Revista Internacional de
BOTANICA
EXPERIMENTAL

ΦYTON

International Journal of
EXPERIMENTAL
BOTANY

Fundada en 1951 por Founded in 1951 by
Miguel Raggio & Nora Moro de Raggio
Editor-in-Chief: Dr. Carlos A. Busso

FUNDACION ROMULO RAGGIO
Gaspar Campos 861, 1638 Vicente López (BA), Argentina
www.revistaphyton.fund-romuloraggio.org.ar

57º ANIVERSARIO (2008) 77: 7-20 57th ANNIVERSARY

Water stress and forage production in *Tetrachne dregei* Nees, *Panicum coloratum* L. and *Eragrostis curvula* (Schrad) Nees.

(With 1 Table & 5 Figures)

Estrés hídrico y producción forrajera de Tetrachne dregei Nees, *Panicum coloratum* L. *y Eragrostis curvula* (Schrad) Nees.

(Con 1 Tabla y 5 Figuras)

Ruiz[1] MA, AD Golberg [1,2], O Martínez [2]

Abstract. *Tetrachne dregei*, *Panicum coloratum* and E*ragrostis curvula* are perennial forage C_4 grasses, introduced from South Africa to the pampean semiarid region. This work was carried out to compare water stress tolerance; forage production and quality of *T. dregei, P. coloratum* and *E. curvula*. Studies were conducted under greenhouse and field conditions. In the greenhouse, watering was stopped after eighty one days of plant emergency in the water stress treatment. Water potential (ψ), stomatal resistance (SR) and shoot and root weights were evaluated. Under water stress, ψ diminished earlier and SR increases were higher in *P. coloratum* than in *T. dregei* and *E. curvula*. Plant survival in *T. dregei* and *E. curvula* was higher than that of *P. coloratum*. Under field conditions (INTA, Agricultural Experimental Station Anguil, La Pampa, Argentina), biomass production of *T. dregei* was lower than that of the other species ($p<0.05$) during the first year, but forage production was higher ($p<0.05$) in *E. curvula*, followed by *T. dregei,* than in *P. coloratum* in the following years. In spring, *P. coloratum* showed a greater forage digestibility ($p<0.05$) than *E. curvula* and *T. dregei*; *P. coloratum* and *T. dregei* had more

[1] INTA EEA Anguil "Ing. Agr. Guillermo Covas", Ruta Nac. 5, km 580, CC11 (6326) Anguil, La Pampa, Argentina.
[2]Facultad de Agronomía, UNLPam, Ruta 35, km 335, CC300 (6300) Santa Rosa, La Pampa, Argentina.
Address Correspondence to: Lic. María de los Ángeles Ruiz,
e-mail: mruiz@anguil.inta.gov.ar, fax (54) 2954-495057.
Recibido/Received 17.X.2007. Aceptado/Accepted 22.X.2007.

protein percent than *E. curvula*. In summer, protein percent of *T. dregei* was higher ($p<0.05$) than that in the other species; however, there were no significant differences in forage digestibility among species. This study provided strong evidence that *T. dregei* could be a suitable species for semiarid environments. *Panicum coloratum* showed very good forage quality characteristics, although its high biomass production was limited to the first year.

Key words: *Tetrachne dregei*, *Panicum coloratum*, *Eragrostis curvula*, water stress, forage production, forage quality.

