CHAPTER 3

DRY MATTER YIELDS OF FIVE SUB-TROPICAL PERENNIAL GRASS SPECIES AT FOUR LEVELS OF WATER AVAILABILITY

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Abstract

The effect of four levels of water availability on the yield of five subtropical perennial grasses (*Cenchrus ciliaris,* a *Cynodon* hybrid*, Digitaria eriantha subsp. eriantha, Panicum maximum* and *Pennisetum clandestinum*) was evaluated in a small plot trial under a rain shelter at the University of Pretoria. The four treatments were: soil profile brought to 25 (W1), 50 (W2), 75 (W3) and 100% (W4 - the control) of field capacity on a weekly basis.

Under W4 (control) and W3 conditions, yields did not differ significantly ($P \geq 0.05$). Where, however, less water was available (W2 and W1), yields were significantly ($P \leq 0.05$) reduced in comparison with the control (W4). By bringing the soil profiles to field capacity at the beginning of the season, a water reservoir was established in the soil which buffered the effect of induced drought, leading to non-significant ($P \geq 0.05$) differences in yield. The capacity of the reservoir, together with the factors affecting

water loss, will thus determine the level of water depletion which can be tolerated before yields will significantly be affected. Due to the large number of variables, no single recipe for success can be advocated, while basic principles should not be overlooked. These include a basic knowledge of soil, and how to improve water infiltration and decrease excessive water loss, climate, and how it affects water loss and fodder species and how they react to different management strategies. Then only can a fodder production system be improved and maintained.

C. ciliaris, a notable drought tolerant species, produced yields (11.7-20.0 t ha^{-1}) under non-control conditions (W1, W2 and W3) which were comparable to yields obtained under control conditions (W4) for traditionally irrigated grasses such as the *Cynodon* hybrid (12.0-15.8 t ha^{-1}) and *P. clandestinum* (5.6-11.8 t ha^{-1}). *P. clandestinum, D. eriantha* and *P. maximum* tended to be better adapted to wetter conditions.

These results also indicated that traditionally drought tolerant grass species (for example *C. ciliaris*) should not be overlooked when identifying species for use under irrigation. By choosing a grass species that can produce the same or higher yields with less water, than another species, water can automatically be used more efficiently.

When production of perennial grasses is investigated, long term trials are the only way to obtain accurate results. Two growing seasons are not enough, especially if the pastures have just been planted, since plants need at least one season to establish. With two growing seasons, after the establishment season,, the variation is just enough to increase the number of uncertainties as to what caused these differences. In future, at least three season's data, excluding the establishment season, should be collected, while five year's data would be ideal. If similar trials were, however, to be conducted in more extensive (drier) conditions, the number of growing seasons should even be higher.

Keywords

Cenchrus ciliaris, a *Cynodon* hybrid, *Digitaria eriantha*, *Panicum maximum*, *Pennisetum clandestinum*, drought, dry matter partitioning

3.1 Introduction

Pastures, planted or natural, will always be part of the South African landscape. They grow, not only as dryland crops, but can often be found in areas where supplementary irrigation is available. Due to the nature of the rainfall in South Africa, even grasses in the latter areas can be subjected to drought, and knowledge of the impact of different levels of water availability on the yield and nutritive value thereof is, therefore, very important. Information on the water usage (Chapter 1) and resultant yields of planted pastures, as well as of natural veld, are, however, very scarce, making decision making, in terms of the best grass species for an area, very difficult.

It was, therefore, the aim of this trial to compare the yield potential of five grass species which can be found as planted pastures and /or as veld grasses in South Africa, at different levels of water availability. The hypotheses are that:

– the grasses will differ in their ability to produce with different amounts of water available;

– and that they will be able to produce good yields, even when subjected to mild water stress.

3.2 Materials and Methods

Five subtropical perennial grasses were established under an automatic rain shelter on the Hatfield Experimental Farm, of the University of Pretoria in Pretoria, (25˚45'S, 28˚16'E), South Africa, during December 1995. The trial ended in June 1998. The five grasses were *Cenchrus ciliaris* cv. Molopo (Blue buffel-grass), a *Cynodon* hybrid cv. Coastcross II (K11) (Coastcross bermudagrass), *Digitaria eriantha subsp. eriantha* cv. Irene (Smuts finger-grass), *Panicum maximum* cv. Gatton (Guinea grass) and *Pennisetum clandestinum* cv. Whittet (Kikuyu grass).

The soil at the site is a Shorrock series of the Hutton form (MacVicar *et al.*, 1991) with 30% clay in the top soil. The A-horizon of the soil is uniform to a depth of 1.2 m, before reaching the B-horizon, which contains coarse gravel. The experimental plots were 2.5 x 2.0 m in size and separated by asbestos plates to a depth of 1.2 m.

