CHAPTER 1

GENERAL INTRODUCTION

In the mid 1980's the withdrawal of marginal arable land from maize production and the establishment of pastures instead was encouraged (Joubert, 1995). An estimated 1 million ha would in this way be planted to pastures, not only relieving pressure on the soil but also on the natural veld. To further encourage the switch to pasture crops, it was deemed necessary to investigate pasture crops in terms of their ability to produce under different growing conditions and also how these growing conditions can alter the quality of the pastures. With this information farmers will have a better idea what to expect from some grass species under conditions with and without adequate levels of water available.

Ensuring enough fodder for the animals is quite difficult under dryland conditions, due to rainfall uncertainty. However, some grasses can produce more mass per area with the same amount of water under the same growing conditions than others. However, research done in the past, in South Africa, involving water and grasses was restricted to only a few grass species, most of which were temperate. Lucerne (*Medicago sativa*), rye grass (*Lolium multiflorum*), kikuyu (*Pennisetum clandestinum*), weeping love grass (*Eragrostis curvula*) and oats (*Avena* sp.) received a lot of attention due to their popularity as planted pastures (Goodenough *et al.*, 1984; Steynberg *et al.*, 1993). Often the research was done with only one water regime to eliminate the influence of drought on the growth and production of the grasses (Smith *et al.*, 1986; Van Heerden, 1986; Pieterse *et al.*, 1988; Le Roux *et al.*, 1991). In other studies the water use and water use efficiency of natural rain fed veld was determined with the aim to improve veld management (Opperman & Roberts, 1975; Opperman *et al.*, 1977; Snyman *et al.*, 1980; Moore *et al.*, 1988). The studies done by Mottram *et al.* (1977); Beukes & Weber (1981); Beukes & Barnard (1985) and Van Heerden & Tainton (1988) were aimed at irrigation scheduling. However, the only subtropical species which was included was kikuyu. In case studies involving irrigation and subtropical grasses, the effect of nitrogen on the yield and water use efficiency were investigated to advise farmers on the amounts of N that should be used (Rethman, 1987; Pieterse *et al.*, 1997; Pieterse & Rethman, 1999). Intensive studies on the effect of different levels of water availability on the growth, yield, water use, water use efficiency and quality of perennial subtropical grasses had not yet been done. It is these factors which will be addressed, with the specific aim to evaluate the grass species's ability to adapt to different levels of water availability.

The initial study was conducted over two summer growing seasons, using five perennial subtropical grass species, and four levels of water availability with the following aims:

- to determine the dry matter yield, water use efficiency and quality of the grass species when applying different amounts of water;

Further studies,

- to evaluate the effect of nitrogen on water use efficiency;
- to evaluate the growth pattern of the five grass species and

– to assess the affect of water availability on the grass' leaf morphology and number of stomata, were conducted in subsequent seasons.

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CHAPTER 2

WATER USE OF FIVE PERENNIAL SUB-TROPICAL GRASSES AT FOUR LEVELS OF WATER AVAILABILITY

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Abstract

The effect of four levels of water availability on the water use 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.

More water was used in the 1997/98 season in comparison with the 1996/97 season. This can be attributed to higher maximum temperatures during the 1997/98 season. Under the prevailing conditions, the *Cynodon* hybrid (1 000 mm) used the least amount of water followed by *C. ciliaris*, *P. clandestinum* and *D. eriantha* (1 100 mm), with *P. maximum* (1 200 mm) using the most water per season at the highest level of

water availability (W4). The results indicate that *P. maximum* tended to have a far greater luxury uptake of water than the other species, but especially the *Cynodon* hybrid, under conditions of unlimited water supply.

The W1, W2 and W3 treatments used more than the allocated water due to the fact that the soil profiles were brought to field capacity at the beginning of the season and the grass plants could then extract the extra water needed from the soil profile. This emphasizes the importance of good water management in drought prone areas. Water infiltration into the soil profile should be encouraged, while excessive runoff should be prevented.

Most of the roots (between 44% and 55% on a mass basis) were found in the top 42 cm of the soil profile, indicating the importance of keeping the top soil moist so as not to lose these roots. Despite the high proportion of roots in the top soil, significant amounts of root (14 - 20% on a mass basis) were found up to a depth of 1.05 m in the soil profile. Deeper soil samples could, however, not be taken due to the gravel layer starting at a depth of between 1.0 and 1.2 m in the soil profile. The soil profiles under *C. ciliaris,* the *Cynodon* hybrid and *P. maximum*, had a water deficit of between 10 and 20 mm at severe water limiting conditions at a depth of 1.6 to 1.8 m, while at the same depth *D. eriantha* and *P. clandestinum* only had a soil water deficit of between 10 and 15 mm. Despite the lack of physical evidence, the above water deficit measurements indicate that roots as deep as 1.8 m could be expected.

There were also minimal differences in the dry root mass under water limiting versus non-water limiting conditions. This is in contradiction to references in the literature, where root mass at deeper levels tended to be higher or lower, but never equal, under water limiting than non-water limiting conditions. During the first season (1995/96) the grasses were not differentially irrigated to encourage establishment. This might explain why there were little differences in the extraction depth, amounts and dry root mass. An important implication of this is that a new pasture, which is pampered in the first growing season, might be able to handle, or be better adapted to, stress conditions in the second and following seasons, than a planting which was stressed from the start.

Water use often impacts on the yield and quality of crops. Subsequent papers will, therefore, address the effect of this water use data on these aspects.

Keywords

Cenchrus ciliaris, a *Cynodon* hybrid, *Digitaria eriantha*, *Panicum maximum*, *Pennisetum clandestinum*, root mass, leaf area

2.1 Introduction

In South Africa, about 85% of the country is covered by natural veld. Of this about 65% receives less than 500 mm of rain per annum (Opperman & Roberts, 1975). A further 200 000 ha are planted to irrigated pastures (Steynberg *et al.*, 1993), but with initiatives to remove pressure from veld and marginal cropping areas (Joubert, 1995), more and more planted pastures are being established under both rainfed and irrigated conditions. Information on the water use, yields and water use efficiency of grasses as influenced by different levels of water availability is, however, scarce.

Gathering information on the afore said situation can be approached from two angles. The one being water, and how it can be managed, and the other the grass itself and the water requirements thereof. The main aim of this study was not so much to schedule irrigation, as to evaluate grass species at different levels of water availability.

There are many environmental factors (especially climatic factors) that can affect the year to year variation of water use (Kramer, 1983). A comparison of species, receiving the same treatment, can, however, give an indication of their relative water use. However, the comparison of other research results of the same species, under different conditions, is not easy and misinterpretations can be made.

As a starting point for this study, the water use of five grasses was evaluated at four levels of water availability. The hypotheses being (1) that there will be differences in water use between species and (2) that species are more adaptable to different levels of water availability than is generally accepted.

2.2 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 (top 30 cm). 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 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 extractionable 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.