Resumen. *Tetrachne dregei*, *Panicum coloratum* y *Eragrostis curvula* son gramíneas forrajeras perennes de ciclo C_4, introducidas de Sud África a la región semiárida pampeana (RSP). El objetivo del presente trabajo fue comparar la tolerancia al estrés hídrico; y la producción y calidad de forraje de *T. dregei*, *P. coloratum* y *E. curvula* bajo condiciones de invernáculo o de campo. En el estudio de invernáculo, luego de ochenta y un días de la emergencia, se suspendió el riego en el tratamiento de estrés hídrico. Se determinaron el potencial agua (ψ), la resistencia estomática (RS) y los pesos de la parte aérea y radical. Bajo estrés hídrico, el ψ de *P. coloratum* disminuyó antes que en *T. dregei* y *E. curvula*. El incremento de RS bajo estrés hídrico fue mayor en *P. coloratum* que en las otras dos especies. La supervivencia de las plantas de *T. dregei* y *E. curvula* fue superior a las de *P.coloratum*. En el ensayo de campo (Estación Experimental Agropecuaria Anguil, La Pampa, Argentina), la producción de forraje de *T. dregei* durante la primer temporada, fue inferior a la de las otras especies ($p<0,05$). Sin embargo, la producción forrajera de *E. curvula*, seguido de *T. dregei*, superaron ($p<0,05$) aquella de *P. coloratum* en los siguientes años. En primavera, *P. coloratum* presentó mayor digestibilidad que *E. curvula* y *T. dregei* ($p<0,05$) pero en verano, no mostraron diferencias. *Panicum coloratum* y *T. dregei* mostraron mayor porcentaje ($p<0,05$) de proteína que *E. curvula* en primavera, mientras que en el verano, el porcentaje de proteína de *T. dregei* fue superior al de las otras especies ($p<0,05$). Este estudio demostró que *T. dregei* parece ser una especie promisoria para ambientes semiáridos. *Panicum coloratum* presentó una muy buena calidad forrajera, aunque su alta producción de biomasa estuvo limitada al primer año .

Palabras clave: *Tetrachne dregei*, *Panicum coloratum*, *Eragrostis curvula*, estrés hídrico, producción de forraje, calidad de forraje.

INTRODUCTION

Rainfall in the Pampean semiarid region decreases from NE to SW with a high inter-annual variation. Since soils have a low water retention capacity (Casagrande & Vergara, 1996), it is important to include water stress resistant grasses as a rancher management strategy. *Tetrachne dregei* Nees (Green grass, Td), *Panicum coloratum* L. (Kleingrass, Pc) and E*ragrostis curvula* (Schrad) Nees (Weeping lovegrass, Ec) are C_4 perennial forage grasses, introduced from South Africa and neighbouring countries. It is important to compare *T. dregei* performance under water stress conditions with that of *E. curvula* and *P. coloratum*. This is because of the well-known perfomance of the last two perennial grasses in the Pampean semiarid region (Cairnie, 1984; Covas, 1991; Petruzzi et al., 2003; Ruiz et al., 2004).

Eragrostis curvula shows a high performance under semiarid conditions (Voigt, 1991; Colom & Vazzana, 2001, 2003), but it has good forage quality characteristics for cattle grazing during a short time period (Stritzler et al. 1996). *Panicum coloratum* was introduced with the purpose of obtaining a better forage quality (Stritzler et al., 1996; Petruzzi et al., 2003).

Tetrachne dregei was introduced in Argentina from South Africa (www.fao.org/AG/aGp/agpc/doc/Gbase/Safricadata/tetradre.htm, 2006), where the cultivated surface is scarce. Since 1970, studies conducted in the Pampean semiarid region showed that *T. dregei* produces better forage quality than *E. curvula* and presents good adaptation to environmental conditions (Galván, 1971; Milano & Rodríguez Sáenz, 1971; Stritzler et al., 1996).

Rainfall limitation and soil with low water retention capacity cause water deficit in plants; decreases of water potential can affect seriously leaf growth, CO_2 exchange rate, tillering and root/shoot ratio in several plant species (Echenique & Curveto, 1986; Boyer, 1995; Ben Haj & Tardieu, 1997; Brevedan et al., 2004; Blum, 2005). Under water stress, plants can increase stomatal resistance and reduce transpiration in seconds (Pugnaire et al., 1994; Colom & Vazzana, 2003). Plants also present other mechanisms to control transpiration such as leaf abscission or increases of leaf specific density (Pugnaire et al., 1994).

Our working hypothesis was that *T. dregei* shows a water stress tolerance similar to that in *E. curvula*, which is well known because of its good performance in semiarid environments. *Panicum coloratum* was included in this study because of its good forage quality. The objectives of this work were to compare the water stress tolerance, forage production and quality of *T. dregei*, *E. curvula* and *P. coloratum* in a semiarid environment.

MATERIALS AND METHODS

Greenhouse trial. A greenhouse study was conducted at the Facultad de Agronomía, Universidad Nacional de La Pampa, Santa Rosa, La Pampa Province (36° 34´ S, 64° 16´ W; 210 m.a.s.l) from March 2002 to October 2002. Greenhouse environmental conditions were: average temperature 17 °C, humidity 69%, average photosynthetic photon flux density 525 mmol/m^2/s. Seeds were sown in PVC pots, filled with 5 kg of regional soil (entic haplustol). After 30 days, only one plant was kept in each pot.

