CHAPTER 4

NUTRITIVE VALUE OF FIVE PERENNIAL SUB-TROPICAL GRASSES UNDER DIFFERENT LEVELS OF WATER AVAILABILITY

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Abstract

The effect of four levels of water availability on the nutritive value, in terms of *in vitro* dry matter digestibility and crude protein content (CP), 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.

With respect to digestibility, no single species was consistently more digestible than the others. It was only the digestibility of *D. eriantha* that stayed relatively constant over the two seasons. The digestibilities varied from 50 - 61% for *C. ciliaris*; 54 - 61% for the *Cynodon* hybrid; 56 - 63% for *D. eriantha*; 50 - 69% for *P. maximum* and 36 - 66% for *P. clandestinum*. Care should, however, be taken when comparing these

digestibilities with results obtained by other researchers, since different analytical methods and diet of the donor sheep could have had a strong effect.
The availability of water did not have any apparent influence on the digestibility of the grasses, which was surprising as it might have been expected that with more vigorous growth (in good conditions) an increase in fibre might have depressed digestibility.

The level of water availability did, however, have an effect on the crude protein content of the whole plant, leaves and stem material. The whole plant CP content of *P. maximum* tended to be higher under water stressed (W1) than well watered conditions (W4) while the plants of *D. eriantha* and the *Cynodon* hybrid with very little or no water stress (W3 and W4) had a higher CP content than the other irrigation levels. Although there was very little difference in crude protein content between the four irrigation treatments of *C. ciliaris* and *P. clandestinum* plants in the1996/97 season, in the following season (1997/98) the crude protein contents under water limiting conditions (W1) were slightly higher than those of the well watered control plants (W4).

The *Cynodon* hybrid and *P. clandestinum* had consistently the highest CP content of the five grasses in both seasons. The *Cynodon* hybrid and *P. clandestinum*, contained on average (8.5% CP) much more crude protein than the three tufted grasses (average of 5.5%). The crude protein content of the latter species did not differ significantly ($P \geq 0.05$) from each other. As with agricultural crops, grass species with higher crude protein contents, often have lower yields, due to the higher energy cost of protein assimilation.

Keywords

Cenchrus ciliaris, Cynodon hybrid*, Digitaria eriantha, Panicum maximum, Pennisetum clandestinum*, digestibility, crude protein

4.1 Introduction

Although the amount of forage, feed or fodder available to an animal is important, the quality thereof will determine if the animal is taking in enough nutrients to maintain health, growth and reproduction. The lower the digestibility of grass, the more the animal has to take in to achieve the same results as with more digestible grass. The animal can, however, only consume a limited amount of bulk feed each day and if this has a low digestibility the animal won't be able to obtain all the energy it needs. The same applies to crude protein content. Each class of animal has a specific crude protein requirement per day. If this requirement is not met, growth and hence production can be seriously affected.

Protein shortages are of major concern to rumen production systems. Protein sources are, however, expensive to buy, and the farmer would like to get as much as possible crude protein from the pasture itself (Van Niekerk, 1997).

Despite differences in yield and quality over species and time, one should identify species with a natural higher fodder quality and or somehow improve the fodder quality of low quality species (Van Niekerk, 1997). Theron and Harwin (1976) confirmed the importance of high quality fodder by achieving a 38% increase in live weight of animals by replacing veld with improved pastures.

The aim of this trial was to determine the effect of four levels of water availability on the nutritive value of different grass species.

The hypotheses are:

1. that the grass species will have different digestibilities and crude protein contents;
2. that the level of water availability will affect digestibility and crude protein content of the grasses, and
3. that there will be a negative correlation between stem material content and digestibility and crude protein content of the forage.

4.2 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 in 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 meters.

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.

Intact plants, as well as the different yield components, were milled after drying. A Wiley no. 3 mill, with a 1 mm sieve was used. The milled product was then used to determine the *in vitro* dry matter digestibility and crude protein content of the crops.

In vitro dry matter digestibility

The dry matter, organic matter and ash contents of the samples were determined by drying 2 g or each milled sample for 24 hours at 60˚C (dry matter content), before incinerating at 600˚C for 4 hours (ash content). The organic matter content was calculated as the difference between the dry matter and ash contents. For the *in vitro* digestibility of the crops, 0.2 g plant material was used for the analysis using the method proposed by Tilley and Terry (1963).

