PROCEEDINGS OF THE AUSTRALIAN RANGELAND SOCIETY BIENNIAL CONFERENCE
Official publication of The Australian Rangeland Society

Form of Reference
The reference for this article should be in this general form;

Author family name, initials (year). Title. *In*: Proceedings of the *n*th Australian Rangeland Society Biennial Conference. Pages. (Australian Rangeland Society: Australia).

For example:

Anderson, L., van Klinken, R. D., and Shepherd, D. (2008). Aerially surveying Mesquite *(Prosopis* spp.) in the Pilbara. *In*: 'A Climate of Change in the Rangelands. Proceedings of the 15th Australian Rangeland Society Biennial Conference'. (Ed. D. Orr) 4 pages. (Australian Rangeland Society: Australia).

The Australian Rangeland Society

Atmospheric nitrogen and carbon transformed by cyanobacteria contribute to productivity in pastoral rangelands

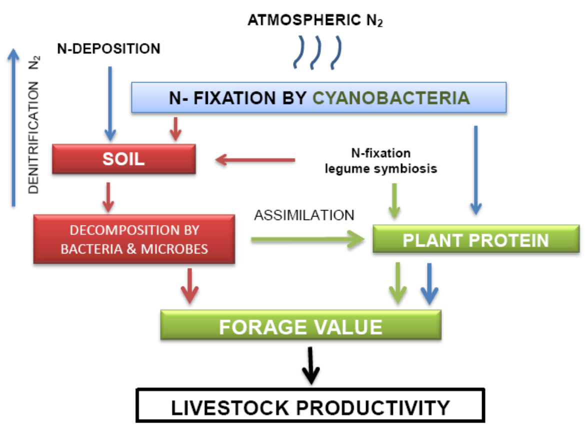
B.M. Alchin and W.J. Williams

School of Agriculture & Food Sciences, University of Queensland Gatton QLD;
b.alchin@uq.edu.au

Keywords: cyanobacteria, nitrogen fixation, soil crusts

Introduction

Cyanobacterial-dominated soil crusts are found worldwide in arid and savannah landscapes where the rainfall occurs mostly in summer (Büdel 2002). Cyanobacteria are single-celled, photosynthetic, blue-green bacteria (previously referred to as blue-green algae). They provide a protective, nutrient-rich layer closely integrated into the soil surface (Belnap et al. 2003). In addition they stabilise the surface soil, augment soil moisture and take up atmospheric carbon and nitrogen via photosynthesis. Cyanobacteria and biological crusts are responsible for around 45% of the world's biologically fixed nitrogen (Elbert et al. 2012). The broad objective of this project was to quantify the importance of nitrogen fixation by cyanobacteria to grazing ecosystems in northern Australia's pastoral rangelands. Figure 1 indicates the conceptual basis for the research.



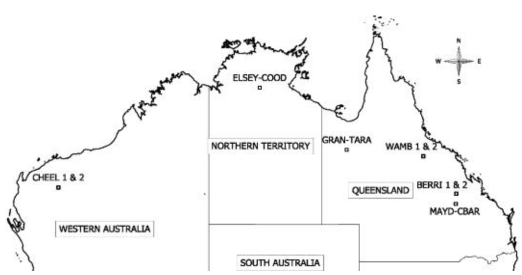


Fig 1: Cyanobacteria in the grazing ecosystem

Fig 2: Location of study sites

Methodology

Field sampling was carried out on six paired sites (properties) located across different rangeland types on grazing properties in northern Australia (Qld, NT and WA) – Figure 2. At each paired site two different grazing systems were assessed (*viz.* cell and continuous; variable stocking rate and exclosure).

Results/Discussion

Cyanobacterial soil crust characteristics

Cyanobacterial soil crusts (CSC) were recorded from all sites, with a high proportion of nitrogen-fixing species present. However, crust cover, diversity and biomass varied between sites and grazing systems. The results are summarised in Table 1. There were significant differences in the CSC crust characteristics between rangeland types and regional locations. The effects of grazing systems on CSC were variable. The overall diversity of cyanobacteria varied from three to ten species at each site under the different grazing systems. The grazing system differences did not appear to significantly influence the species diversity except on the WA floodplain site. In a previous study, Alchin et al (2008) demonstrated that grazing systems in the Victoria River Downs (NT) influenced cyanobacteria species diversity and abundance.

