

Chapter

Nutritional Value of Some Algerian Legumes from the *Medicago* Genus

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Abstract

In this work, we studied about some populations of spontaneous annual alfalfa from Algeria: *Medicago ciliaris* (Population.: S and C); *Medicago intertexta* (Population.: I); *Medicago truncatula* (Population.: Tr); *Medicago polymorpha* (Population.: Poly) and incidentally *Medicago granadensis*, *Medicago muricoleptis*, and *Medicago sativa*. All crops are grown under rainfed conditions. The vegetative parameters were harvested at the early flowering stage and chemical analyses: nitrogenous matters (CP), walls, and mineral matter were carried out at the early flowering stage and *in vitro* digestibility for some of these populations is also carried out. The number of stems per m² measures the vigor of plant development, approaching on average 1000 units with a reasonable standard deviation of 0.33 on 21 populations. Tr 27 stands out with 1340 stems/m² close to the control *M. muricoleptis* (1300 stems), and the minimum recorded is for another *M. truncatula*, Tr238: 410 stems. The 2015 crop, although their growth and development were weaker, their stems had more leaves than stems compared to that of 2013. The average *in vitro* digestibility corrected by the control of the *in vivo* reference digestibility varies from 73.37 to 77.14%.

Keywords: annual alfalfa, morphometry, chemical composition, digestibility, plant genetic resources

1. Introduction

Following independence, through successive agricultural development plans, up to the national agricultural development plan in 2000 and its extensions, national rural agricultural development plan, regional rural agricultural plan, and the national regional agricultural development fund for financing, the search for food security has always been the objective.

Among the dormant sources of productivity, the most important is the absorption of fallow land [1–3]. Indeed, Algerian agriculture is characterized by a traditional agricultural system based on the triptych: wheat-fallow-livestock (brought by the Romans almost 2000 years ago). In 1981, fallow represented 47% of the land and still 43% (more than 3 million ha) today [3, 4]. For grazing animals, it would only provide between 200 and 360 fodder unit/ha [1, 2], while the deficit in fodder units amounts to 3–4 billion UF out of a need of 10–12 billion.

For years, voices have been raised to encourage the profession to adopt a cereal alfalfa rotation, which has the advantage of increasing wheat yield at lower cost (alfalfa as an antecedent enriching the soil with nitrogen), but also that of fodder unit production that could reach up to 1500 units/ha [5]. An animal weight gain of 400 kg without counting the weight of the wool is indicated by Gachet [6].

This production system called Ley-Farming has been, and continues to be, very successful in Australia. Experimented in Algeria in the 1970s, with Australian alfalfa varieties, unsuitable for Algerian conditions, the results were not convincing. Hope then focused on the country's very numerous species and populations of spontaneous alfalfa. For 40 years, they have been inventoried and harvested and their qualities have been studied, in order to offer the best ecotypes to a selection program with a view to obtaining local varieties intended to be used in the alfalfa-cereal rotation to absorb the fallow all by intensifying agricultural production: killing two birds with one stone.

It is within this ambitious framework that our work begins with the heavy work of prospecting and harvesting carried out by our predecessors already in the nineteenth century (1873) by Urban Trabut (in Trabut) [7]. But also and above all for almost 50 years: the 70s and 80s as mentioned in Refs. [8–11]. This fruitful prospecting still continues, since, recently, Boulaacheb *et al.* [12] identified *M. sativa* L in DjebelMegriiss, north of Sétif in fields and bushes as well as two annual species (*M. hispida* and *M. orbicularis* L). In another plant survey in DjebelYoucef and DjebelZdim south of Sétif, Chermat *et al.* [13] recorded seven species of annual alfalfa (*M. hispida*, *M. minima*, *M. tuberculata*, *M. laciniata*, *M. secundiflora*, *M. intertexta*, and *M. tribuloides*).

At the same time, numerous works were devoted to the adaptation of foreign varieties in our country before independence (works of Laumont [14] and Couranjou [15]) and after independence by research establishments such as: national higher agronomic school, technical institute for field crops (ITGC), national agronomic research institute, which for the latter cases, probably, did not allow constant support to advance research toward obtaining varieties from local populations adapting to various pedoclimatic conditions of the territory: at least in the North of the country, because in the South local varieties are cultivated on a large scale with success (Aoulef, In Salah, El-Menia, Tamentit and Tamacine, Magali, Lodi, Chott, as witnesses).

This work, modestly, aims to continue research on the potential of our local populations of annual alfalfa with a view to submitting the best for selection, the final stage of this journey that began 50 years ago. It comes largely from the research work that we have been carrying out for 15 years at national agronomic research institute (INRA), but started at national higher agronomic school (ENSA) as part of Magister. Our objective at this stage of the work is not to propose populations of alfalfa to be popularized but to provide phenological, biometric, and nutritional parameters capable of being integrated into a selection program in order to configure, according to needs, the variety which would come out.

After a brief overview of plant classification and a more in-depth look at legumes, we will discuss the importance of legumes in the human economy, focusing more particularly on forage legumes from the *Medicago* genus, which are more particularly annual.

We present the collection of species and populations of spontaneous alfalfa from Algeria, collected and identified by national institutes (INRAA, ITGC, etc.) and school (ENSA) from which we will extract those whose characteristics and qualities will be studied under the 'corner [16]:

- Biomass production parameters,
- Linked to different phenological and biometric characteristics;
- Their chemical composition, and their nutritional value for the animal.

Our study methods having been specified, we will develop our results and discuss them.

