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Morphological and Growth Characteristics of Perennial Grass Cultivars Grown under Semi-Arid Conditions of the Algerian High Plateaus

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Abstract: The objectives of the present study, conducted during the 2005-2007 cropping seasons, were to characterize variation for dry matter yield, forage maturity, LSR, LA, SLM, EG, RC, RWC, EL and WUE among sixteen perennial grass cultivars grown under drought conditions in the semi arid climate of the Algerian high plateaus. The results indicated that the tested genotypes varied widely for the measured characteristics. Dry matter performance was positively associated with early heading, high water use efficiency and plant stature. DMY performance appeared to be independent from leaf area, leaf to stem ratio, leaf specific mass, relative growth rate and etiolated growth. Best dry matter performing genotypes were Partenope, Fraydo and Fletcha^{EF} and were characterized by high WUE, earliness, above average RGR and below average LSR and EL, but varied for the others measured traits. These results were based on data obtained in the establishment and first production years, when little time has elapsed for the cumulative effects of stress to impact stand persistence.

Key words: Cool-season perennial grasses, dry matter yield, relative growth rate, earliness, persistence, principal component analysis, semi-arid climate

INTRODUCTION

In the semi arid area of the Algerian high plateaus, water is the main limiting factor for plant production, vegetation growth and eco-environmental rehabilitation. Severe water deficits accompanied by extreme heat in summer and cold winter, determine agricultural productions (Tutwiler *et al*., 1997). The predominant land-use pattern is cereals and fallow as wheat and barley are among the few adapted crops to this environment, while fodder occurs only on a very limited scale (Adem and Ferrah, 2002). There is a rising concern, in the region, for natural resource conservation and rehabilitation of rangelands to halt degradation and to improve productivity. Flocks of small ruminants are fed primarily on weedy fallow, barley and wheat stubbles and grains. This feed does not supply animals with the necessary energy and protein, thus, it is urgent to study and likely to cover the animals needs even during the dry periods of the year (Mohguen and Abdelguerfi, 2004).

The availability of water in the soil is the main limiting factor for Mediterranean pasture production (Medrano *et al*., 1998) and plant survival. Some species develop morphological and physiological changes (reduction of leaf area, increase of root growth, stomatal control, osmotic adjustment etc.) in order to improve their water use efficiency and consequently, to ameliorate their survival (Lefi *et al*., 2004).

Cool-season grasses are an important source of high quality forage which complements grazed fallow and reduces from the required energy supplementation. These species contribute to environmental sustainability of the agro ecosystems by reducing soil erosion, conserving soil water and improving soil physical and chemical properties (Reuter and Horn, 2002). For a sustainable development of agriculture in the region, it is important to study the performances of these species to semi arid climate. This was the rationale of setting up this experiment whose objective was to characterize variation for dry matter yield, forage maturity, plant height, leaf to stem ratio, leaf water status, etiolated growth, persistence and water use efficiency among cool-season perennial grass varieties evaluated under semi-arid conditions of the eastern high plateaus of Algeria.

MATERIALS AND METHODS

Experimental site characterization: The field study was conducted in 2005-2007 at the Setif Agricultural Experimental Station (ARS) of the Field Crop Institute (ITGC) located at grid reference 36°12'N, 5°24'E and altitude 1023 masl. The long term annual mean

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Corresponding Author: M. Mefti, Department of Agronomy, Faculty of Sciences, University of M'Sila, 28000, Algeria precipitation of the experimental site is 396.0 mm, recorded mainly from November to March with a winter mean temperature of 6.6°C and a spring mean temperature of 12.5°C. The climate is temperate continental, varying from arid to semi-arid. The soil is loamy clay, with a bulk density of 1.35 g cm^{-3}. The area has a sparse vegetation and experiences serious soil erosion as a result of human activities and unfavorable land-use.

Plant materials: The field, with chickpea as preceding crop, was prepared in the autumn of 2005. One hundred kilogram per hectare of super phosphate 46% fertilizer, the ordinary application level for cereals production in the area, was applied just before the field was ploughed. The sowing was done by hand in October 2005, where sixteen perennial forage grass varieties, were implanted, among which seven varieties of tall fescue (*Festuca arundinacea* Shreb.), seven varieties of orchard (*Dactylis glomerata* L.) and two genotypes of phalaris (*Phalaris aquatica* L.). The plant material originated mainly from Portugal, Italy, France and Australia, was obtained via the Permed project.

Each grass variety was sowed on a 10 row-plot 2.5 m long and 0.20 m row spacing. The experiment was laid down in a simple lattice with four replications. Average seeding rate was 12 kg ha^{-1}. The seed germination percentages measured, varied but were all above 70% within 7 days. Weeds were controlled chemically by application of Zoom (4.1% Trisulfuron+65.9% Dicamba) at a rate of 120 g ha^{-1} in March 2006 and 2007. Nitrogen fertilizer was applied during the same months at a rate of 100 kg ha^{-1} as urea 35% and in November 2006. During the sward establishment year, the experiment was given 40 mm irrigation, in March 2006, after a severe drought spell (Fig. 1).