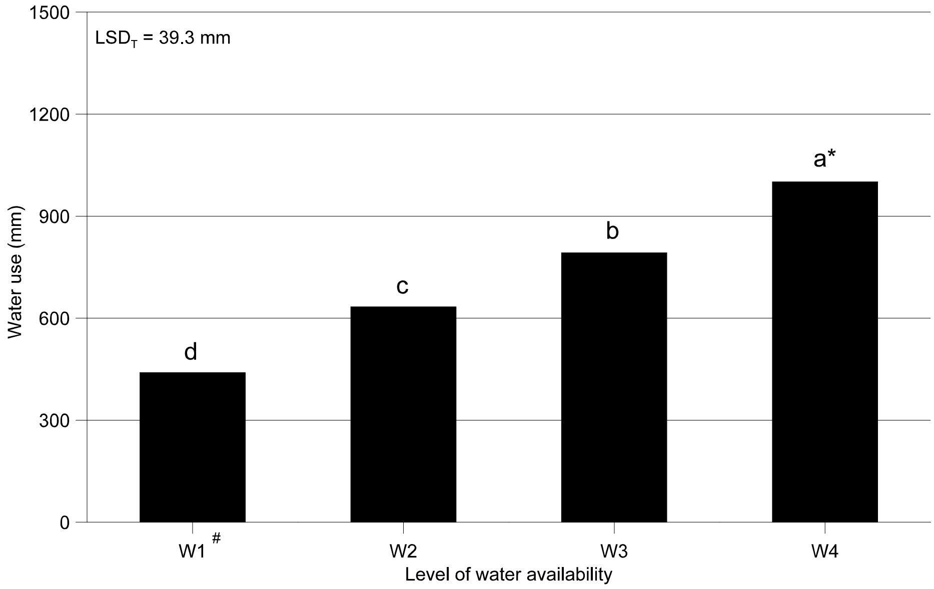
Root samples were collected in the summer of 1999. The soil cores were taken with a soil auger to a depth of 105 cm in 21 cm increments. The whole 1.8 meter soil profile was not investigated due to the presence of gravel from the 105 - 126 cm increment downwards. The gravel tended to either break the auger or was so coarse that a representative sample from these deeper layers was not achieved. After collecting the cores in the field, the soil was carefully washed away under running water. The roots were then left to dry at room temperature for seven days, before weighing it again.

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 are presented in the Appendix (Tables A 2.1 - A 2.10).

2.3 Results

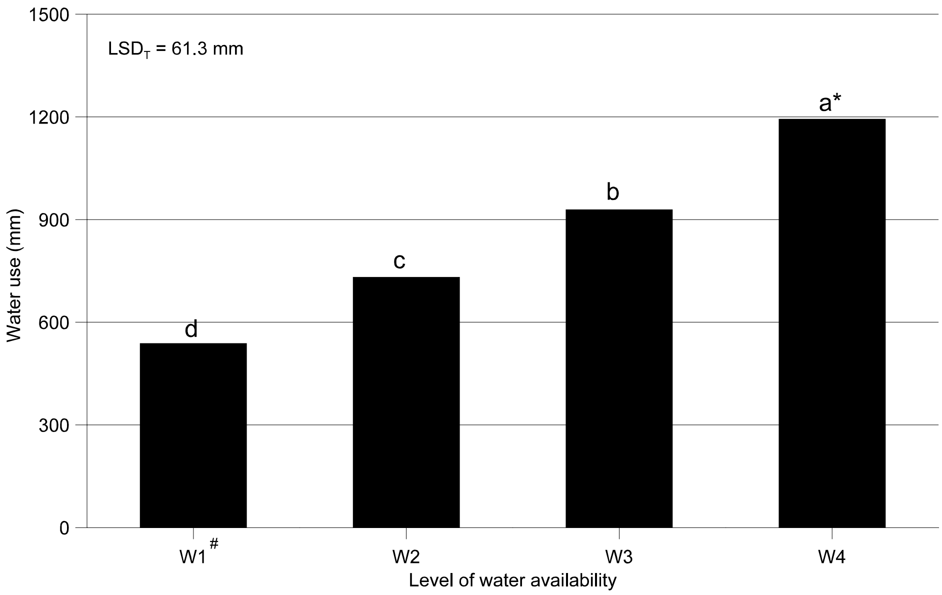
2.3.1 Water use

As stated earlier, the soil profiles were brought to field capacity at the beginning of the growing season. The deficit was measured weekly and water was applied according to the treatment. After the final harvest of the season, the soil water deficit was again measured. The water use was then calculated as the sum total of the amounts of water applied during the growing season and the soil water deficit at the end of the season. With the amounts used in this trial, four distinct treatments were established which differed significantly from each other (Figures 2.1 and 2.2).



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

Figure 2.1 Average water use of grass species at 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 2.2 Average water use of grass species at four levels of water availability in the 1997/98 season.

The water use of the 1997/98 season was higher than in the previous season. The average minimum and maximum temperatures per month as registered for the period 1996 to 1998 are presented in Table 2.1. According to these data, the temperatures from August to February differed with a maximum of 2˚C between the two seasons. During March and April 1998 the maximum temperatures were about 5˚C higher than in 1997 over the same time period. With these higher temperatures, transpiration can expected to be higher resulting in higher water use.

Apart from the obvious, it should be noted that although there was a 25% difference in amount of water applied between sequential treatments, this is not reflected in the water use (Table 2.2). This can be attributed to the uptake of stored water from the soil profile. This has important practical implications. Bringing the soil profile to field capacity at the beginning of the season can help the grasses to survive drought conditions. The severity of the drought that could be tolerated would depend on the water holding capacity of the soil (clay versus sand), the length and intensity of the drought, prevailing temperatures, the growth stage of the plants and the plants inherent ability to tolerate drought.

Table 2.1 Minimum and maximum temperatures recorded at the Hatfield Experimental Farm, Pretoria, during the trial period.

	Minimum temperature (˚C)			Maximum temperature (˚C)		
Month	1996	1997	1998	1996	1997	1998
January	16.5	17.0	16.7	27.1	27.1	27.4
February	15.2	15.0	15.1	23.4	26.1	25.8
March	13.4	15.2	16.1	25.2	23.5	28.3
April	10.4	9.7	12.1	21.6	21.2	26.0
May	8.3	6.6	5.8	20.5	19.2	21.6
June	4.5	3.4	2.6	18.5	18.2	15.9
July	3.4	4.8	5.1	17.2	18.7	20.1
August	6.7	7.4	6.6	20.3	22.7	21.9
September	10.1	11.5	10.9	24.8	23.2	24.5
October	14.3	12.7	11.0	27.5	25.4	19.8
November	14.3	14.0	13.4	25.0	26.1	24.6
December	15.8	16.0	15.4	26.7	27.8	25.5

Another interesting observation was made when determining the percentage water use of the W1, W2 and W3 treatments relative to that of the control. Despite higher water use in the 1997/98 than the 1996/97 season, there was only a one percent difference between the two seasons (Table 2.2 - values in brackets). From this two conclusions may be drawn: (1) it is not necessary to irrigate to field capacity when starting the season with a full profile; (2) when extrapolating from the values in Table 2.2, it seems as if the application of ± 80-85% of the amount necessary to reach field capacity may make it unnecessary for the plants to also use some of the water stored in the soil profile. It is not, however, as simple as that, as temperatures and other factors may also play a role.

Table 2.2 The percentage water use of the three treatments (W1, W2, W3) relative to that of the control (W4), over two seasons.