2. Materials and methods

2.1 Plant material, sowing device, cultivation management

The plant material (species and populations of alfalfa) used in this work is taken from the collection of the Ecole Nationale Supérieure Agricole which has been built up over the years (**Table 1**).

The annual alfalfa species studied are categorized according to their color and size into three groups:

- Species with large seeds, *M. intertexta*, *M. ciliaris*, black in color,
- Species with medium seed weight, *M. muricoleptis*, black in color,
- Species with small seeds, *M. polymorpha*, *M. truncatula*, yellow-brown in color.

The species	Population code	1000 grain weight (Species)	Seed color	Native country
<i>M. ciliaris</i>	C ₂	13.21 g	Black	Algérie (2004)
	C204			
	C52			
	C59			
	S3			
	S5			
<i>M. truncatula</i>	Tr27	3.58 g	Yellow brown	Algérie (2004)
	Tr55			
	Tr221			
	Tr238			
	Tr 334			
	Tr407			
<i>M. intertexta</i>	I11	15.77 g	Black	Algérie (2004)
	I31			
	I40			
	I107			
	I756			
Witness	—	3.90 g	Black	Australia (—)

Table 1.
 Codes and origins of the populations studied as well as the average weight of 1000 grains.

In legumes, there is often a relationship between the coloring of the seed coats and the percentage of hard seeds [17]. The seed shape of all species is kidney-shaped. The first test was installed on 13/12/2012 (for data collection in 2013) and the second on 24/12/2014 (for data collection in 2015) at the ENSA experimental farm.

The test is of the complete randomized block type with three repetitions. Each block is spaced 1.50 m apart from the other for the first test and 60 cm for the second test. The surface area of the tests in 2013 was 3585.6 m² (228 m x 15.77 m) and 31,488 m² in 2012 (5248 m x 6 m). The tests were carried out dry and permanently maintained, against weed infestations.

2.2 Soil analysis

Soil analyses of samples taken from the soil of the two plots at a depth of 20 cm and 40 cm (P20 and P40) before sowing method [18] and AISS (International Association of Soil Science) carried out in 2012 and repeated in 2013 show a loamy-sandy texture (clay: 23%, sand: 41%, and silt 36%), for the two horizons 20 and 40 cm. This soil has a neutral pH (potentiometric method on an earth/liquid suspension equal to 1/2.5) to slightly alkaline (>7.23), a very low electrical conductivity (C.E. < 0.2dS/m: method: soil - 1504: total conductivity on extract 1/25 (m/v) at 25°C), indicating the absence of salinity, a limestone rate of 7% (moderately calcareous soils: Bernard calcimeter volumetric method).

For fertility parameters, the soil is well provided with organic matter (method: Walkley-Black): respectively 5.53% and 5.15% for the surface horizon and the subsurface horizon. This richness is the result of burying organic amendments.

The total nitrogen rate (method: Kjeldahl) of the surface and subsurface horizon is respectively 0.11 and 0.09, and this result is that of a soil very poor in nitrogen (Table 2).

The soil on both plots is poor, and we have not made any amendments. The analyses were carried out at the soil science department of ENSA in 2013 and 2015. The comparison with an experimental soil for alfalfa trials reported by Larbre *et al.* [19], whose previous crop of sorghum, is comparatively as follows (in ppm):

- Organic matter (in %): 3.21
- Phosphorus (ppm): 110
- Potassium (ppm): 288
- Magnesium (in ppm): 166

2.3 Climatic conditions

Table 3 shows the climatic conditions for the two years 2013 and 2015. The average temperature in the month of May for 2013 and 2015 was comparable (around 18°C) but colder in January and February in 2015 (9.4°C compared to 11.7 for 2013). On the other hand, while on average, for the first 4 months of 2013, 83 mm of rain fell, the quantity is only 69 mm in 2015 with a strong deficit in the month of May for 2013 and a near drought in April for the year 2015. More details are given in **Table 3**.

Settings	Year 2014		Year 2012	
	P20	P40	P20	P40
—	—	—	10.05	6.85
Average	0.7220		8.67	
Potassium mg/100 g	0.1750	0.1621	5.62	3.57
Average	0.1685		4.59	
Ph	7.22	7.75	7.23	7.0
Average	7485		7115	
CEE	0.1526	0.0654	—	—
Average	0.109			
Azote %	0.1121	0.0934	0.075	0.058
Average	0.1027		0.0665	
Organic material (%)	—	—	1.15	0.68
CaCo3 (%)	73.330	70.000	2.6	—
Average	71.665			
Argile (%)	21.2500	21.5000	25.0	25.5
Average	21.375		25.25	
Limon (%)	40.4900	39.7200	41.89	55.66
Average	39.605		48.77	
Sable (%)	38.2500	38.7800	27.75	8.06
Average	38.51		1790	
Texture	L	L	LA	LA

Bold in tables indicates means and standard deviation.

Table 2.
Sown soil analysis results.

Month	2013		2015	
	Average temperature in °c	Rainfall in mm	Average temperature in °c	Rainfall in mm
January	11.7	120.4	9.4	98.9
February	11.5	89.8	9.6	80.0
March	16.3	45.9	14.8	96.3
April	15.6	76.0	17.7	1.6
May	17.8	5.3	18.8	28.4
June	13.0	71.5	22.4	14.4

Table 3.
Climate data for 2013 and 2015.

