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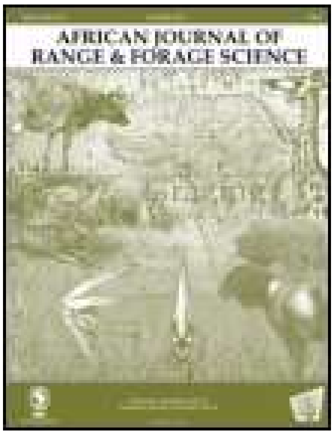

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Evapotranspiration, water-use efficiency and quality of six dryland planted pasture species and natural vegetation, in a semi-arid rangeland[1]

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Abstract

Hydraulic, non-floating lysimeters were used to determine evapotranspiration (Et) and water-use efficiency (WUE) of several dryland planted pasture species over a period of three years. The species were *Anthephora pubescens*, *Cenchrus ciliaris*, *Chloris gayana*, *Digitaria eriantha subsp. eriantha*, *Eragrostis curvula* and *Panicum maximum*. The WUE was expressed as the amount of above-ground phytomass as well as the crude protein produced per unit volume of water evapotranspired. The water-balances of the planted pastures were also compared with that of a natural grassland (veld) in good condition. Differences in Et between the various species were not significant ($P>0.05$). Deep percolation, beyond the root zone (i.e. more than 0.8 m), did not occur in any of the species nor in the veld treatment throughout the study. *Chloris gayana* produced more above-ground phytomass ($P\leq0.01$) than all the other species in both wet and drier conditions. The average WUE (7.2 kg dry matter (DM) ha^{-1} mm^{-1} and 0.39 kg crude protein (CP) ha^{-1} mm^{-1}) of this species was the highest ($P\leq0.01$) throughout the experimental period. During the first half of the season (July – December) the crude protein content (7.94%) of *Panicum* was the highest ($P\leq0.01$), while that of *Anthephora* (5.02%) was the highest ($P\leq0.01$) during the second half (January – June). The exceptionally low ($P\leq0.01$) crude protein content of natural grassland and *Eragrostis* during the second half of the season indicated that these are not well suited for use as foggage (grown out forage), while the high values for *Anthephora* and *Digitaria* suggests these to be suitable foggage species.

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Additional index words: Crude protein, deep percolation, foggage, lysimeter, water-balances

Introduction

The potential of natural grassland for animal production in southern Africa is only a fraction of that attainable from cultivated pastures. It is therefore not surprising that the area under cultivated pastures has increased dramatically in recent years (Miles 1991). The Soil Conversion Scheme implemented by the South African government during 1987, and which subsidized the conversion from cash crops to dryland cultivated pastures on marginal soils, contributed towards the renewed interest in planted pastures by farmers and researchers alike (Dannhauser 1991a).

Research on dryland planted pastures in the arid and semi-arid regions of South Africa has concentrated on aspects such as the production potential with respect to quality and quantity, as well as fertilisation requirements (Dickinson *et al.* 1990; Dannhauser 1991b). However, since soil water is the most limiting environmental factor which determines plant production in these areas (Snyman & Fouché 1991), selection of species for dryland planted pastures should be based on the efficiency of using available water. The only water-balance studies in these regions have been undertaken on dry *Themeda–Cymbopogon* natural grassland of the central Orange Free State (Opperman 1975; Opperman & Roberts 1975; Snyman 1982, 1985, 1988, 1989, 1993) and on savanna plant communuties (Moore *et al.* 1982; Stuart-Hill *et al.* 1987; Moore *et al.* 1988; Smit 1989a, 1989b; Brönn 1994; Smit & Swart 1994). No information is available on the water requirements and water-use efficiencies of dryland pasture species in these semi-arid regions. The objective of this study was to determine the long-term (two-year) production potential and water-balance of six dryland planted pastures under semi-arid rangeland field conditions. Natural grassland in good ecological condition was also included as one of the treatments in this study.

Procedure

Study area

The research was conducted at Sydenham, the experimental farm of the University of the Orange Free State, 5 km west of Bloemfontein (29°06'S, 26°57'E, 1 350 m a.s.l.) which is situated in the semi-arid, summer rainfall region of South Africa. Mean annual rainfall is 560 mm, with 55% falling from January to April. In January, the average maximum daily temperature ranges from 30°C to 33°C, and in July it is *c.* 17°C, but extremes of 41°C in January and 28°C in July have been recorded. On average, frost occurs on 119 days each year (Schulze 1979).

