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Variation and relationships among agronomic traits in Algerian sympatric populations of *Medicago minima* L. Bart. and *Medicago truncatula* Gaertn.

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Summary : Legumes of *Medicago* genus have particular ecological and agro-pastoral importance in the Mediterranean region. This work was initiated in order to develop local species by identifying and selecting suitable cultivars. The main objective of this study is to assess the variation and relationships among agronomic traits in four sympatric populations of *M. minima* and *M. truncatula* collected in different sites of region of Djelfa. The trial was conducted during the 2016/2017 cropping season. The study focused on dry matter yield and pod and seed production. Populations were sown on 22 December 2016 at a density of 100 scarified seeds/row of 1 m long spaced by 1.5 m. A randomized block design with 03 replications was used. The obtained results showed that the populations of the two species differ significantly for all measured variables. ANOVA showed significant difference between populations. Higher degree of variation for the most of agronomic traits was observed among sympatric populations of *M. minima* and *M. truncatula*. From the obtained results, several populations had good biomass and high yield of seed and pod. These populations could be developed and exploited in Algerian pastures.

Mots clés : *Medicago truncatula*, *Medicago minima*, seed yield, forage yield, variability.

Résumé : Les légumineuses du genre *Medicago* ont une importance écologique et agropastorale particulière dans les régions méditerranéennes. Ce travail est initié afin de développer des espèces locales en identifiant et en sélectionnant des cultivars adaptés. L'objectif principal de cette étude est d'évaluer la variation et les relations entre les caractères agronomiques chez quatre populations sympatriques de *M. minima* et *M. truncatula* collectées dans différentes sites de la région de Djelfa. L'essai est mené durant la compagne agricole 2016/2017. L'étude a porté sur le rendement en matière sèche et la production de gousses et de graines. Les graines sont semées le 22 décembre 2016 à une densité de 100 graines scarifiées/rang de 1 m de long espacées de 1,5 m. Une conception en blocs

randomisés avec 03 réplications est utilisée. Les résultats obtenus montrent que les populations testées diffèrent significativement pour l'ensemble des variables mesurées. L'analyse de la variance montre des différences significatives entre les populations. Un degré de variation plus élevé est noté pour la plupart des caractères agronomiques parmi les populations sympatriques de *M. minima* et *M. truncatula*. D'après les résultats obtenus, plusieurs populations présentent une bonne biomasse et un rendement élevé en graines et en gousses. Ces populations pourraient être développées et exploitées dans les pâturages Algériens.

Key words : *Medicago truncatula*, *Medicago minima*, rendement en graines, rendement fourrager, variabilité.

INTRODUCTION

Insufficient fodder and pastoral production is a major obstacle to the development of husbandry in Algeria. Most of the livestock feed is provided by natural environments. These latter are subject to continuous degradation caused by overgrazing and irrational exploitation of rangelands, illegal and uncontrolled clearing as well as the influence of climatic hazards particularly drought, which consequently leads to a significant reduction plant cover.

Medicago L. (Leguminosae), a predominantly Mediterranean genus, comprises a high number of species, annual herbs, herbaceous perennials and rare shrubs, many of which are markedly polymorphic (Brundu *et al.,* 2004). Medics are encountered in all bioclimatic zones from wet to desert. Some have a wide spectrum of distribution; others have a more defined spatial distribution (Abdelkefi and Marrakchi, 2000). Medics constitute a potential fodder resource for the semi-arid zones of the Maghreb and Mashreq (Guckert *et al.,* 2003).

Among crops reliable to promote pastoral zones that produce forage and restore destroyed pasture land especially in arid and semi-arid areas, the genus *Medicago L.* (Fabaceae) constitutes an important genetic resource (Haddioui *et al.,* 2012). Legumes of the genus *Medicago* are of special ecological and agropastoral importance in the Mediterranean region. They include forage species expressing high levels of N-fixation and protein production per hectare (Huguet *et al.,* 1994). Medics grown as regenerating pasture in the agro-pastoral Mediterranean systems or cereal farming systems are an important feed resource not only as green forage throughout the growing season but also as stubbles and pods in summer and early autumn (Porqueddu, 2001). Other benefits can be listed for incorporating annual *Medicago* into farming systems.

These include their potential to increase forage production and extend the grazing season (Interrante *et al.,* 2011), ability to increase soil fertility and structure and capacity to break disease and pest life cycles of crops when grown in rotation (Hawieson *et al.,* 2000), as well as their high levels of hard seededness makes them well adapted to ley farming systems and to persistence in regions of unreliable rainfall (Nichols *et al.,* 2007). They improve natural pastures, provide a source of forage with high quality, and confer benifits such as symbioticaly fixed nitrogen, which becomes available to subsequent crops.