2.4 Data records for vegetative parameters

Vegetative parameters are important to know in order to discriminate between alfalfa populations with a view to obtaining high-performance local varieties in the medium term, adapted to the needs of breeders. Thus, the leaf-to-stem ratio (F/T) is known to be related to the nutritional value of the plant as is the number of stems

for biomass production. The production of green and dry matter, the width of the branches, the number of stems per square meter, the length of the cycle are correlated. The % viability is given by the following formula:

$$\% \text{viability} = \text{number of plants mowed} / \text{number of seeds sown} \times 100$$

These data are taken at the start of flowering stage for 23 days: March 30 to April 21, 2015, explained by the completely logical variations in precocity observed, between blocks, between species, and between populations of the same species.

The instruments and tools used for the different operations are: pruners, measuring tapes, and scales. About 5-kg paper bags receive the collected samples.

- The mowing height chosen is 8–10 cm from the ground to avoid exhaustion of still young alfalfa plants and contamination by soil. This height is also that of animal grazing.
- Mowing begins after sunrise between 10 a.m. and 10:30 a.m. to minimize humidity on the plant.
- Weighing (whole plant, stems, and leaves separately) takes place on the same day as harvesting as well as putting it in the oven to measure the dry matter.
- The precocity of alfalfa species and populations is calculated in the number of days at the stage: beginning of flowering.

2.4.1 Evaluation of the nutritional value of alfalfa

Good quality alfalfa, in terms of content of chemical components and nutritional value, is strictly essential since the aim is to make it into nutritious fodder, knowing also that a good diet can partly compensate for a genetic deficiency.

In ruminants, the digestibility of forage is the most significant marker of its nutritional value [20].

For more than a century, indirect methods, called laboratory methods, which are faster and much less expensive, have been proposed. Among these, the most used microbiological test worldwide is inspired by the method recommended by Tilley and Terry [21]. It gives reliable digestibility values that correlate very well with the reference *in vivo* method [22, 23]. The samples that will be used for this test come from the 2015 crops developed above. Its total accomplishment requires:

- A Bain Marie system with 100-ml test tubes,
- An artificial saliva buffer solution
- A solution of trace elements is added at the end to the artificial saliva
- A control forage whose *in vivo* digestibility is known with precision and accuracy, obtained with the international reference method [24], and which gave an average of $61.36\% \pm 2.61$. It is used to assess the activity of the rumen juice
- *Rumen inoculum* (called “rumen juice”).

Products	Quantities (g)
Na ₂ HPO ₄ , 12H ₂ O	23.25
NaHCO ₃	24.5
NaCl	1.18
KCl	1.43
CaCl ₂	0.1
MgCl ₂	0.15

Table 4.
Composition of Mc Dougall artificial saliva (for 0.5 liter of solution) [25].

Elements	Quantity (mg)	Salts used	Weight of salt (g)
Zn	300	Zn SO ₄ 7H ₂ O	13.196
Co	3	CoCl ₂ , 6H ₂ O	0.012
Mn	615	Mn SO ₄ , H ₂ O	1.889
Fe	575	Fe SO ₄ 7H ₂ O	2.862
Se	0.6	Se	0.0006
Cu	55	Cu SO ₄ 5H ₂ O	0.216
Mo	0.7	MO ₂ (NH ₄) ₅ , 5 H ₂ O	0.009
I	1.4	I	0.0014

Table 5.
Composition of the trace element solution (l).

Details of their composition are given in **Tables 4** and **5**, respectively.

To this 0.5 liter of mother solution are added 2 liters of distilled water and 5 mL of trace elements. The pH is adjusted with CO₂ gas.

All results were subjected to simple descriptive statistical analysis: mean, standard deviation, coefficient of variation, and analysis of variance (ANOVA).

3. Results and discussion

3.1 Precocity of populations

The notion of precocity is understood by specialists as the arrival at the heading stage for grasses and at the beginning of flowering stage for legumes. In the latter, the early flowering stage corresponds to 5–10% of the stems examined on a 1 m line with at least one flower in bloom [26].

The values that appear in **Table 6** result from this definition. They do not call for any particular comments. Variations between populations of the same species are not very discriminating, as one might expect, nor between species. Thus, the coefficient of variation varies from 3 to 6%, although 71% of the variations observed are explained by precocity ($p < 0.05$). However, the species *M. ciliaris* would be 5 to 6 days earlier compared to *M. truncatula* and *M. intertexta*.

Species	Populations	Precocity(day)
<i>M. ciliaris</i>	C204	116 a
	C2	113 ac
	C11	116 a
	C58	121 b
	S7	114 ac
	S15	113 ac
	S5	110 ac
	S3	116 a
Average		115.0 a
Standard deviation		3.35
CV		0.03
<i>M. truncatula</i>	Tr238	117 a
	Tr27	130 b
	Tr334	127 b
Average		124.83 b
Standard deviation		6.90
CV		0.06
<i>M. intertexta</i>	I52	130 ac
	I756	125 b
	I107	124 b
	I58	127 b
	I31	127 b
	I11	126 b
Average		126.39 b
Standard deviation		3.19
CV		0.03
Overall average		120.43
Standard deviation		6.47
CV		0.05
RSE		3.82
R2		0.71
P		0.0001
<i>a, b, c homogeneous groups.</i>		

Table 6.
Precocity of the different populations studied.