The average CSC cover across the soil surface (e.g. between grass tussocks or clumps) was 51% in the dry season and 43% in the wet season. There was a trend for the cover to be higher under cell grazing on the brigalow south, northern savannah and WA floodplain. On a regional basis there was a tendency in the dry season for the cover to be higher in the northern than the southern sites. These crust cover figures need to be taken into context of the dry season cover representing the established crusts from the previous wet season.

There was a high level of variability in the biomass of cyanobacteria. However, the grazing system did not have any marked effect on the biomass for any one rangeland type. Cyanobacterial biomass across these sites ranged from 8.5 – 32.9 mg chlorophyll a (per g soil) or an estimated 55.9 – 97.8 mg m^{-2}.

Table 1: Results for cyanobacterial soil crust diversity

Rangeland type	Brigalow south		Brigalow north		Mitchell-Gulf		Northern savannah		WA flood plain		Open savannah	
Property Grazing system	MayD CTS	Coonabar CELL	Berrigurra CTS	Berrigurra CELL	Granada CTS	Tara CELL	WestE CTS	Coodardie CELL	Cheela CTS	Cheela CELL	Wambiana EXC	Wambiana VSR
Dry season crust cover %	40.6	47.3	88.5	36.9	87.9	84.6	51.5	59.8	14.2	30.4	9.5	60
Wet season crust cover %	42.5	70.8	61.7	50	22.5	60	22.5	16.7	12.5	54.2	37.5	60
Biomass mg/g (Ca)*	9.7	8.5	13.2	12.4	23.6	17.9	13.6	32.9	7.4	5.4	7.4	19.9
Overall diversity (cyanobacteria spp.)	6	6	6	10	6	5	7	7	3	9	4	3
Predominant species	5	3	3	0	4	2	4	3	2	3	2	3
No. N-fixing species	2	2	1	1	1	1	3	1	0	2	1	0

Biological nitrogen fixation

Nitrogen-fixation rates varied greatly across sites and between seasons – they were significantly higher for wet season samples compared to the dry season. Dry season uptake ranged from 0.04 to 4.6 g N_2 m^{-2} $hour^{-1}$ across all sites and projected wet season uptake was between 0.2 and 33.1 g N_2 m^{-2} $hour^{-1}$. Nitrogen isotopes indicated the majority of plant-available nitrogen was of cyanobacterial origin.

Plant available nitrogen

The effects of different grazing management strategies were variable on CSC and the resulting plant-available nitrogen (mineralisable N) – data from sites are in Figure 3. Eleven of the twelve sites had higher plant-available N in the 0-1 cm depth compared to the 1-5 cm depth. Nitrogen isotopes showed that the nitrogen concentration found in the surface soils (0-1 cm) from five sites originated from cyanobacterial nitrogen fixation. At the remaining sites the isotopic signatures indicated some fractionation was occurring (i.e. multiple processes taking place that incorporated cyanobacterial fixation). At all sites except May Downs there was higher plant-available nitrogen N) in the 0-1 cm zone than the 1-5 cm zone.

The study into biological fixation of nitrogen by cyanobacteria and its subsequent availability to plants is focused around the top centimetres of the soil profile. In this study ten of the twelve sites had greater levels of plant-available N at 0-1 cm.