Crude protein content

The milled plant samples were analysed for nitrogen content using the Kjeldahl technique (Association of Official Analytical Chemists, 1984). The analyses were done by the Soil Science Laboratory of the Department of Plant Production and Soil Science, University of Pretoria. The values were multiplied by 6.25 (Van der Merwe and Smith, 1991) to express the results in terms of crude protein content.

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 A4.1 - A4.28).

4.3 Results

4.3.1 In vitro *dry matter digestibility*

There is some controversy over the comparability of quality analyses done by different researchers. Quality data from other researchers will, therefore, only be included to illustrate the variation that exists in the literature.

Inflorescence material was not taken into account, due to the very limited amount of material produced before harvesting. The dry matter digestibility of the whole plant, stem and leaf material (Figure 4.1) was significantly ($P \leq 0.05$) better in 1996/97 than in 1997/98. It was speculated that the lower whole plant digestibility could possibly be attributed to the amount of stem relative to leaf material in the two seasons. There was, however, no significant ($P \geq 0.05$) correlation between the leaf:stem ratio in the material harvested and the whole plant digestibility (Appendix Tables A4.1 - A4.4). t'Mannetje (1975) also found no correlation between leaf percentage and digestibility. He did, however, report a negative correlation between dry matter yield and digestibility and a positive correlation between N percentage and digestibility. According to Singh *et al.* (1995), however, there was a significant positive correlation between the number of leaves and the leaf:stem ratio and digestibility, while an increase in the number of tillers per plant was significantly correlated with a reduction in digestibility. O'Reagain and Mentis (1989) also concluded that leafy grass species with few stems were more highly acceptable to cattle. Leaf material digestibility was better than that of the stem material in both seasons. This was also confirmed by t'Mannetje (1975); Fianu and Winch (1984) and Marais (1990).

The fact that leaf and stem digestibility was lower than that of the whole plant was totally unexpected. It have been influence by the age of the plants. This is, however, unlikely, because the plants were cut back after each harvest and it was the regrowth which was analysed at a similar physiological growth stage. The only significant ($P \leq 0.05$) correlations were between the stem and whole plant digestibilities in the 1996/97 season (Appendix Table A4.1). When the stem material was more digestible so too was the digestibility of the whole plant.