The soil was the Shorrocks Series (Hutton Form) (Macvicar *et al.* 1977). According to the new soil classification system (Soil Classification Working Group 1991) the fine sandy loam soil is that of the Bloemdal Form (Roodeplaat family – 3200). The three distinct horizons (A: 0–200 mm, B_2: 200–600 mm and IIB_2: 600–800 mm) contained 10.6, 19.0 and 38.8% clay respectively, and the respective bulk densities were 1 484, 1 563 and 1 758 kg m^{-3}.

Methods

Hydraulic, non-floating lysimeters used in this study were similar to those described by Snyman (1988, 1989). The soil container was 0.80 m deep with a diameter of 0.60 m (0.2828 m^2). The construction, mass and temperature calibration, as well as the layout of the lysimeters are described in detail by Snyman *et al.* (1980) and Snyman (1982). The lysimeters were read on a daily basis.

The lysimeters were filled to field capacity at the beginning of September 1988 to attain the same soil water content in all lysimeters at the onset of the study. Percolation (drainage) was determined in the lysimeters as described by Snyman *et al.* (1980) and Snyman (1982). Rainfall, as well as class A pan evaporation (Eo) was determined daily over the experimental period using standard meteorological instruments.

Treatments

The experimental layout was a fully randomised design consisting of six treatments replicated twice. The treatments were represented by the following species, *Anthephora pubescens*, *Cenchrus ciliaris* (Molopo), *Chloris gayana*, *Digitaria eriantha subsp. eriantha*, *Eragrostis curvula* (Ermelo) and *Panicum maximum* (Green Panic) (hereafter only generic names are used for convenience), and were established in the lysimeters at the beginning of March 1988. Initial establishment was successful for all species except *Panicum* which was re-established at the end of March 1988. With the start of the 1989/1990 season the plants in each lysimeter were thinned out to achieve a basal cover of between 8 and 9%, which represented approximately 8 000 to 9 000 plants per hectare.

The water-balance of natural grassland in good condition, which is typical of the dry *Themeda-Cymbopogon* veld (Acocks 1988) and dominated by *Themeda triandra*, was investigated during the same period for comparative purposes. The veld was on the same soil type as used for the lysimeters. Because the veld was not part of the initial experimental lay-out, it could not be compared statistically with the planted pastures. Soil water content of the veld was determined gravimetrically at regular intervals throughout the season. Evapotranspiration (Et) was determined by quantifying the soil water-balance equation (Hillel 1971), ignoring surface run-off and deep percolation as these did not occur during the study period. All defoliation treatments applied to the planted pasture species were also applied to the veld. No fertilization was undertaken on the veld. The veld condition score and basal cover were determined as described by Snyman & Fouché (1991) and were 858 and 8.5% respectively.

The plants were defoliated to a height of 50 mm every time they reached seeding stage. This meant that the plants had to be defoliated once in the first half of the season (January) and once in early winter (June) each year. The first half of the season refers to the period July-December and the second half from January-June. The early winter defoliation was carried out following the onset of plant dormancy which occurred after the first frosts of winter. Crude protein analysis of the plant material removed with the early winter defoliation was used to evaluate the quality of the species (or veld) as foggage.

At the start of the study the P-status of the soil was increased to c. 15 ppm $NaHC0_3$ extractable P (Olsen & Dean 1965). Superphoshate was mixed with the soil to a depth of 50 mm. During spring of each year 10 kg P ha^{-1} as superphosphate was applied as topdressing. N-fertilisation with limestone ammonium nitrate was applied in two dressings of 25 kg N ha^{-1}, during the first spring rains and after the first defoliation.

A colorimetric technique (Technicon 1977) was used to determine N-content following Kjeldahl digestion of the plant material in concentrated sulphuric acid. Crude protein content, calculated from N-content of the whole aboveground plant (leaves, stems and seed) was determined on plant material removed during January and June 1991. Water-use efficiency was calculated both as the amount of above-ground phytomass and crude protein produced per unit volume water evapotranspired. All data were analyzed using a one-way analysis of variance technique (Winer 1974).

Results and discussion

Evapotranspiration (Et)

Evapotranspiration of the various species did not differ significantly when compared within the same growing season (Table 1). Evapotranspiration for almost all species did not differ greatly (P>0.05) between the first and second half of the 1989/1990 season, but differed significantly ($P\leq0.01$) during the 1990/1991 season.