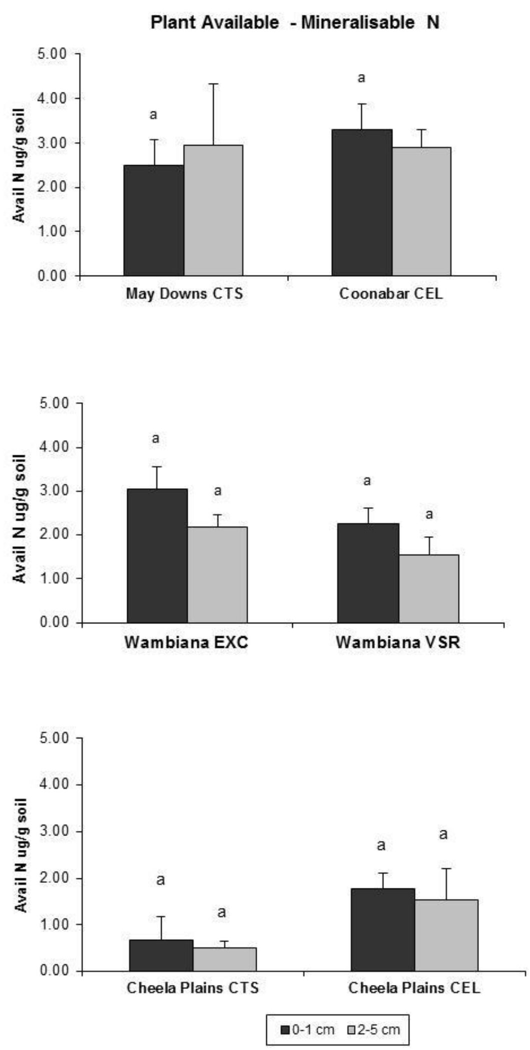
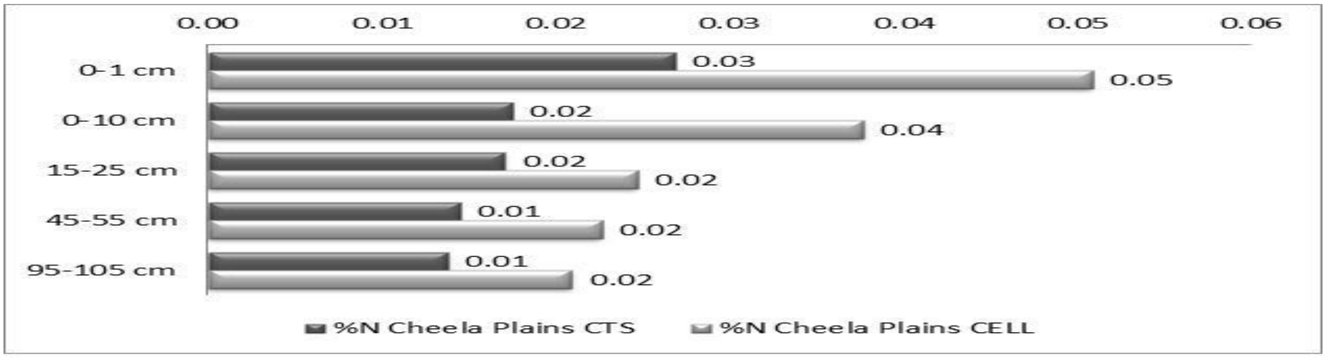


Figure 3: Plant-available N concentration in dry season (mean values [± SEM] for ammonium and nitrate ions at two depths (0-1, 1-5 cm) for paired sites; 'a' denotes a significant difference).

Nitrogen and carbon in the soil ecosystem

Figure 4 presents data from Cheela Plains for total percentage nitrogen (N) and carbon (C) at five depths for 1 metre core samples - cell grazing was higher than the continuous for %N and %C. The results were variable for the other sites.