Measurements: The plots, 6 inner rows×2 m long in size, were harvested in June 2006, November 2006, April 2007 and June 2007 by clipping mechanically at a height of 7.0 cm. Fresh plant material samples, of varying size (100-500 g), were dried at 70°C for 48 h at each harvest for dry matter determination. Defoliation was initiated in the autumn before the onset of kill frost and in the spring and summer seasons when inflorescence emerged in at least 4 among the test varieties. Days to heading were recorded as number of Julian days from January 1st to when 50% panicles fully emerged from the flag leaf, on the outer rows. Aboveground biomass was the sum of cumulative herbage Dry Matter Yield (DMY) per cycle, defined as the period from September through August. Samples of plant material were taken, from outer row-segment 0.30 m long, on March 3rd and April 28th, 2007, (207 and 240 days after September 1st, 2nd cycle, corresponding to the active growth period) with the aim to determine the Leaf Area (LA) and the Relative Growth Rate (RGR). The RGR was calculated using the equation given by Wilhelm and Nelson (1978).

Leaves were separated from the stems, then the leaf lamina length (L) and width (l) were determined from a random subsample of 10 leaves and the leaf area of the subsample calculated according to Vaylay and Van Santen (1999).

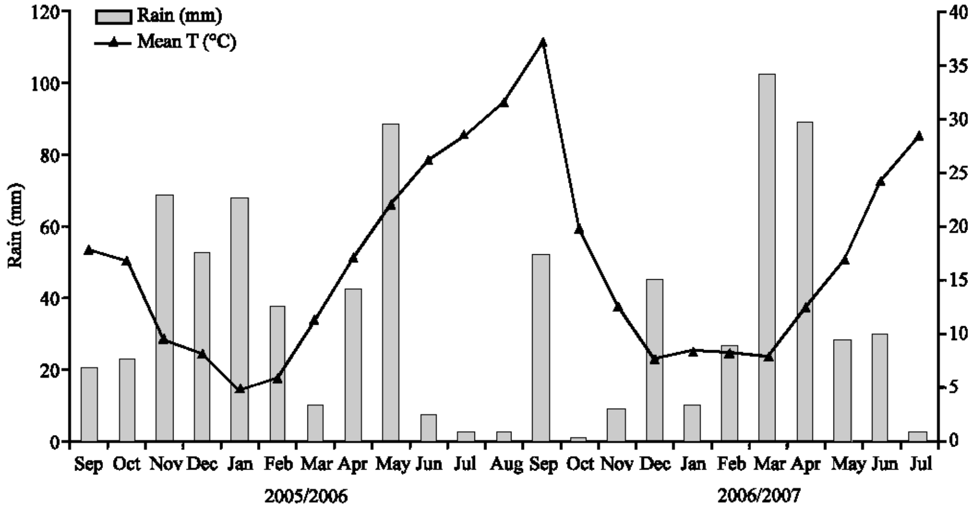

Fig. 1: Monthly rainfall and mean monthly temperature recorded at the weather station of the national office of meteorology during 2005/06 and 2006/07 cropping seasons

The Specific Leaf Mass (SLM) was determined from the 10-leaf subsample and the Leaf Stem Ratio (LSR) was calculated from the total leaves dry weight over tillers dry weight of the harvested samples. Leaf Relative Water Content (LRWC) was determined in May by taking 5 first and second fully expanded leaves per genotype from the first replicate. Leaves were clipped and weighted to obtain the Fresh Weight (FW), they were placed into vials containing 10 mL of distilled water and let to stand for 4 h at 4°C, under dime light. The leaves were then weighted after excess moisture was removed with paper towels to obtain the Turgid Weight (TW). The sampled leaves were dried in an oven at 70°C for 24 h to obtain the Dry Weight (DW). The leaf relative water content was calculated with the formulae given by DaCosta *et al.* (2004).

Electrolyte Leakage (EL) was determined in May from leaf sample of 10 disks placed in stoppered vials. The leaf samples were washed three times with distilled water to remove dust from their surface. Ten milliliter of de-ionized water was added to each sample and let to stand at room temperature for 6 h. The Electrical Conductivity (EC_1) of the bathing solution was read. The sample vials were returned to water bath sets at 100°C for one hour and let to stand for 24 h before a second reading of the bathing solution was made (EC_2). The relative amount of electrolyte leakage was estimated according to the formulae given by DaCosta *et al.* (2004).

Plant height was determined as an average of three measurements taken per plot from the soil surface to the highest point of the vegetation. Ground cover percent of living grown tissue was visually rated on each plot immediately after the last harvest, in May-June and at the beginning of the crop season, in September. Variation in the ground cover was used as a measure of persistence according to Casler *et al.* (2002). Etiolated growth was measured to quantify total organic reserves of a genotype and thereby its regrowth ability according to Reece *et al.* (1988). In the spring, of the second cropping cycle, sods were covered with plastic pots, 22 cm diameter×15 cm deep to exclude light. Weights were placed on top of each pot to prevent it from being blown over. Etiolated growth dry matter was measured by clipping all etiolated plant materials (new regrowth) one week later. Clipped biomass was dried in a forced air oven at 70°C for 24 h and the dry mass determined.

