P10	2.40
P11	2.16
P12	2.28
P13	2.16
P14	2.28
P15	2.40
P16	2.16
P17	2.52
P18	2.64
P19	1.92
P20	2.40
P21	1.80
P22	2.16
P23	1.08
P24	1.44
P25	1.68
P26	2.28
P27	1.68
P28	1.92
P29	1.44
P30	1.92
P31	1.92
P32	2.28
P33	2.04
P34	2.64
P35	2.28

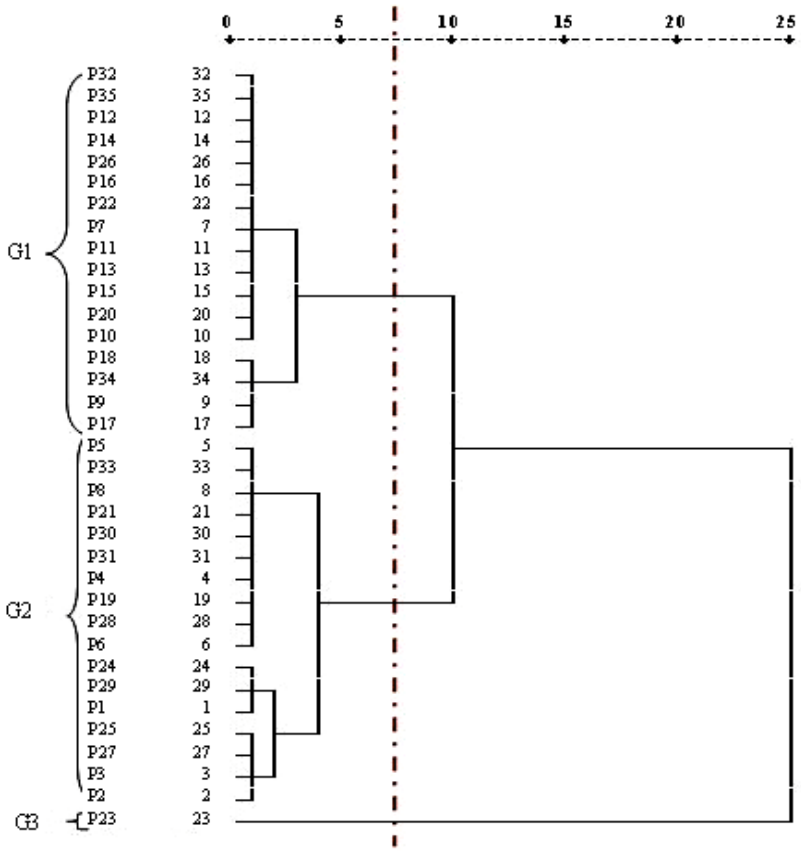

Fig. 4: Hierarchical classification with K^+ composition

Hierarchical classification: The potassium contents are analyzed by the software SPSS which made it possible to group the various populations in 3 groups carried by the dendrogram of Fig. 4.

Group 1 (G1): Gathers the populations: Prosementi, African, Dgach, Zaafarane, Melissa, Jersine, EcotipoSicilia, Metwia, Bouhlel, Hamma jerid, Nouael, Stiftimia, Essdada, Limaguess, Cossouls, Zerkine and Elgolaa, which are characterized by potassium contents (ranging between 2.16 and 2.64%).

Group 2 (G2): Included: Chenenni 3, Mamuntanas, Ghannouch, Sardi, Tamentit, Magali, Chenenni 2, Douz, Rich 2, Tboulbou, Ameristand 801S, Demnat 203, Kattana, Erfoud 1, Siriver, Chenennil and Chenchou, of which average contents potassium (ranging between 1.32 and 2.05%).

Group 3 (G3): Included only one population; it is ABT805 which is characterized by the lowest potassium content (1.08%).

Phosphoric profile

Phosphorus contents: The phosphorus contents for the various populations of alfalfa are shown in Table 6 which shows that the phosphorus contents at these populations vary between 0.06 and 0.259%.

Hierarchical analysis: The phosphorus contents are treated by software SPSS version 12.0, the various populations were arranged in three groups carried by the dendrogram from Fig. 5.

Group 1 (G1): Formed by Tamentit, Cossouls, Bouhlel, Elgolaa, Ghannouch, Degach, Stiftimia, Tboulbou, Chenenni 2, Chenenni 3 and Zaafarane Limaguess, Prosemet, Essdada, Kattana, Esicilia, Mamuntanas, Melissa, Ameristand 801S, Rich 2, Erfoud 3, Jersine, Siriver, Hamma jerid, Nouael, Sardi, Chenenni1, Magali, Chenchou and Metwia which are characterized by average contents phosphorus (vary between 0.175 and 0.2%).