During June 1995, seeds of *C. ciliaris*, *P. maximum*, *D. eriantha* and *P. clandestinum* were sown in seedling trays and kept in a greenhouse until December 1995. *C. ciliaris, P. maximum* and *D. eriantha* which are tufted or bunch grasses, were established at a rate of 300 000 plants ha^{-1}, while the creeping grasses (the *Cynodon* hybrid & *P. clandestinum*) were established at 160 000 plants ha^{-1}. The *Cynodon* hybrid was established using vegetative material collected on the experimental farm. The initial germination rate of *D. eriantha* was less than adequate and additional seedlings had to be propagated. This delayed transplanting of this species from trays to the field site by ten weeks compared to the other species.

A neutron probe access tube was located in the centre of each plot. Neutron probe counts, using a Campbell neutron probe (503 DR), were taken at nine depth increments, each of 200 mm, on a weekly basis for all plots. These counts, which are related to the volumetric water content, were then incorporated into a calibration equation to determine the water deficit for each layer. Just before the onset of each growing season, the soil profiles of all the plots were brought to field capacity. Only then were the plants subjected to four levels of water availability

The water availability levels used were:

W1 - apply 25% of the amount given to W4.

W2 - apply 50% of the amount given to W4

W3 - apply 75% of the amount given to W4

W4 - control, the soil profiles were brought to field capacity on a weekly basis

Water was applied by means of flood irrigation and the amounts of water applied were monitored using water flow metres.

During the establishment season (1995/96), the grasses were not subjected to differential irrigation treatments to ensure a good establishment as it has been found that some of these grasses only start to produce optimally during the second or third year . To ensure a fair comparison of the species, treatments were thus only imposed in the second (1996/97) and third seasons (1997/98).

According to soil analyses, the pH(H_2O) of the experimental soil was neutral. The phosphorus (Bray II) and potassium (Ammonium acetate extractable cations) status in the top soil (30 mg kg^{-1} P; 108 mg kg^{-1} K) was much higher than that of the subsoil (8 mg kg^{-1} P; 67 mg kg^{-1} K). To achieve a non-limiting soil phosphorus and potassium status of 40 mg kg^{-1} P and 150 mg kg^{-1} K, which would ensure that these nutrients were not limiting, annual applications of these nutrients were necessary. As the plots were not grazed, but removed as hay, N, P and K were lost from the soil and the fertilizer regime was designed to replace these losses. At planting (1995/96 season), the plots received 75 kg N ha^{-1}, 40 kg P ha^{-1} and 200 kg K ha^{-1}. Nitrogen and potassium were also applied to all plots as top dressings during the summer growing season, resulting in a total of 450 kg N ha^{-1} a^{-1}, 40 kg P ha^{-1} a^{-1} and 400 kg K ha^{-1} a^{-1}. In the subsequent seasons (1996/97 and 1997/98), nitrogen and potassium were applied to all plots as top dressings at rates of 225, 338, 394 and 450 kg N ha^{-1} a^{-1} and 200, 300, 350 and 400 kg K ha^{-1} a^{-1} for the W1, W2, W3 and W4 water availability levels respectively. The fertilizers used were limestone ammonium nitrate (LAN) (28.0% N), superphosphate (8.3% P) and potassium chloride (KCl) (50.0% K).

The grasses were harvested at the 10% flowering stage, except for *P. clandestinum*, which was not allowed to grow taller than 40 cm. This resulted in an average of three to four cuts during each season. *C. ciliaris, D. eriantha* and *P. maximum* (tufted grasses) were cut to a height of 10 cm while the *Cynodon* hybrid and *P. clandestinum* (creeping grasses) were cut to 5 cm. A sample plot of one square metre, in the middle of each plot, was harvested, after which the rest of the plot was also cut to the same height. The sample plots were permanently marked to ensure that the samples were taken from the same area at each harvest. The material was dried to constant mass for 48 hours at 65˚C.

During the harvesting process, sub-samples of 0.25 x 0.25 m were taken of the creeping grasses, while tufts were regarded as sub-samples of the tufted grasses. These samples were sorted into leaves, stems and inflorescences. A direct comparison between these two sub-samples could thus not be made. To make comparison possible, the dry matter contribution per unit area was determined.

A fully randomized block design with three replications was used. The statistical analysis was done using the Statistical Analysis System (SAS, 1996). Tukey's least significant difference at the 5% level of probability was used to determine significant differences between treatment means. Relevant statistical analysis data is presented in the Appendix (Tables A 3.1 - A 3.14).

3.3 Results

3.3.1 Dry matter yield

The yields reported in the literature (Table 3.1) sometimes correspond well with the results (Figures 3.1, 3.2 and Table 3.2) obtained in this trial, but sometimes they differ widely. This is not due to good or bad research practices, but rather the variety of growing conditions that makes extrapolation from one situation to another very difficult. Results of other researchers are, however, not useless because more often than not, similar trends are observed even if the yield *per se* is not comparable.

