Chapter 7 . General conclusion

7.1 Introduction

Napier grass underpins livestock production in east Africa owing to its comparative advantages over other grasses that include high dry matter yields, good regeneration after frequent cutting, and its relative drought-tolerance. Cultivation of this grass is currently confined to productive arable lands, but its expansion into marginal areas is likely to increase in the future due to rising human population and the associated demand for livestock products. Despite this likely expansion, this grass and its various cultivars and accessions have received limited research attention, especially for their physiological performance in relation to biomass accumulation when subjected to environmental stresses. This is disappointing in view of the widely reported vulnerability of tropical Africa to climate changes associated with increases in temperatures, ambient CO_2 levels and reduced precipitation (Wigley and Raper 2001; Dijkstra *et al.* 2010).

This thesis therefore, provides some empirical insight into physiological responses by Napier grass under a range of controlled and field conditions to address the aims and objectives stated in Chapter 1.

The first objective was to assess if differences in water relations could be associated with productivity potential and fodder quality in Napier grass to assist selection for hot and dry environments. This was tested in a glasshouse experiment (Chapter 3) and the results demonstrated that the cultivars were generally similar and also accumulated similar biomass. Neither tissue hydration nor carbon assimilation rates were related to biomass accumulation. This was further investigated in field trials where fluctuations in water supply and other ambient conditions were larger than in the control environment of the glasshouse; this chapter also addressed Objective 2. There were minor differences in tissue water status at around midday that resulted in the cultivar with higher status having marginally more biomass. In addition, the cultivars generally had similar water use efficiency that ranged from 28—35.1 kg $ha^{-1}mm^{-1}$ under low temperatures and 16.9—22.9 kg $ha^{-1}mm^{-1}$ under elevated temperatures. Leaf to stem ratio, that preferably should be high in fodder as it is associated with improved digestibility, varied between the cultivars and temperature regimes. Atherton cultivar had lower leaf to stem ratio under low temperatures but then higher than Bana under high temperatures. Using a wider range of Napier grass cultivars, and under a more variable environment in the field, it was hypothesized that an association between productivity and tissue moisture indices would be revealed.

The second phase had the objective to characterise drought tolerance, and productivity and quality of forage for Napier grass accessions in contrasting tropical environments in Kenya (Chapter 4). This was approached by evaluating 10 Napier grass accessions for their forage yield and quality in moist and dry environments. Compared with the moist, the dry environment reduced the yields by about 50%, but there were differences amongst the accessions. The biomass yields showed that the 10 accessions fell into three clusters of low yielding (LYC), moderate yielding (MYC) and high yielding (HYC). Although the accessions did not return physiological differences in LWP and RWC just like the earlier study in the glasshouse, there were differences in biomass production that was not observed in the glasshouse study with the Atherton and Bana varieties. The three accessions in LYC produced the least and there was clear advantage in the use of a cultivar from either the MYC or HYC to achieve high forage production in water-limited environments. However, the LYC accessions appeared to allocate more DM to the roots and at greater depth, suggesting that the members of this cluster could possibly be more persistent under in hot and dry climatic conditions, than either MYC or HYC.

The other component of this second objective was to determine responses to transient water stress amongst the three yield clusters in the two contrasting environment (Chapter 5). The results showed that the clusters maintained largely similar tissue moisture at either site, despite the LYC having higher stomatal conductance than both MYC and HYC at the dry site. As such, stomatal conductance proved unreliable in estimating productivity potential in Napier grass as I found earlier in the glasshouse study in addressing the first objective (Chapter 3). Furthermore, total water-use at the semiarid site was in the order HYC ≈ MYC > LYC, and water-use efficiency followed the same order HYC (34.3 kg $ha^{-1}mm^{-1}$) > MYC (32.6 kg $ha^{-1}mm^{-1}$) > LYC (24.9 kg $ha^{-1}mm^{-1}$). Water-use at the wet highland averaged 710 mm for HYC and MYC, larger than 676 mm for LYC, while water-use efficiency averaged 29.2 kg $ha^{-1}mm^{-1}$ for HYC and MYC and was 19.4 kg $ha^{-1}mm^{-1}$ for LYC. This observation was close to the range in water-use efficiency (16.9─35.1 kg $ha^{-1}mm^{-1}$) observed in the earlier glasshouse study. The objective of exploring the link between tissue moisture and/or stomatal conductance, on the one hand, with productivity, on the other, was pursued further under predicted climatic conditions due to global warming and increased atmospheric CO_2 concentration.

The final objective of understanding the impacts of short-term exposure to elevated ambient CO_2 and temperatures on water-stress responses for the C_3 (common reed) and a C_4 (Napier grass) was presented in Chapter 6. Exposure to elevated CO_2 (eCO_2) level improved the plant's tolerance to water-stress resulting in higher leaf water potential (LWP) during the day in Napier grass, but not in common reed. This difference would have contributed to the higher biomass yield in Napier compared to reed. Similar to observations in the previous experiments, there was no association between biomass and tissue moisture in either of the species. Exposure to elevated CO_2 also enhanced recovery from water-stress upon rewatering; this was especially remarkable in Napier grass under high temperature. The better tissue moisture in Napier grass than common reed was largely achieved through transpiration control and osmoregulation. Both species adjusted stomatal morphology where abaxial stomatal density increased in Napier grass and reduced in common reed.