Group 2 (G2): Formed by only two populations which are ABT 805 and Demnat 203 and which is characterized

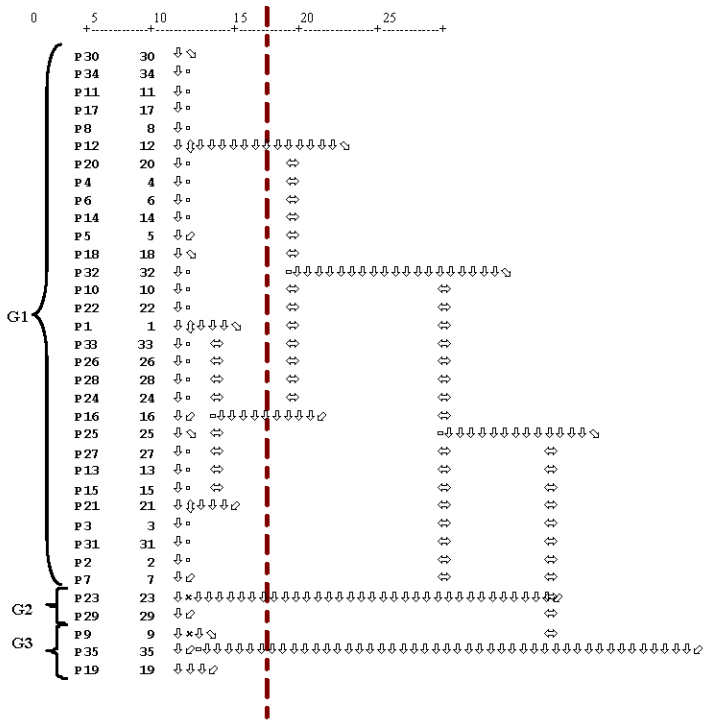

Fig. 5: Hierarchical classification with phosphorus composition

Table 6: Phosphorus percentage for the different populations of Lucerne

Population	P%
P1	0.150
P2	0.120
P3	0.134
P4	0.182
P5	0.175
P6	0.183
P7	0.124
P8	0.188
P9	0.254
P10	0.160
P11	0.200
P12	0.187
P13	0.110
P14	0.185
P15	0.100
P16	0.145
P17	0.210
P18	0.160
P19	0.270
P20	0.190
P21	0.100
P22	0.162
P23	0.070
P24	0.140
P25	0.110
P26	0.140
P27	0.110
P28	0.140
P29	0.060
P30	0.200
P31	0.130
P32	0.160
P33	0.150
P34	0.200
P35	0.240

by low contents of phosphorus (ranging between 0.06 and 0.07%).

Group 3 (G3): Formed by three different populations which are: African Zerkine, Douz and which is characterized by high percentages of phosphorus (ranging between 0.24 and 0.274%).

Combination of various minerals: Software SPSS 12.0 allows the classification of the various populations studied by combining three minerals according to the dendrogram of Fig. 6, presenting 3 different groups.

Group 1 (G1): Included: Erfoud 3, Siriver, Chenenni1, Chenchou, Ghannouch, Sardi, Chenenni 2, Tboulbou, Tamantit, Rich 2, Magali and Douz which are characterized by average contents of potassium, sodium and phosphorus.

Group 2 (G2): Formed by: Ameristand 801S, Demnat 203, Kattana and ABT 805 which are characterized by high percentages of sodium, averages out of potassium and contents fairly weak phosphorus.

Group 3 (G3): Formed by: Limaguess, Cossouls, Zerkine, Elgolaa Chenenni 3, Mamunts, Metwia, Hamma Jerid, Jersine, Esicilia, Bouhlel, Essdada, Stiftimia, Nouael,