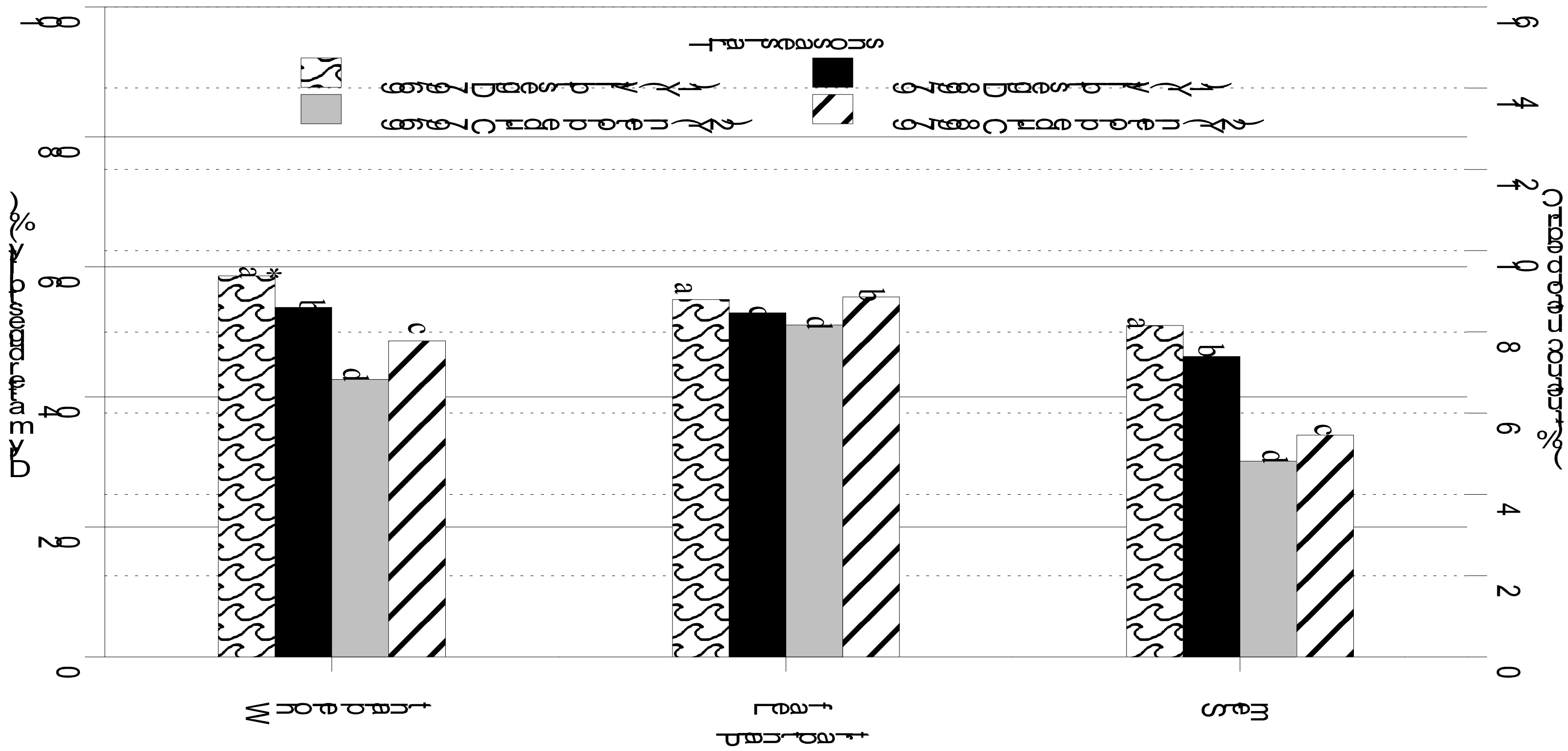
Almost no similarities were found in terms of the whole plant digestibilities in the two seasons (Figures 4.2 and 4.3). In the 1996/97 season *C. ciliaris* and the *Cynodon* hybrid were the least digestible (Figure 4.2), while in the following season (1997/98) they tended to be the most digestible (Figure 4.3), with the trend being reversed in the case of *P. clandestinum* (Figures 4.2 and 4.3). *D. eriantha* tended to be more digestible than the *Cynodon* hybrid (Figure 4.2) in 1996/97, while this difference was not evident in 1997/98 (Figure 4.3). In digestibility studies reported by Dannhauser (1991(a)); Grunow and Rabie (1985) and Theron and Arnott (1977) the authors respectively found that *P. maximum* was more digestible than *D. eriantha*; *C. ciliaris* more digestible than *D. eriantha*; and *P. clandestinum* more digestible than the *Cynodon* hybrid.

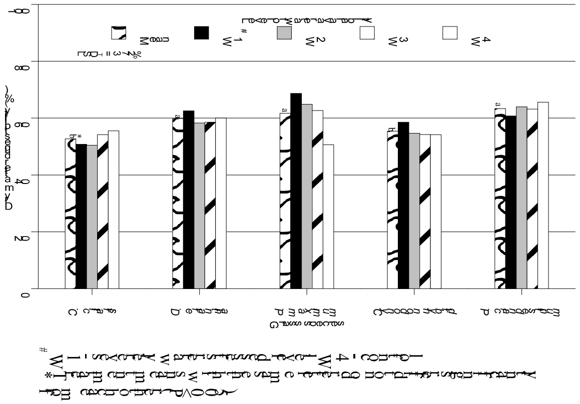
The whole plant digestibilities of *C. ciliaris*, *D. eriantha* and *P. clandestinum* tended to increase with higher amounts of water applied, while those of the *Cynodon* hybrid and *P. maximum* tended to decrease with more water applied in the 1996/97 season (Figure 4.2) . In the 1997/98 season (Figure 4.3) three of the grass species *(D. eriantha, P. maximum and the Cynodon* hybrid) tended to become less digestible with more water supplied. It was only *C. ciliaris* that exhibited a higher digestibility with more water added. *P. clandestinum* did not exhibit a clear tendency. Fianu and Winch (1984) observed better digestibilities in a wet than in a dry season.