The findings in the literature (Table 3.1) can be summarized as follows: *C. ciliaris* is said to produce well under extreme drought conditions(<300 mm annual rainfall) (Fianu and Winch, 1983; Anonymous, 1989 (b)), while *P. clandestinum* is said to fare far better when growing with 700 mm or more water per year (Dale and Read, 1975; Dannhauser, 1988; Anonymous, 1989 (a)). *D. eriantha*, *P. maximum* and the *Cynodon* hybrid fall in a group between these two extremes, needing between 400 - 500 mm water per year (Anonymous, 1989 (a) & (b), 1995), and can be found under both irrigation and dryland cultivation (Theron and Arnott, 1977; Burton *et al.*, 1987; Oosthuizen, 1987; Dannhauser, 1988; Cilliers, 1989; Nel, 1989; Gouws, 1990). Being a drought tolerant species, *C. ciliaris* is seldom found under irrigated conditions, despite the fact that it still produces good yields under higher rainfall conditions (Anonymous, 1989 (b)). *P. clandestinum* is, however, not to be found in low rainfall areas without supplemental irrigation.

Table 3.1 Yield data obtained from literature for *C. ciliaris*, the *Cynodon* hybrid, *D. eriantha*, *P. maximum* and *P. clandestinum*.

Grass specie	Growing conditions	Yield (t dry material ha^{-1})	Reference
C. ciliaris	Dryland (Malawi, Tanzania) Dryland (Ghana) KwaZulu-Natal - 714 - 1190 mm rain (South Africa) Dryland (South Africa)	2.0 - 8.0 5.4 - 6.0 6.2 - 8.1 2.5 - 6.9	Bogdan, 1977 Fianu and Winch, 1983 Brockett and Gray, 1984 Anonymous, 1989 (b)
D. eriantha	KwaZulu-Natal - 714 - 1190 mm rain (South Africa) Dryland and irrigation (South Africa) Highveld - dryland (South Africa) Potchefstroom- dryland (South Africa) Potchefstroom - 478 and 803 mm rain (South Africa)	9.3 - 10.8 4.0 16.0 7.1 - 12.0 4.0 - 11.0 4.5 and 13.1	Brockett and Gray, 1984 Oosthuizen, 1987 Pieterse *et al.* 1988 Dannhauser, 1991 Dannhauser, 1991
Cynodon hybrid	KwaZulu-Natal, dryland (South Africa) KwaZulu-Natal, irrigation, 500 kg N ha^{-1} (South Africa) KwaZulu-Natal (South Africa) Dryland and irrigation with fertilizers (South East, USA) Highveld + irrigation + 300 kg N ha^{-1} (South Africa) Eastern Transvaal (South Africa) 600 - > 1 000 mm (South Africa) 360 kg N ha^{-1} (Kentucky, USA)	7.6 - 13.0 26.0 7.4 - 7.7 13.1 - 14.4 17.6 - 20.0 4.0 - 9.1 3 - 30 3 - 8	Theron and Arnott, 1977 Theron and Arnott, 1977 Brockett and Gray, 1984 Burton *et al.*, 1987 & 1988 Pieterse *et al.* 1988 Rethman and De Witt, 1988 Nel, 1989 Belesky *et al.*, 1991
P. maximum	French Guiana Venda, > 750 mm rain Different cutting regimes (Malaysia) Potchefstroom - dryland (South Africa) Potchefstroom - 478 and 803 mm rain (South Africa) 550 - 750 mm rain (South Africa)	14.4 15.0 - 30.0 1.7 - 44.5 7.0 - 11.0 6.0 and 12.0 4 - 12	Bogdan, 1977 Cilliers, 1989 Wan Hassan *et al.,* 1990 Dannhauser, 1991 Dannhauser, 1991 Nel, 1994 (a) & (b)
P. clandestinum	Hawaii with different N applications KwaZulu-Natal, dryland (South Africa) Queensland, Australia KwaZulu-Natal with 40 - 80 kg N ha^{-1}, 714 - 1190 mm rain (South Africa) Irrigation with fertilizers and different cutting regimes (Western Cape, South Africa) Eastern Transvaal (South Africa)	4.8 - 35.3 8.2 - 12.2 Max of 12.0 4.3 - 13.1 12 - 22 4.0 - 5.7	Whitney, 1974 Theron and Arnott, 1977 Bogdan, 1977 Brockett and Gray, 1984 Van Heerden, 1986 Rethman and De Witt, 1988