A Complete Randomized Design with a factorial treatment (3 species X 2 water conditions; 6 replicates) was used. Treatments were water stress and control. In the water stress treatment, plants were first watered near field capacity and thereafter watering was withheld during 81 days after plant emergence. At the same time, control plants were maintained near field capacity throughout the experimental period. At the time water was withheld, number of tillers was 1-3 in *T. dregei*, 1-4 in *E. curvula* and 2-4 in *P. coloratum*, and number of expanded leaves in the main stem was 5 in *T. dregei* and *E. curvula*, and 8 in *P. coloratum*.

Stomatal resistance (SR) was determined weekly after withholding water by using a Delta T Porometer, AP4-UM-2, 2.28 Version, 1991. At the same time, leaf water potential (ψ) was evaluated with a Scholander pressure chamber.

Leaf area was measured at the end of the experiment using a LICOR, LI 3000 leaf area meter. Shoot and root dry weights were determined. This allowed calculation of specific leaf area (leaf area/leaf weight) and root/shoot ratios.

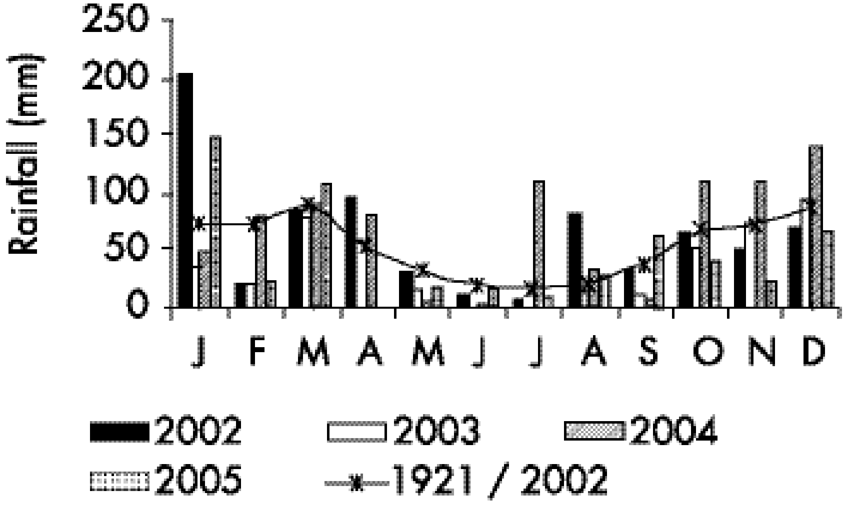
Data were statistically analysed by ANOVA and LSD test ($p<0.05$).

Field trial. This study was conducted in the Estación Experimental Agropecuaria Anguil, Instituto Nacional de Tecnología Agropecuaria (INTA) (36º 30´ S, 63º 59´ W, 165 m.a.s.l), La Pampa, Argentina. Soil was an entic haplustol (organic matter: 1.46%; Phosphorus: 30.25 ppm and pH 6.14). The experimental design was a complete randomized block with eight replicates. Sowing was performed in November 2001. Plots (2.1 x 3.0 m each) had row interspaces of 0.70 m. Rainfall during the study is shown in Fig. 1. For 2003 and 2005, annual rainfall was 449 or 543 mm, respectively; these values were lower than or similar to the historical long-term mean, respectively (Meteorological Service, EEA Anguil).

Clipping of forage was made in April and November of 2002, 2003 and 2004, and in November of 2005. It was performed in the central row (two linear meters) in each plot, and fresh weight was determined. Afterwards, 200 grams were oven-dried at 60 ºC to constant weight. In November 2003 and April 2004, the following forage quality determinations were made: acid detergent fiber (ADF), dry matter digestibility (DMD), metabolised energy (Mcal/kgDM) and protein concentration (PC). Data were statistically analysed by ANOVA and LSD test ($p<0.05$).

Fig. 1. Monthly rainfall during 2002, 2003, 2004 and 2005, and long-term (1921-2002) monthly rainfall in the Agricultural Experimental Station of INTA Anguil, La Pampa, Argentina.