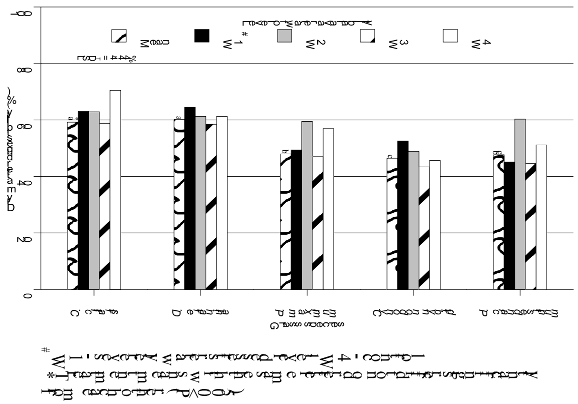
The leaves of *C. ciliaris* and *D. eriantha* tended to be the most digestible in both seasons with those of *P. clandestinum* being the least digestible (Figures 4.4 and 4.5).

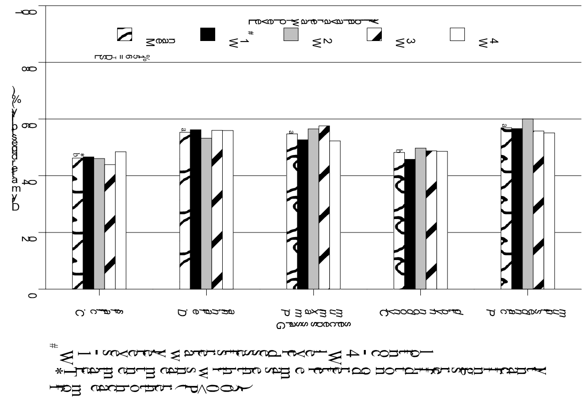
The stems of *C. ciliaris, D. eriantha*, *P. maximum* and the *Cynodon* hybrid were less digestible than the leaves, while the digestibility *P. clandestinum* stem material tended to be better than that of the leaves in both seasons (Figures 4.4, 4.5, 4.6 and 4.7). There was then also a positive correlation ($r^2 = +0.60$) between the whole plant digestibility and that of the stem material of the *P. clandestinum* plants in the 1996/97 season only.

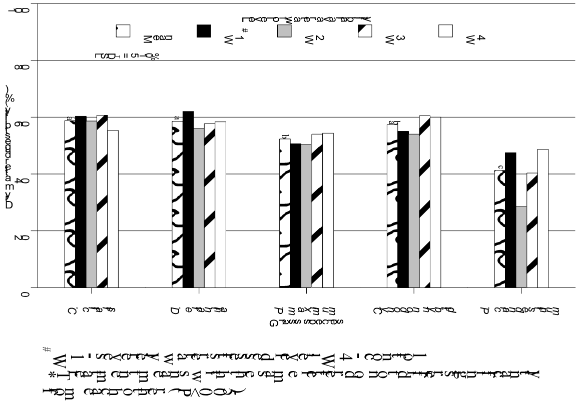
As with the whole plant digestibilities, there were no clear reactions of the digestibility of the leaves and stems when water availability was manipulated (Figures 4.4, 4.5, 4.6 and 4.7).