3.2 Biometric parameters determining dry matter production

3.2.1 Culture 2013

The results appear in **Table 7**. Of the 80 seeds sown per line and per population, on average, 19 plants remained for data collection. The average viability percentage is 26% for our endemic populations. It is comparable for *M. ciliaris*, *M. truncatula*, and *M. polymorpha* (24 to 25%) and a little higher of 15% for *M. intertexta* (29%). The

Species	Populations	Number of plants/m ²	% de viabilities	Number of stems per m ²	Stem height (cm)	Green material		Dry matter g/m ²	Leaves on stems in dry
						g/m ²			
<i>M. ciliaris</i>	S5	1767	22.08	209.33	18.00	160.00		53.79	4.33
	S15	1650	20.62	154.00	13.50	91.20		12.56	2.43
	C2	25.00	31.25	244.00	19.50	129.61		27.25	4.02
	S7	16.00	20.00	260.00	22.25	205.46		37.06	3.16
	S3	11.00	13.75	156.00	20.00	80.00		32.00	5.00
	C11	16.00	20.00	276.00	18.00	244.40		47.68	3.21
	C204	14.00	17.50	136.00	23.00	158.04		33.00	3.64
	C58	13.67	18.12	189.33	20.33	252.87		91.57	2.33
	average ± sd	16.23 4.11	20.42 5.05	203.08 52.89	19.32 2.95	165.20 65.09		43.27 25.19	3.51 0.93
	CV	0.25	0.25	0.26	0.15	0.39		1.29	0.26
<i>M. truncatula</i>	Tr238	19.00	23.75	312.00	18.50	256.54		74.06	2.81
	Tr334	14.50	18.13	209.33	13.00	80.00		51.72	1.03
	Tr27	7.00	18.50	172.00	19.00	140.00		36.00	1.28
	average ± sd	13.50	20.13	231.11	16.83	158.85		53.93	1.86
		6.06	3.14	72.50	3.33	89.77		19.13	0.96
	CV	0.45	0.16	0.31	0.19	0.56		0.35	0.52

Species	Populations	Number of plants/m ²	% de viabilities	Number of stems per m ²	Stem height (cm)	Green material	Dry matter g/m ²	Leaves on stems in dry
						g/m ²		
<i>M. intertexta</i>	I253	28.00	35.00	420.00	38.33	1072.00	196.00	2.07
	I756	23.67	23.88	353.33	36.00	749.33	141.33	1.94
	I107	15.00	25.79	314.67	40.67	942.67	174.67	1.66
	I11	21.67	27.08	332.00	27.00	41.50	166.00	2.53
	I58	15.33	19.17	248.00	29.67	530.67	117.33	1.55
	I31	18.50	25.00	290.00	28.33	113.33	453.33	1.32
	I52	21.67	27.08	420.00	44.00	1277.06	260.00	1.11
	average ± sd	20.55 4.65	26.14 4.75	339.71 64.09	34.86 6.61	675.22 471.68	215.52 114.15	1.74 0.48
	CV	0.23	0.18	0.19	0.19	0.70	0.50	0.28
	Overall average	16.76	22.23	257.97	20.34	362.31	117.57	2.37
Jemalong/Témoin	average ± sd	10.00 2.65	12.50 0.88	152.00 31.24	17.67 1.15	103.65 32.15	25.60 11.78	1.72 0.94
	CV	0.26	0.26	0.21	0.06	0.31	0.46	0.54
	Bold in tables indicates means and standard deviation.							

Table 7.
Biometric parameters determining dry matter production (2015).

behavior of the two witnesses for this viability criterion is mixed. Based on 26% average viability for our populations, *M. muricoleptis* (Aus 106 cultivar of Turkish origin) is better at 33% (+ 21%). As for the Australian cultivar (Jemalong), it almost did not germinate (**Table 8**).

The height of the stems, significant parameters of biomass production on average, is distributed as follows: 57, 47, 42, and 22 cm respectively for *M. intertexta*, *M. ciliaris*, *M. polymorpha*, and *M. truncatula*, which gives us almost the same hierarchy for the production of dry matter with quantities of: 751, 468, 502, and 234 g/m². The witness *M. muricoleptis* with a stem height and dry matter production of 41 cm and 534 g/m² respectively is very honorably placed. The height of the stems is in fact a well-known indicator of dry matter production, just like the number of stems.

As for the leaf-stem ratio (F/T), accepted as a reliable criterion of digestibility, *M. truncatula* (with an average value of 2.33) would carry more leaves than stems, compared to *M. ciliaris* (1.55), *M. intertexta* (1.30), and *M. polymorpha* (1.22) and *M. muricoleptis* (1.44) (**Table 8**).

3.2.2 Culture 2015

The same data collection protocol was applied to the 2015 crop which, however, only included the Jemalong witness. The results appear in **Table 7**.

The first observation is that the values are lower than for the 2013 crop. The calculations made from **Tables 9** and **10** reveal: 11% for the number of plants; 14% for the viability rate; 73% for the number of rods/m²; 52% for stem height; and 76% for MS production. On the other hand, an increase of 55% is noted for the F/T, which admits that the alfalfas of the 2015 crop, although their growth and development were lower, their stems carried more leaves than stems compared to that from 2013. Perhaps not surprisingly, these stems were two times shorter. The number of stems being an indicator of the vigor of the crop.

3.2.3 Summary of the years 2013 + 2015 for dry matter production

We have synthesized the two years of cultivation in the sense that each year represents a repetition, and the results are presented. These average data do not call for any particular comments, other than that the 2013 culture, with its higher performances compared to that of 2015, prints the results. All the parameters studied clearly discriminate between alfalfa populations with R² values varying between 25 and 65%. This is for F/T where variations are less well explained by alfalfa populations (weighing and leaf loss are in fact sources of error). On the basis of this synthesis, we have drawn up the correlation matrix between the parameters that determine biomass production (**Table 9**).

It appears that the correlations cover all possibilities existing in statistical terms: positive connections, significant or not—negative connections, significant or not.