Season	Treatments			
	W1 = 25%	W2 = 50%	W3 = 75%	W4 = 100%
1996/97	44% (19%)*	63% (13%)	79% (4%)	100%
1997/98	45% (20%)	62% (12%)	78% (3%)	100%

*The values in brackets are the percentage deviation from the percentage applied.

Murtagh (1975) had already reported that *P. clandestinum* can grow well without bringing the soil profile back to field capacity, but that as soon as 50% or more of the plant available water has been depleted, one could expect *P. clandestinum* to perform poorly. When turfgrass growers in California were faced with water restrictions, they were forced to use less water, but together with Meyer and Gibeault (1986) they realized that a good turf quality could be maintained, even when less water was applied. Thus grasses can withstand a measure of drought, depending on the severity of the drought and grass species.

Garrot and Mancino (1994) found that with unrestricted water availability, grass plants tended to have a luxury uptake of water, but by making use of a "room for rain" strategy, it can improve water use, but then management is very important to keep the grasses in good production. Management in this case can include an appropriate cutting or grazing strategy. Julander (1945) observed a 60% die back in fields that were overgrazed during a drought, in comparison to the 20% die back in ungrazed fields. The pastures that were not overgrazed during the drought also reacted faster, on drought relief, than the over-utilized counterparts. Masters and Britton (1990) confirmed this by saying that by applying the right clipping intensity and frequency, for a specific species and environmental conditions, the productivity of the grass can be improved or kept at desired production levels.

The observation made by the above scientists can be explained by the summary given by Nel and Annandale (1987), who stated that plants can easily extract water from the soil profile till a certain level (which differ from crop to crop and area to area), where-after extraction becomes more and more difficult, leading to yield losses due to the link between stomata closure, transpiration and photosynthesis (dry matter accumulation). Furthermore, plants will already have started to lose production long before it is visually noticeable. Thus, appropriate instruments/methods should be used to measure what the plant is experiencing.

Although this study is on fodder crops, where the yield is of great importance, visual acceptance has a higher value for turfgrass growers. However, to have as broad an application as possible for the results generated here, it should be kept in mind that different users (sheep, cattle, wildlife, turfgrass etc.) will have different needs. These needs will also determine how much water will be used, thereby adding an additional dimension to the severity of the drought that can be tolerated.

Thus far, the average water use over the two seasons has been discussed, but no attention has been given to as how the different levels of water availability affected the individual grass species. In Figures 2.3 and 2.4 the amount of water used by the five species at four levels of water availability is illustrated.

Although the water use was higher in the 1997/98 than in the 1996/97 season, the amount by which it increased differed for the five grass species. Under the specific conditions of this trial, *C. ciliaris* used 2 mm and the *Cynodon* hybrid about 20 mm more water during the respective seasons under W4 conditions, while *P. clandestinum* used about 60 mm more. *D. eriantha* used about 340 mm and *P. maximum* 560 mm more water during the 1997/98 season. The average water use under W4 conditions, over two seasons, for *C. ciliaris* was 1 100 mm, that of the *Cynodon* hybrid 970 mm, *D. eriantha* 1 100 mm, *P. maximum* 1 200 mm and that of *P. clandestinum* 1 100 mm.

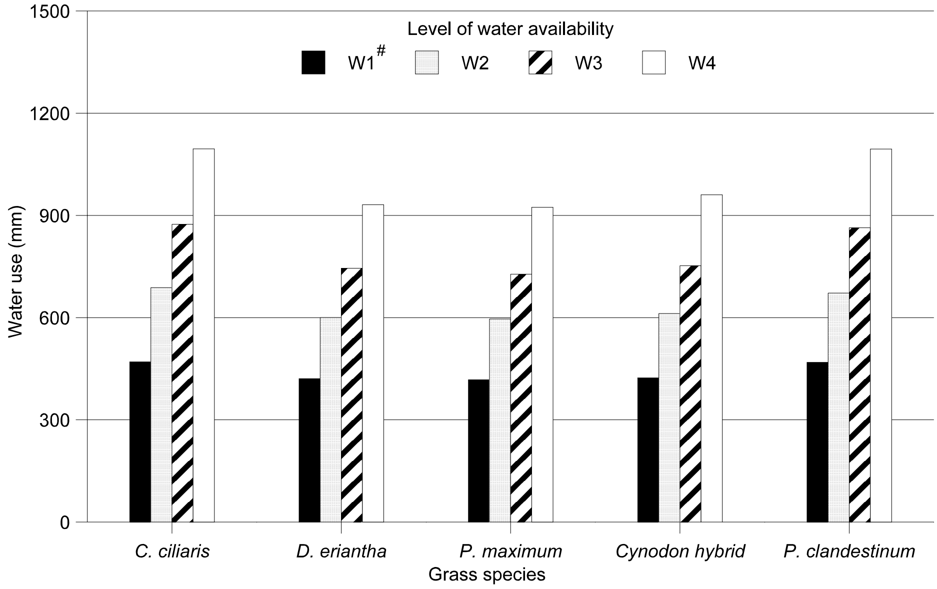
For the conditions applied in this trial, the *Cynodon* hybrid used the least amount of water followed by *C. ciliaris*, *P. clandestinum* and *D. eriantha*, with *P. maximum* using the most water per season under well watered conditions (W4 conditions). From well watered data alone one can, however, not say that the *Cynodon* hybrid is the most drought tolerant and *P. maximum* the least. It can at best provide information about the tendency of luxury uptake of water of different species with unlimited water.

The amounts of water applied to the W1, W2 and W3 treatments were derived from the amount applied to W4. Any increase in water use by the W4 treatment should, therefore, be automatically reflected by an increase in water use by the other three treatments. An examination of the data (Figures 2.3 and 2.4), however, showed that although this was true for most grass species and water treatment combinations, W3 *C. ciliaris* and W2 *P. clandestinum* used less water in the 1997/98 than 1996/97 seasons. These two water treatments used 17 and 29 mm less water respectively in the 1997/98 than in the 1996/97 season. The leaf area data (Figures 2.5 and 2.6) generally reflects higher leaf areas on those treatments using more water, and thus higher transpiration rates, in the 1997/98 than in the 1996/97 season. The lower water use of W3 *C. ciliaris* in 1997/98 could be explained by the smaller leaf area in 1997/98 (1.02 m^2) in comparison to that of 1996/97 (1.13 m^2). The same can, however, not be said about W2 *P. clandestinum* which had a far greater leaf area in 1997/98 (1.20 m^2) than in 1996/97 (0.44 m^2).

Although *P. maximum*, on average, tended to use far more water than *P. clandestinum* in the 1997/98 season, this was not reflected in the leaf area of the two species. *P. clandestinum* had a far greater leaf area, but used less water than *P. maximum* which had a lower leaf area. This may be explained by the growth habit of the two species, with *P. clandestinum* having a dense mat, covering the whole 5 m^2 of the experimental plot, and *P. maximum* plants forming individual tufts with open spaces visible between the tufts. This could have caused the *P. maximum* plots to lose more water through evaporation, especially with the slightly higher temperatures experienced in the 1997/98 season. With a poorer ground cover, raised soil temperatures might also damage the roots. Temperature differences as high as 10˚C have been recorded in the top 25 mm of soil surfaces of overgrazed and protected grass plots (Julander, 1945). Such temperature differences, however, dropped to about 2.5˚C at a soil depth of 200 mm. The main root mass usually occurs in the top soil layers indicating that a large effect can be expected where there is a low basal cover.