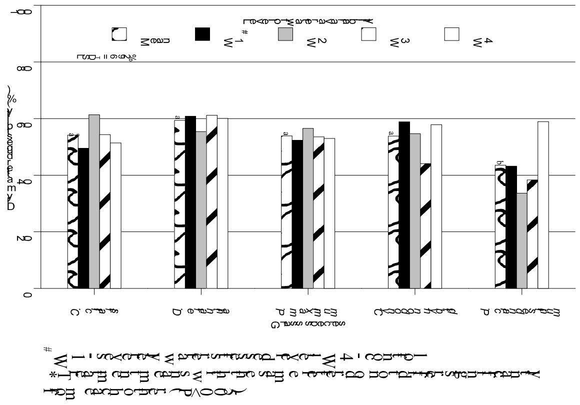


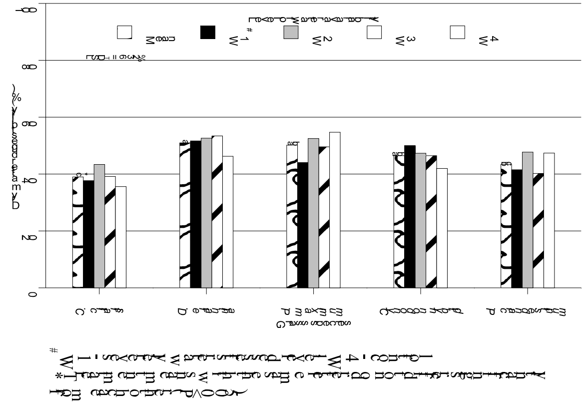












4.3.2 Crude protein content

The crude protein (CP) content followed the opposite trend over the two seasons to that of digestibility (Figure 4.1), with plants tending to have a higher CP content in the 1997/98 than 1996/97 season, leading to the question on the possibility of a negative correlation between CP content and digestibility. While t'Mannetje (1975) reported a strong positive correlation between N% in the plant material and digestibility, Minson (1973) reported a poor correlation between the two parameters which agrees with the present results of no correlation (data not shown).

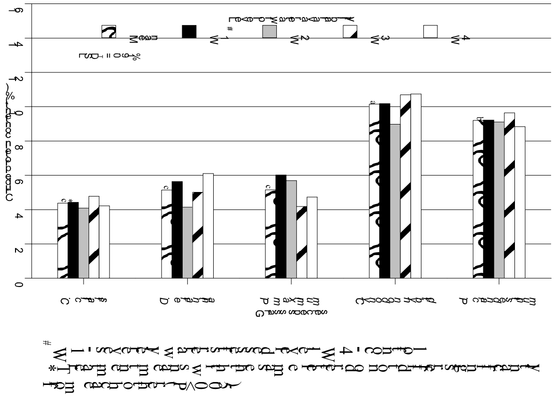
The leaf material tended to have a higher CP content than the stem material in both seasons (Figure 4.1). The same trend was reported by Fianu and Winch (1984) and t'Mannetje (1975). There was also a strong positive correlation between stem and leaf CP content and that of the whole plant . The whole plant CP content correlated with the CP of the leaves (r^2 = +0.75 to +0.95) and that of the stems (r^2 = +0.55 to 0.95).

A comparison of the whole plant CP content (Figures 4.8 and 4.9) indicates slightly higher CP contents in 1997/98 than in 1996/97 for *C. ciliaris*, *P. maximum* and the *Cynodon* hybrid, while that of *D. eriantha* was almost the same in the two seasons and that of *P. clandestinum* was slightly lower in 1997/98. In both seasons (Figures 4.8 and 4.9) the whole plant CP contents of the *Cynodon* hybrid and *P. clandestinum* were higher than those of the other three grasses. High CP contents for the *Cynodon* hybrid and *P. clandestinum* were also observed by Rethman and De Witt (1988). Theron and Arnott (1977) also recorded CP contents of over 12% for both the *Cynodon* hybrid and *P. clandestinum*.

In a trial reported by Snyman (1994) *C. ciliaris* had the lowest CP content when compared to *P. maximum* and *D. eriantha*, but *C. ciliaris* was able to maintain the CP content over the season while the other two grasses showed a ± 4% reduction in CP over the same period. Dannhauser (1991(a), (b)) concluded that the CP content of grass species is influenced by soil type. Nutrient content of the soil can thus play a significant role in the CP content of species and the CP content of a species can thus vary from one location to the next.

The whole plant CP content of *P. maximum* tended to be higher under water stressed (W1) than under well watered conditions (W4) while the plants with very little or no water stress (W3 and W4) of *D. eriantha* and the *Cynodon* hybrid had a higher CP content than the other irrigation levels (Figure 4.8). In the 1996/97 season there was very little difference in crude protein content between the four irrigation treatments of *C. ciliaris* and *P. clandestinum* plants (Figure 4.8). In the following season (Figure 4.9), however, the crude protein contents under water limiting conditions (W1) were slightly higher than those in the well watered control plants (W4).