The connections observed do not pose any particular constraints on understanding. So:

- It is logical that the number of stems/m² (NT) varies in the same direction as the number of plants/m² (NP) also, when the latter increases, NT does the same,
- NP is also positively linked to stem height (HT) and the F/T ratio, although this link is not significant. However, it can be assumed that under high seed density

Species	Populations	Umber of plants/m ²	% of viability	Number of stems per m ²	Stem height cm	Green material /m ²	Dry matter g/m ²	Leaf on stems Sec
<i>M. ciliaris</i>	C52	17.50	21.88	1165.0	40.34	3350.0	446.7	1.32
	C204	17.00	21.25	746.7	49.89	3670.0	567.9	1.73
	S5	21.50	26.88	950.0	43.93	2926.7	401.1	1.51
	C2	23.17	28.96	1166.7	59.76	5056.7	574.2	1.38
	S3	19.17	23.96	996.7	53.08	3233.3	451.9	1.37
	C58	18.67	23.33	1125.0	35.94	3050.0	367.3	1.68
	Average. ±DS	19.50	24.38	1025.0	47.16	3547.78	468.21	1.55
	CV	2.38	2.99	163.4	8.76	782.72	85.54	0.17
<i>M. truncatula</i>	CV	0.12	0.12	0.16	0.19	0.22	0.18	0.11
	Tt334	29.67	37.08	1610.0	22.83	2123.3	469.4	2.25
	Tt55	15.33	19.17	1128.3	29.23	1500.0	204.8	2.31
	Tt238	5.50	20.60	410.0	10.53	1392.1	41.3	2.70
	Tt407	15.75	19.69	870.0	17.50	2015.0	227.2	2.15
	Tt27	25.83	32.29	1340.0	32.11	1674.2	247.2	2.27
	Tt221	12.33	23.13	580.0	21.07	1852.5	216.8	2.30
	Average. ±DS	17.40	25.33	989.7	22.21	1759.52	234.37	2.33
		8.90	7.53	457.1	8.76	288.41	137.06	0.19
	CV	0.51	0.29	0.46	0.35	0.16	0.58	0.08

Species	Populations	Umber of plants/m ²	% of viability	Number of stems per m ²	Stem height cm	Green material /m ²	Dry matter g/m ²	Leaf on stems Sec
<i>M. intertexta</i>	I11	10.67	20.00	1036.7	50.51	6593.3	622.3	1.31
	I756	24.50	30.63	958.3	60.69	4920.0	706.7	1.39
	I107	24.83	31.04	1116.7	54.15	6630.0	610.6	1.09
	I253	22.50	28.13	1030.0	63.71	6545.0	849.8	1.42
	I31	26.33	32.92	1268.3	50.23	5826.7	798.4	—
	I52	27.33	34.17	975.0	62.02	6730.0	920.4	1.17
	Average ± DS	22.69	29.48	1064.17	56.89	6207.50	751.35	1.30
<i>M. polymorpha</i>	CV	6.12	5.08	114.47	6.00	709.50	125.67	0.14
	Poly205	18.00	22.50	1091.1	58.65	636.7	856.2	1.31
	Poly27	13.67	25.62	433.3	26.25	203.6	148.9	1.13
	Average ± DS	15.83	24.06	762.22	42.45	419.91	502.5	1.22
	CV	3.06	2.21	465.12	22.91	435.8	500.1	0.13
	CV	0.19	0.09	0.61	0.54	1.04	0.99	0.11
	Overall average	18.85	25.81	960.28	42.17	2983.68	489.12	1.53
<i>M. muricoleptis</i>	Average ± DS	26.33	32.92	1300.0	41.20	3626.67	534.6	1.44
	Aus106	3.79	4.73	173.49	15.59	611.58	90.18	0.02
	Witness 1	0.14	0.14	0.13	0.38	0.17	0.17	0.01
<i>Jemalong witness 2</i>	Average	6.5	8.0	0	0	0	0	0
	Witness 2	0.14	0.14	0.13	0.38	0.17	0.17	0.01

SD: standard deviation; CV: coefficient of variation.
 Bold in tables indicates means and standard deviation.

Table 8.
 Biometric parameters (2013) determining dry matter production.

	Number of plants/ m ²	Number of stems per m ²	Stem height (cm)	Leaves on stems in dry	Green material g/ m ²	Dry matter g/m ²
Number of plants/ m ²	1					
Number of stems per m ²	0.685***	1				
Stem height (cm)	0.188	0.481***	1			
Leaves on stems in dry	0.127	-0.167	-0.291*	1		
*correlated						
**highly correlated						
***very highly correlated						

Table 9.
Correlation matrix between biometric parameters.

conditions, the binding could be negative. On the other hand, it is logical that the production of dry matter (DM) under normal growing conditions is a function of the NP (therefore indirectly of the sowing density).

- The NT is positively correlated with the HT: We can think that the NT increasing with age leads in the same direction to the growth in height of the stems. Likewise, NT is in negative connection with F/T (but $p > 0$); indeed if the NT increases with age, the number of leaves could decrease. The NT is logically in a positive and significant connection with the production of biomass, represented here by MS;
- HT is negatively and significantly related to F/T; in fact, HT, being a function of the age of the alfalfa, impacts the stem-leaf distribution of the plant. The sign of the connection would indicate that when the stems progress in height, they take precedence over the weight of the leaves. We find the same trend (but $p > 0$) between F/T and MS: When the production of MS increases, the share of stems in this biomass increases, causing F/T to fall.
- Finally, the very strong correlation (0.934) recorded between green and dry biomass does not call for comment, the latter being the result of the former.

3.2.3.1 Chemical composition and digestibility of the alfalfa populations studied

3.2.3.1.1 Chemical composition

The chemical composition of the populations of the two 2013/2015 trials is close to the 2007 trial.