7.2 Overall synthesis and contribution to science

Napier grass accessions/cultivars differ to some extent in their physiological and growth attributes as shown in both the controlled conditions and field trials. Maintaining favourable tissue water status is pivotal for growth and plant function, but there were no consistent differences in the relevant variables amongst accessions that displayed clear differences in their biomass accumulation, especially under field conditions.

The intake of carbon dioxide and water loss through the stomata is a balancing process in achieving high biomass production. In the current study, some accessions sacrificed opportunities for C gain in order to maintain tissue hydration when exposed to water stress. Differences in biomass accumulation amongst the Napier grass cultivars were related largely to the amount of C assimilated when conditions were favourable, and thus the Napier grass lines that kept their stomates open yielded the most when water supply was limited. Since stomates are located on the leaves, lines that maintain a large canopy would not only have more stomates, but in addition, would intercept more light energy leading to higher biomass production. Therefore, leaf area index that is most likely inherent amongst species and cultivars, has a strong bearing on the amount of C fixed. Therefore identifying tools for rapid evaluation of productivity potential in Napier grass should not be limited to LWP, relative water content (RWC) or stomatal conductance, but should evaluate other traits such as canopy development, osmotic adjustment and hydraulic conductivity.

The study has provided empirical evidence on a number of Napier grass accessions that are currently not in commercial use. These accessions can be used to improve fodder production in either semi-arid or more mesic environments. The specific accessions identified as having productivity and quality potential are in MYC (16806, 16796, 16783, and 16835) and HYC (16809, 18448, 16791) groupings in Chapters 4 and 5. Although forage quality was lower (low nitrogen content and high neutral detergent fibre) in these two clusters compared with LYC, the much lower biomass in the LYC minimizes the benefit. Both quantity and quality of fodder are usually limiting in most smallholder livestock systems in east Africa, and the shortfall in quality in MYC and HYC could probably be easier to remedy with supplementation. This is because it would be more costly to buy basal forage than supplements. In view of climate change adaptation, MYC and HYC could assist livestock managers to increase forage production for improved livestock productivity.

The study in Chapter 3 has shown to some extent that it is possible to use tissue water hydration (LWP, RWC) in Napier grass to assess quality. Coefficients of determination of up to 0.82 between neutral detergent fibre and LWP and RWC were obtained, but only under low temperatures of 15─25°C. Where specialized equipment for neutral detergent fibre (NDF) determination is not available, NDF could be approximated from RWC or LWP. Neutral detergent fibre is a key parameter for forage nutritional quality and is usually inversely correlated with digestibility of the forage.

Elevated CO_2 concentration enhanced leaf water potential to some extent in Napier grass and common reed. Furthermore, it increased osmotic adjustment in Napier under high temperatures and under low temperature in common reed. Although it was not possible to include Napier grass accessions used in the field study in Kenya, it is likely osmotic adjustment was involved especially during dry periods, in contributing to the observed differences in biomass accumulation. Future investigation on osmotic adjustment using a wider range of Napier grass accessions would be worthwhile.

Exposure to elevated CO_2, regardless of temperature, improved water use efficiency as more carbon was assimilated than at ambient concentration. Also, the CO_2 compensation point was lower in Napier grass than in common reed since it varies between 0─0.5 Pa in C_4 and 4─5 Pa in C_3 grasses (Osborne 2012), the common reed would be expected to have higher rate of respiration when the stomates are closed. Consequently this process is likely to have contributed to accumulated biomass being lower for the reed than the Napier grass especially under eCO_2 concentration. The predicted future increase in ambient CO_2, will likely improve growth of grasses and fodder availability. However, the potential gain is likely to be limited by availability of water and nutrients (Atkin *et al.* 2000). Differences in water-stress between Napier grass and common reed were successfully quantified in this study. The C_4 Napier grass showed superior tolerance of water stress and a more rapid recovery from the stress than the profligate C_3 common reed.

I have therefore succeeded in answering the questions stated in Chapter 2. The first question was whether tissue water status could be used to predict production and forage quality potential in Napier grass cultivars. The results showed no relationship between tissue water status and the biomass that was accumulated by either of the cultivars used in Chapter 3 or accessions in Chapters 4 and 5, or even when Napier grass was exposed to elevated CO_2 concentration in Chapter 6. Therefore it is unlikely that tissue water status alone can explain productivity potential for Napier grass under stressful environmental conditions. However, digestibility based on neutral detergent fibre (NDF) was positively correlated with LWP under low temperature (15/25^{o}C). The LWP could therefore be a reliable estimator of NDF in Napier grass under the low temperatures, but not under high temperatures.

The second question whether there were differences in yields and quality in Napier grass accessions when grown under contrasting climatic conditions of lowland or highland tropical environments of Kenya? The results obtained showed clear differences in dry matter yields amongst the 10 accessions, both within and between the sites. These allowed the accessions to be grouped into high yielding (HYC), moderate yielding (MYC) and low yielding (LYC) clusters. The clusters also differed in their forage quality such that the LYC had higher nitrogen content and lower NDF when compared to MYC or HYC. Both MYC and HYC had similar nitrogen and NDF contents in most of the cases. Based on the biomass accumulated, accessions in MYC and HYC would be more preferable than accessions in LYC for forage production, under either of the environments considered in the study and other areas with similar conditions.