Table 1 Total rainfall (mm), evaporation (Eo) and evapotranspiration (Et), as well as the daily average Et (mm) and Eo (mm), of various treatments consisting of a number of pasture species grown in lysimeters over the 1989/1990 and 1990/1991 seasons. V = veld, Ap = *Anthephora pubescens*; Cc = *Cenchrus ciliaris*, Cg = *Chloris gayana*, De = *Digitaria eriantha* subsp. *eriantha*, Ec = *Eragrostis curvula* and Pm = *Panicum maximum*. Water balance data for natural grassland (veld) was calculated using soil water-balance equations (Hillel 1971). Least significant differences (LSD) are calculated at the 5% level

Season	Rain	Et							Eo
		V	Ap	Cc	Cg	De	Ec	Pm	
5/7/89-2/1/90									
Total	305	280	331	270	333	297	317	278	1 035
LSD=63.92									
Daily average		1.5	1.8	1.5	1.8	1.6	1.7	1.5	5.7
3/1/90-30/6/90									
Total	326	313	328	318	303	291	320	302	806
LSD=39.56									
Daily average		1.8	1.8	1.8	1.7	1.6	1.8	1.7	4.5
Total 1989/1990	631	593	659	588	636	588	637	580	1 841
LSD=81.54									
6/7/90-7/1/91									
Total	126	103	145	128	152	126	129	132	1 164
LSD=31.58									
Daily average		0.5	1.0	0.9	1.1	0.9	0.9	0.9	8.0
8/1/91-28/6/91									
Total	441	414	422	421	431	465	451	467	679
LSD=75.11									
Daily average		2.4	2.5	2.5	2.5	2.7	2.6	2.7	4.0
Total 1990/1991	567	517	567	549	583	591	580	599	1 843
LSD=78.12									

Cenchrus had the lowest Et, although non-significant (P>0.05), over the experimental period. The Et from the veld was similar to that of *Cenchrus*. Evapotranspiration was of the same order as rainfall during each growth period. Small differences between the Et values of planted *Cenchrus* pasture and semi-arid grasslands (*Tyridolepis mitchelliana*, *Themeda triandra*, and *Manachather paradosea*) have been demonstrated in Australia (Christie 1978). The Et for both communities ranged from 0.2 to 6.4 mm d^{-1}.

The highest daily average Et in all the species occurred during the week of 04 Feb 1991 when all the plants had a large leaf area and 70 mm of rain was recorded. During this week the highest daily Et of 7.6 and 6.2 mm d^{-1} occurred in *Chloris* and *Panicum* respectively. These maximum Et values are within the range reported by Kopec *et al.* (1988) for *Festuca arundinaceae* in the USA (6.6 to 7.2 mm d^{-1}), and by Shih & Snyder (1985) for *Stenotaphrum secundatum* pasture (2.0 and 6.3 mm d^{-1}).

Evapotranspiration values as low as 0.2 mm d^{-1} were recorded in some species during early spring. The lowest average daily Et values were recorded for *Cenchrus* and veld, while the values from other species did not differ significantly (P>0.05,

Table 1). These values are extremely low when compared with the values obtained for climax veld in a semi-arid grassveld where the highest daily Et was 7.4 mm under normal rainfall conditions (Snyman 1988) and 11.9 mm under optimal rainfall conditions (Snyman *et al.* 1980), while the highest Et of the climax species *Cymbopogon plurinodis* and *Themeda triandra* were 4.9 and 4.5 mm d^{-1} respectively (Snyman 1989).

Deep percolation (drainage)

Deep percolation beyond the root zone, (i.e. more than 0.8 m) did not occur in any of the species nor on the veld at any time during the study. Similarly, Snyman & Fouché (1991) did not find evidence of deep percolation in a semi-arid grassland over a 12-year study period. It appears that in the arid and semi-arid areas, deep percolation on dryland pastures and veld only occurs under extremely high rainfall conditions.

Above-ground phytomass production

Above-ground phytomass production of all treatments did not differ greatly between die first and second half of the 1989/1990 season (Figure 1), probably due to the similar rainfall during each period (Table 1). However, during the first half of the 1990/1991 season an exceptionally low production was observed in all the species, whereas a markedly higher production was observed during the second half of that season (Figure 1). The exceptionally low rainfall of September, October and November (only 1 mm compared to the long-term average of 128 mm), and the high rainfall experienced during January and March (179 and 159 mm, respectively 100 and 90% more than the long-term average) probably contributed to the marked seasonality of phytomass production during the 1990/1991 period.