The total nitrogenous matter of the populations varies between 12.47 (I125) and 37.43 (C35) with an average of 26.09%. The CP contents of the introduced species that vary from 22.83% (AUS100) to 28.79% (AUS103) are lower than those of the perennial population El Méniaa (31.5%).

Thus, the *M. ciliaris* (C) is with a higher nitrogenous content of 32.49% and a moderate fiber content (NDF: 30.08% and CB1: 18.18%), while the species poorest in walls are

Populations	MS2%	MM%	MAT%	CB1 (%MS)	NDF%	ADF%	Hc%	CB2%	Ln%
S15	98.79	15.26	28.83	12.70	27.56	16.80	10.76	11.55	5.06
S9	98.75	15.33	25.27	20.51	35.63	22.77	12.86	7.18	10.67
S6	98.81	14.82	30.51	16.72	20.39	14.11	6.28	7.62	7.37
S8	98.36	17.35	23.94	16.15	41.53	18.90	22.63	10.00	8.97
S5	98.80	15.68	33.77	17.62	31.68	14.23	17.46	8.34	7.62
S4	99.16	14.30	24.94	20.76	37.80	18.56	19.25	13.16	5.90
S11	98.69	16.98	28.34	20.50	36.36	15.27	21.09	7.38	8.88
S7	98.59	15.87	26.49	16.75	36.21	18.05	17.25	9.96	9.52
S3	98.75	17.22	23.49	15.14	33.36	17.46	15.84	8.21	7.89
POL205	98.66	19.71	32.94	15.71	33.69	16.82	17.79	10.41	7.46
POLY58	99.40	18.80	25.68	23.84	36.77	19.43	17.34	15.04	8.18
POL218	99.33	20.40	24.56	17.20	42.63	24.15	18.48	6.86	6.11
POLY236	99.10	16.82	28.05	22.96	54.31	25.96	28.35	11.23	16.66
POLY60	99.18	17.59	35.44	18.64	38.17	17.89	20.27	18.90	6.99
POLY27	99.23	14.97	22.79	20.59	40.12	16.63	23.50	5.54	4.65
TR55	98.92	15.86	29.15	20.20	45.62	24.48	21.14	5.22	15.54
TR201	98.96	21.14	28.28	15.48	43.29	25.04	18.26	1.29	16.67
TR238	99.21	16.84	26.59	20.88	48.97	23.55	25.43	8.54	21.52
TR27	99.02	14.06	21.34	28.17	43.69	28.98	14.71	7.84	18.39
TR221	99.33	21.55	21.68	22.15	38.34	20.03	18.31	11.97	12.09
C242	98.95	15.84	31.24	16.85	45.11	20.96	24.15	13.58	9.82
C2	98.97	15.55	30.01	15.78	38.07	17.77	20.31	8.82	3.45
C11	98.88	13.60	28.83	18.39	26.04	12.17	13.87	6.80	3.94
C58	99.04	15.73		16.59	21.37	15.74	5.63	12.26	5.63
C204	99.06	20.12	27.48	21.06	54.80	18.64	36.16	12.05	15.13
C35	98.84	20.30	37.43	19.96	49.00	23.04	25.97	6.67	8.78
C52	98.95	14.59	28.85	18.67	37.75	19.30	18.45	9.98	9.90
I11	99.14	15.96	26.26	21.06	35.06	21.78	13.28	12.67	15.22
I31	99.07	12.68	24.11	28.46	74.91	27.58	47.32	12.22	15.22
I756	99.22	14.28	18.89	21.96	39.15	22.09	17.06	10.50	13.71
I58	99.05	16.27	22.91	24.50	36.58	21.68	14.90	17.67	6.24
I253	99.14	12.47	19.57	27.17	44.02	29.32	14.70	19.88	6.13
I52	99.42	13.31	28.50	27.01	40.49	21.42	19.08	14.30	7.96
I107	99.44	15.13	17.18	24.92	38.48	20.80	17.68	14.96	4.82
I755	99.16	23.81	22.70	15.57	42.42	16.81	25.61	5.90	10.10
AUS100	99.57	17.79	22.83	18.92	35.30	18.47	16.83	11.20	6.10
AUS106	99.05	16.49	26.06	20.40	39.18	21.87	17.31	12.33	6.35

Populations	MS2%	MM%	MAT%	CB1 (%MS)	NDF%	ADF%	Hc%	CB2%	Ln%
AUS103	99.39	18.05	28.79	22.70	41.69	21.33	20.36	4.29	7.08
AUS107	99.36	14.79	28.32	20.95	46.54	15.34	31.20	4.57	11.63
ElMéniaa	99.30	14.29	31.51	16.62	33.46	18.40	15.06	11.06	7.71
Tamentit	99.34	14.81	23.47	24.34	31.24	18.33	12.91	8.36	8.00
Temacine	99.05	16.40	25.56	21.35	30.87	19.09	11.19	11.0	8.83
Moyenne	96.72	16.05	26.09	19.65	39.25	19.78	18.20	10.10	9.28

Table 10.
Chemical composition of populations of 42 annual alfalfas studied in 2007.

the *M. ciliaris* (S) (ADF: 17.46%, CB1: 17.43%). The highest rate of indigestible chemical elements (lignin) is found in *M. intertexta* (6.10%). The correlation of fibers and nitrogenous matter is negative (CB1: $r = -0.45^{**}$ and ADF: $r = -0.36^*$) (Table 10).