The objective of the present work is to assess the variation and relationships among agronomic traits in four sympatric populations of *M. minima* and M. *truncatula*.

MATERIAL AND METHODS

Plant material used in this study consisted of four sympatric populations of *M. truncatula* and *M. minima* collected in 2008 in different sites of Djelfa area by the National Institute of Agronomic Research of Algeria (INRAA) (Table I). The experimentation was carried out at the experimental station of Baraki (INRAA) during 2016/2017 cropping season. The climate of this area is characterized by mild winters and hot summers. Populations were sown on December 2016 at a density of 100 scarified seeds/row of 1 m long spaced by 1.5 m. The experimental design was a randomized complete block with three replications. Trial was conducted under rain-fed conditions. At the beginning of flowering, the green matter yield (**GMY, g**) and dry matter yield (**DMY, g**) were measured. To determine dry matter yield, sample was dried in a forced air oven at 65°C during 48 hours. Total number of pods (**TNP**), pod weight (**PW, g**), total number of seeds (**TNS**) and seed weight (**SW, g**) were measured after harvest.

Analysis of variance (ANOVA) was performed for each character using R

Table I : Altitude and geographic coordinates of the four sampling sites of sympatric populations of *Medicago minima* and *M. truncatula.*

Geographical origin	Altitude (m)	Latitude	Longitude	Symbols of *M. minima* populations	Symbols of *M. truncatula* populations
Ain Oussera	758	35° 17’ 08’’	2° 57’ 37’’	**MmAO**	**MtAO**
Mliliha	806	34° 48’ 89’’	3° 48’ 94’’	**MmMli**	**MtMli**
Charef	960	34° 40’ 31’’	2° 43’ 13’’	**MmCh**	**MtCh**
Oued Touil	718	35° 16’ 43’’	2° 33’ 23’’	**MmOT**	**MtOT**

software version 3.6.1. Comparison of population means of measured traits was performed using Least Significant Difference (LSD) test at 5% probability level. Relationships among measured traits were tested using Pearson correlation coefficients. Principal components analysis (PCA) was performed to establish the importance of different traits in explaining multivariate polymorphisms using STATISTICA 6.0 software.

RESULTS AND DISCUSSION

Analysis of variance showed a significant difference between populations (Table II). Populations of *M. minima* and *M. truncatula* showed significant variation for agronomic traits. This suggested the existence of a large genetic variability. Such variability can be exploited in different breeding program of forage species to select adapted pre-breeding material. Flowering date is mainly influenced by genotype, temperature and photoperiod (Roberts *et al.,* 1996). In the present study, flowering time vary significantly between sympatric populations. The *M. truncatula* populations from Oued Touil and Ain Oussera were the earliest ones with 86 calendar days, while the *M. minima* population from Charef region was the latest (98 days). Annual legumes show both ecotypic differentiation and a high degree of plasticity in flowering time (Del Pozo and Aronson, 2000). Chebouti *et al.* (2019) reported that Flowering time varied from 70-75 calendar days in *M. truncatula* and from 74-84 days in *M. laciniata*. In Sicilian *M. polymorpha* populations, the flowering time ranged from 110 to 128 days (Graziano *et al.,*

Table II : Means and standard deviations of seven agronomic traits measured in four sympatric populations of *Medicago minima* and *Medicago truncatula*.