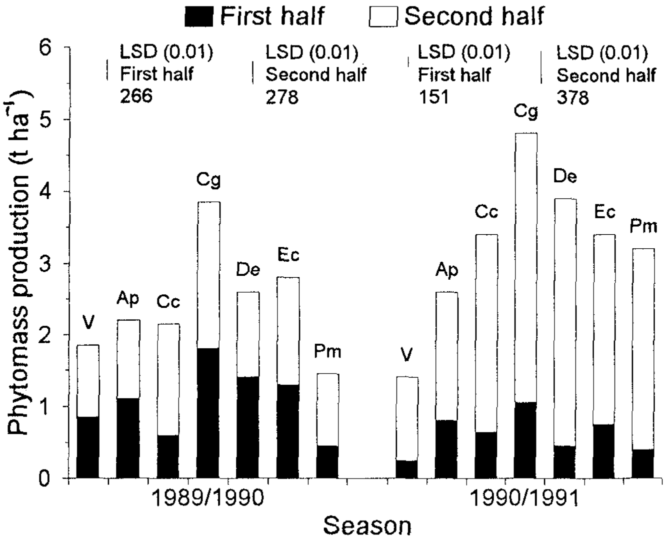

Figure 1 Average above-ground phytomass production (t ha^{-1}) of six pasture species and natural grassland (veld) over the 1989/1990 and 1990/1991 seasons (V = Veld, Ap = *Anthephora pubescens*, Cc = *Cenchrus ciliaris*, Cg = *Chloris gayana*, De = *Digitaria eriantha* subsp. *eriantha*, Ec = *Eragrostis curvula* and Pm = *Panicum maximum*).

It appears that *Chloris*, regardless of the season, was more productive ($P \leq 0.01$) than the other species (Figure 1). During the 1990/1991 season this species produced 4 790 kg ha^{-1}, which was 234% more than that of veld. Since this species is a weak perennial (Rethman & De Witt 1991), it is probably adapted to regrow quickly (invest in above-ground biomass production) than to invest in survival mechanisms. Under wet conditions (1990/1991), *Chloris* and *Digitaria* produced more biomass ($P \leq 0.01$) than any of the other species (Figure 1). A similar trend was found by Dannhauser (1991a) on marginal soils at Potchefstroom.

Panicum showed some of the lowest pre-summer phytomass production values during the study period. The low values for this species were most pronounced during the first half of the year and were sometimes even lower than the values for veld (pre-summer, 1989/1990). The cold sensitivity of this species (Dickinson *et al.* 1990; Dannhauser 1991b), and its delayed bud break (personal observation) may contribute to its low pre-summer production values. Although this species starts to grow later in the spring than the other species, its production during late summer compares well with that of the other species. These disadvantages may limit its establishment in colder areas. Under dry conditions this species had low production values but shows elevated production values during wetter periods, which contradicts Dannhauser's (1991a) findings.

Anthephora and the veld maintained a reasonably consistent production throughout the season, regardless of moisture conditions. Over the experimental period the seasonal (July to June) production from veld averaged 1 614 kg ha^{-1} (average 555 mm of rain), compared with 1 107 kg ha^{-1} (average 525 mm rain) over a 14-year period recorded by Snyman & Fouché (1993) on the same area, also from veld in good condition.

In an attempt to elucidate the differences among species with respect to water use, above-ground phytomass production was regressed against rainfall (Figures 2 & 3). The total production for each season was also included in the relations.