The third question of whether there were differences in physiological attributes (water stress indices, water use and water use efficiency) in response to transient droughts amongst Napier grass accessions in contrasting tropical environments. As would be expected the grass was more stressed at the dry site than the wet site. The ability of LYC to maintain higher stomatal conductance was not matched with high productivity when compared with either MYC or HYC under the semi-arid environment. The reason for this could not be fully explored in the study, but may suggest higher rates of photorespiration and/or nighttime respiration in LYC. It was also possible that differences in osmotic adjustment amongst the cultivars could be masking those in the LWP and RWC.

The last question; what is the impact of elevated CO_2 concentrations at different temperatures on Napier grass water relations and productivity compared to a grass possessing the C_3 photosynthetic pathway? Elevated CO_2 improved tissue water status in both the C_3 and C_4 but at different times occurring in Napier grass at around midday and at around predawn for the common reed when the grasses were water stressed. Upon re-watering, Napier grass expressed quicker recovery than common reed. Further, Napier grass regulated transpirational water loss better than the common reed and accumulated more biomass than common reed when subjected to elevated CO_2 under either of the temperatures regimes (15/25°C or 17/30°C). Therefore Napier grass will most likely be more tolerant than the common reed under conditions as used in the experiment. The data collected in this phase also suggested a strong osmotic adjustment by the Napier grass, which was often larger than observed in common reed, when subjected to water-stress. Osmotic adjustment is an important mechanism plants used to maintain favourable tissue water status and to sustain C assimilation. This would largely explain the similarity in C assimilation in Napier grass subjected to water and/or heat stress in the earlier phases of the study.

Overall, this study has provided empirical values for water use, water use efficiency and root to shoot ratio (Chapters 3, 4 and 5) that are rare for Napier grass, although common in food crops. The water use and water use efficiency obtained could assist in estimating water requirement for irrigated Napier grass and similar forage species. The study, however, revealed that leaf level physiological traits would not be reliable indicators of productivity for Napier grass in hot and water-limited environments. Whole plant traits, especially early canopy development, appeared to be consistently associated with productivity.

Future research

1.) Investigate the role of ambient temperature on forage quality. It was clear in the current study neutral detergent fibre levels of Napier grass are correlated with midday tissue water status under low temperature (15–25°C) but not under high temperature (25–30°C). Does radiation level affect this relationship?

2.) Evaluate the persistence of Napier grass accessions in LYC under limited soil water conditions. Due to the limited scope of the current study I could not explore whether the LYC with large root/shoot would persist better than accessions in the HYC or MYC groups over several years

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Appendices

Appendix for Chapter 3

Table A1.Treatment effects on diurnal RWC and LWP responses under 25^{o}C or 35^{o}C for Bana and Atherton Napier grass cultivars combined for three growth cycles

Treatments	Diurnal RWC (%)								Diurnal LWP (MPa)							
	Before watering		After watering						Before watering		After watering					
	5pm	12pm	5am	7am	9am	12pm	4pm	7pm	5pm	12pm	5am	7am	9am	12pm	4pm	7pm
25^{o}C																
Cultivar	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns
Watering regime	ns	ns	ns	*	ns	**	ns	**	ns	ns	***	ns	**	***	***	**
Cultivar x watering regime	*	**	ns	*	ns	***	**	**	*	*	ns	*	**	**	***	**
35^{o}C																
Cultivar	*	*	*	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	*	ns	ns
Watering regime	ns	ns	***	**	ns	ns	ns	ns	ns	ns	***	***	ns	ns	ns	**
Cultivar x watering regime	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns

$P < 0.05$ *, $P < 0.01$ **, $P < 0.001$ *** , ns not significant

Table A2. Summary of treatment effects gas exchange in Bana and Atherton Napier grass cultivars under 25^{o}C or 35^{o}C over three growth cycles

Treatment	Cycle 1	Cycle 2		Cycle 3		Cycle 1	Cycle 2		Cycle 3	
	Week 4	Week 4	Week 7	Week 3	Week 8	Week 4	Week 4	Week 7	Week 3	Week 8
25^{o}C	*Carbon assimilation*					*Stomatal conductance*				
cultivar	ns	*	ns	ns	ns	ns	*	ns	ns	ns
watering	ns	ns	***	ns	***	ns	ns	***	*	***
cultivar x watering	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	Transpiration					*Instantaneous WUE*				
cultivar	ns	**	ns	ns	ns	ns	*	ns	ns	ns
watering	ns	ns	***	*	***	ns	ns	ns	ns	***
cultivar x watering	ns	*	ns	ns	ns	ns	ns	ns	ns	ns
35^{o}C	*Carbon assimilation*					*Stomatal conductance*				
cultivar	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
watering	ns	ns	**	ns	**	ns	ns	**	ns	**
cultivar x watering	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	Transpiration					*Instantaneous WUE*				
cultivar	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
watering	ns	ns	*	ns	***	ns	ns	ns	ns	*
cultivar x watering	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

$P < 0.05$ *, $P < 0.01$ **, $P < 0.001$ ***, ns not significant. Each growth cycle lasted 8 weeks.