Fig. 1. *Lluvias mensuales durante 2002, 2003, 2004 y 2005, y promedio de lluvias mensuales durante 1921-2002 en la Estación Experimental Agropecuaria INTA Anguil, La Pampa, Argentina.*



RESULTS AND DISCUSSION

Greenhouse trial. The interaction water level x species was significant ($p<0.05$) for ψ and SR in all five dates. This was because *E. curvula* showed the least differences in the control and water stress treatments. In *P. coloratum*, ψ and SR of watered plants showed significant differences ($p<0.05$) compared to plants of the water stress treatment at 24 days after withholding water (DAWW). At 61 DAWW, ψ of water-stressed plants showed values lower than –1 MPa, and SR increased to 80 s/cm (Fig. 2 and 3). Leaf wilting was observed between 57 and 66 DAWW.

Water potential and SR in control plants of *T. dregei* showed significant differences ($p<0.05$) in comparison to stressed plants after 24 and 35 DAWW, respectively. From 45 to 60 DAWW, however, stomatal resistance was not different between treatments. Plants under water stress started to wilt gradually by 104-157 DAWW; these plants showed a 40 day-delay in exhibiting this symptom in comparison to plants of *P. coloratum*. Water potential and SR of *T. dregei* showed the highest differences among individual plants at the wilting stage.

Water potential and SR showed significant differences ($p<0.05$) between treatments after 65 days of water withholding in *E. curvula*. This occurred 41 days later than in the other two species. Plants of *E. curvula* wilted by 93-106 DAWW, almost simultaneously with *T. dregei*. However, differences among individual plants were lower than those in *T. dregei*. Similar to results in our study, Colom & Vazzana (2001, 2003) found high stability of water potential, stomatal conductance, photosynthetic rates and leaf pigments content in cultivars of *E. curvula* exposed to water stress.

Leaf area of *T. dregei* and *P. coloratum* was significantly higher ($p<0.05$) in control than water-stressed plants. *Eragrostis curvula*, however, did not show significant differences between both treatments. While mortality of some mature leaves was observed, young leaves were kept alive in water-stressed plants of *T. dregei*. This is similar to results of Blum (2005) in *Sorghum*. Because of this, green leaf area of *T. dregei* plants was lower under water stress than in the control treatment. These plants, however, showed a higher level of stomatal conductance and ψ for a longer time period than *P. coloratum*.

Fig.2. Effect of water stress on leaf water potential (MPa) of *T. dregei*, *P. coloratum* and *E. curvula*. DAWW: days after withholding water.

Fig.2. *Efecto del estrés hídrico en el potencial (MPa) hídrico foliar de T. dregei, P. coloratum y E. curvula. DAWW: días desde la suspensión del riego.*