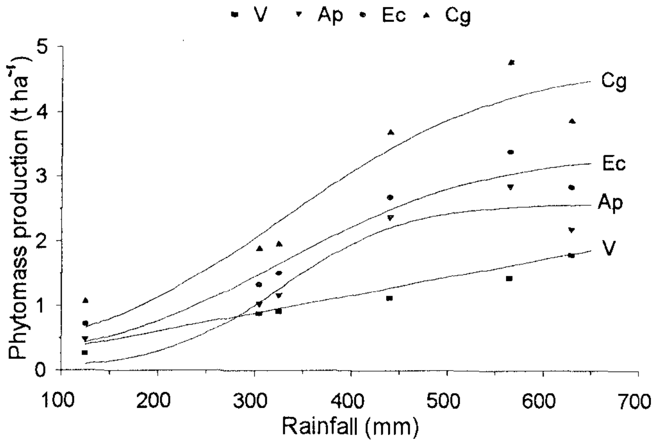

Figure 2 Relation between above-ground phytomass production (kg ha^{-1}) and rainfall (mm), for six pasture species and natural grassland (veld) over the 1989/1990 and 1990/1991 seasons (n = 6). V = Veld: $y = 45.5673 + 2.8094x$ (r=0.99; $P \leq 0.0001$), Ap = *Anthephora pubescens*: $y = 2590.8353 / (1 + 185.9123e^{-0.0159x})$ (r=0.95; $P \leq 0.03$), Ec = *Eragrostis curvula*: $y = 3383.0622 / (1 + 22.3086e^{-0.0094x})$ (r=0.96; $P \leq 0.02$), and Cg = *Chloris gayana*: $y = 4767.4085 / (1 + 18.5952e^{-0.0088x})$ (r = 0.95; $P \leq 0.03$).

Figures 2 & 3 clearly indicate that planted pastures and veld responded differently to rainfall in terms of production. Natural grassland species (veld) appear to be inefficient in using higher rainfall to benefit above-ground phytomass production, whereas fertilised planted pastures appear to be more effective in this regard. *Chloris* appears to be the most effective and above-ground phytomass production increased rapidly with increasing rainfall. *Cenchrus* and *Panicum* reached their maximum production at about 400 mm rainfall; *Digitaria* and *Anthephora* at 500 mm; while *Chloris* and *Eragrostis* with 630 mm rainfall still showed an increase in production (Figures 2 & 3). Although these findings are based on a few observations, these relations can serve as a simple empirical model for managers.

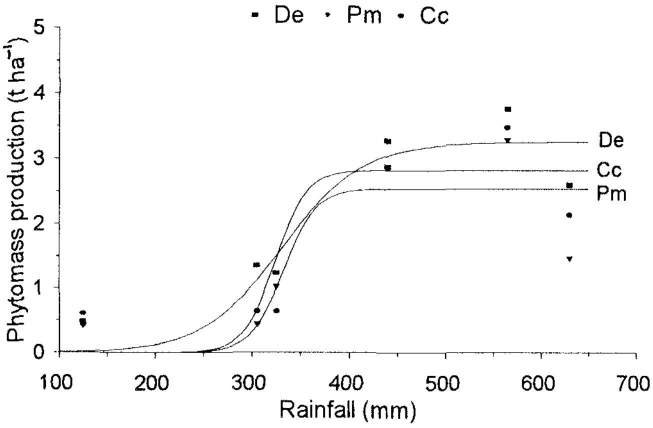

Figure 3 Relation between above-ground phytomass production (kg ha^{-1}) and rainfall (mm), for seven pasture species over the 1989/1990 and 1990/1991 seasons (n = 6). Cc = *Cenchrus ciliaris*: $y = 2\ 826.4109 / (1 + 504698509.6255\ e^{-0.0619x})$ (r=0.92; $P \leq 0.06$), De = *Digitaria eriantha* subsp. *eriantha*: $y = 3257.6987 / (1 + 3222.1999\ e^{-0.0244x})$ (r = 0.93; $P \leq 0.05$), and Pm = *Panicum maximum*: $y = 2540.6822 / (1 + 397950370.3652\ e^{-0.0596x})$ (r = 0.88).

Crude protein (CP)

During the second half of the 1990/1991 season all species had a lower ($P \leq 0.01$) percentage of CP than during the first half (Figure 4). The lower values during the second half can be attributed to the plants being harvested after they had been killed by frost. The CP percentage values obtained for the second half can be regarded as nutritive values of foggage. Relatively little research has been undertaken on the potential values of foggage in the drier parts of southern Africa. The information presently available applies only to higher rainfall regions (Rethman & Gouws 1973; Rethman *et al.* 1977; Rethman & De Witt 1991). The CP % values obtained with this study therefore represent some of the first foggage-value indications for semi-arid regions of southern Africa. The findings of Dannhauser (1985, 1988) from the Potchefstroom region (629 mm rainfall) are also relevant in this regard.