Appendix for Chapter 4

Table A3. Napier grass accession performance attributes at Katumani semi-arid lowland in Kenya in 2012

Growth cycle	Attribute	accession										
		16783	16790	16796	16806	16808	16809	16835	16837	18448	16791	LSD
1	LAI	0.6	0.5	0.5	0.5	0.4	0.7	0.4	0.2	0.5	0.7	0.4628*
	L:S ratio	1.4	1.8	1.2	1.4	1.3	1.4	1.8	1.4	1.6	0.7	0.7544*
	Plant height (m)	0.19	0.18	0.17	0.14	0.19	0.25	0.17	0.16	0.2	0.29	0.0794*
	Tiller number	12.2	13.0	8.2	13.1	11.7	13.2	12.7	7.5	13.4	9.4	2.984*
	Leaf (DM) t/ha	0.55	0.42	0.54	0.39	0.34	0.63	0.38	0.26	0.42	0.65	0.4225
	Yields (DM) t/ha	1.00	0.65	1.04	0.70	0.62	1.11	0.62	0.50	0.71	1.54	0.8271*
	NDF (%)	69.4	64.3	70.0	67.4	64.2	68.8	65.7	61.5	66.0	69.9	3.566***
	N (%)	2.3	2.9	2.1	2.4	2.7	2.4	2.8	2.9	2.4	2.5	0.775
2	LAI	4.9	4.9	3.9	3.6	4.2	4.6	3.5	3.7	3.4	3.8	1.4512*
	L:S ratio	1.0	0.8	1.1	1.0	0.7	0.8	1.2	0.8	0.7	0.6	0.2685**
	Plant height (m)	0.64	0.78	0.62	0.50	0.73	0.60	0.40	0.88	0.70	1.02	0.116***
	Tiller number	38.0	35.4	35.1	47.9	39.3	49.8	38.5	24.9	52.1	28.9	11.18*
	Leaf (DM) t/ha	3.16	3.02	2.80	2.61	2.68	3.02	2.35	2.90	2.57	2.80	0.81
	Yields (DM) t/ha	6.30	6.81	5.53	5.55	6.34	6.64	4.51	6.57	6.07	7.24	1.943*
	NDF (%)	66.7	66.9	66.8	65.9	66.3	67.7	66.4	67.3	66.7	69.4	3.075*
	N (%)	2.4	2.1	2.3	2.1	2.2	2.3	2.5	2.2	2.2	2.1	0.3955
3	LAI	2.3	1.2	2.1	1.7	1.3	2.1	2.4	1.2	1.7	1.2	0.8895*

	L:S ratio	1.7	2.0	1.5	1.6	1.5	1.3	1.9	1.9	0.9	1.1	0.6401*
	Plant height (m)	0.14	0.12	0.15	0.16	0.11	0.17	0.15	0.139	0.15	0.17	0.0538
	Tiller number	88.9	60.9	79.9	101.1	66.9	109.2	87.2	53.4	121.5	66.1	25.91***
	Leaf (DM) t/ha	1.77	1.12	1.66	1.50	1.14	1.88	2.37	1.21	1.65	1.12	0.644**
	Yields (DM) t/ha	2.83	1.7	2.87	2.61	1.88	3.45	3.7	1.89	3.54	2.14	1.326*
	NDF (%)	62.6	59.9	63.5	62.1	62.4	61.5	62.8	61.8	63.1	65.7	2.873*
	N (%)	2.8	2.8	2.6	2.5	3.1	2.9	2.9	2.8	2.4	2.6	0.3343**
4	LAI	1.2	0.5	1.2	0.7	0.7	1.7	1.6	2.5	1.1	0.5	1.966
	L:S ratio	1.3	2.7	1.4	1.6	1.8	1.4	2.1	2.3	1.4	1.3	0.9112*
	Plant height (m)	0.13	0.08	0.19	0.12	0.13	0.17	0.14	0.11	0.16	0.13	0.07261
	Tiller number	113.4	113.8	105.1	155.8	106.5	157.6	127.4	82.1	196.1	121.7	42.93***
	Leaf (DM) t/ha	1.02	0.45	1.10	0.67	0.62	1.54	1.61	0.45	0.94	0.52	0.8525*
	Yields (DM) t/ha	1.79	0.66	2.1	1.09	1.02	2.74	2.47	0.68	1.62	0.93	1.614*
	NDF (%)	66.0	63.8	67.1	65.8	63.9	64.1	65.0	64.6	67.2	64.8	2.685*
	N (%)	1.9	2.2	2.0	2.1	2.4	2.5	2.5	2.3	1.9	2.2	0.7012
5	LAI	1.6	1.8	2.8	2.4	2.1	2.9	2.6	1.4	2.5	1.8	1.518
	L:S ratio	2.3	3.8	2.6	2.5	3.0	2.2	2.3	3.5	2.0	2. 5	1.76*
	Plant height (m)	0.16	0.11	0.19	0.16	0.17	0.18	0.17	0.13	0.19	0.15	0.05521*
	Tiller number	123.5	158.4	119.4	168.5	165	150	145.9	135.6	196.7	158.2	38.62*
	Leaf (DM) t/ha	1.10	1.04	1.72	1.22	1.08	1.63	1.39	0.75	1.42	1.09	0.8931*
	Yields (DM) t/ha	1.68	1.35	2.36	1.77	1.49	2.41	2.02	0.99	2.22	1.60	1.227*
	NDF (%)	62.1	57.3	68.5	60.5	59.4	63.0	62.3	57.6	60.7	59.3	5.954*
	N (%)	2.4	2.8	2.1	2.5	2.8	2.3	2.6	3.0	2.5	2.7	0.5795*