Soil water measurements were made with neutron probe at the start of the cropping season in September and just after the last cut in May-June. The measurements were made for soil extending to a depth of 100 cm. The neutron probe readings were calibrated against the soil moisture content which was determined gravimetric for each depth: 0-20, 20-40, 40-60, 60-80 and 80-100 cm. The total of water evapotranspired (TWU) by the crop was estimated according to Chen *et al.* (2003).

$$\text{TWU} = \text{ASW}_{09}+\text{Rainfall}-\text{ASW}_{06}$$

Where:

ASW_{09} = The available soil water at the start of the season, measured in September

Rainfall = The accumulated rainfall during the season, which was monitored at the national weather station, located 5 km away from the experimental field

ASW_{06} = The available soil water measured just after the last harvest in May-June

Water-Use Efficiency (WUE) was expressed as kilograms of forage dry matter yield per hectare per mm of water evapotranspired, according to Chen *et al.* (2003):

$$\text{WUE (kg ha}^{-1}\text{ mm}^{-1}) = \text{DMY/TWU}$$

Statistical analyses: The collected data were statistically analyzed with the balanced ANOVA subroutine of IRRISTAT (2005), the correlation analysis was done using the product-moment correlation subroutine of Stats4U (2007) and the principal component analysis was done using the Multivariate analysis procedure of Kyplot (2001) software package. Data collected during two seasons were analyzed as a factorial in randomized complete block design, in which blocks were nested into years, genotypes were considered as fixed and years as random. Differences among the entry means were tested using the Least Significant Difference (LSD) test at the 0.05 probability level.

RESULTS AND DISCUSSION

Persistence and earliness: Climatic conditions during the two evaluation years differed somewhat. The 2005/06 growing season had a cold rainy winter and a warm spring with a rainfall peak in May, followed by a dry and hot summer. The 2006/07 cropping season was characterized by a cold and relatively dry winter and a rainy spring leading to a good vegetative growth (Fig. 1). Row cover showed no significant difference between years, no significant genotype x year interaction but a significant genotype main effect (Table 1). This indicated that the different genotypes showed little reduction in the row cover, so maintaining acceptable swards persistence during the first-two evaluation years (Table 2). The genotypes differed, however, in their sensitivity to the establishment conditions. In fact row cover means, averaged over cycles, varied from 42.6 to 88.9% (Table 3). Persistence is an important sward characteristic and traits which generally contribute to this characteristic are

Table 1: Mean square of the combined analysis of variance for dry matter yield, row cover, plant height, number of days to heading and water use efficiency measured during two cropping seasons

Source of variation	DF	RC	DMY	PHT	DHE	WUE
Year (Y)	1	705.00^{ns}	177442000**	106.00^{ns}	10749.00**	1172.00**
Rep/Year	6	2936.00	1646150	47.50	66.99	12.03
Genotype (G)	15	1023.90**	3224960^{ns}	1968.00**	202.00^{ns}	20.00^{ns}
G×Y	15	7.34^{ns}	3656850**	159.00*	169.00**	27.00**
Residual	90	118.50	3369930	77.62	22.52	1.87

DMY= Dry Matter yield (kg ha^{-1}), RC= row cover (%), PHT= plant height (cm), DHE= number of days from January 1st to heading (days), WUE= water use efficiency (kg ha^{-1} mm^{-1}); ns,*, **= Effects non significant and significant at the 5 and 1% probability levels, respectively

Table 2: Mean dry matter yield (kg ha^{-1}), row cover (%), plant height (cm), number of days to heading and water use efficiency, averaged over genotypes

Season	DMY	RC	PHT	DHE	WUE
2006	1231.8	62.8	86.6	132.3	3.29
2007	3586.6	58.2	84.8	114.0	9.34
$Lsd_{5\%}$	554.7	23.4	2.9	3.5	1.49

Table 3: Row cover and plant height means averaged over both-growing seasons and leaf area, leaf stem ratio, specific leaf mass, relative growth rate, etiolated growth, leaf relative water content and electrolyte leakages means measured during the second year

Genotype	RC	PHT	LA	LSR	SLM	RGR	EG	RWC	EL
Jana	69.9	81.9	59.7	0.46	13.2	39.3	270.00	64.1	19.4
Medly	68.3	80.4	53.1	0.34	20.6	45.6	257.50	68.3	17.9
Kasbah	59.2	66.0	34.5	0.21	37.9	44.6	204.00	50.4	42.0
Delta	56.3	73.2	78.7	0.36	20.1	51.3	181.00	72.3	26.5
Currie	62.2	65.3	102.6	0.57	16.4	43.8	275.00	80.4	28.6
Porto	55.3	61.8	105.3	0.81	13.3	42.0	404.00	76.7	18.0
Ottava	51.1	73.6	80.8	0.27	20.8	63.4	150.00	67.3	28.8
Tanit	63.2	89.9	65.7	0.24	32.8	44.3	115.00	81.1	36.5
Sisa	45.6	99.9	140.5	0.48	12.4	36.9	670.00	66.6	14.5
$Fletcha^{EI}$	53.5	99.9	77.5	0.16	45.8	38.9	335.00	69.8	13.2
Centurion	57.9	102.8	80.6	0.19	18.3	54.4	75.00	76.5	31.5
$Fletcha^{EF}$	66.0	110.3	80.9	0.18	30.9	51.3	225.00	70.8	16.3
Lutine	42.8	93.5	140.7	0.63	17.5	49.4	407.50	81.1	14.0
Fraydo	54.8	108.7	107.0	0.22	15.2	49.6	42.50	82.0	23.8
Partenope	88.9	79.8	98.2	0.37	28.9	51.0	277.60	65.6	22.5
Australian	73.3	84.2	118.5	0.93	13.9	40.8	50.00	84.5	21.7
$Lsd_{5\%}$	2.9	13.4	21.5	0.08	6.2	7.3	--	3.7	--