During the first half of the season the highest CP (7.94%) was found in *Panicum* ($P \leq 0.01$) and the lowest (5.18%) in *Cenchrus* ($P \leq 0.01$). Dannhauser (1991a) similarly found a high CP content of *c.* 11% for *Panicum* at Potchefstroom, with the values for *Digitaria* and *Anthephora* being significantly lower. The CP percentage of veld was surprisingly 15% higher than that of *Cenchrus*, in spite of the latter having been fertilised. The CP content of the other four species did not differ significantly ($P>0.05$) during the first half of the season. Veld had a relatively high CP content compared to the fertilised pastures during the dry first half of the 1990/1991 season.

For the second half of the season (Figure 4) *Eragrostis* (2.8%) showed the lowest crude protein values ($P \leq 0.05$), while *Anthephora* (5.1%) had the highest values ($P \leq 0.01$). The exceptionally high CP content of *Anthephora* even after being killed by frost, emphasises the potential value of this species as foggage. The CP content of the other four species as foggage, did not differ significantly ($P> 0.05$).

Barnes (1966) illustrated that animals may lose weight if the CP content drops below 3.5%. There should, therefore, be no detrimental effects to animal production if these dryland pasture species or veld are consumed during the first half of the season.

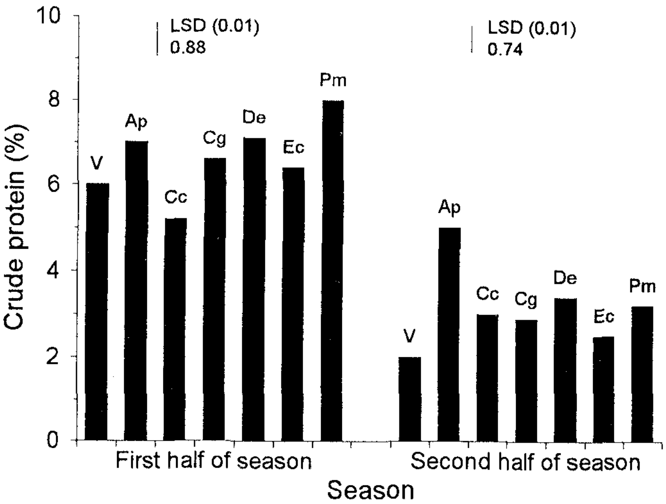

Figure 4 Average crude protein (%) of six pasture species and natural grassland (veld) over the 1990/1991 season. V = Veld, Ap = *Anthephora pubescens*, *Cenchrus ciliaris*, Cg = *Chloris gayana*, De = *Digitaria eriantha* subsp. *eriantha*, Ec = *Eragrostis curvula* and Pm = *P. maximum*.

However, during the second half of the season most of the species have values below 3.5% where animal weight loss might be experienced. The higher CP content of *Anthephora* and *Digitaria* (more than 3.5%) after they have been killed by frost, justify further research on the potential of these species as foggage in drier areas. *Anthephora* has not previously been evaluated as foggage in the semi-arid areas, except in its late physiological stage (Fourie *et al.* 1984). *Digitaria* was also identified by Rethman & De Witt (1991) and Dannhauser (1991b) as a species suitable for use as foggage on the eastern Transvaal Highveld.

Water-use efficiency (WUE)

Chloris used water more efficiently ($P \leq 0.01$) than any of the other species throughout the experimental period (Figure 5). This species produced an average of 7.2 kg above-ground phytomass for each millimetre of water evapotranspired, compared to the 2.9 kg of veld for the entire experimental period. During the first half of the 1989/1990 season (Figure 5) veld showed an exceptionally high WUE in comparison to some of the pasture species, while for the remainder of the experimental period veld WUE values were consistently the lowest. Over the two-year study period veld maintained a reasonably constant WUE, whereas the WUE values of the planted pasture species varied greatly among growing periods.