Table A4. Napier grass accession performance attributes at Muguga wet mesic highlands in Kenyan in 2012

Growth cycle	Attribute	accession										LSD
		16783	16790	16796	16806	16808	16809	16835	16837	18448	16791	
1.	LAI	4.17	0.95	3.46	3.29	2.13	3.66	3.63	2.88	3.19	3.27	1.573*
	L:S ratio	0.86	0.62	0.88	1.13	1.08	0.71	1.01	1.15	0.95	0.71	0.2809**
	Plant height (m)	0.81	0.47	0.68	0.39	0.41	0.62	0.44	0.39	0.52	0.69	0.1203***
	Tiller numbers	21.2	22.8	19.9	33.1	26.6	46.2	29.1	28.5	42.1	37.0	11.41***
	Leaf (DM) t/ha	3.97	0.96	3.25	2.58	1.85	3.12	3.44	2.54	2.61	3.31	1.335**
	Yields (DM) t/ha	8.67	2.52	6.97	4.88	3.61	7.7	6.95	4.8	5.41	8.08	2.91**
	NDF (%)	70.7	67.4	71.1	69.3	66.1	68.9	71.5	68.6	69.3	71.3	2.967*
	N (%)	1.8	1.9	1.8	1.9	2.0	1.9	1.8	2.1	1.8	1.8	0.531
2.	LAI	4.51	2.11	4.17	4.95	2.7	5.49	4.4	5.13	4.25	4.49	1.598**
	L:S ratio	1.26	0.57	1.40	1.09	1.00	0.72	1.42	0.85	0.96	0.73	0.2847***
	Plant height (m)	0.60	1.15	0.57	0.57	0.67	1.26	0.60	0.91	0.72	0.99	0.33***
	Tiller numbers	40.1	31.5	45.4	80.4	51.2	91.2	65.9	55.4	86.5	68.5	23.54***
	Leaf (DM) t/ha	3.06	1.46	2.87	3.52	2.17	3.78	3.36	3.49	2.95	3.08	1.094**
	Yields (DM) t/ha	5.52	4.02	4.93	6.86	4.34	9.28	5.87	7.66	6.09	7.29	2.597**
	NDF (%)	62.2	64.7	64.3	61.8	63.5	64.4	65.7	64.7	63.8	66.8	2.863*
	N%	2.7	2.8	2.8	2.6	3.0	3.0	2.6	2.8	2.6	2.5	0.4291*
3.	LAI	3.77	0.66	3.20	3.84	1.62	2.74	2.74	2.44	3.05	2.15	1.009***
	L: S ratio	2.23	3.32	1.86	2.26	1.94	2.00	3.44	2.17	1.81	1.75	0.7824***
	Plant height (m)	0.18	0.07	0.16	0.18	0.14	0.11	0.13	0.15	0.20	0.13	0.06257*
	Tiller numbers	109.6	58.6	108.6	186	87.8	200.8	131.4	102.1	184.8	117.9	45.87***
	Leaf (DM) t/ha	2.07	0.38	1.99	2.21	1.10	1.47	1.95	1.46	1.74	1.17	0.5176***
	Yields (DM) t/ha	3.01	0.52	3.13	3.18	1.69	2.24	2.56	2.13	2.77	1.84	0.8253***
	NDF (%)	59.8	55.6	61.0	59.9	60.1	57.5	62.5	57.0	59.9	60.5	2.556***

	N (%)	3.2	4.0	3.2	3.1	3.3	3.9	2.7	3.6	3.5	3.6	0.5084**
4.	LAI	3.91	0.72	3.39	4.02	1.85	2.57	3.30	2.72	3.91	2.54	0.9097***
	L:S ratio	1.77	1.49	1.84	2.15	1.59	1.46	2.97	1.91	2.06	1.27	0.4442***
	Plant height (m)	0.33	0.21	0.27	0.24	0.21	0.29	0.15	0.24	0.29	0.36	0.06483***
	Tiller numbers	140.2	104.6	165.0	271.5	125.9	453.1	219.1	144.5	292.5	174.8	71.45***
	Leaf (DM) t/ha	3.17	0.52	2.60	2.90	1.43	1.97	2.67	2.10	2.38	1.98	0.6541***
	Yields (DM) t/ha	4.96	0.87	4.01	4.27	2.34	3.31	3.6	3.21	3.58	3.54	1.05***
	NDF (%)	64.6	59.9	66.1	61.7	64.4	60.9	65.6	61.6	63.3	65.5	1.884***
	N (%)	2.6	3.2	2.4	2.5	2.6	3.2	2.4	2.7	2.6	2.5	0.4128**
5.	LAI	6.96	2.28	5.50	8.25	2.98	6.16	5.38	4.23	5.06	5.28	2.626**
	L:S ratio	1.38	0.97	1.52	1.35	1.28	1.42	1.46	1.58	1.13	1.17	0.2264***
	Plant height (m)	0.61	0.63	0.56	0.56	0.43	0.42	0.53	0.52	0.58	0.64	0.1644*
	Tiller numbers	171.9	128.2	195.6	277.0	210.9	388.8	171.2	184.5	321.6	253.1	80.28***
	Leaf (DM) t/ha	4.21	1.61	3.91	4.99	2.27	4.1	4.36	3.45	3.53	3.45	1.116***
	Yields (DM) t/ha	7.39	3.31	6.51	8.7	4.03	7.00	7.33	5.62	6.64	6.41	2.031***
	NDF (%)	69.3	64.4	68.2	65.9	68.0	63.8	68.1	67.3	68.6	69.3	2.545**
	N (%)	2.0	2.3	1.8	2.0	2.0	2.5	1.9	2.1	1.9	2.2	0.328**