In alfalfa (as in all forages), the chemical composition follows the stage of development of the plant. Thus, Guy [24] notes the increase in the MAT content from 24.6% to 13.90% from April 20 to June 1. Similarly, Mauriès [27] indicates that, when moving from the vegetative stage to the flowering stage, the MAT content dropped from 27 to 15%. At the same time, the leaf-to-stem ratio decreases, while the DM content increases. This ratio can go from 1.4 at the flower bud stage to 0.7 in full flowering.

This author also specifies that the weight of the leaves increases linearly with the height of the stems, while the weight of the stems increases as the square of the height. The chemical composition of the leaves being little variable, it is that of the stem which is responsible for the reduction in the leaf-stem ratio and therefore in the MAT content, since the content of the leaves varies between 21.9 and 24.4% compared to 11.9 and 15.0% [24]. Other factors of genetic variability between species or populations are added, such as leaf surface area. Thus, *M. falcata* cultivars have a leaf surface area of 98 m² compared to 138 m² for *M. sativa*. [24].

Little attention has also been paid to stem thickness, which is associated with the physical distribution of structural components including lignin. Thus, the less rigid stems are more digestible just as the base of the stem is more lignified than the top.

In vitro digestibility of dry matter from the populations studied:

The results appear in Table 11 and the digestibility values on average 75%. The average digestibility per species is 77, 73, and 75% for *M. ciliaris*, *M. truncatula*, and *M. intertexta*.

The aim of analyzing a table of chemical composition of fodder as we did above is to be able to assess the nutritional value of the fodder through its content of the main components, which determines this nutritional value. Since the eighteenth century, crude cellulose (replaced more or less from the 1970s by NDF or ADF in light of the work of Van Soest [28]) has been recognized as a factor negatively impacting food value as well as lignin at a higher level. Its content in the plant increases with the age of the plant, while, on the other hand, the nitrogenous materials, a positive factor in the nutritional value of the fodder, quantitatively decrease with the age of the plant [27, 29].

On this basis, thousands of works around the world have established general models making it possible to achieve the nutritional value of fodder by introducing into these mathematical models, the chemical components of the fodder as explanatory

Species	Populations	Average trials	Average species
<i>M. ciliaris</i>	C2	78.75	77.14
	C58	77.20	
	S5	75.46	
<i>M. truncatula</i>	Tr238	69.94	73.34
	Tr334	76.75	
<i>M. intertexta</i>	I11	74.04	74.60
	I31	76.33	
	I52	76.34	
	I253	75.02	
	I58	73.98	
	I107	70.63	
	I756	75.88	
	Avg ± ET	75.3 ± 2.60	75.17 ± 2.34
	CV	0.034	0.031
	RSE	6.01	—
	R ²	0.51	—
	P	0.44	—
	—	**	—

R²: coefficient of determination; RSE: residual standard deviation:
 *P<0.05; significant
 **P<0.01; highly significant
 ***P<0.001; very highly significant

Table 11.
 Digestibility value of the alfalfa populations studied.

variables of their nutritional value. For example internationally: INRA France (1978, 1988); and ARC, Great Britain (1980, 1993) NRC: USA (2001; 2007) and in Algeria, very recently [30].

3.2.3.1.2 Performance in DM and MAT (CP)

The quantity of DM produced per unit of soil used is an important nutritional and economic criterion. It contains all the nutrients that justified cultivation. Annual and perennial alfalfas are rich in nutritional compounds: minerals, nitrogenous materials rich in amino acids, carotenes, vitamins [31, 32] and minerals including calcium, phosphorus, manganese, magnesium and many important trace elements such as zinc, boron, and selenium [26].

We have previously commented on the correlations between the different parameters of DM production from biomass: The number of stems/m² and the height of the stems are significant explanatory variables (**Table 9**). The highest DM productions were found within *M. intertexta*: more than half of the populations (4 out of 7) exceed 4 tons of DM/ha.

The general average for all species combined is 2.8 tons (**Table 12**). The situation is different for MS production in Syria, Cocks *et al.* [33] measured the production of 6

Species	Populations	DM		Total nitrogen material (TNM)
		g/m ²	Tons/ha	Tons/ha
<i>M. ciliaris</i>	C2	300.75	3.01	0.747
	C58	229.45	2.29	0.636
	S5	227.46	2.27	0.666
	C52	446.70	4.47	—
	C204	333.62	3.34	0.827
	S3	385.97	3.86	0.852
	S15	12.56	0.13	0.032
	S7	53.79	0.54	0.156
	C11	12.56	0.13	0.029
Average species		222.57	2.23	0.523
<i>M. truncatula</i>	Tr238	57.66	0.58	0.153
	Tr334	260.56	2.61	0.580
	Tr55	204.84	2.85	—
	Tr407	227.23	2.27	—
	Tr27	141.58	1.42	0.326
	Tr221	216.78	2.17	—
Average species		175.81	1.76	0.346
<i>M. intertexta</i>	I11	331.89	3.32	0.728
	I31	625.85	6.25	1.428
	I52	590.21	5.90	1.386
	I253	522.88	5.23	1.132
	I58	117.33	1.17	0.280
	I107	392.62	3.93	0.800
	I756	424.00	4.24	1.086
Average species		429.25	4.29	0.977
Overall average		275.25	2.76	0.615
Jemalong: T1	CV	25.6	0.26	0.077
Muricoleptis: T2	Aus	534.57	5.35	1.246

Bold in tables indicates means and standard deviation.

Table 12.