Anthephora and *Panicum* were the least efficient of all the planted pasture species in water use, which ranged from 4.0 to 4.2 kg ha-1 mm^{-1}. *Eragrostis*, *Cenchrus* and *Digitaria* maintained comparable water-use efficiencies and their average values for the entire experimental period ranged from 5.00 to 5.38 kg ha^{-1} mm^{-1}. All species maintained higher WUE during the wetter second half of the season than during the dry early summer (Figure 5). The average WUE values of a number of climax grasses in semi-arid grassveld were found to range between 4.7 and 7.8 kg ha^{-1} mm^{-1} (Snyman 1989), while that of climax veld in the same area varied between 2.0 and 4.1 kg ha^{-1} mm^{-1} (Opperman 1975; Snyman 1988; Snyman & Fouché 1991). These values compare well with the average value of 2.9 kg ha- 1 mm^{-1} obtained for climax veld over the two-year period in this study. However, it is likely that the WUE of

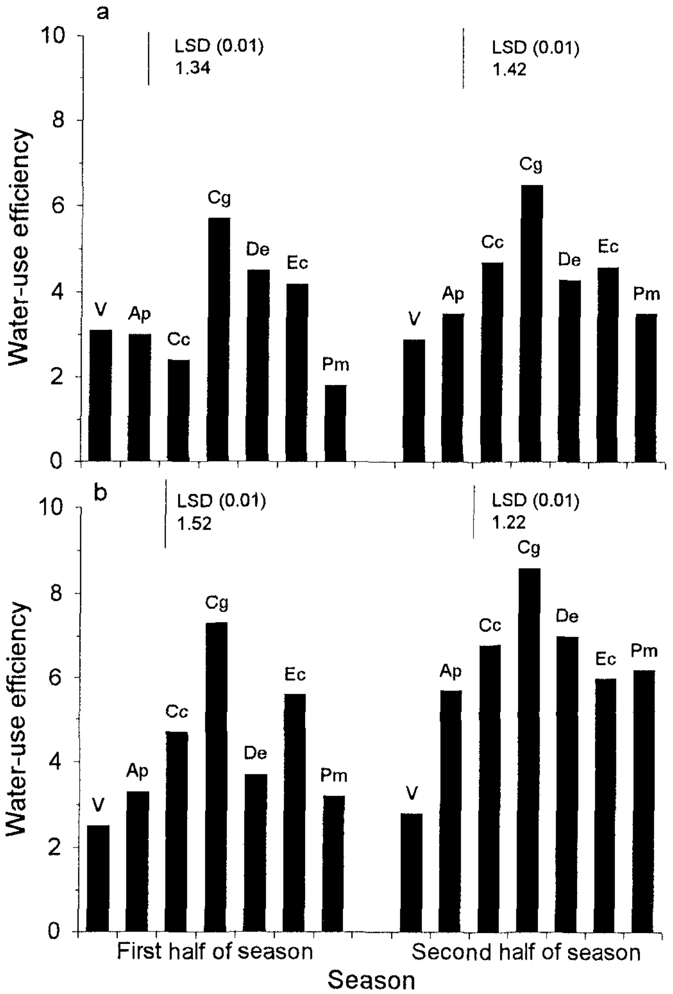

Figure 5 Average water-use efficiency (kg phytomass production ha^{-1} mm^{-1}) of six pasture species and natural grassland (veld) over the 1989/1990 season (a) and the 1990/91-season (b). Ap = *Anthephora pubescens*, Cc = *Cenchrus ciliaris*, Cg = *Chloris gayana*, De = *Digitaria eriantha* subsp. *eriantha*, Ec = *Eragrostis curvula* and Pm = *Panicum maximum*.

climax veld may reach values as high as 9.2 kg ha^{-1} mm^{-1} under optimal conditions (Snyman *et al.* 1980).

Veld had the lowest WUE in terms of CP content, namely an average of 0.11 kg CP ha^{-1} mm^{-1} for the 1990/1991 season (Figure 6). During the second half of the season, veld produced only 0.06 kg CP ha^{-1} for each mm water that was evapotranspired.

The highest ($P \leq 0.01$) WUE in terms of CP content was obtained in *Chloris* (0.47 kg CP ha^{-1} mm^{-1}) during the first half of the season. The average WUE (for the whole year) of this species as well as that of *Anthephora* were higher ($P \leq 0.01$) than that of any of the other species. The total WUE values of the other species did not differ significantly ($P > 0.05$) over the whole season, and average values varied from 0.17 to 0.23 kg CP ha^{-1} mm^{-1}.