RC = Row Cover (%), PHT = Plant Height (cm), LA = Leaf Area of 10 random leaves (cm^2), LSR = Leaf Stem Ratio; SLM = Specific Leaf dry Mass (mg cm^{-2}) RGR = Relative Growth Rate, EG = Etiolated Growth (kg ha^{-1}) RWC = leaf Relative Water Content (%), EL = Electrolyte Leakage (%)

summer dormancy, grazing or defoliation tolerance and earliness (Casler and Vogel, 1999). Prolonged summer droughts and poor management practices adversely affect it; and as a result, swards are short-lived and require frequent re-establishment (Malinowski *et al*., 2005).

The swards took longer time to head during the first year of establishment compared to the second year, with a mean number of days to head, averaged over genotypes, of 132.3 in 2005/2006 against 114.0 days in 2006/2007 (Table 2). The accumulated growing degree days (base 0°C) of the October-April period reached 2187 and 3417°C in 2005/2006 and 2006/2007, respectively. The number of days to head showed a significant genotype×season interaction (Table 1). The phalaris Australian headed 5 days earlier in 2006/2007 than in 2005/2006 and genotypes such as Medly, Fraydo, Kasbah and $Fletcha^{EF}$ were late to head in 2005/2006 but they are classified among the earliest, in 2006/2007 (Fig. 2). According to Piano *et al.* (2005), early-flowering perennial grasses are more suited to environments with terminal abiotic stress, since they grow actively during winter and early spring.

Plant height, dry matter yield and water use efficiency: Mean plant height, averaged over genotypes, showing no significant difference between years (Table 1, 2). Significant differences appeared, however, between genotypes for mean plant height averaged over years (Table 3). The orchard grass Porto, with 61.8 cm, was the shortest and the fescue $Fletcha^{EF}$ was the tallest among the evaluated entries with a mean plant height of 110.3 cm (Table 3). During the establishment year, only one harvest was done, identifying the phalaris cultivars Partenope and Australian as the top dry matter yielding entries, followed by the fescue genotypes $Fletcha^{EF}$ and Fraydo. All the remaining entries yielded significantly less (Fig. 3). During the second year, three harvests were done, in autumn, spring and summer. The autumn and summer yields were relatively low, with an average dry matter yield of 517.2 kg ha^{-1} for the autumn harvest and 653.2 kg ha^{-1} for the summer harvest. The spring harvest allowed however better expressions of the yielding ability of the different genotypes, with an overall mean dry matter yield of 2415.9 kg ha^{-1}. During the second year Fraydo, $Fletcha^{EF}$,

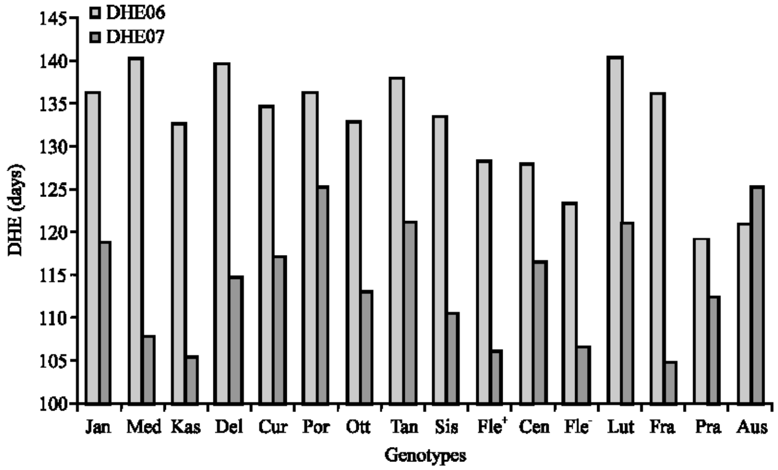

Fig. 2: Mean number of days to heading of the different genotypes during two years (Jan = Jana, Med = Medly, Kas = Kasbah, Del = Delta, Cur = Currie, Por = Porto, Ott = Ottava, Tan = Tanit, Sis = Sissa, Fle^+ = Fletcha endophyte infected, Fle^- = Fletcha endophyte free, Cen = Centurion, Lut = Lutine, Fra = Fraydo, Par = Partenoppe and Aus = Australian)