Appendix for Chapter 6

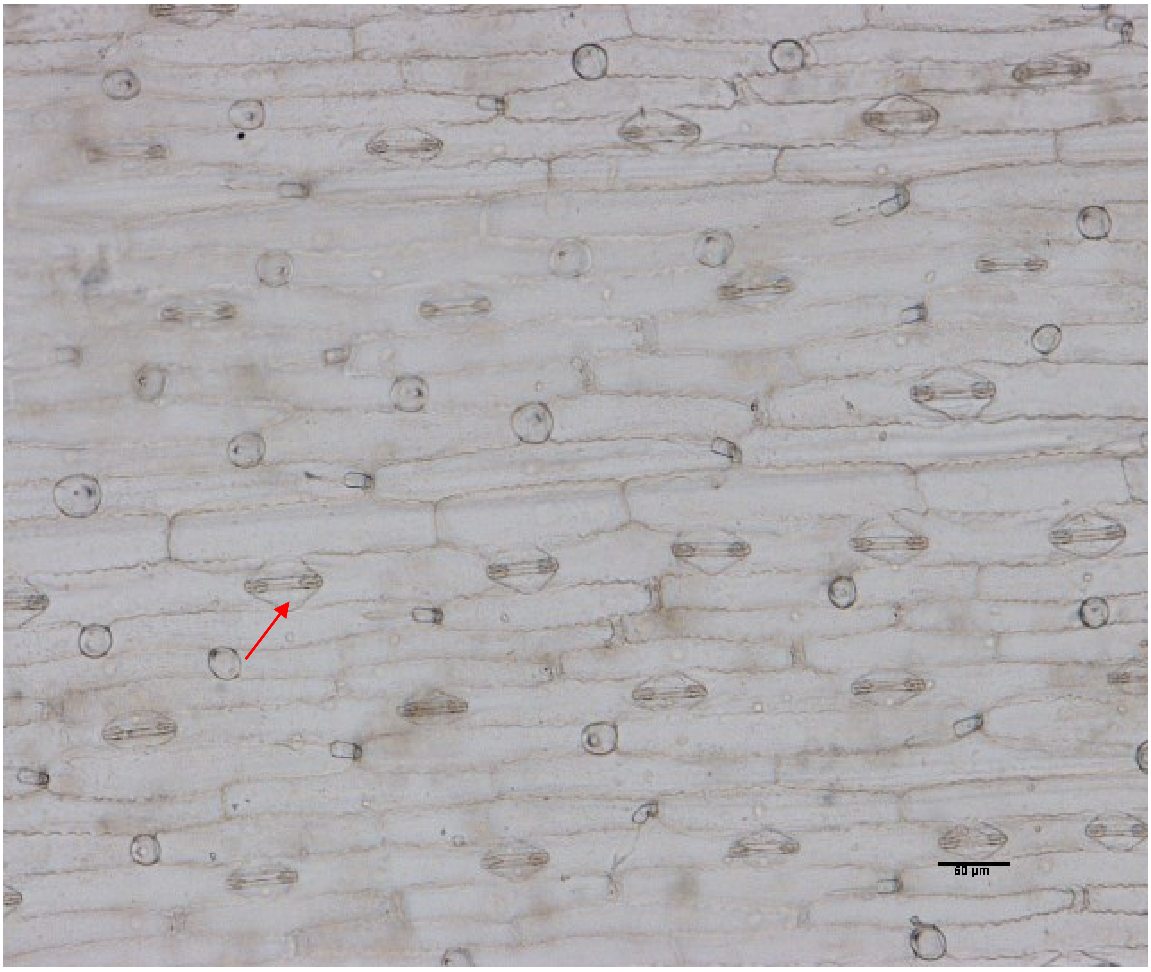

Figure A1. Stomata on the abaxial leaf surface of Napier grass (*Pennisetum purpureum* Schumach.) under x10 magnification. The red arrow indicates a stomate.

