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Dry matter production and agronomical characteristics of perennial grass genotypes grown under drought conditions in the semi-arid climate of the Algerian high plateaus[1]

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SUMMARY – 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. 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.

Keywords: Dry matter yield, relative growth rate, earliness, persistence, semi-arid climate.

RESUME – *"Production de matière sèche et caractéristiques agronomiques des génotypes de graminées pérennes cultivés en conditions sèches sous le climat semi-aride des hauts plateaux algériens". Les objectifs de la présente étude étaient de caractériser la variation du rendement de matière sèche, la précocité, LSR, LA, SLM, EG, RC, RWC, EL et EUE de 16 variétés de graminées pérennes, conduites en sec, en 2005-2007, sous climat semi-aride dans les hauts plateaux algériens. Les résultats montrent que les génotypes étudiés différaient largement pour les caractéristiques mesurées. Les meilleures variétés pour le rendement de matière sèche étaient Partenope, Fraydo et Fletcha^{EF}, elles étaient caractérisées par une EUE élevée, la précocité, un RGR au-dessus de la moyenne, et un LSR au-dessous de la moyenne.*

Mots-clés : *Rendement, taux de croissance relative, précocité, persistance, climat semi-aride.*

Introduction

In the semi arid area of the Algerian high plateaus the predominant land use pattern is cereals and fallow as wheat and barley are among the few adapted crops to this environment. Fodder occurs only on a very limited scale. There is a rising concern to conserve natural resources and to halt rangelands degradation. Perennial grasses are an important source of high quality forage which could complement grazed fallow, and contribute to the agro ecosystems sustainability by reducing soil erosion and conserving soil water. For a sustainable development of agriculture in the region, it is important to study the performances of these species under 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, persistence and water use efficiency among perennial grass varieties evaluated under semi-arid conditions of the eastern high plateaus of Algeria.

Materials and methods

The field study was conducted in 2005–2007 at the Setif Agricultural Experimental Station of the Field Crop Institute located at grid reference 36°12′N, 5°24′E and altitude 1023 asl. Sixteen perennial forage grass varieties of tall fescue, cocksfoot and phalaris, were sown in Oct. 2005, on a 10 row-plot 2.5 m long and 0.20 m row spacing. Weeds were controlled chemically. Nitrogen was applied, as urea 35%, in the spring (100 kg ha^{-1}) and in the autumn (50 kg ha^{-1}). The plots were harvested in June and November 2006, and in April and June 2007. Fresh plant material was dried for dry matter yield

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determination (DMY). Samples of plant material were taken to determine leaf area (LA), relative growth rate (RGR), specific leaf mass (SLM), leaf: stem ratio (LSR), leaf relative water content (RWC), and electrolyte leakage (EL). Plant height (PHT) was measured as an average of 3 values per plot. Ground cover percent of living plant material (RC) was visually rated per plot, immediately after the last harvest, and at the start of the cropping season, and used as a measure of persistence (Casler *et al.,* 2002). Etiolated growth (EG) was measured to quantify the genotype regrowth ability (Reece *et al.,* 1988). Soil water measurements were made with neutron probe, in September and just after the last harvest. Water-use efficiency (WUE) was expressed according to Chen *et al.,* (2003). The collected data were statistically analyzed with Irristat software package (2005). Differences among the entry means were tested using the LSD test at the 0.05 probability level. The genotypic characteristics representing plant performances (DMY, WUE), dry matter partitioning (LA, LSR, SLM, PHT) and stress tolerance (DHE, EL, LRWC, RC, EG), expressed during the second production year, were used in the principal component analysis (PCA).

Results and discussion

Persistence, earliness, dry matter yield and water use efficiency

The RC showed no significant difference between years, indicating that the different varieties maintained acceptable persistence during the first-two evaluation years. 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 days, in 2005/06, against 114.0 days in 2006/07. Medly, Fraydo, Kasbah and Fletcha^{EF} were classified among the earliest. Piano *et al.,* (2005) mentioned that early-flowering varieties are more suited to environments with terminal abiotic stress, since they grow actively during winter and early spring. Significant differences appeared, between genotypes, for mean PHT, averaged over years. Porto was the shortest and Fletcha^{EF} was the tallest (Table 1). During the establishment year, Partenope and Australian were the top dry matter yielding entries, followed by Fletcha^{EF} and Fraydo. During the second year, Fraydo, Fletcha^{EF}, Centurion and Lutine were the top yielding with a mean DMY ranging from 4748.4 to 4030.5 kg ha^{-1}. Ottava was the least yielding genotype with a DMY mean of 2982.0 kg ha^{-1}. The DMY, accumulated during the two years, indicated that Partenope was the top yielding with an average DMY of 8479.8 kg ha^{-1}, followed by Fraydo, Fletcha^{EF}, Australian, Fletcha^{EI}, and Centurion with a mean yield ranging from 6156.7 to 4954.0 kg ha^{-1}. Australian and Fletcha^{EF} showed relatively high WUE during both years; while Lutine and Kasbah had low WUE means in the establishment year and relatively high WUE means in the second year (Fig. 1).