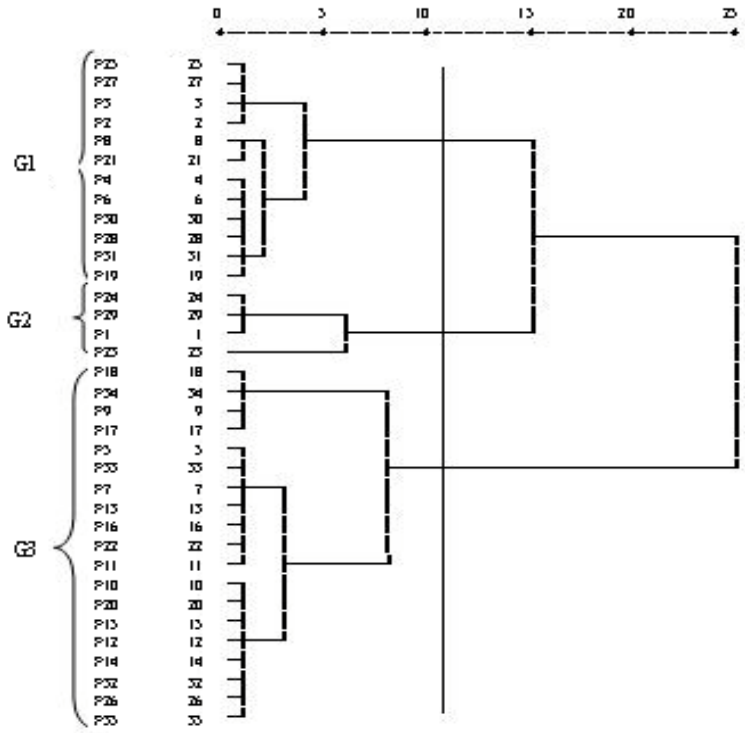

Fig. 6: Hierarchical classification by combing all parameters

Degach, Zaafarane, Prosemet, Melissa and African, which is characterized by high percentages of sodium and potassium and average contents phosphorus.

DISCUSSION

At the alfalfa (*Medicago sativa* L.) the new studied parameters made it possible to differentiate the various populations. The groups highlighted are distinguished geographically. The introduced populations form a separated group with weak performances. The local populations present average performances at high. Variability is rather weak or null on the level of parameters (LP, NBP, LFC, IFC and SFC). However on the level of the parameters of reproductions (NIP and NGP) as well as parameters of output (PSI and PSF), variability remain significant and can constitute a parameter of characterization of genetic variability.

The importance of a number of pods was stressed by other study (Laouar and Abdelguerfi, 2000). The morphological characterization of the alfalfa was approached by other research tasks of which those on *Medicago truncatula* and *Medicago laciniata* on *Medicago ciliaris* on Medicago polymorpha and *Medicago orbicularis* and out of *Medicago sativa* L. in the area of Ouargla (Algeria) which shows that the variety Gabès 2355 is relatively more productive than the other local populations. It is characterized by a fresh weight, a dry weight, a number of ramifications, a height of the plant, a No. of the inflorescences by plant and a No. of seeds by relatively significant plants and a No. of seeds. Other quantitative parameters were studied at *Medicago sativa* L. by Jenczewski *et al*. (1999), in particular, leaf area, the length and the diameter of the stem, the number of primary branches and the vegetative productivity. This study shows significant differences inter populations and finds that these parameters can characterize variability. In addition 17 criteria relating to the development vegetative and reproductive were studied at 28 populations of *Medicago polymorpha* and they are analyzed by statistical procedures (variance analysis, varied analysis multi...), it was shown that the parameters of flowering (precocity, a number of flowers by inflorescence) contribute more to the structuring of variability.

The composition out of sodium, potassium and out of phosphorus shows a significant variability between the populations. In this study the sodium contents vary from 0.061 to 0.159 %, those out of phosphorus lie between 0.06 and 0.274%, whereas those out of potassium vary between 1.08 and 2.67%. These results agree with those obtained by Mauriès (2003). This same researcher showed

that the alfalfa is rich in other minerals, in particular, the magnesium whose contents vary between 0.12 to 0.22% and the calcium whose content varies from 1.1 to 1.9%.

It proved that the alfalfa (*Medicago sativa* L.) is richer in potassium than out of sodium or phosphorus. This gradient of content of minerals, also, is obtained at *Artemisia bleached* on *Grass alba*. According to the variability of the mineral composition at the plants can be allotted to the nature of the ground which can change a site of taking away to the other, to the climatic conditions which vary from one place to another (pluviometry, altitude, temperature) and the age of the plant without forgetting the period of the collection.

The highest content sodium characterizes the introduced population, Mamuntanas. Whereas the lowest content (0.06%) characterizes the two populations: Chenenni1 and Rich2. For potassium, the majority of the local populations are characterized by high contents (between 2.16 and 2.64%), whereas the majority of the introduced populations are characterized by average contents with weak (between 1.08 and 2%). The phosphorus content is average for all the populations (ranging between 0.175 and 0.2%), except for Zerkine, Douz and African which show the rather high contents (0.24 and 0.274%). However the two introduced populations, ABT 805 and Demnat 203 are characterized by the lowest contents (between 0.06 and 0.07%). It was shown that the alfalfa produced in the irrigated perimeters is richer in potassium than that produced in the oases, whereas the phosphorus contents remain almost identical in the two agro systems. For its part showed that the sodium contents, out of potassium and phosphorus are variable on the level of the 4 populations of alfalfa originating in the Tunisian south. In addition this author showed that under the combined action of the saline stress and the irradiation by the R have γ has provoqu a 3rd enrichment of air fabrics out of Na^+ more particularly on the level of the sheets and stems. The high Na amounts$^+$ in the medium of watering, generated a certain competition on the level of the sites of absorption of K^+ and thus limited the absorption of this essential element for the growth and the development of the plant.

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