The leaves (Figures 4.10 and 4.11) in both seasons, for all the species, had more crude protein than the stems (Figures 4.12 and 4.13). Leaves and stems of the *Cynodon* hybrid and *P. clandestinum* had the highest crude protein content in both seasons (Figures 4.10, 4.11, 4.12 and 4.13).



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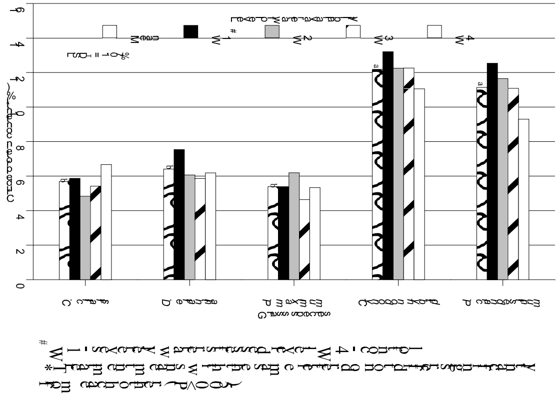

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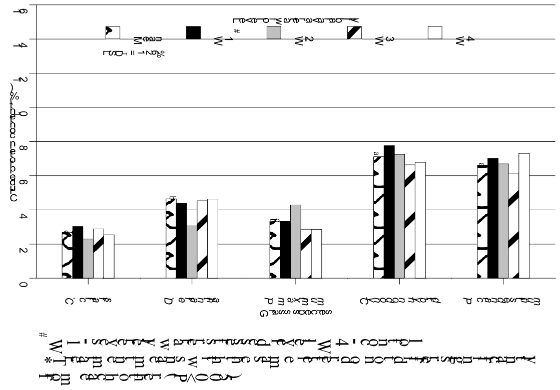

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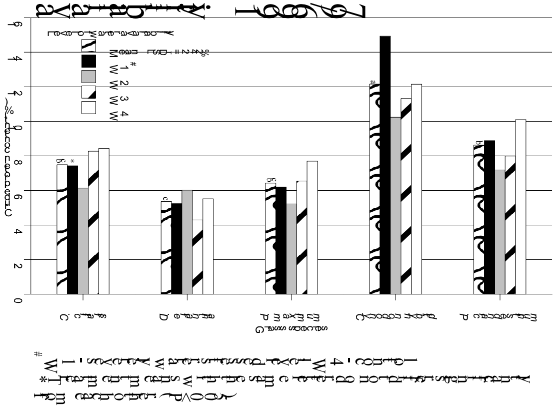
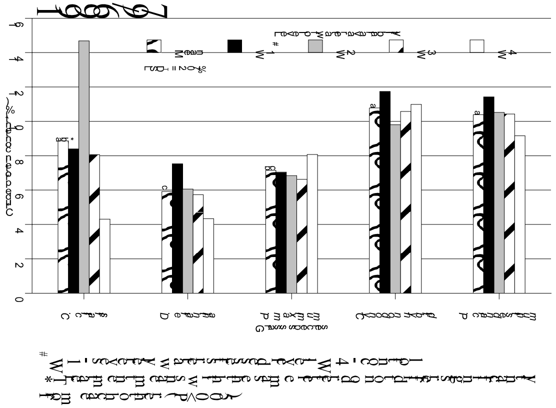


Figure 4.9 … 1997/8



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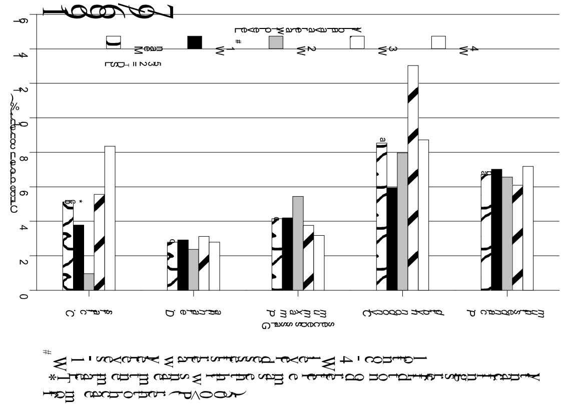