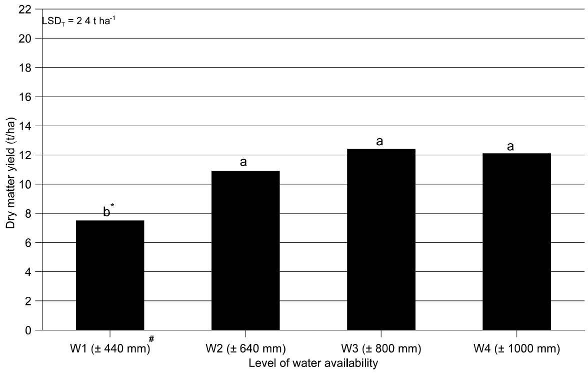
The dry matter yields presented in Figures 3.1 and 3.2, represent the total above ground yields for each season. There was no significant ($P \geq 0.05$) grass species x level of water availability interaction in either the 1996/97 nor the 1997/98 season. The average yields at the four levels of water availability, however, differed from each other in both seasons. In the 1996/97 season (Figure 3.1(a)) only the W1 level resulted in a significantly ($P \leq 0.05$) lower yield than the remaining three levels. In the following season (Figure 3.2(a)) both the W1 and W2 levels resulted in significantly ($P \leq 0.05$) lower yields than under control conditions (W4). It is important to note that although grasses at the W1 level received 75% less water than the control plots (W4), the same reduction in yield was not experienced. The same is true for the W2 and W3 levels, which received 50 and 25% less water respectively than the control (W4). In the 1996/97 season the W3 plants even produced higher yields than the control with 25% less water. Burton *et al.* (1987 & 1988) (Table 3.1) also harvested the same or higher yields from the *Cynodon* hybrid without than with supplementary irrigation. Beukes and Weber (1981) reported luxury water uptake by *Medicago sativa*, resulting in non- significant differences in yield with and without adequate amounts of water. This implies that by bringing a profile back to field capacity on a weekly basis, where the profile was at field capacity at the beginning of the season, might not result in greater yields, which in turn would make the extra inputs (water, electricity, labour, time, fertilizers) non-profitable.

In 1996/97 *(*Figure 3.1(b)) *C. ciliaris* produced significantly ($P \leq 0.05$) the highest yield followed by *D. eriantha* and the *Cynodon* hybrid which did not differ significantly ($P \geq 0.05$) from each other. *P. maximum* produced significantly ($P \leq 0.05$) lower yields than the two highest producing grasses, but significantly ($P \leq 0.05$) more than *P. clandestinum*. During 1997/98 (Figure 3.2(b)) *C. ciliaris* and the *Cynodon* hybrid produced significantly ($P \leq 0.05$) higher yields than the other three grass species. The yields of *D. eriantha*, *P. maximum* and *P. clandestinum* did not differ significantly ($P \geq 0.05$) from each other. On average over the two seasons *C. ciliaris*, the *Cynodon* hybrid and *D. eriantha* produced more dry material than *P. maximum* and *P. clandestinum*.

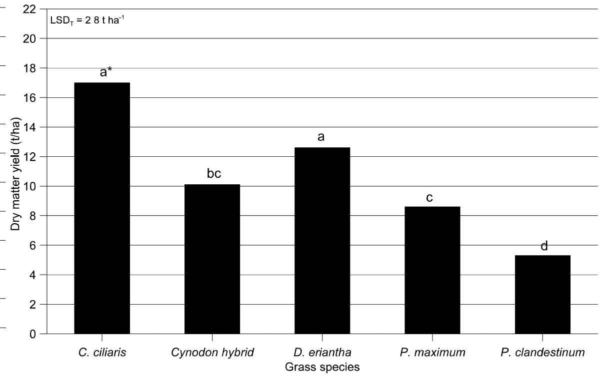
In a long term trial (5 - 7 years) conducted in KwaZulu-Natal by Brockett and Gray (1984), *D. eriantha* (9 - 11 t ha^{-1}) had the highest yields, followed by the *Cynodon* hybrid (7 - 8 t ha^{-1}), *C. ciliaris* (6 - 8 t ha^{-1}) and *P. clandestinum* (4 - 8 t ha^{-1}). Where *P. maximum* and *C. ciliaris* were compared in terms of drought tolerance, *C. ciliaris* plants were able to survive a drought that led to 50% die-back of *P. maximum* plants (Anonymous, 1978).

In the 1996/97 season (Figure 3.1(b)) the yields of the two creeping grasses were quite low in comparison to the yields reported in the literature (Van Heerden, 1986; Burton *et al.*, 1987; Pieterse, *et al.*, 1988 & 1989). Despite these initial low yields *P. clandestinum* and the *Cynodon* hybrid did quite well in the 1997/98 season (Figure 3.2(b)), with the *Cynodon* hybrid producing higher yields than *P. clandestinum*. The same trend was found in Pietermaritzburg (KwaZulu-Natal) (Hefer & Tainton, 1990) where the *Cynodon* hybrid yielded about 3.5 to 4.5 t ha^{-1} in comparison with the 3.0 to 4.3 t ha^{-1} of *P. clandestinum* in the same trial.

(a)



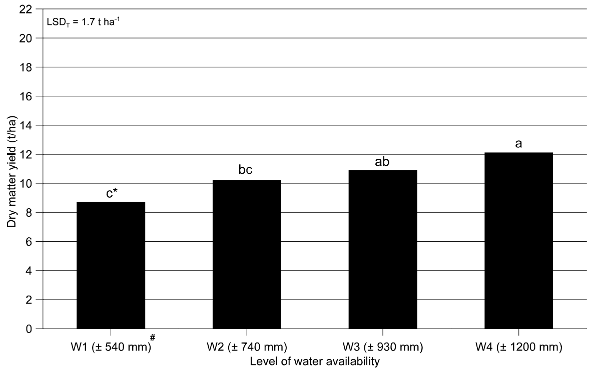
(b)