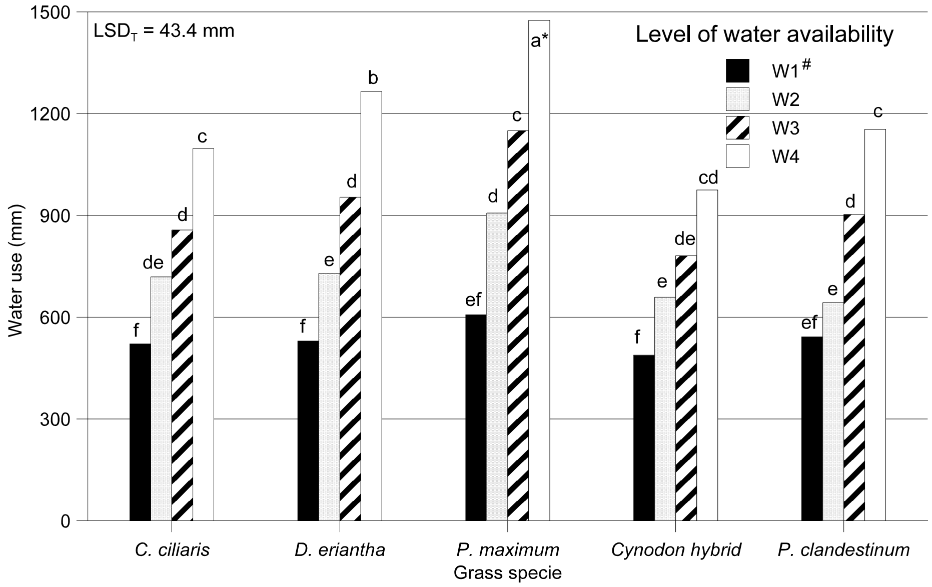
Stem density, amount of leaves per unit area and leaf orientation also contribute to resistance to water loss (Kim & Beard, 1988). Leaf width and vertical leaf extension rate influences total leaf area and thus evaporation area, indicating the importance of knowing the growth habit of the grass species being evaluated.

Although W2 *D. eriantha* had a smaller leaf area (± 3% less leaf area) in the 1997/98 than in the 1996/97 season, it was not reflected in lower water use, but this could be due to the very small difference in leaf area between the two seasons.



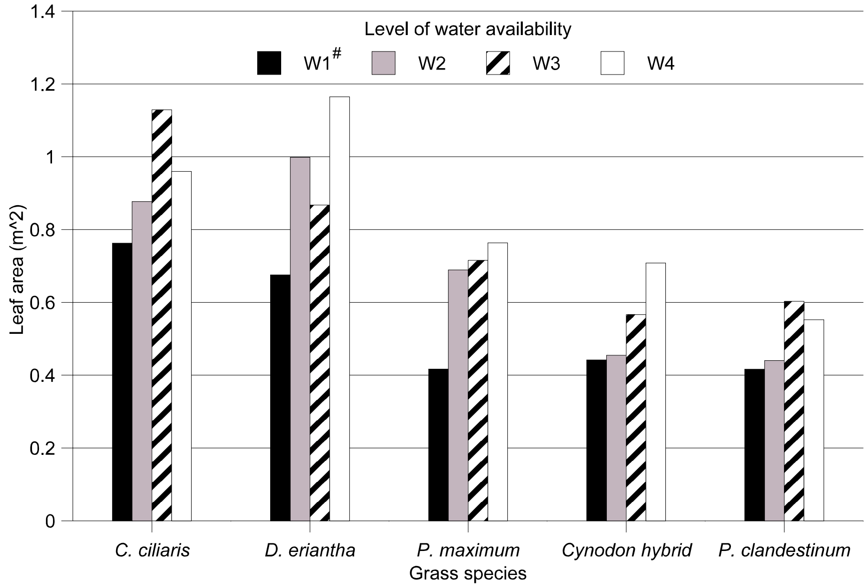
W1 - severely water stressed level, W4 - control
No significant Grass specie x Level of water avialability interaction (P<0.05)

Figure 2.3 Water use of five grass species at four levels of water availability, during the 1996/97 season.



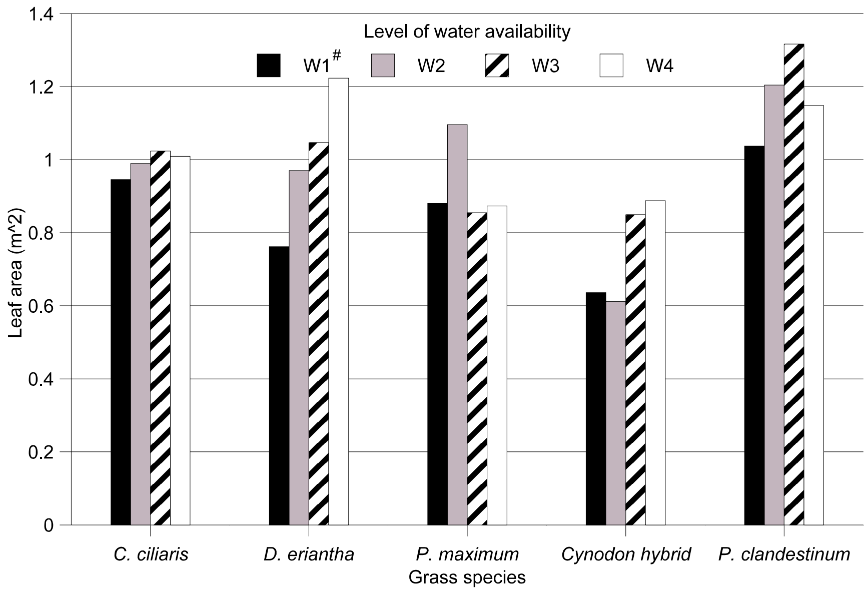
* Treatments with the same letter do not differ significantly from each other (P<0.05)
# W1 - severely water stressed level, W4 - control

Figure 2.4 Water use of five grass species at four levels of water availibility, during the 1997/98 season.



W1 - severely water stressed level, W4 - control
No significant Grass specie x Level of water availability interaction (P<0.05)

Figure 2.5 Leaf areas of five grass species at four levels of water availability in the 1996/97 season.



W1 - severely water stressed level, W4 - control
No significant Grass specie x Level of water availability interaction (P<0.05)

Figure 2.6 Leaf areas of five grass species at four levels of water availability in the 1997/98 season.

2.3.2 Soil profile water loss

The water loss from different layers of the soil profile, for the five grass species at the four levels of water availability, are presented in Figures 2.7 - 2.11. These graphs represent the situation at the end each growing season.

The water loss from the soil profiles in both seasons differed for the five grass species. For the *Cynodon* hybrid (Figure 2.8), *P. maximum* (Figure 2.10) and *P. clandestinum* (Figure 2.11) losses from the soil profiles were greater in the 1997/98 than in the 1996/97 season. This was true for all water treatments. With *C. ciliaris* (Figure 2.7) soil profiles also tended to lose more water during the 1997/98 season, but only on the W2, 3 and 4 treatments. On W1 plots, *C. ciliaris* profiles tended to lose more water during the 1996/97 than the 1997/98 season. The difference between the two seasons was, however, only 6 mm and for all intents and purposes the water loss was approximately the same for the two seasons. The same could be said about the water loss of the W2 *C. ciliaris*, profiles where the difference between the two seasons was also 6 mm. The soil profiles of *D. eriantha* (Figure 2.9) tended to lose approximately the same amount of water in the two seasons.