Figure 4.13 … 1997/8

4.4 Discussion and Conclusions

Differences in the dry material digestibility of the different grasses, under different water regimes, over the two seasons, made it difficult to draw definite conclusions. However, it was evident that the digestibility of the grass species evaluated was quite low and varied between 40 and 70% with a mean digestibility of about 55%. This is not uncommon, as other scientists have also recorded digestibilities ranging between 39 - 70% for *C. ciliaris* (Fianu and Winch, 1984; Grunow and Rabie, 1985; Dannhauser, 1991(a), (b); Moolman, 1993) and 54 - 70% for *P. clandestinum* (Theron and Arnott, 1977; Dugmore *et al.*, 1985; Van Heerden, 1986; Dugmore and Du Toit, 1988; Tainton, 1988; Dickinson *et al.*, 1990; Dannhauser, 1991(a), (b)). Digestibilities of 49 - 88% for *P. maximum* (WanHassan *et al.*, 1990; Dannhauser, 1991(a), (b); Nel, 1994; Singh *et al.*, 1995; Pieterse *et al.*, 1997), 51 - 65% for *Cynodon* (Theron and Arnott, 1977; Nel, 1989; Dannhauser, 1991(a), (b); Viljoen, 1994) and 40 - 65% for *D. eriantha* have also been reported (Grunow and Rabie, 1985; Dannhauser, 1991(a), (b)).

The absence of significant ($P \geq 0.05$) differences in digestibility, due to level of water availability, should not be seen as a lack of results, but as good news as it seems as if water, or the lack thereof, does not affect the digestibility of the grass plants. Data quoted by Thompson *et al.* (1989), however, stated that better digestibilities were recorded under water stressed than under non-stressed conditions. Increased temperatures, however, did decrease the cell wall digestibility (Thompson *et al.*, 1989).

The age of plants at harvest has a more profound effect on the digestibility as noted by Dannhauser (1991(a), (b)). He reported that the dry matter digestibility of *Cynodon* declined from 65% in the beginning of the growing season (spring) to 40% at the end of the growing season (autumn/winter). Due to the harvesting regime followed in this trial, where new regrowth was harvested, it was not possible to compare digestibilities at the beginning and end of the season. *In vitro* digestibility from hand harvesting, is, however, only an indication of the potential digestibility and could be different from what the animal consumes due to selective grazing (Van Niekerk, 1997).

There were no significant ($P \geq 0.05$) correlations between the digestibility or CP content of stem material and that of the whole plant. This can be attributed to the relatively young stage at which the grasses were harvested. If it had been delayed until after flowering, there might have been a significant affect on the nutritive values of the grasses.

The crude protein content of the grasses tended to be more affected by the amount of water available than was digestibility. This may be due to the mode of uptake of nitrogen, where water plays an important role. With respect to CP there were clear differences between grass species, with the two creeping grasses, the *Cynodon* hybrid and *P. clandestinum*, containing much more crude protein (average of 8.5%) than the three tufted grasses (average of 5.5%). Hefer and Tainton (1990) found that *P. clandestinum* had a higher CP content than *Cynodon* under growing conditions in Natal. The opposite was, however, found in this trial. According to Tainton (1988) CP contents of as high as 32% have been reported for *P. clandestinum*. Crude protein content values for *P. clandestinum* in other literature ranged from 7.6 to 23.3% (Theron and Arnott, 1977; Dugmore and Du Toit, 1988; Rethman and De Witt, 1988), while CP of *Cynodon* ranged from 7.3 to 20.8% (Olsen, 1974; Theron and Arnott, 1977; Dugmore *et al.*, 1985; Rethman and De Witt, 1988; Nel, 1989). Van Niekerk (1997) indicated that grasses high in CP, often produce lower yields. This might explain the relatively low yields of *P. clandestinum* (Marais *et al.*, unpublished). The CP content of the other grasses ranged from high (15 - 25%) to low (3 - 5%) (Olsen, 1972; Rodel and Boultwood, 1981; Grunow and Rabie, 1985; Pieterse *et al.,* 1989; Dickinson *et al.*, 1990; WanHassan *et al.*, 1990; Dannhauser, 1991(a), (b); Nel, 1994; Snyman, 1994; Singh *et al.,* 1995; Pieterse *et al.*, 1997).

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