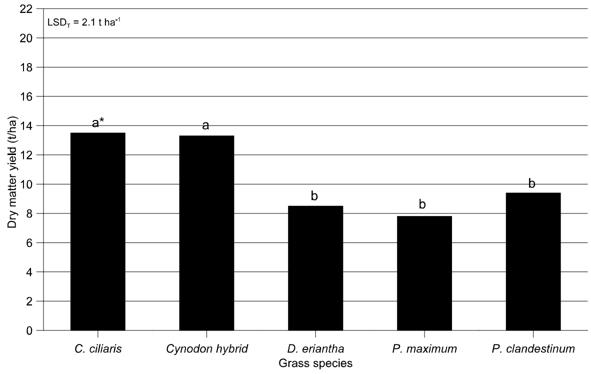
* Treatments with the same letter do not differ significantly from each other (P<0.05)
# W1 - severely water stressed level, W4 - control

Figure 3.1(a) Average dry matter yield at four levels of water availability in the 1996/97 season
Figure 3.1(b) Average dry matter yield of five subtropical perennial grasses in the 1996/97 season.

(a)



(b)



* Treatments with the same letter do not differ significantly from each other (P<0.05)
# W1 - severely water stressed level, W4 - control

Figure 3.2(a) Average dry matter yield at four levels of water availability in the 1997/98 season
Figure 3.2(b) Average dry matter yield of five subtropical perennial grasses in the 1997/98 season.

Although there was no significant ($P \geq 0.05$) water availability x grass species interaction, it is important to note the yield differences of the five grasses for the four levels (Table 3.2). Some grass species like *C. ciliaris* produced higher yields under non-control conditions (W1, W2 and W3) than *D. eriantha*, *P. maximum* and *P. clandestinum* produced under control conditions (W4). This was true for both seasons. The same was true for *D. eriantha* in the 1996/97 season which produced higher yields under W2 and W3 conditions than the *Cynodon* hybrid, *P. maximum* and *P. clandestinum*. During 1996/97 the *Cynodon* hybrid and *P. maximum* also produced higher yields under non-control conditions (W1, W2 and W3) than *P. clandestinum* under control conditions.
In 1997/98 the *Cynodon* hybrid produced higher yields under W2 and W3 conditions than *D. eriantha*, *P. maximum* and *P. clandestinum* under control conditions. By choosing a grass species that can produce the same or higher yields with less water, than another specie, water can automatically be used more efficiently.

According to the literature *P. maximum* is better adapted to drought conditions than *D. eriantha*, while *D. eriantha* grew better than *P. maximum* and *C. ciliaris* with higher amounts of water available (Dannhauser, 1991; Snyman, 1994). In the two seasons of the trial, however, it was *D. eriantha* which produced higher yields than *P. maximum* under drought conditions, and it did not correlate with the trend indicated by the literature. *D. eriantha* although, producing better than *P. maximum* under wet conditions could not outyield *C. ciliaris* under these conditions.

The *Cynodon* hybrid can produce good yields under both irrigated and dryland conditions. This was confirmed by the results of the second season (Table 3.2). In comparison to *P. clandestinum*, the *Cynodon* hybrid used less water and is more drought tolerant (Theron and Arnott, 1977; Rethman and De Witt, 1988; Nel, 1989). This was confirmed in the current study.

Table 3.2 Influence of level of water availability on the dry matter yield (t ha^{-1}) of five perennial grasses.

Grass	Level of water availability (I)*				Mean
	W1	W2	W3	W4	
		1996/97 season			
C. ciliaris	11.7	17.0	20.0	19.2	17.0
Cynodon hybrid	7.4	8.8	12.1	12.0	10.1
D. eriantha	8.2	14.9	14.1	13.2	12.6
P. maximum	6.2	8.7	9.2	10.4	8.6
P. clandestinum	4.0	5.1	6.3	5.6	5.3
Mean	7.5	10.9	12.4	12.1	
LSD_T(G) = 2.8					
LSD_T(I) = 2.4					
		1997/98 season			
C. ciliaris	12.4	13.9	13.9	13.7	13.5
Cynodon hybrid	9.7	13.2	14.7	15.8	13.3
D. eriantha	6.9	8.2	9.0	9.9	8.5
P. maximum	7.0	7.0	7.7	9.4	7.8
P. clandestinum	7.7	8.7	9.3	11.8	9.4
Mean	8.7	10.2	10.9	12.1	
LSD_T(G) = 2.1					
LSD_T(I) = 1.7					

* W1 -severely water stressed level, W4 - control

The *Cynodon* hybrid regularly produced better yields than *D. eriantha* under highveld conditions in Gauteng (Pieterse *et al.*, 1988 & 1989), correlating well with the trend in Table 3.2. According to Rethman and De Witt (1988) *Cynodon* is less well adapted to the high rainfall, but cool conditions of the eastern highveld of Mpumulanga, while *P. clandestinum* was able to produce well under those conditions. Dannhauser (1988) confirms this by stating that *P. clandestinum* is recommended for high rainfall cooler areas, while *D. eriantha*, *Cynodon* and *P. maximum* could be used under high and low water availability conditions, which correlates well with the findings in Table 3.2. Snyman (1994) confirmed that *D. eriantha* and *C. ciliaris* did better than *P. maximum* under drought conditions, but also stated that *D. eriantha* did better than *C. ciliaris* under dryland conditions in the Free State Province, which is in contrast with the present results.