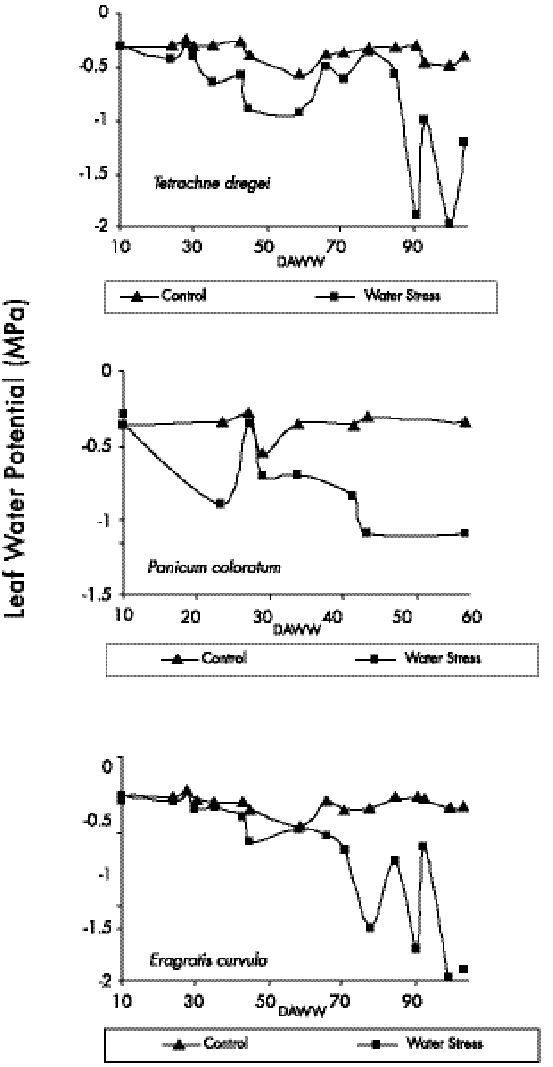
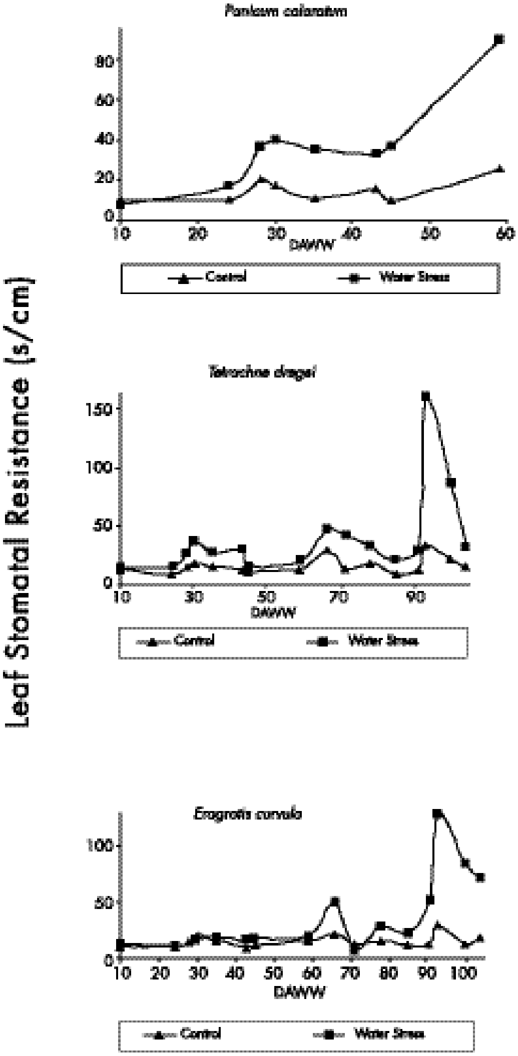


Fig. 3. Effect of water stress on leaf stomatal resistance (s/cm) (SR) of *T. dregei*, *P. coloratum* and *E. curvula* during the water stress period. DAWW: days after withholding water.

Fig. 3. *Efecto del estrés hídrico en la resistencia estomática (s/cm) (SR) de T. dregei, P. coloratum y E. curvula. DAWW: días desde la suspensión del riego.*



Root / shoot ratios did not differ among treatments in none of the three species (Fig. 4a). This relation decreased under water stress because shoot growth was more affected than root growth (Blum, 2005).

Leaf thickness of *P. coloratum* increased significantly ($p<0.05$) under water stress (Fig. 4b). This finding is similar to that reported by Pugnaire et al. (1994). However, no significant differences ($p>0.05$) were found in the other species.

Field trial. During the first year of growth (2002), biomass production of *E. curvula* and *P. coloratum* was 2.6 times higher ($p<0.05$) than that in *T. dregei* on average. This shows a slower early growth in *T. dregei* (Fig. 5). *Panicum coloratum* reached the highest ($p<0.05$) biomass production among the three species during summer (October 2001 to April 2002). It was followed by *E. curvula*, while *T. dregei* produced two thirds of *P. coloratum* biomass production. In spring (November 2002), *E. curvula* showed more forage production than the other two species. Slow growth in *T. dregei* was previously reported by Zacharias (1990); plants of this species reach maturity in a ten-year-period. In the present study, although *T. dregei* showed low initial growth, its forage production increased during the following years.

The second year (2003) was rather dry for this region (449 mm, Fig. 1). Forage production of *E. curvula* was higher than that in *T. dregei*, and forage production of *T. dregei* was significantly higher ($p<0.05$) than that in *P. coloratum* (Fig. 5). In *E. curvula*, forage production was half that in the previous year. Forage production in *P. coloratum* was 4.5 times lower in 2003 than in 2002. However, *T. dregei* had similar forage production in both years. In the first clipping (April 2003), *E. curvula* had more ($p<0.05$) forage production than *P. coloratum*, while *T. dregei* showed an intermediate forage production. In November, forage production of *E. curvula* was higher ($p<0.05$) than that in *T. dregei*, which reached a greater yield than *P. coloratum*.