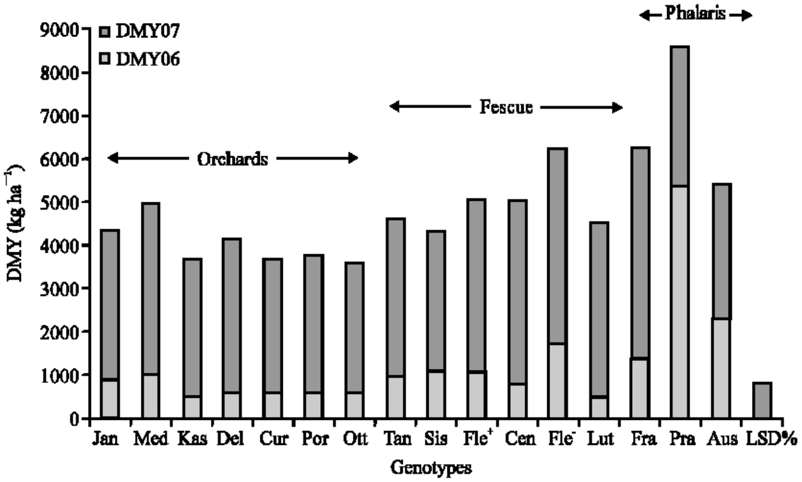

Fig. 3: Dry matter yield means accumulated during the two years for the different genotypes (Jan = Jana, Med = Medly, Kas = Kasbah, Del = Delta, Cur = Currie, Por = Porto, Ott = Ottava, Tan = Tanit, Sis = Sissa, Fle^+ = Fletcha endophyte infected, Fle^- = Fletcha endophyte free, Cen = Centurion, Lut = Lutine, Fra = Fraydo, Par = Partenoppe and Aus = Australian)

Centurion and Lutine were the top yielding with a mean dry matter yield ranging from 4748.4 to 4030.5 kg ha^{-1}. Ottava was the least yielding genotype with a dry matter yield mean of 2982.0 kg ha^{-1} (Fig. 3).

The analysis of variance of the dry matter yield accumulated during the two years indicated that the phalaris Partenope was the top yielding with an average dry matter yield of 8479.8 kg ha^{-1}, followed by a second and significantly different ($LSD_{5\%}$ = 1254.2 kg ha^{-1}) group formed by Fraydo, $Flectcha^{EF}$, Australian, $Fletcha^{EI}$ and Centurion with a mean yield ranging from 6156.7 to 4954.0 kg ha^{-1}. The least yielding group was formed by Kasbah (3640.0 kg ha^{-1}), Currie (3632.0 kg ha^{-1}) and Ottava (3538.9 kg ha^{-1}) (Fig. 3). Water use efficiency varied significantly between years; the establishment year being less efficient in terms of water use for almost all tested entries (Table 1, 2). The genotype×year interaction indicated changes in magnitude and in direction of responses. In fact Partenope showed a higher WUE during the first year than in the second year (Fig. 4). Australian and $Fletcha^{EF}$ showed relatively high WUE during both years; while Lutine and Kasbah had low

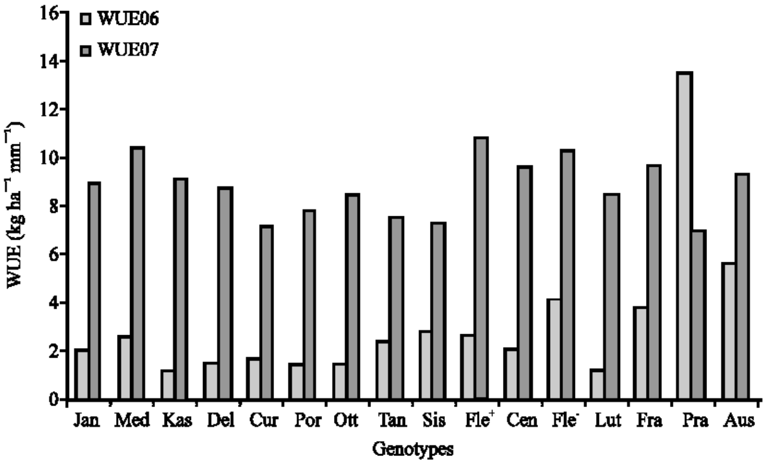

Fig. 4: Mean water use efficiency of the different genotypes measured during the two years (Jan = Jana, Med = Medly, Kas = Kasbah, Del = Delta, Cur = Currie, Por = Porto, Ott = Ottava, Tan = Tanit, Sis = Sissa, Fle$^+$ = Fletcha endophyte infected, Fle$^-$ = Fletcha endophyte free, Cen = Centurion, Lut = Lutine, Fra = Fraydo, Par = Partenoppe and Aus = Australian)

WUE means in the establishment year and relatively high WUE means in the second year (Fig. 4).

Leaf structure, water status, cell membrane integrity and etiolated growth: The tested genotypes differed significantly for the traits measured during the second year (Table 3). Cultivars Sisa, Lutine and Australian produced leaves with significantly Large Area (LA) while Kasbah and Tanit exhibited leaves with a smaller area. Australian, Porto and Lutine had a high Leaf to Stem Ratio (LSR), in contrast to Fletcha^{EI}, Fletcha^{EF} and Fraydo which showed a low LSR (Table 3). Fletcha^{EI}, Fletcha^{EF}, Tanit, Partenope and Kasbah had a high Specific Leaf dry Mass (SLM) while Jana, Porto, Sisa, Australian had a low SLM. Ottava, Centurion, Flecha^{EF}, Partenope and Delta showed a high relative growth rate. A high etiolated growth capacity was expressed by Sisa, Porto and Lutine. Kasbah was the outlier among the evaluated genotypes, showing a low LRWC in comparison with the other genotypes and expressed a high percentage of electrolyte leakage with Tanit and Centurion (Table 3). Cuomo *et al*. (1998) found no significant differences in etiolated growth biomass between grass cultivars. Anderson *et al*. (1999) reported, however, that defoliation had a greater impact on energy reserves when apical meristems were removed. Wilhelm and Nelson (1978) found that high dry matter yielding genotypes exhibited greater increases in leaf dry weight than did the low yielding genotypes.