Theoretical production of DM and nitrogenous materials per hectare for the populations studied.

to 8 tons under normal rainy conditions (200–300 mm) and up to 9–10 tons in wetter conditions. These same authors, in Australia, with a view to a Ley farming project, compared the production of dry matter in three species of candidate fodder legumes: *Medicago littoralis*, *Trifolium subterraneum*, and *Trifolium repens*, the respective annual DM production was 9.9; 6.0 and 3.4 tons per hectare.

Papastilianou [34] for his part showed with annual Alfalfa in Cyprus (rainfall of 200–260 mm) that DM production could vary between 4.6 and 7.5 tons depending on

the variety and bacterial strain. For *M. rigidula* for example, this quantity is between 5.0 and 6.0 kg ha/year.

In Tunisia, Seklani and Hassen [35] evaluated the DM production of 5 annual *Medicago*: *M. rugosa*; *M. polymorpha*; *M. orbicularis*; *M. truncatula*; *M. turbinata* at different sites throughout the country: field yield in DM varied between 1 and 5 tons.

In Morocco, Birouk *et al.* [36] on around twenty local populations and in 5 different regions and on local populations of alfalfa obtained average yields per cut in DM of 2.8 to 3.12 tons per hectare, that is, on the 3 cuts practiced 8.4 to 9.4 tons of MS. These values are close to those of Cocks *et al.* [33], obtained in Syria.

What emerges from these series of experiments in the Mediterranean basin is the very wide dispersion of MS yields. It is due to the variability of pedoclimatic conditions but also to the specific characteristics of the alfalfa varieties [37].

According to Sultan-Tubeileh [38], one of the fairly common causes of the variability of productive yields of alfalfa in the Mediterranean regions is the unadaptability and inefficiency of the strains of *Sinorhizobium meliloti* whose annual alfalfas are more demanding in terms of strain-specific than perennial alfalfa. According to this author, in addition to classic selection methods, a look at the quality of the suitability of the alfalfa-*Sinorhizobium meliloti* association is an important reserve for productive improvement of annual alfalfa.

Regarding the production of total nitrogenous materials of the alfalfa populations studied, the results appear in **Table 13**. The MAT content being little dispersed, respectively on average: 27, 25, and 23% for *M. ciliaris*, *M. truncatula*, and *M. intertexta* (**Table 12**) and being expressed in relation to the DM, it is therefore the quantity of DM produced, which discriminates the populations in terms of their production of nitrogenous materials. The species *M. intertexta* with almost 1 ton of MAT produces two times and three times more than *M. ciliaris* and *M. truncatula*, respectively. The population I52 exceeds 1.4 tons, follows: I31 (1400), I253, and I756 with each 1.1 tons.

What can we ultimately say about the quality of the populations studied on the two criteria: production of MS and MAT?

	Div	Lig	TNM	GT	NT	F/T
Div	1					
Lig	-0.52*	1				
MAT	0.63**	-0.53*	1			
GT	0.05	0.33	-0.29	1		
NT	0.31	0.15	-0.01	0.78***	1	
F/T	0.21	-0.29	0.63**	-0.34	0.22	1
LT	-0.51*	0.55*	-0.66***	0.33	0.04	-0.43

Div: *in vitro* digestibility; Lig: lignin; NT: number of stems/m²; GT: stem size; TNM: total nitrogen material:

**p* > 0.05; significant

***p* < 0.02; highly significant

***0.01; very highly significant

Bold in tables indicates means and standard deviation.

Table 13.
Correlation matrix of parameters determining the Div.

- For dry matter, on the basis of one harvest compared to 3 or 4 in the literature, we would be at a good level: with two harvests we would approach on average 6 tons annually,
- For MAT, production is very high with *M. intertexta* (up to 1.4 tons given that it is a single harvest). On average for the three species: 0.6 tons for a harvest is more than respectable.

3.2.3.2 Parameters that can impact digestibility

It is presented in the variable correlation matrix (R) (**Table 13**). Here, we find results already presented previously: Div correlated negatively with lignin and positively with nitrogen. The age of the plant being related to the width of the branches and its lignin content, we see it appear in the form of a negative R between Div and LT and positive between lignin and LT.

4. Conclusion

This work aimed to contribute to the deepening of knowledge in the species and populations of spontaneous annual alfalfa in Algeria.

Our work focused on six species of medics: (*M. ciliaris*; *M. truncatula*; *M. intertexta*; *M. polymorpha*; *M. sativa*; and *M. muricoleptis*), bringing together up to 22 populations. But, all of our investigations particularly concerned the three species: *M. ciliaris*; *M. truncatula* and *M. intertexta* whose availability of plant material was greater. Most of the phenological or biometric samples were taken at the beginning of flowering. Several points emerge from the results of this work:

- In addition to the very broad spectrum of genetic variability contained in our populations, the quality criteria for alfalfa are already at high levels in our alfalfa. Thus, the MAT content averages 27% for *M. ciliaris* (peak at 30% for the S5 population).
- For these three quality criteria, the Australian control *M. truncatula* (CV Jemalong), collected in Algeria and acclimatized in Australia, showed itself to be totally unsuitable with 0.3 tons of DM per hectare and infertile (0 g of seed)
- The *M. ciliaris* species is also well placed for the F/T ratio, another indicator of digestibility. There appears to be a presumption of good digestibility of the *M. ciliaris* species.

Finally, we provide the breeder with a whole series of phenological and biometric criteria and statistical combinations of this quality (for the zootechnician) and quantity (for the farmer) criteria:

- Number of stems per square meter, stem height (cm), MS g/m² F/T Dry; NDF, ADF, HC, ADL, MSg/m², MAT%MS; Div, lignin, MAT, stem size, number of stems/m², stem length; length of stems (cm), number of stems/m².

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