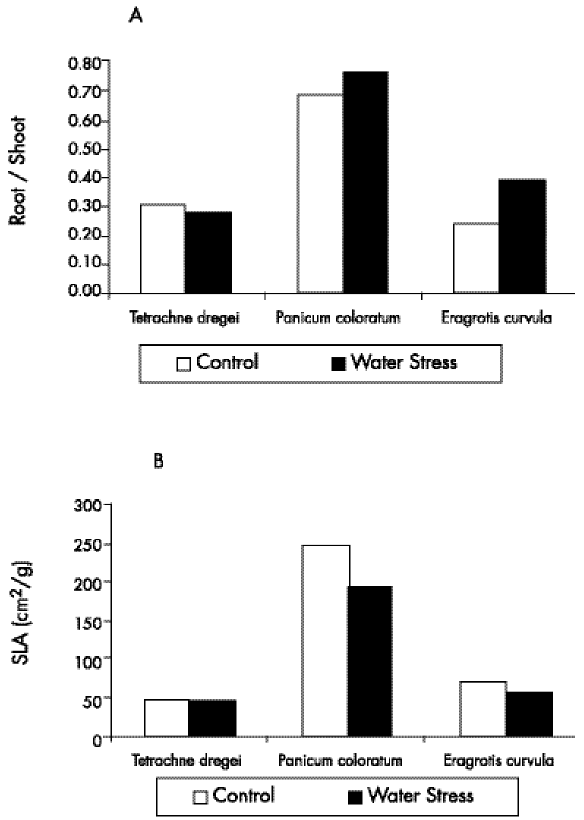
In 2004, forage production of *E. curvula* and *T. dregei* was similar, and significantly higher ($p<0.05$) than that in *P. coloratum* (Fig. 5). Although rainfall was higher in 2004 (814 mm) than in 2003, yields continued decreasing. During the summer 2004, growth of *E. curvula* and *T. dregei* was similar ($p>0.05$), and their forage production was higher ($p<0.05$) than that in *P. coloratum*. In spring of the same year, however, growth was similar in all three species.

In 2005, a dry year (543 mm), *E. curvula* showed the highest yield ($p<0.05$) among all the study species. This is similar to results in 2003 (Fig. 5). It has been reported that cultivars of *E. curvula* can differ in their response capacity to water stress (Echenique & Curvetto, 1986).

During spring (September to November), forage digestibility was higher in *P. coloratum* than in *E. curvula* and *T. dregei*, which had similar

Fig. 4. Effect of water stress on A) root / shoot ratios (R/S), and B) specific leaf area (SLA, cm^2/g) in *T. dregei*, *P. coloratum* and *E. curvula*.

Fig. 4. *Efecto del estrés hídrico en la A) Relación raíz / parte aérea (R/S), y B) área foliar específica (SLA, cm^2/g) en T. dregei, P. coloratum y E. curvula.*



values for this parameter (Table 1). *Panicum coloratum* and *T. dregei* showed higher protein concentrations than *E. curvula* (Table 1).

During summer (December to April), although significant differences in DMD, ADF and metabolizable energy were not detected ($p>0.05$), *E. curvula* reached higher fiber concentrations and lower dry matter digestibility than the other two species. *Tetrachne dregei* showed the highest ($p<0.05$) protein concentrations. Stritzler et al. (1996) found that *T. dregei* generally produces better forage quality than other warm-season perennial grasses in semiarid Argentina. In previous experiments at different locations of the pampean semiarid region, Ruiz et al. (2004) reported higher protein concentrations in green and differed forage in *P. coloratum* than in *E. curvula*.