The results of Taylor *et al.*, (1976) (New Zealand) are quite different than those reported in the current study. According to them, the yields of *C. ciliaris* and *P. clandestinum* were similar under dryland conditions, while *P. clandestinum* produced almost 10 t ha^{-1} more dry material under irrigation conditions than *C. ciliaris*.

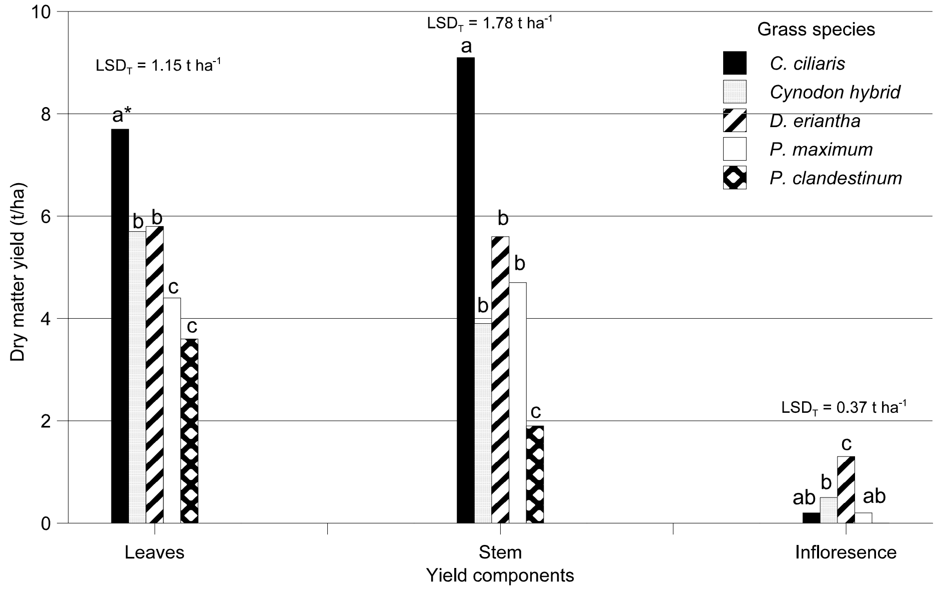
In the 1997/98 season the yields of *P. clandestinum* practically doubled for all the levels of water availability in comparison to the previous season. In 1997/98 *P. clandestinum* and *P. maximum* yields under control conditions (W4) were much higher than under the other levels. These two species appear to be better adapted to cooler and more moist conditions, and water stress resulted in large yield decreases. Snyman (1994) also stated that *P. maximum* was not adapted to drought conditions and had a better potential under better water supply conditions.

3.3.2 Contribution of the yield components to the above-ground dry matter yield

Due to the cutting regime followed, the reproductive component made up only a very small proportion of the above-ground dry matter yield (Figures 3.3 and 3.4), which consisted mainly of leaves and stem.

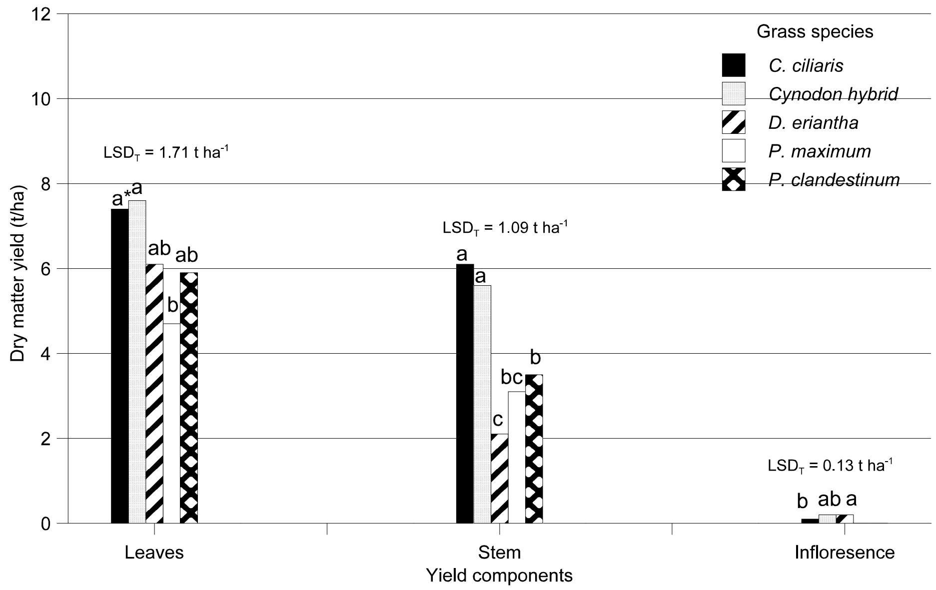
The *Cynodon* hybrid, *D. eriantha* and *P. clandestinum* followed the same trend in terms of leaf and stem material. These grasses had more leaf than stem in both seasons. Dannhauser (1991) also mentions a high leaf : stem ratio for the *Cynodon* hybrid as well as a large amount of leaf material being produced by *D. eriantha*. From the literature it is also evident that *P. clandestinum* produces an abundance of leaves (Gibbs-Russel *et al*., 1991) while *D. eriantha* can easily be ensiled due to its leafiness (Dickinson *et al*., 1990).