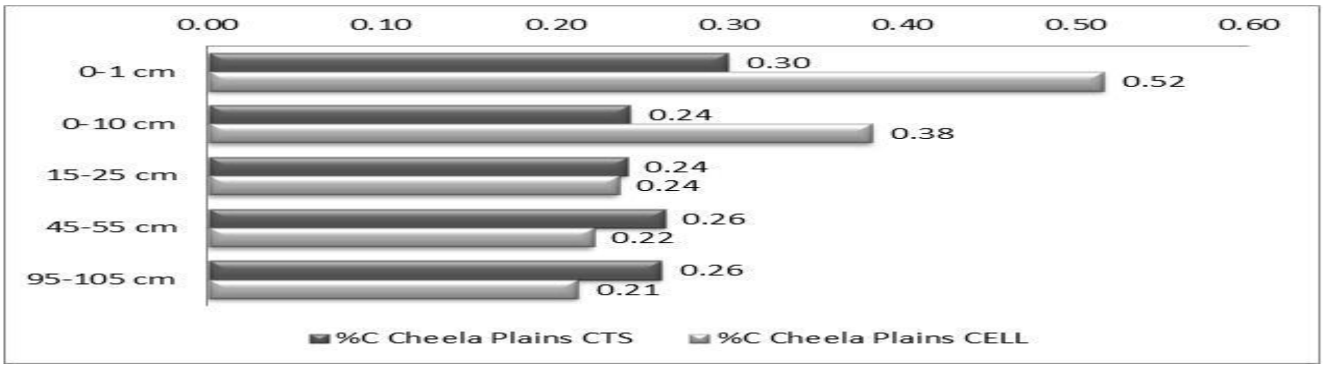


Fig. 4: Percentage Nitrogen (%N) and Carbon (%C) on Cheela Plains for 5 depths (CTS = continuous gazing; CELL = cell grazing; mean values shown at end of bar).

Conclusions

This pilot study provided preliminary data for the rates of N-fixation by cyanobacteria on pastoral rangelands in northern Australia. In summary:

- N-fixing cyanobacteria were a common component of CSC at all study sites.
- Grazing systems influenced cyanobacteria species occurrence and distribution.
- The level of influence of particular grazing systems on CSC varied in different regions.
- There were useful daily rates of N-uptake by cyanobacteria at all sites.
- Rates of N-fixation recorded were significantly higher in the wet than the dry season.
- Grazing management can influence N availability from cyanobacteria for uptake by forage.
- Characteristics of CSC compared to other detailed studies in Australia (Williams and Budel, 2012).
- Rates of N-fixation, available N and cyanobacterial biomass compared with other studies in Australia and overseas.
- CSC are an important part of the soil ecosystem in grazed rangelands of northern Australia.

While the importance of cyanobacteria has been demonstrated from this study, there remains a lack of more detailed and informative research on biological soil crust-plant interactions and a higher level of quantification of N-inputs is needed. Consideration could also be directed to studying the flow of nitrogen through the cyanobacteria-soil-plant ecosystem to the animal.

The focus of future research may further identify the contribution by cyanobacteria to nitrogen on a landscape scale under different management systems. There is a need for the determination of the levels of cyanobacterial nitrogen-fixation seasonally and its link to plant protein levels.

The application of this research relates to the contributions by cyanobacteria to soil nitrogen and the flow-through to plant protein levels. There is potentially an opportunity for graziers to take advantage of seasonal increases in the nitrogen supplied by cyanobacterial activity. An understanding of this may support grazing management decisions in enhancing rangeland resource sustainability and productivity.

References

Alchin, B., Page, M. and Bosch, O. (2008). Ecosystem response to cell grazing. Australian Rangeland Society 15th Biennial Conference Proceedings, Charters Towers, Qld.

Belnap, J., Prasse, R. and Harper, K.T. (2003). Influence of biological soil crusts on soil environments and vascular plants In: J. Belnap & O. Lange (eds.): Biological Soil Crusts: Structure, Management and Function. Ecological Studies 150: 281-300. Springer-Verlag, Berlin.

Büdel, B. (2002). Diversity and ecology of biological soil crusts. Progress in Botany 63: 366-404

Elbert, W., Weber, B., Burrows, S., Steinkamp, J., Büdel, B., Andreae, M.O. and Pöschl, U. (2012). Contribution of cryptogamic covers to the global cycles of carbon and nitrogen. Nature Geoscience Letters, DOI 10.1038/NGEO1486.

Williams, W. and Budel, B. (2012). Species diversity, biomass and long-term patterns of biological soil crusts with special focus on Cyanobacteria of the Acacia aneura Mulga Lands of Queensland, Australia. Algological Studies: (In press).

Acknowledgements: MLA provided funding for the laboratory analysis in the project.