Although *Eragrostis* had a higher ($P \leq 0.01$) WUE than the other species (with the exception of *Chloris*) during the first half of the season (Figure 6), its WUE measured up to foggage (second half of season), was lower ($P \leq 0.01$) than the other species. In contrast the WUE of *Anthephora*, measured up to foggage, was 22% higher than its pre-summer WUE. The relativelyconsistent production potential (Figure 1) and WUE (Figure 6) of this species, under high and low rainfall conditions, suggests a good survival ability and an excellent potential as dry-

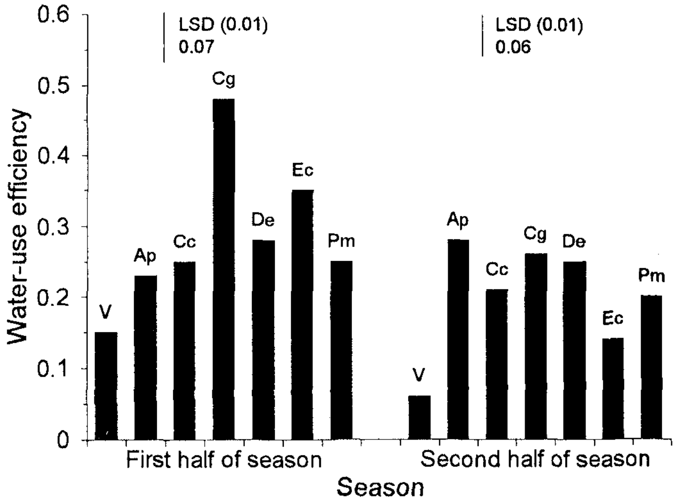

Figure 6 Average water-use efficiency (kg crude protein ha^{-1} mm^{-1}) of six pasture species and natural grassland (veld) over the 1990/1991 season. V = Veld, Ap = *Anthephora pubescens*, Cc = *Cenchrus ciliaris*, Cg = *Chloris gayana*, De = *Digitaria eriantha* subsp. *eriantha*, Ec = *Eragrostis curvula* and Pm = *Panicum maximum*.

land pasture species in areas of low rainfall. The relatively low yield (Figure 1) and WUE in terms of phytomass production (Figure 5) is counterbalanced by its drought tolerance (Dannhauser *et al.* 1987) and its high CP content (Figure 4) which may explain the high palatability status of this species (Dannhauser 1991b).

Conclusions

Evapotranspiration and rainfall values were similar throughout this study which suggests that perennial planted pastures and veld in the semi-arid areas extract water from the whole soil profile during average rainfall seasons and do not leave much surplus water for the following growing period. Snyman (1993) also found a similar trend on veld in semi-arid grassveld. The absence of deep percolation (i.e. more than 0.8 m) throughout this study, further supports these findings. However, water extraction patterns may be quite different when above-average rainfall seasons occur and surplus water may remain from the one season to the next, which could increase the production potential during the following season. Information on depth and distribution of roots may allow predictions of which species can benefit from surplus water and may also explain differences in Et and WUE among species. Root studies in the field, should therefore be undertaken in order to understand (and predict) performance of dryland pasture species.

The non-significant differences in seasonal Et that were found between species in this study can, to a large extent, be ascribed to the minor physiological differences between them. Because significant differences did occur in WUE (in terms of phytomass production and CP content) between the species, it can be concluded that the production and CP values are the determining factors influencing WUE under dryland conditions. In arid and semi-arid regions an understanding of the efficiency of water-use by pasture species and indigenous grasses is important, because factors that would increase the productivity and nutritive value, would therefore also increase the WUE. From a management point of view in particular, such information is needed for the evaluation of the production potential of comparable grazing plants.

Although the unfertilised natural grassland (veld) maintained the lowest production and WUE, as expected, it was very constant with a reasonable CP value for the experimental period. This implies that in spite of an erratic moisture supply, no cultivation and fertilisation, veld provides cheap, reliable forage for the ruminant. This can only be true, provided that the veld is in good condition, because veld in poor ecological condition contributes to an increased frequency and intensity of droughts, as well as so-called man-made or apparent droughts (Snyman & Fouché 1991, 1993).

Findings from this study showed that only *Anthephora* and *Digitaria* foggage will have CP% values greater than 3.5%, while the rest of the species studied represent foggage CP percentages of below 3.5%. These foggage values are some of the few available for use in fodder flow programmes in semi-arid regions. This study showed, and several others (I'Ons 1968; Brockett 1983; Dannhauser 1988) have illustrated, that summer grasses should be grazed or cut in the early summer and left to rest for foggage from early January. However, the closing dates (viz. mid-December, beginning-January, end-January and late-February) and nitrogen application rates on the quality and quantity of foggage, should be evaluated economically under semi-arid conditions in future.

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