P. maximum and *C. ciliaris* were not consistent in the two seasons. In the 1996/97 season the stem dry matter yields of the two species were 0.9 and 1.3 t ha^{-1} respectively more than for the leaves. In the following season, however, the leaf dry matter yields were 1.0 and 1.2 t ha^{-1} respectively more than the stem dry matter yields for *P. maximum* and *C. ciliaris* respectively. In the 1996/97 season, *P. maximum* was only cut twice and *C. ciliaris* three times, while in the 1997/98 season three cuttings were taken from *P. maximum* and four cuttings from *C. ciliaris*, resulting in shorter regrowth periods, with less accumulation of stem material, thus explaining the higher leaf dry matter yields relative to the stem yields in the 1997/98 than in the 1996/97 season.



* Treatments with the same letter do not differ significantly from each other (P<0.05)

Figure 3.3 The contribution of different plant components to the production of five perennial grasses in the 1996/97 season.



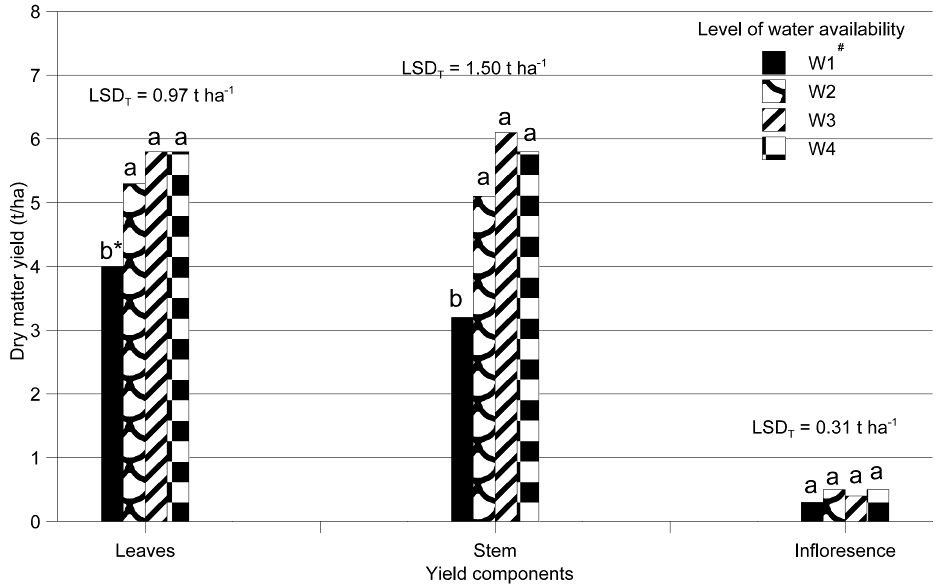
* Treatments with the same letter do not differ significantly from each other (P<0.05)

Figure 3.4 The contribution of different plant components to the production of five perennial grasses in the 1997/98 season.

As with whole plant dry matter yields, the yields of the different yield components tended to increase with greater water availability (Figures 3.5 and 3.6).

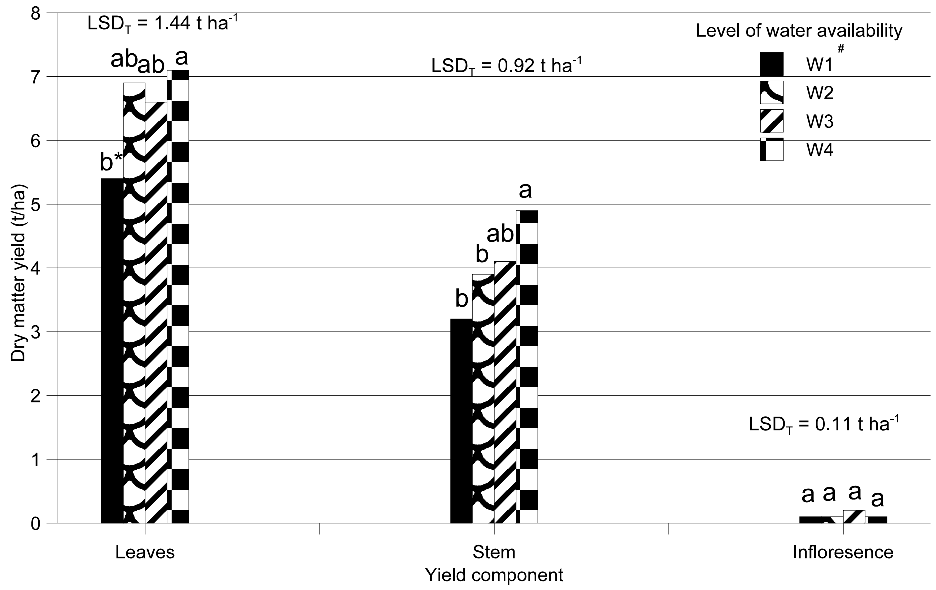
In both seasons there were no significant ($P \geq 0.05$) differences between the yield contributions of the leaf and stem material at the W2, W3 and W4 levels (Figures 3.5 and 3.6). Significantly ($P \leq 0.05$) lower stem and leaf material yields were, however, produced at the W1 level of water availability in both seasons.