Genotypic characterization: The variables presented in Table 3, together with the total dry matter yield, maturity and water use efficiency, expressed during the second year were used in the principal component analysis. These traits represented roughly plant performances (DMY, WUE), dry matter partitioning (LA, LSR, SLM, PHT) and stress tolerance (DHE, EL, LRWC, RC, EG). The first 3 principal components (PC) accounted for 70% of the variation (30, 23 and 17% for PC$_1$, PC$_2$ and PC$_3$, respectively) within the data subjected to analysis. PC$_1$ had large positive loadings for LA and LSR, LRWC and DHE and negative loadings for SLM and EL (Table 4). PC$_2$ was influenced primarily by DMY, PHT and WUE, all having positive loadings. PC$_3$ was influenced by RC and RGR, with positive loadings and by EG, with a negative loading (Table 4).The biplots of the first three principal components showed a wide spread of the different genotypes across the multi-dimensional spaces of the analyzed variables, indicating that these genotypes harbored different combinations of the traits subjected to the PCA (Fig. 5-7). Porto and Kasbah sheared large scores on the first 2 principal components; and due to their relative position along the PC$_1$ axis, Porto was characterized by high values for LA, LSR, LRWC, DHE and low values for SLM and EL, while Kasbah, on the opposite, harbors low values for LA, LSR, LRWC, DHE and high values for SLM and EL. Both cultivars had low DMY, PHT and WUE, as indicated by their relative position along the PC$_2$ axis (Fig. 5). The large score of Jana on the PC$_2$, indicated its low yielding ability associated with intermediate values LA, LSR, LRWC, DHE, SLM and EL, while the relatively high score of Medly on the PC$_1$ indicated its intermediated DMY, PHT and WUE means associated with low values for LA, LRWC, LSR and high values for SLM, EL and DHE (Fig. 5).

Table 4: Principal component analysis on the correlation matrix among the agronomic traits of perennial grass cultivars

	Principal components		
	1	2	3
Variance acconnted for (%)	30	23	17
	Latent vectors		
RC	-0.195	0.276	0.475
PHT	0.084	0.771	-0.361
LA	0.886	0.228	-0.175
LSR	0.819	-0.358	0.233
SLM	-0.685	0.244	-0.209
RGR	-0.290	0.282	0.395
EG	0.352	-0.297	-0.783
LRWC	0.682	0.268	0.382
EL	-0.569	-0.237	0.571
DHE	0.650	-0.358	0.513
WUE	0.440	0.804	0.149
DMY	-0.006	0.854	0.087

RC = Row Cover (%), PHT = Plant Height (cm) LA = Leaf Area of 10 leaves (cm^2), LSR = Leaf: Stem Ratio, SLM = Specific Leaf dry Mass (mg cm^{-2}), RGR = Relative Growth Rate, EG = Etiolated Growth (kg ha^{-1}) LRWC = Leaf Relative Water Content (%) EL = Electrolyte Leakage (%) DHE = No. of days to heading, days, WUE = Water Use Efficiency (kg ha^{-1} mm^{-1}) DMY = Total Dry Matter Yield accumulated during the two years, kg ha^{-1})

Partenope, Fraydo, Fletcha^{EF} and to a lesser extend Centurion had large positive scores on the PC$_2$ axis, they were opposed to Currie and Delta$_1$ which had large negative scores. Partenoppe, Fraydo and Fletcha^{EF} were characterized by high mean values for DMY, PHT and WUE. Currie and Delta$_1$ harbored low mean values for the same traits, Centurion being intermediate. Both groups were characterized by relatively intermediate mean values for RC, RGR and EG (Fig. 6). Fletcha^{EI} had large negative score on the PC$_{3,}$ it was characterized by a relatively large EG mean value and low RC and LRWC mean values associated with intermediate DMY, PHT and WUE mean values, approaching the mean values exhibited by Centurion (Fig. 6). Australian was characterized by large mean values of LA and LSR, associated with high mean values for RC and RGR, while Lutine had large mean values for LA and LSR and intermediate mean values for RC and RGR (Fig. 7). Sisa was opposed to Australian for the features related to PC$_3$, having high mean values for LA, LSR and EG and low mean values for RC and RGR (Fig. 7). Tamit and Ottava were characterized by low mean values for LA, LSR and EG associated with high mean values for RC and RGR (Fig. 7).

The amount of water available to agriculture in the North African countries is declining because of greater incidence of drought, inciting to maximize the efficiency of the use of water for agricultural production (Tutwiler *et al*., 1997). In this context, perennial forage grasses are likely to contribute to greater sustainability of rainfed agricultural systems if adapted cultivars are developed. These species can utilise water throughout the whole year besides being able to halt rangeland degradation, restoring soil fertility and enhancing forage production in autumn. They are better suited as complementary forage source to straw, crop residues and supplementation feed (Malinowski *et al*., 2005). The objectives of the present study were to characterize variation for dry matter yield, forage maturity, LSR, LA, SLM, EG, RC, RWC, EL and WUE among sixteen perennial grass cultivars. According to Reece *et al*. (1988) and to Donaghy and Fulkerson (1997) EG is a measure of the energy reserves stored by the plant and used after defoliation in regrowth; it is related to plant vigor.