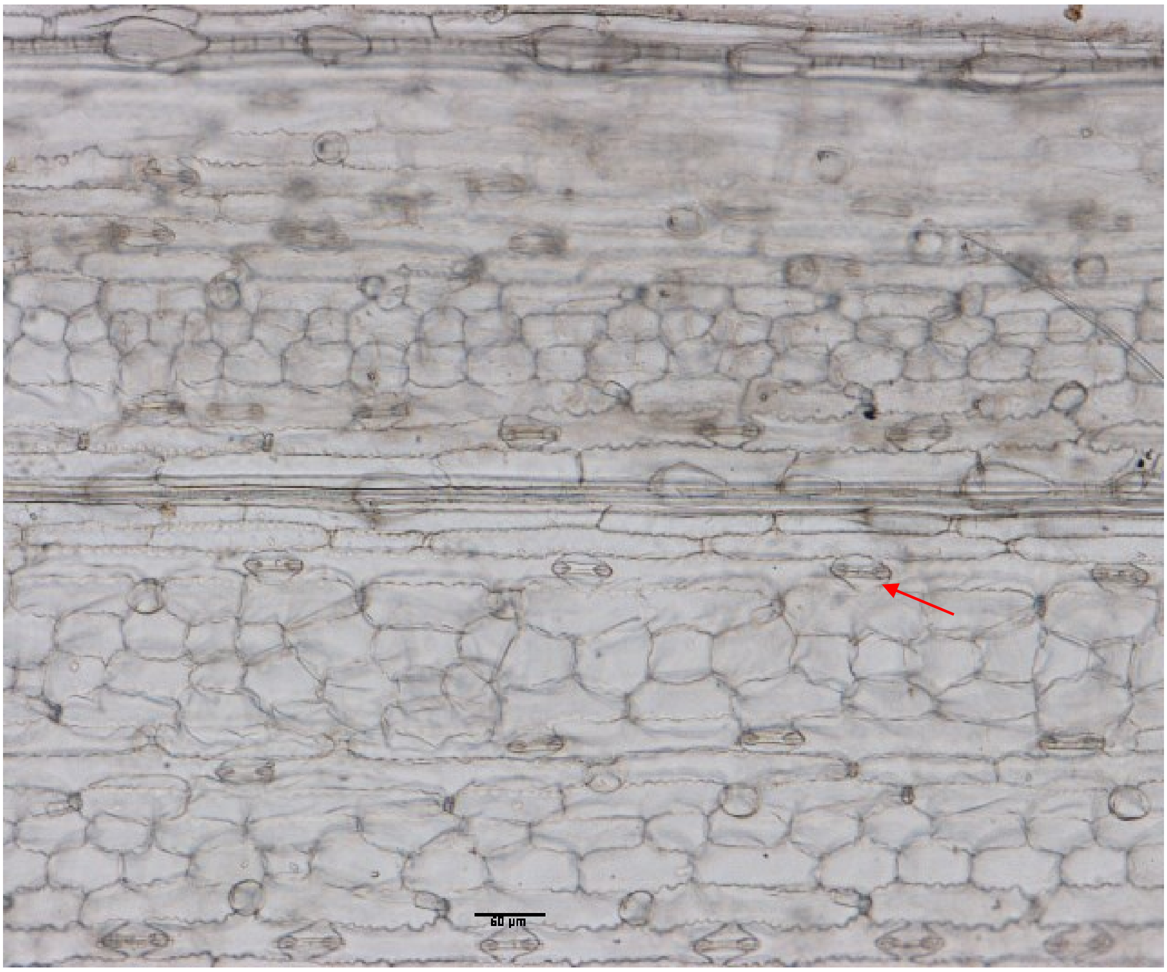

Figure A2. Stomata on the adaxial leaf surface of Napier grass (*Pennisetum purpureum* Schumach) under x10 magnification. The red arrow indicates a stomate.