When water was not limited (W3 and 4 treatments), the soil profiles tended to be quite wet at the end of the growing season, indicating a minimal water extraction by the grass roots, and thus strengthening the extrapolation made earlier that the application of less water than that necessary to reach field capacity, could result in minimal water extraction from the soil profile. The fact that the soil profile shows water loss at a depth of 1.8 m is an indication that very little, if any, water loss was due to deep percolation. For *P. maximum* (W4 treatment) it even seems as if not enough water was applied, resulting in a dryer soil layer at 1.8 m than for the other grass species.

The high water loss of the soil profiles on the W1 treatments, emphasizes the contribution that a soil profile, filled to field capacity at the beginning of the season, can make if drought conditions develop later in the season. As with the W4 treatments, grass roots of the W1, 2 and 3 treatments made use of the whole soil profile to extract water.

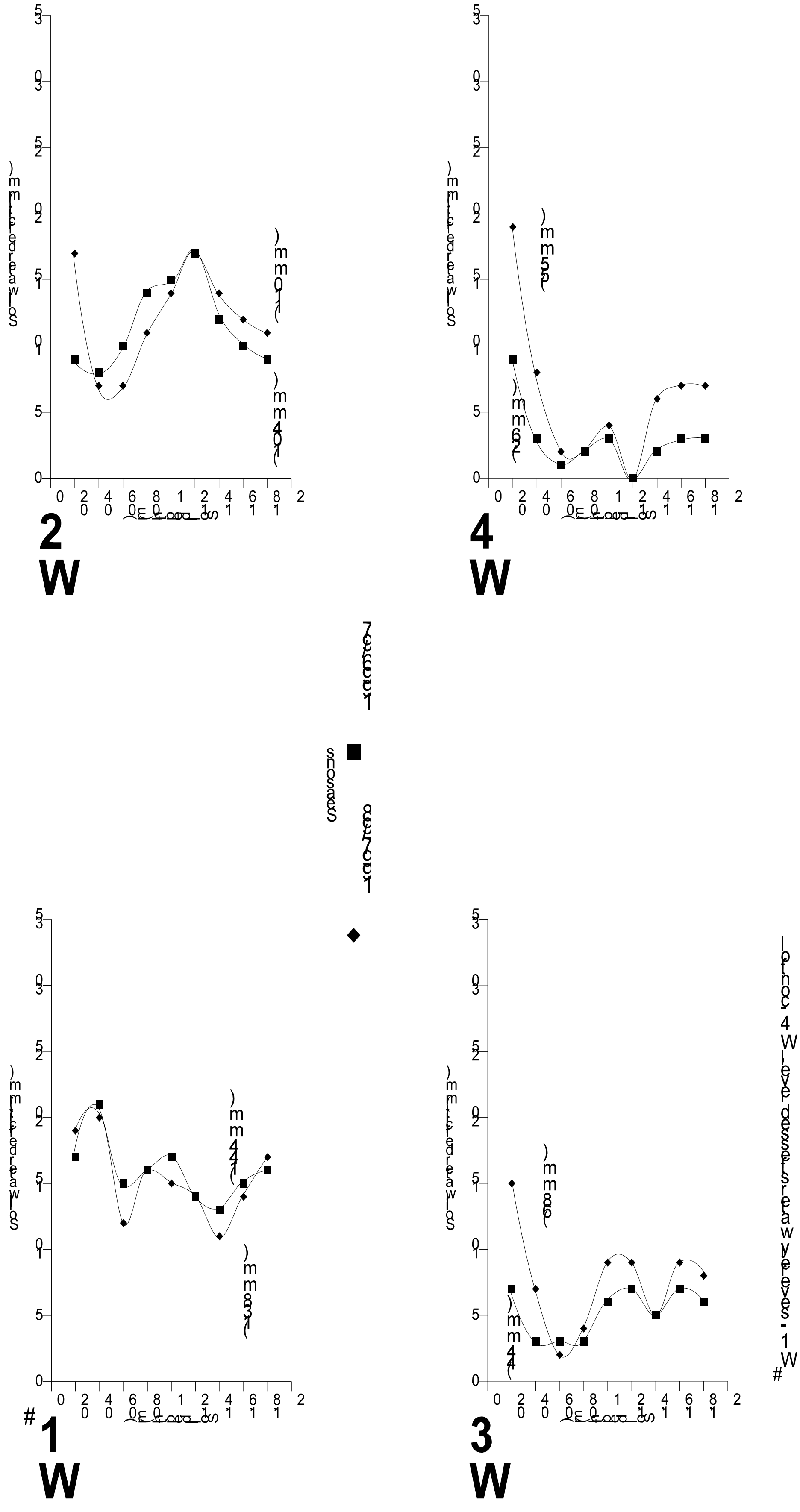
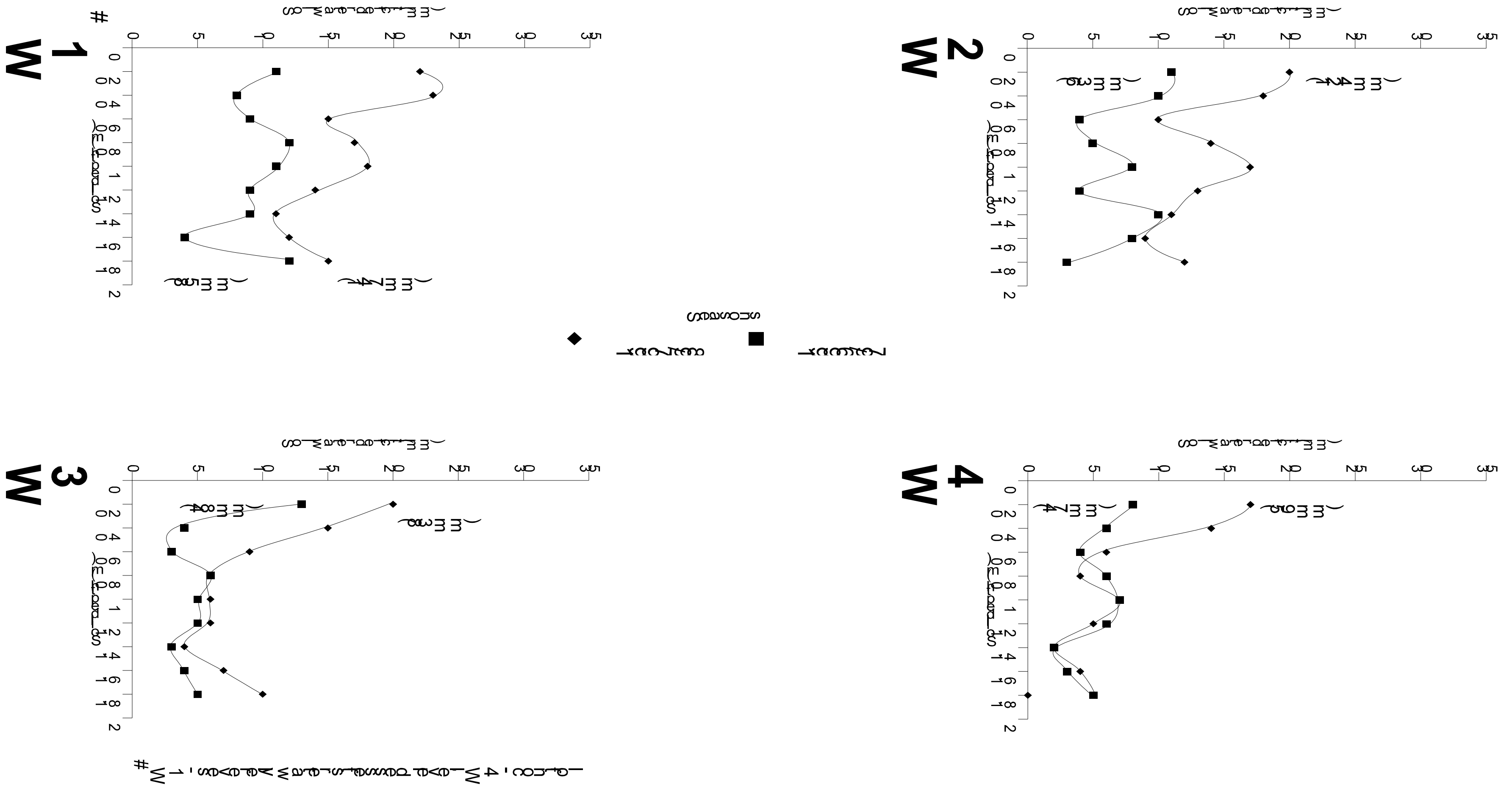