In both seasons more leaf than stem material was produced at level W1. For the other levels it differed in the two seasons. In 1996/97 (Figure 3.5) more leaf material at W2, less at W3 and the same at W 4 was produced, while in the 1997/98 season (Figure 3.6), more leaf material was produced at all four levels of water availability. Overman and Wilkinson (1989) found that, regardless of the amount of N applied, the leaves made out the biggest proportion of the bermudagrass dry matter produced. In a dry season the final yield of *C. ciliaris* was 5.36 t ha^{-1} and in a wet season 6.04 t ha^{-1} . For the latter results, the stem : leaf ratio was initially 50:50 during the dry season but the proportion of stem increased over time. In the wet season the proportion of leaf was initially higher but later settled to a 50:50 leaf : stem ratio (Fianu and Winch, 1983).



* Treatments with the same letter do not differ significantly from each other (P<0.05)
\# W1 - severely water stressed level, W4 - control

Figure 3.5 The contribution of different plant components to production as affected by four levels of water availability in the 1996/97 season.



* Treatments with the same letter do not differ significantly from each other (P<0.05)
\# W1 - severely water stressed level, W4 - control

Figure 3.6 The contribution of different plant components to production as affected by four levels of water availability in the 1997/98 season.

3.4 Discussion and Conclusions

When the grass species were subjected to different levels of water availability, they were able to keep on producing well under mild water stress. When the soil profiles were brought back to field capacity on a weekly basis, the grasses sometimes even produced lower yields than plants receiving 25% less water. These disappointing yields on the W4 plots may be attributed to luxury water uptake without contributing to yield, nutrient deficiencies and/or nutrient leaching.

As expected, the five grass species differed in terms of their production ability when treated alike. Over a two year period, *C. ciliaris* (15.3 t ha^{-1}), the *Cynodon* hybrid (11.7 t ha^{-1}) and *D. eriantha* (10.6 t ha^{-1}) produced the highest average yields, while *P. maximum* (8.2 t ha^{-1}) and *P. clandestinum* (7.4 t ha^{-1}) produced the least.

The growth of the creeping grasses (the *Cynodon* hybrid and *P. clandestinum*), were lower than expected in the 1996/97 season, but caught up in the 1997/98 season. According to literature, some grasses take longer to establish and that is why long term trials are advisable when growing and evaluating perennial crops.

Some grass species, like *C. ciliaris,* produced higher yields under non-control conditions (W1, W2 and W3) than *D. eriantha*, *P. maximum* and *P. clandestinum* produced under control conditions (W4). By choosing a grass species that can produce the same or higher yields with less water, than another species, water can automatically be used more efficiently.

It is, however, not only the availability of water that affects the success of a species in a specific area. Several authors have emphasized the importance of temperature tolerance for the success of a species. In line with this, Brockett and Gray (1984) found that *C. ciliaris* could produce acceptable yields in the high rainfall areas of the Highland sourveld of KwaZulu-Natal, but due to it's lack of tolerance of cold temperatures, better adapted weeds and grasses invaded and dominated the *C. ciliaris* stand. *Cynodon* (Theron and Arnott, 1977; Rethman and De Witt, 1988; Coetsee, 1993) and *P. maximum* (Snyman, 1994) can also not tolerate severe frost conditions . *P. clandestinum* can, conversely, not tolerate high temperatures (Nel, 1989), while *P. maximum* proved to be better adapted to such temperature conditions (Nel, 1994(a) and 1994(b)). *C. ciliaris* is said to be adapted to growing under high temperature conditions, and can keep on producing at 35˚C, when the leaves of other grasses start to become necrotic (Christie, 1975).

The partitioning of dry matter between the yield components often influences the acceptability of the forage for animals. Grazers prefer softer material, with less lignin, which is more easily digested. The *Cynodon* hybrid, *D. eriantha* and *P. clandestinum* had more leaf than stem material in both seasons. The leaf contribution for *P. maximum* and *C. ciliaris* was lower than that of the stem in the first season, but with a change in cutting regime in the second season it changed. In the second season *P. maximum* and *C. ciliaris* were cut more frequently, resulting in the accumulation of proportionately less stem material. By adjusting the cutting frequency, grasses can still produce well and at the same time accumulate less stem material, which is difficult to digest. The optimum cutting frequencies were not tested in this trial, but from the literature it can be deduced that a single harvest per growing season is too little while six cuts or more can have a negative effect on the profitability of the system (Whitney, 1974; Singh et al., 1995).

3.5. References

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