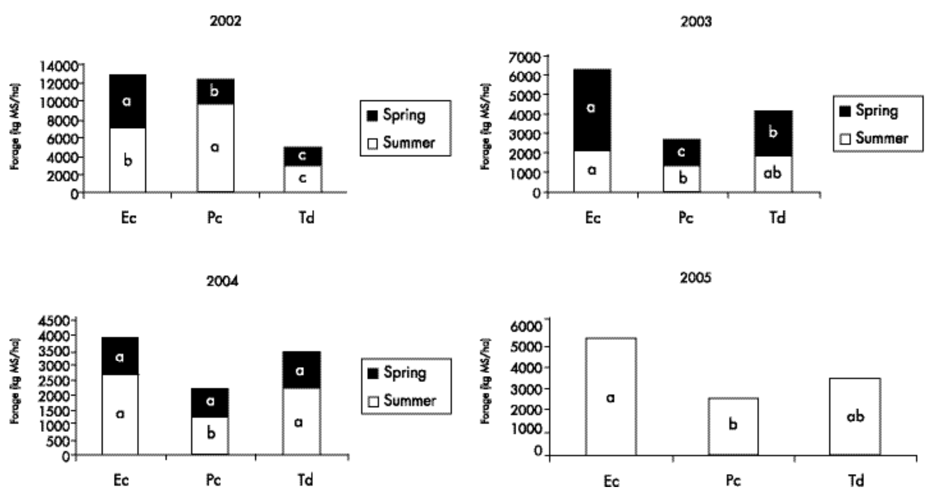
Table 1. Forage quality of *T. dregei*, *P. coloratum* and *E. curvula* in spring and summer 2003, Anguil, La Pampa. Different letters in the same column, within each season, indicate significant differences, LSD ($p<0.05$).

Tabla 1. *Calidad del forraje de T. dregei, P. coloratum y E. curvula en primavera y verano 2003, Anguil, La Pampa. Diferentes letras en la misma columna, dentro de cada estación, expresan diferencias significativas, LSD (p<0,05)*

Species	Acid detergent fibre (%)	Dry matter digestibility (%)	Metabolizable energy Mcal/KgMS	Crude protein (%)
Spring				
T. dregei	39.83 a	57.88 b	2.09 a	8.13 a
P. coloratum	33.69 b	62.66 a	2.26 a	8.98 a
E. curvula	38.83 a	58.65 b	2.12 b	5.83 b
Summer				
T. dregei	38.98 a	58.53 a	2.11 a	4.38 a
P. coloratum	37.64 a	59.58 a	2.15 a	3.00 b
E. curvula	41.85 a	56.30 a	2.03 a	3.33 b

Fig. 5. Forage production (kg/ha) of *T. dregei* (Td), *P. coloratum* (Pc) and *E. curvula* (Ec) during 2002 - 2005. Anguil, La Pampa. Different letters among bars indicate significant differences, LSD ($p<0.05$).

Fig. 5. *Producción de forraje (kg/ha) de T. dregei (Td), P. coloratum (Pc) y E. curvula (Ec), durante 2002 - 2005. Anguil, La Pampa. Entre barras, letras diferentes expresan diferencias significativas, LSD (p<0,05)*



Conclusions. Under water stress, *E. curvula* exhibited a better performance than *P. coloratum* and *T. dregei*. However, *T. dregei* showed more forage quality than *E. curvula* and it presented good response to water stress. *Panicum coloratum* exhibited the lowest drought resistance, but its forage quality was superior to that of *E. curvula* and *T. dregei*. Also, it showed a higher forage production during the first growing period. Since *T. dregei* showed a good water stress resistance and forage quality, it should be considered an important forage resource in semiarid regions. However, it is necessary to point out that *T. dregei* has a slow initial growth, while at the same time the initial growth of *P. coloratum* is good.

ACKNOWLEDGMENTS

The authors thank to Osvaldo Tuya for helpful suggestions on this paper, Lic. Pamela D. Lerner for correcting a previous version of this manuscript, and the assistant staff of the Animal Production Unit of the Agricultural Experimental Station at INTA Anguil "Ing. Agr. Guillermo Covas" for field and laboratory assistance.

REFERENCES

Ben Haj, S. & F. Tardieu (1997). Control of leaf expansion rate of droughted maize plants under fluctuating evaporative demand. A superposition of hydraulic and chemical messages? *Plant Physiology* 114: 893-900.

Blum, A. (2005). Drought resistance, water-use efficiency, and yield potential – are they compatible, dissonant, or mutually exclusive? *Australian Journal of Agricultural Research* 56: 1159-1168.