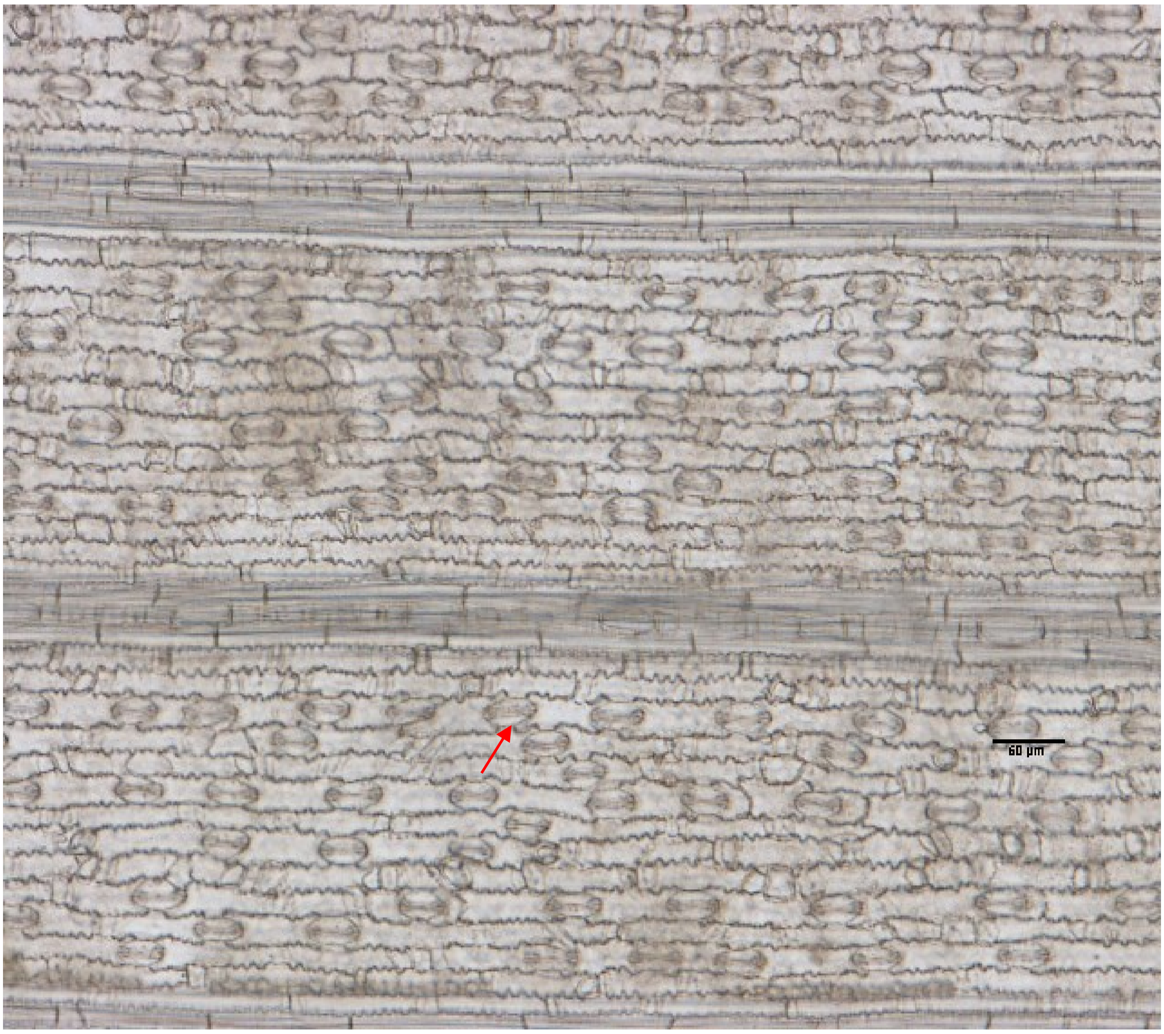

Figure A3. Stomata on the abaxial leaf surface of common reed (*Phragmites australis* (Cav.) Trin. Ex Steud) under x10 magnification. The red arrow indicates a stomate.

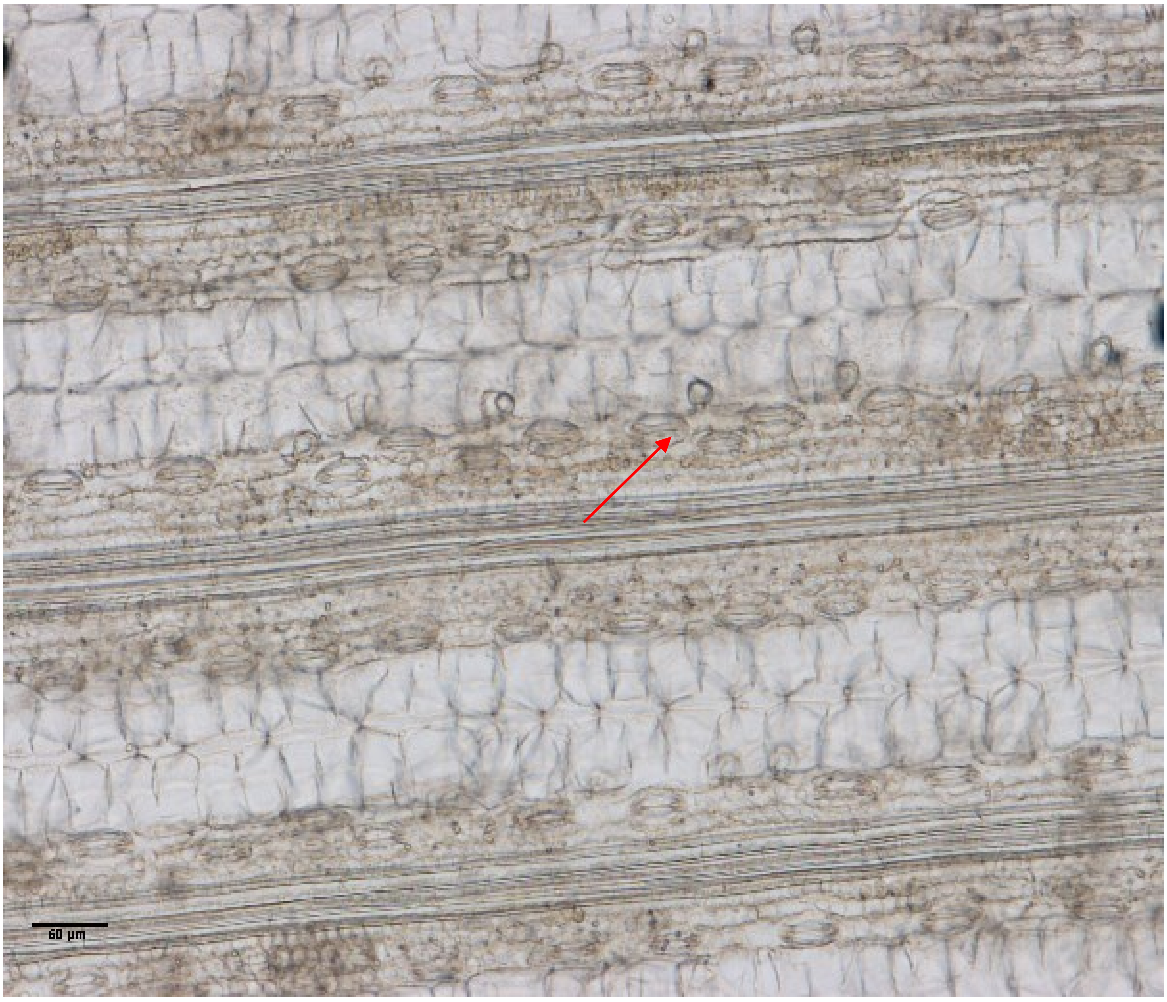

Figure A4. Stomata on the adaxial leaf surface of (*Phragmites australis* (Cav.) Trin. Ex Steud) under x10 magnification. The red arrow indicates a stomate.