Genotypic characterization

The first 3 PC accounted for 70% of the variation within the data set subjected to PCA. PC_1 had large positive loadings for LA and LSR, LRWC, and DHE, and negative loadings for SLM and EL (Fig. 2). 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 (data not shown).The biplots of the first three PC's 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. Porto and Kasbah sheared large scores on the first 2 PC. Due to their relative position along the PC_1 axis, Porto was characterized by high values for LA, LSR, RWC, DHE and low values for SLM and EL, while Kasbah, on the opposite, harbors low values for LA, LSR, RWC, 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. 2). The large score of Jana on the PC_2, indicated its low yielding ability associated with intermediate values LA, LSR, RWC, 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, RWC, LSR, and high values for SLM, EL and DHE (Fig. 2). 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 (Table 1).

Table 1. Genotypic means of the traits measured during the second production year

Genotype	RC	PHT	LA	LSR	SLM	RGR	EG	RWC	EL
Jana	69.9	81.9	59.7	0.46	13.2	39.3	270.0	64.1	19.4
Medly	68.3	80.4	53.1	0.34	20.6	45.6	257.5	68.3	17.9
Kasbah	59.2	66.0	34.5	0.21	37.9	44.6	204.0	50.4	42.0
Delta	56.3	73.2	78.7	0.36	20.1	51.3	181.0	72.3	26.5
Currie	62.2	65.3	102.6	0.57	16.4	43.8	275.0	80.4	28.6
Porto	55.3	61.8	105.3	0.81	13.3	42.0	404.0	76.7	18.0
Ottava	51.1	73.6	80.8	0.27	20.8	63.4	150.0	67.3	28.8
Tanit	63.2	89.9	65.7	0.24	32.8	44.3	115.0	81.1	36.5
Sisa	45.6	99.9	140.5	0.48	12.4	36.9	670.0	66.6	14.5
Fletcha^{EI}	53.5	99.9	77.5	0.16	45.8	38.9	335.0	69.8	13.2
Centurion	57.9	102.8	80.6	0.19	18.3	54.4	75.0	76.5	31.5
Fletcha^{EF}	66.0	110.3	80.9	0.18	30.9	51.3	225.0	70.8	16.3
Lutine	42.8	93.5	140.7	0.63	17.5	49.4	407.5	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	277.6	65.6	22.5
Australian	73.3	84.2	118.5	0.93	13.9	40.8	50.0	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, %.