Populations/traits	FT (days)	GMY (g)	DMY (g)	TNP	PW (g)	TNS	SW (g)
MmAO	95±0.58^{b}	1322±250.31	322±59.23^{ab}	6885±988.8^{cd}	307.1±23.36^{b}	39964±3937.1^{cde}	67.8±6.56^{cd}
MmCh	98±0.57^{a}	1012±141.74	183±41.06^{cd}	14867±3623.17^{a}	237.5±24.8^{b}	74928±8016.8^{a}	95.1 ±10.15^{b}
MmMli	96±1.73^{ab}	768±64.24	120±14.74^{d}	11206±2383.44^{b}	258.5±52.43^{b}	60959±12965.9^{b}	82.5±17.54^{bc}
MmOT	88±1.15^{c}	1077±74.54	220±61.07^{bcd}	10296±942.96^{b}	282.9±21.6^{b}	51510±4299.9^{bc}	59.2±4.95^{d}
MtAO	86±1.73^{c}	1305±550.06	243±90.18^{abc}	8861±589.04^{bc}	407.2±24.1^{a}	40759±2709.4^{cd}	119.8±7.96^{a}
MtCh	88±0.58^{c}	1495±701.12	302±109.12^{ab}	7663±334.37^{c}	477.7±12.1^{a}	33412±1457.6^{def}	90.9±3.97^{b}
MtMli	88±0.57^{c}	877±274.68	235±8.66^{abcd}	4221±1827.24^{e}	256.8±112.6^{b}	23404±10115.9^{f}	65.8±28.43^{cd}
MtOT	86±1.73^{c}	1997±638	340±88.9^{a}	4627±342.5^{de}	279.3±20.9^{b}	28315±2096.0^{ef}	79.8±5.43b^{cd}
Mean of *M. minima*	94±4.27	1045±243.17	211.2±86.5	10813±3261.3	271.5±39.2	56840±15090.1	81.8±16.64
Mean of *M. truncatula*	87±1.40	1418±637.02	280±84.4	6353±2224.2	355.2±107.5	31472±8132.8	89.1±21.92
Lsd	1.915	753.1	116.6	2432.0	80.47	12356.7	22.70
p-value	0.001	0.068	0.018	0.001	0.001	0.001	0.001

Lsd : Least significant difference ; **FT** : Flowering time ; **GMY** : Green matter yield per line ; **DMY** : Dry matter yield per row ; **TNP** : Total number of pods per row ; **PW** : Pods weight per row ; **TNS** : Total number of seeds ; **SW** : Seed weight per row.

2010). According to Badri *et al.* (2016), the latest flowering plants invest most of their effort in the aerial growth. Tested populations presented appreciable green matter and dry matter yields. The most productive population was *M. truncatula* population from Oued Touil with 1997 g for green matter yield and 340 g for dry matter yield. While *M. minima* population from Mliliha recorded the lowest values (768 g and 120.3 g, respectively). Results showed that *M. truncatula* had the higher green matter and dry matter yields than *M. minima*. The dry matter yield is an important characteristic in determining the choice of selected varieties in forage species (Mefti *et al.,* 2012). In their study on the renovation of pastures by the introduction of forage legumes, Hadjigeorgiou *et al.* (2017) reported that Medicago species (*M. polymorpha* and *M. litoralis*) produced the most abundant biomass followed closely by *Trifolium michelianum*. According to Porqueddu and Gonzalez (2006), forage yields depend on specific growing conditions, especially rainfall during the growing season. Graziano *et al.* (2010) reported that under the favorable bioclimatic conditions (with good water availability during the reproductive phase) it is likely that a longer duration of the vegetative phase increases dry matter yield. Fresnillo (2011) reported that the spring dry matter production accounted more than 60% of the annual aerial production of the herbaceous layer in in *M. minima*. Zhu *et al.* (2001) mentioned that medics (annual species) have the potential to produce high yields in the north-central United States and could be used as short-season annual crops for use in the fall and summer when traditional forage supplies are insufficient.

High seed yield potential is of particular importance in medics (annual *Medicago* species) which self-regenerate year after year from the seeds left buried in the soil (Somaroo, 1988). Pod and seed production varied widely among sympatric populations of *M. minima* and *M. truncatula*. Thus, *M. minima* produced a high number of pods and seeds. In contrast, *M. truncatula* had the highest pods and seed weights. The highest pod and seed yields were recorded by *M. truncatula* populations from Charef and Ain Oussera (477.7 g and 119.8 g respectively). Loi *et al.* (2000), studying the potential of new legume alternatives to pasture for Australia Mediterranean farming systems, showed that annual *Medicago* produced more seeds than most other species.

Several correlations among agronomic traits were observed (Table III). Traits related to pod and seed production were positively correlated. This relationship suggests that these traits vary in similar

Table III : Pearson coefficient between seven agronomic traits among four sympatric populations of *Medicago minima* and *Medicago truncatula.*

Variables	FT	AB	DMY	NTP	PW	NTS	SW
FT	**1**						
AB	-0.519	**1**					
DMY	-0.410	**0.907****	**1**				
NTP	**-0.708***	-0.482	-0.501	**1**			
PW	-0.473	0.389	0.474	-0.195	**1**		
NTS	0.063	-0.501	-0.523	**0.975*****	-0.373	**1**	
SW	**-0.773***	0.155	0.010	**0.711***	0.500	0.790*	**1**