Casler and Vogel (1999) mentioned that in grasses leaves and stems have similar in vitro dry matter digestibility and selection for increased whole-plant forage quality had little effect on LSR which was associated with a reduction in forage DMY. According to Mayland and Sleper (1993) leaf and stem ash content were negatively associated with WUE and positively correlated with LSR. Cultivars that matured rapidly had low ash content and high SLM that slower maturing ones. They maintain a higher tissue water status or higher transpiration rate by extracting more deep soil moisture because they are able to develop deeper rooting system. Selection to improve WUE, under drought conditions, might reduce LSR and forage quality. Ray *et al*. (1998) reported that SLM was positively associated with whole plant transpiration efficiency. In addition to DMY, selection for key morphological and physiological traits including LA, SLM, LSR, DHE and PHT offers the opportunity to improve WUE in perennial grasses as a surrogate to the expensive carbon isotope discrimination determination. Early-flowering perennial grasses grow actively during winter and early spring, they are more synchronized in development, ceasing growth in response to soil water deficits and high temperatures during summer. They initiate autumn regrowth in response to decreasing day length and lower temperatures (Volaire, 1995; Piano *et al*., 2005). Wilson and Sarles (1978) reported that under drought conditions these species performed better because they developed a greater distribution of roots deeper in the soil profile, making a best use of the available soil water. These adaptive features suggest that, in semi-arid areas such as the eastern high plateaus of Algeria, early cool-season perennial grasses might be more persistent and sustainable than late ones.

The results of the present study indicated that the tested genotypes varied widely for the measured characteristics. Dry matter performance was associated with early heading, high water use efficiency and plant

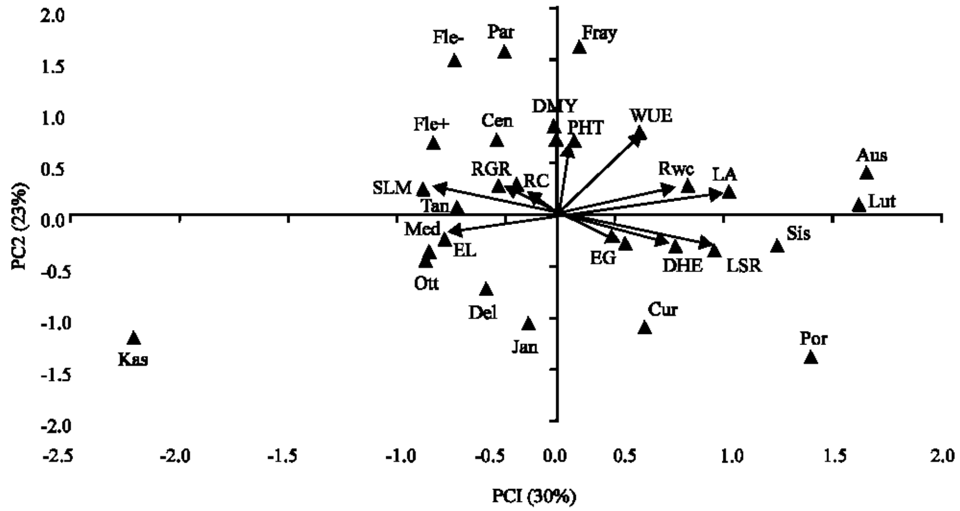

Fig. 5: Biplot of the first 2 dimensions in the principal component analysis of the morphological traits among perennial grass cultivars, arrows indicate the directions of the original variables in relation to the principal components (Jan = Jana, Med = Medly, Kas = Kasbah, Del = Delta, Cur = Currie, Por = Porto, Ott = Ottava, Tan = Tanit, Sis = Sissa, Fle$^+$ = Fletcha endophyte infected, Fle$^-$ = Fletcha endophyte free, Cen = Centurion, Lut = Lutine, Fra = Fraydo, Par = Partenoppe, Aus = Australian; RC = Row Cover (%), PHT = Plant Height (cm), LA = Leaf Area of 10 leaves (cm^2), LSR = Leaf Stem Ratio, SLM = Specific Leaf dry Mass (mg cm^{-2}), RGR = Relative Growth Rate, EG = Etiolated Growth (kg ha^{-1}), RWC = Leaf Relative Water Content (%) EL = Electrolyte Leakage (%) DMY = Dry Matter Yield (kg ha^{-1}), DHE = No. of days from January 1st to heading (days), WUE = Water Use Efficiency (kg ha^{-1} mm^{-1})