Boyer, J.S. (1995). Growth. In: Kramer, P.J. and Boyer, J.S. (eds), pp. 344-376. Water Relations of Plants and Soils. San Diego Academic Press, San Diego, California, USA.

Brevedan, R.E., H.E. Laborde, M.N. Fioretti & S.S. Baioni (2004). Características relacionadas a la deficiencia hídrica y la fertilización con nitrógeno de *Digitaria eriantha*. II Reunión Binacional de Ecología. Mendoza, Argentina. 295 p.

Cairnie, G. (1984). Ciclo de reuniones de actualización sobre producción animal. INTA, E.E.A. Anguil, Argentina.

Casagrande, G.A. & G.T. Vergara (1996). Características climáticas de la región. In: pp 11-17. Labranzas en la Región Semiárida Pampeana. INTA. Centro Regional La Pampa-San Luis. EEA Ing. Agr. Guillermo Covas, Anguil, La Pampa, Argentina.

Colom, M.R. & C. Vazzana (2001). Drought stress effects on three cultivars of *Eragrostis curvula*: photosynthesis and water relations. *Plant growth regulation* 34: 195-202.

Colom, M.R. & C. Vazzana (2003). Photosynthesis and PSII functionality of drought-resistant and drought-sensitive weeping lovegrass plants. *Environmental and Experimental Botany*. 49: 135-144.

Covas, G. (1991). Introducción del pasto llorón en la república Argentina. In: Fernández, O.A., Brevedan, R.E. & Gargano, A.C. (eds), pp. 1-6. El pasto llorón. Su biología y manejo. CERZOS (CONICET), Bahía Blanca, Buenos Aires, Argentina.

Echenique, C.V. & N.R. Curvetto (1986). Efecto del déficit hídrico en cinco cultivares de pasto llorón, *Eragrostis curvula* (Schrad) Nees. Niveles de clorofila y prolina foliar y permeabilidad de membranas celulares.*ΦYTON*, *International Journal of Experimental Botany* 46: 195-206.

Galvani, A.R. (1979). Observaciones sobre el comportamiento de 123 especies en la Prov. de San Luis- EEA San Luis- INTA, Villa Mercedes, San Luis, Argentina. Boletín de divulgación. p. 105-107.

Milano, V.A. & A.J. Rodríguez Sáenz (1971). Analogías climáticas e importancia de los grados de abundancia para la introducción de especies forrajeras. Ejemplo en *Tetrachne dregei* Nees. IDIA, INTA. 280: 29-39.

Petruzzi, H.J., N.P. Stritzler, E.O. Adema, C.M. Ferri & J.H. Pagella (2003). Mijo perenne. Publicación Técnica Nº 51. INTA EEA Anguil "Ing. Agr. Guillermo Covas", Anguil, La Pampa, Argentina. 28 p.

Pugnaire, F.I., L. Serrano Endolz & J. Pardos. (1994). Constraints by stress on Plant Growth. In: Pessarakli, M. (ed), pp. 247-259. University of Arizona, Tucson, Arizona, USA.

Ruiz, M.A., E.O. Adema, T. Rucci & F.J. Babinec (2004). Producción y calidad de forraje de gramíneas perennes en diferentes ambientes del caldenal. Publicación Técnica Nº 54. INTA EEA Anguil "Ing. Agr. Guillermo Covas. 36 pp.

Stritzler, N.P., J.H. Pagella, V.V. Jouve & C.M. Ferri (1996). Semiarid warm-season grass yield and nutritive value in Argentina. Journal of Range Management. 49: 121-125.

Voigt, P.W. (1991). *Eragrostis curvula*: sus características y potencial para el mejoramiento a través de la hibridación. In: Fernández, O.A., Brevedad, R.E and Gargano, A.O. (eds), pp. 39-56. El pasto llorón. Su biología y manejo. CERZOS (CONICET), Bahía Blanca, Buenos Aires, Argentina.

www.fao.org/AG/aGp/agpc/doc/Gbase/Safricadata/tetradre.htm. (2006) Hoare, D.B. *Tetrachne dregei* Nees.

Zacharias, P.J.K. (1990). Acocks´ Notes: key grasses of South Africa. Grassland Society of Sourthern Africa, Howick.