Significant levels ; *< 0.05 ; **< 0.01 ; ***< 0.001

ways and the seed yield is strongly dependent on the number of pods. Total number of pods and seeds were closely related and vary in similar ways (r = 0.975***). Populations that recorded high seed yield had the highest pods and seeds number (r = 0.711* and r = 0.7*, respectively). In many legumes, pod number is one of the most effective factor on seed yield is pod number and commonly there is a linear function between pod number and seed yield (Bagheri *et al.,* 2010). According to Cocks (1988), seed yield was closely related to number of pods in all ecotypes of annual *Medicago sp*. Jabri *et al.* (2012) mentioned significant correlations between pod and seed weight in *M. ciliaris*. Flowering time was negatively correlated with number total of pods and seed yield (r = - 0.708* and r = - 0.773*, respectively). These results are in accordance with Chebouti *et al.* (2015) in *M. minima*, who indicated that flowering time was negatively correlated with seed yield. Populations with high green matter yield had high dry matter yield (r = 0.907**).

The principal component analysis (PCA) was performed to visualize the main sources of variability between populations. PCA identified two principal components, which together accounted for 80.06% of the total variation (Figure 1). The first component (PC1) explains 53.01% of the total variation and was positively associated to total number of pods and seeds and negatively to green matter yield and dry matter yield. The second component (PC2) accounted for 27.05% of the variation. It is positively correlated with pod and seed weight. In fact, populations of *M. minima*

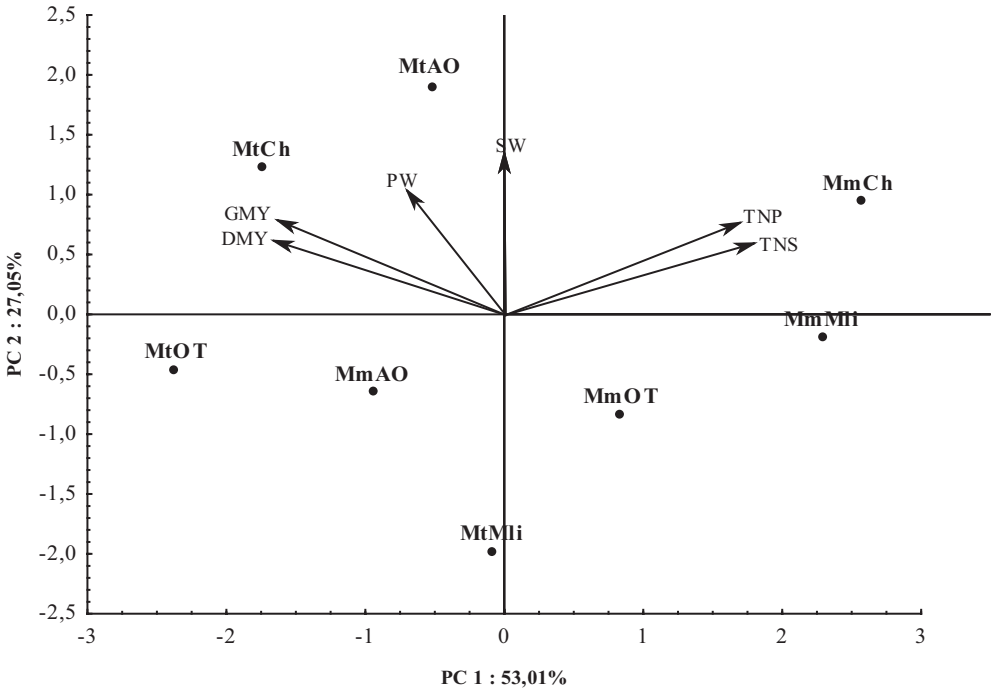

Figure 1 : Biplot of Principal Components Analysis performed on traits and sympatric populations of *M. minima* and *M. truncatula.*

from Charef, Mliliha and Oued Touil regions, plotted on the positive side of PC1, produced high number of pods and seeds. In contrast, population of *M. truncatula* from Charef and Oued Touil with *M. minima* population from Ain Oussera region are characterized by high biomass and high dry matter yield. Population of *M. truncatula* from Ain Oussera region, projected on the positive side of the PC2, was distinguished by high yields of pods and seeds, unlike the population of *M. truncatula* from Mliliha and population of *M. minima* of Oued Touil.

CONCLUSION

In conclusion, this study showed high level of genetic variability among sympatric populations of *M. minima* and *M. truncatula* for all agronomic traits. This variability offers possibilities for selection of adapted plant and can be exploited in pastures to improve forage production and in crop-livestock farming systems in Algeria. High forage and seed yields were obtained in populations of *M. truncatula*. These populations could be recommended for use in forage breeding programs. Further investigations should

be needed to evaluate the water stress responses in local populations of *M. truncatula* in order to develop tolerant populations to drought.

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