Figure 27 Soil water [illegible]



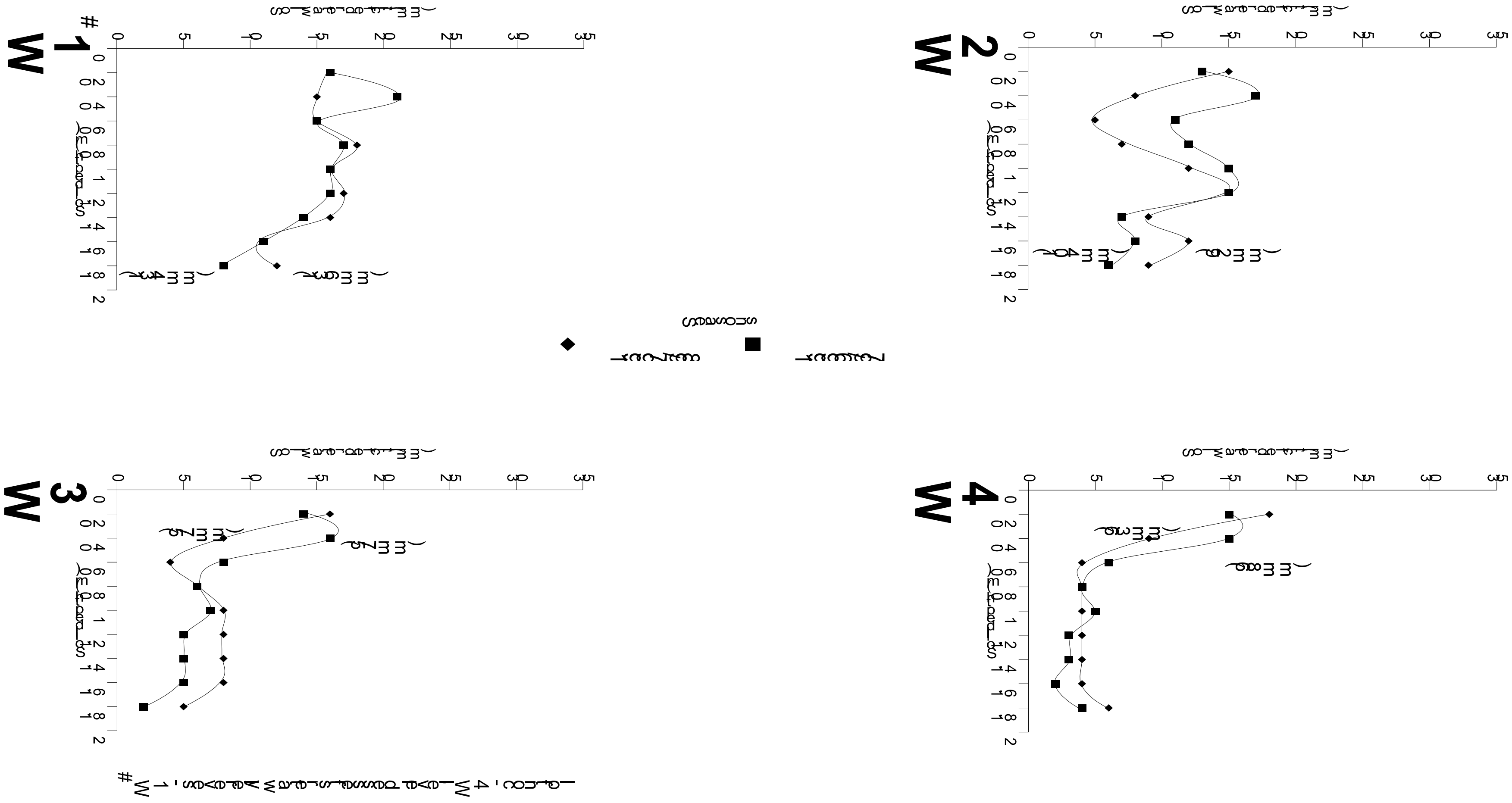
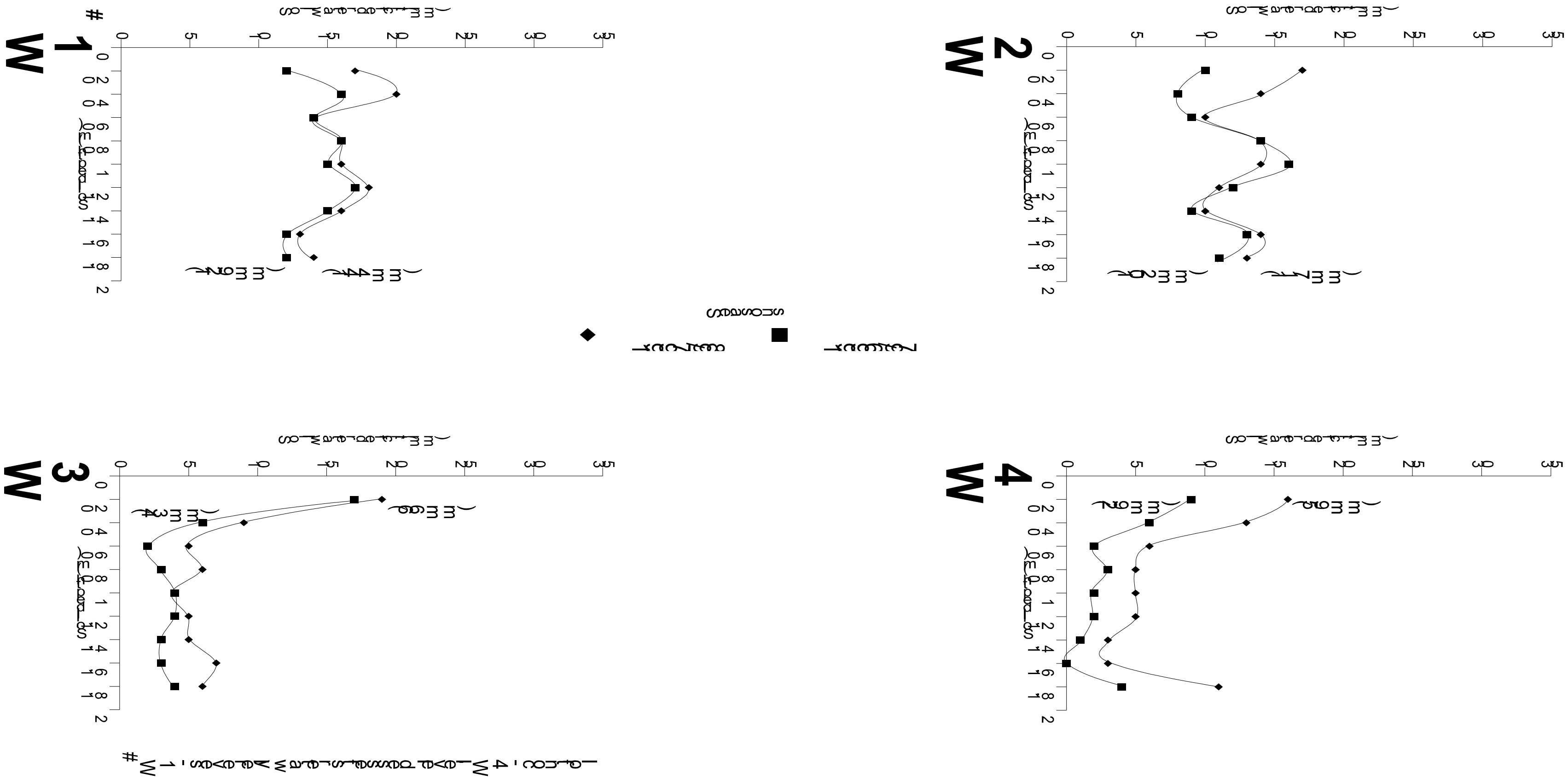
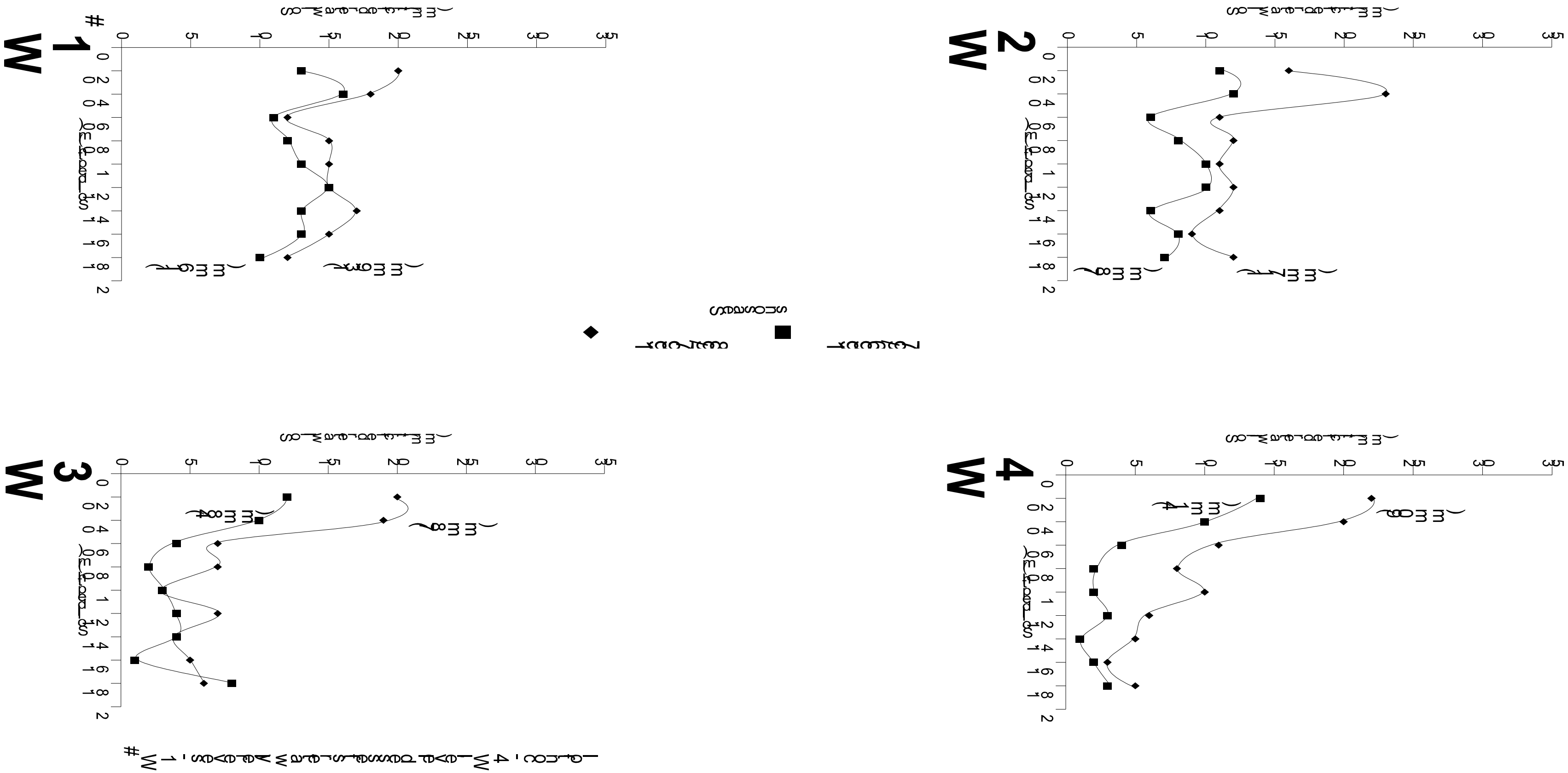


Figure 26 [illegible]


W1
W2
W3
W4



2.3.3 Root study

Root studies are often neglected, but without the development of a healthy root system, the above ground parts cannot produce optimally (Huang *et al.*, 1997) and it also affects the ability of the plant to withstand drought (Meyer & Green, 1980 & 1981).

Only *D. eriantha* and *P. clandestinum* tended to have a higher dry root mass under wet than under dry conditions (Figure 2.12). The dry root mass of *C. ciliaris*, the *Cynodon* hybrid and *P. maximum* tended to have a higher root dry mass under dry than under wet conditions.
With less water available, *D. eriantha* had the lowest root mass, followed by the *Cynodon* hybrid, *C. ciliaris* and *P. clandestinum,* with *P. maximum* having the highest root mass. With unlimited water available the picture changed with the *Cynodon* hybrid having the lowest root mass, followed by *P. maximum*, *C. ciliaris* and *D. eriantha*, with *P. clandestinum* having the highest root mass. With unlimited water the two creeping species, the *Cynodon* hybrid and *P. clandestinum,* tended to have the lowest and highest root masses respectively with the tufted species having intermediate root masses. This is in line with the findings of Rodel and Boultwood (1981) who reported lower root masses for stoloniferous grass species in comparison to those of rhizomatous species, which had the highest root mass, and tufted species having intermediate root masses.