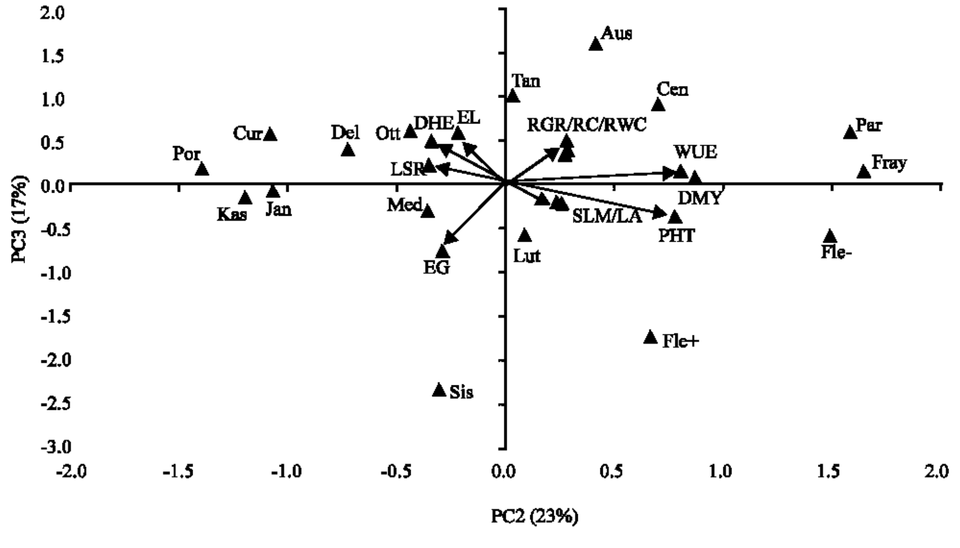

Fig. 6: Biplot of the second and third dimensions in the principal component analysis of the morphological traits among perennial grass cultivars, arrows indicate the directions of the original variables in relation to the principal components (Jan = Jana, Med = Medly, Kas = Kasbah, Del = Delta, Cur = Currie, Por = Porto, Ott = Ottava, Tan = Tanit, Sis = Sissa, Fle$^+$ = Fletcha endophyte infected, Fle$^-$ = Fletcha endophyte free, Cen = Centurion, Lut = Lutine, Fra = Fraydo, Par = Partenoppe and Aus = Australian; RC = Row Cover (%) PHT = Plant Height (cm), LA = Leaf Area of 10 leaves (cm^2), LSR = Leaf:Stem Ratio, SLM = Specific Leaf dry Mass (mg cm^{-2}), RGR = Relative Growth Rate, EG = Etiolated Growth (kg ha^{-1}), RWC = Leaf Relative Water Content (%), EL = Electrolyte Leakage (%), DMY = Dry Matter Yield (kg ha^{-1}), DHE = No. of days from January 1st to heading (days), WUE = Water Use Efficiency (kg ha^{-1} mm^{-1})

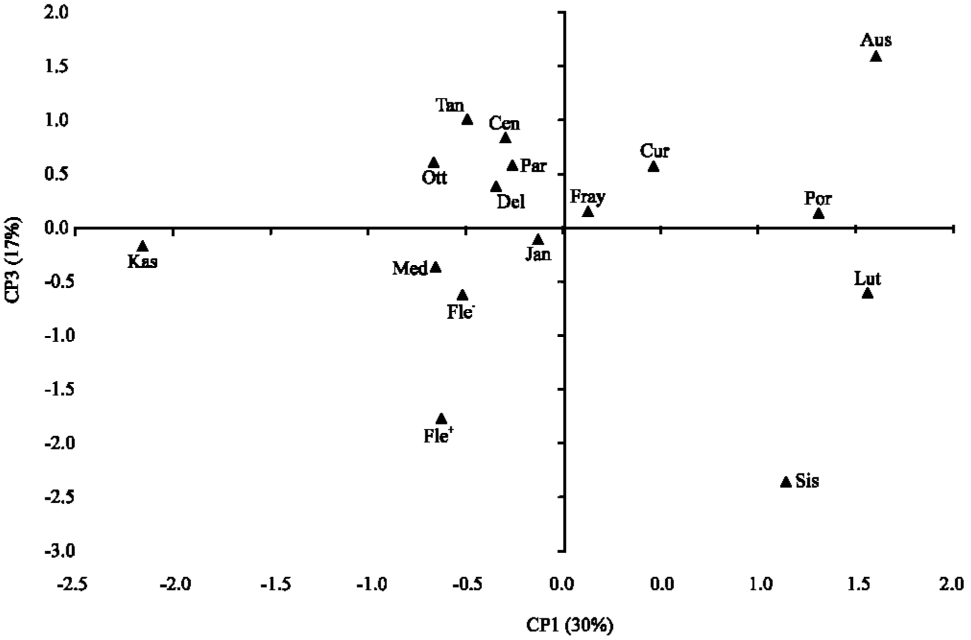

Fig. 7: Biplot of the first and third dimensions in the principal component analysis of the morphological traits among perennial grass cultivars (Jan = Jana, Med = Medly, Kas = Kasbah, Del = Delta, Cur = Currie, Por = Porto, Ott = Ottava, Tan = Tanit, Sis = Sissa, Fle$^+$ = Fletcha endophyte infected, Fle$^-$ = Fletcha endophyte free, Cen = Centurion, Lut = Lutine, Fra = Fraydo, Par = Partenoppe and Aus = Australian)

stature. DMY performance appeared to be independent from leaf area, leaf to stem ratio, leaf specific mass, relative growth rate and etiolated growth. Best dry matter performing genotypes, which were Partenope, Fraydo and Fletcha^{EF}, were characterized by high WUE, earliness, above average RGR and below average LSR and EL, but varied for the others measured traits. These results were based on data obtained in the establishment and first production years, when little time has elapsed for the cumulative effects of stress to impact stand persistence.

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