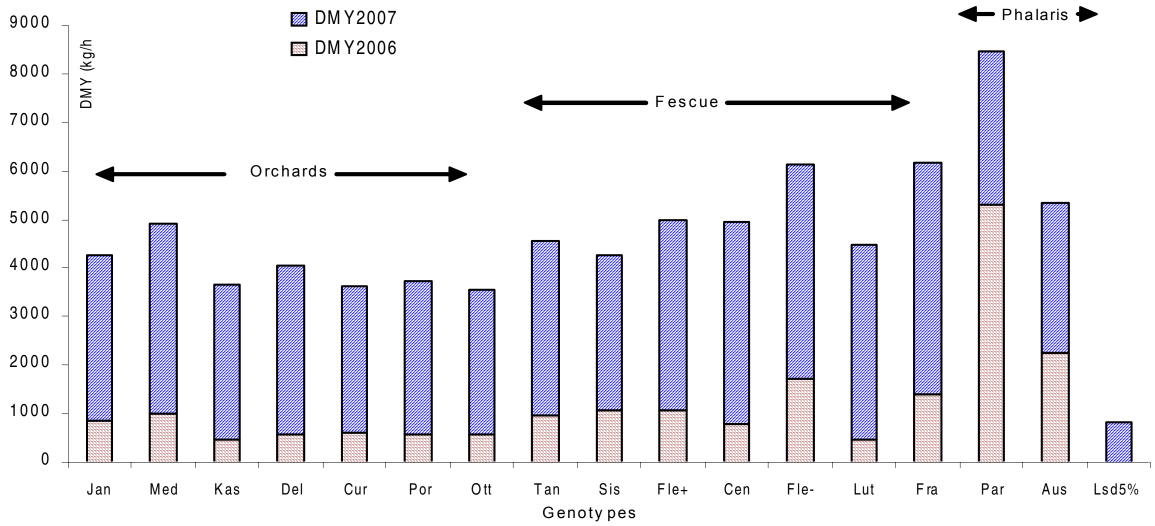

Fig. 1. Means of dry matter yield accumulated during the two years for the different genotypes (Jan=Jana, Med=Medly, Kas=Kasbah, Del=Delta, Cur=Currie, Por= Porto, Ott=Ottava, Tan=Tanit, Sis=Sissa, Fle^+=Fletcha endophyte infected, Fle^-=Fletcha endophyte free, Cen=Centurion, Lut=Lutine, Fra=Fraydo, Par=Partenoppe, Aus=Australian).

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 (Table 1). 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. 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. Tanit and Ottava were characterized by low mean values for LA, LSR and EG associated with high mean values for RC and RGR. In addition to DMY *per se*, selection for key morphological and physiological traits including LA, SLM, LSR, DHE and PHT offers the opportunity to improve WUE in perennial grasses. 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.

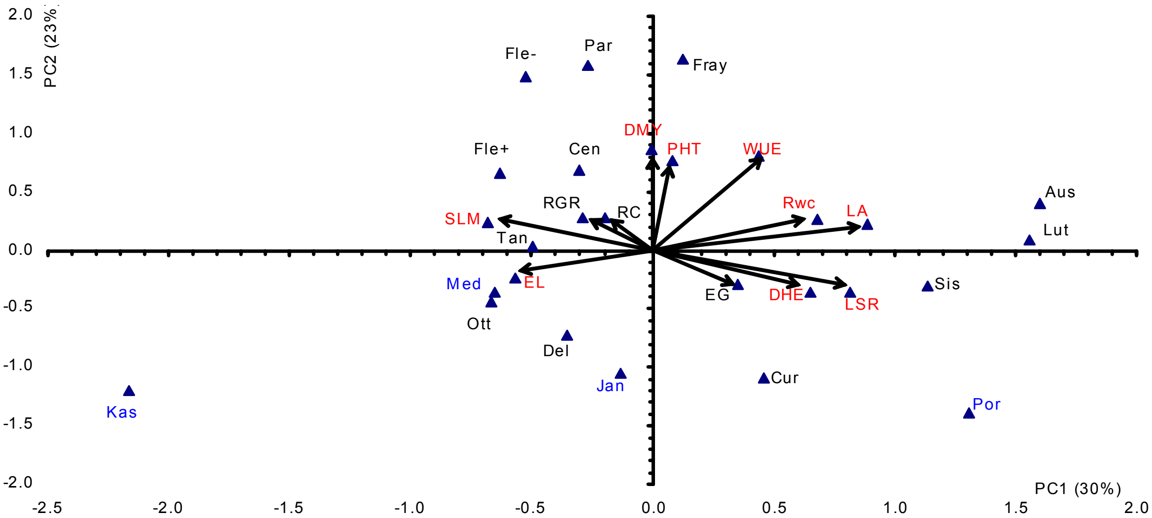

Fig. 2. Biplot of the first 2 dimensions in the principal component analysis of the morphological traits among perennial grass cultivars, arrows indicate the directions of the original variables in relation to the principal components (Jan=Jana, Med=Medly, Kas=Kasbah, Del=Delta, Cur=Currie, Por= Porto, 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 = relative water content, %; EL = electrolyte leakage, %, DMY= Dry matter yield (kg ha^{-1}), DHE= number of days from January 1^{st} to heading, WUE= water use efficiency (kg ha^{-1} mm^{-1}).

Conclusions

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 WUE and PHT. DMY performance appeared to be independent from LA, LSR, SLM, RGR and EG. Best dry matter performing genotypes, Partenope, Fraydo and $Fletcha^{EF}$, were characterized by high WUE, earliness, above average RGR, and below average LSR and EL. 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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