On a dry root mass basis, the grasses tended to have between 44 - 55% of the roots in the top 42 cm of soil (Figure 2.12). There were, however, differences between the species in terms of wet and dry conditions. *C. ciliaris*, the *Cynodon* hybrid and *P. maximum* dry root mass tended to be higher under low (W1) than high (W4) water availability levels, while the dry root mass *D. eriantha* and *P. clandestinum* exhibited the opposite tendency.

Christie (1978) found 75% of the roots of both native and introduced *C. ciliaris* plants in the top 40 cm of the soil profile in a sandy red soil in Charleville (Australia), receiving between 647 - 664 mm rainfall. Horowitz (1972) found the below ground dry mass of the *Cynodon* hybrid to be 62%, 26% and 12% for the 0 -15 cm, 15 - 30 cm and 30 - 45 cm soil increments respectively

Rethman *et.al.* (1997) found 49 - 62% of grass roots (*C. ciliaris*, *D. eriantha*, *P. maximum*) in the top 40 cm. For *C. ciliaris* it was 50% in the top 40 cm and 50% deeper as 40cm; 49% and:51% for *D. eriantha* for the two depths and 62% and 38% for *P. maximum at the two depths*. The different species all exhibited a reduction in root mass with increased drought stress. *C. ciliaris* showed a reduction of 0.38 g, while *D. eriantha* only showed a difference of 0.15 g but the root mass of *P. maximum* decreased by 0.78 g. Despite lower root masses, *C. ciliaris* and *D. eriantha* produced better yields than *P. maximum*. There was, however, not a good relation between the above and below ground dry mass and it is suggested that this could be due to only taking vertical cores, which did not cater for horizontal root spread.

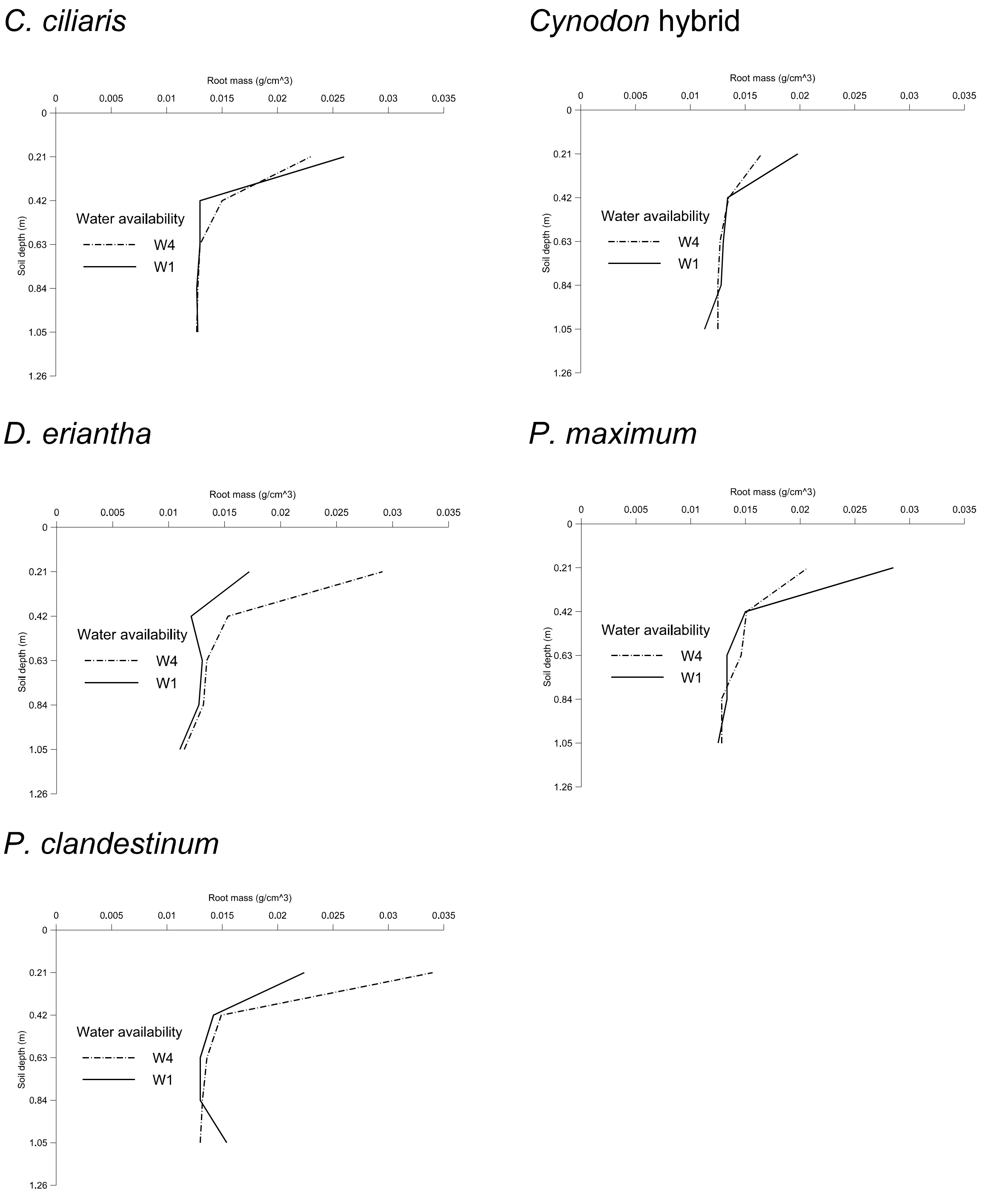


Figure 2.12 Dry mass of roots in the well watered control (W4) and the most water limited treatment (W1) of five grass species.

2.4 Discussion and Conclusions

The grasses did react differently to the four levels of water availability, confirming the first hypothesis, but the amount of water used is not an indication of a grasses ability to withstand drought. To confirm the latter, the above ground production (yield), quality (dry matter digestibility and crude protein content) and water use efficiency could be used as indicators of drought tolerance. The hypothesis on species being more drought tolerant, than is commonly acknowledged, could not, however, be confirmed at this stage.

An examination of water use, however, did highlight the following:

– it is 'n good practice to start the growing season with a wet profile, or in other words a profile brought to field capacity, where possible;
– it is not necessary to bring the soil profile back to field capacity every time water is applied, if the season started with a wet profile. Leaving at least 10% room for rain, could lead to water savings in the long term;
– following the aforesaid watering regime, even the grasses with unlimited water would develop a deep root system;
– most of the roots (on a dry mass basis) were found in the top 42 cm of the soil profiles. With poor soil cover, leading to increased soil temperatures, a strong effect on survival and production can be expected;
– development of a good canopy/basal cover, not only prevents excessive water loss from the soil profile, but also prevents high soil temperatures which can result in the death of the shallow roots;
– in conducting such studies, root studies together with soil temperature data

and canopy structure, are invaluable, as these play an important role in the water loss and production ability of the grass plants under different water regimes.

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