CEH Technical Report A

Desert Margins Programme Phase II

Influence of land management on mycorrhizal inoculum potential in South African soils.

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Prepared by:
Kevin Ingleby and Dr Jan Dick

CEH Edinburgh
Bush Estate
Penicuik, Midlothian
Scotland. UK.
EH26 0QB
Contact: ki@ceh.ac.uk
http://www.ceh.ac.uk

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

DMP

Executive summary
This report details the work undertaken to determine the mycorrhizal inoculum potential (MIP) of rangelands and home gardens of the western Bophirima District in the Ganyesa sub region of North-West Province, South Africa. The MIP of soil collected from enclosed and open rangeland at three sites (Austrey, Eska-Neuham and Tseoge) was determined by assessing arbuscular mycorrhizal (AM) spore numbers and diversity. Similarly, the effect of management practices in householder gardens (cropping frequency and inorganic manure application) on the abundance and diversity of AM spores was assessed. Numbers of AM spores, and in particular numbers of live spores, present in the plots was extremely low at all sites compared to other studies in natural grassland and pasture. Numbers of spores were also lower at the Tseoge site than the other sites. Fewer AM spores were found in grazed plots compared with ungrazed plots, particularly at the Austrey site. Soils from householder gardens contained lowest numbers of AM spores, which was unexpected as cropping and tillage are thought to increase AM spore production. This small scale study suggests that levels of viable AM propagules are extremely low in these soils, and that measures should be taken to increase them. However, assessment of AM spore populations often poorly reflects the number of viable AM propagules present in a soil, and bioassay experiments are recommended as a more accurate means of determining MIP.

Introduction
Overgrazing of rangeland is a major problem in South Africa (Moussa et al, in prep) and is known to reduce aboveground species diversity, but the effect on belowground diversity is largely unknown, although it is thought that AM diversity is a major factor in maintenance of aboveground plant diversity (van der Heijden, 1998). Plants act as reservoirs for AM fungi and, as grazing reduces vegetation cover and increases the potential for erosion and soil degradation, it is expected that grazing will be detrimental to AM populations belowground. In addition, use of fertilizers and animal manure on farms is thought to be detrimental to AM populations. This study was therefore conducted to examine the effect of such factors on the MIP of rangeland soils. It was hypothesized that the MIP of sites within enclosures will have a greater AM spore numbers than open veldt or house gardens.

Methods
Rangeland soil collection
From 5-7 Oct 2005, soil was collected from three sites in the western Bophirima District in the Ganyesa sub region of North-West Province, South Africa, part of the Molopo DMP target area (Table 1). The climate in the region is semi-arid, characterized by average annual rainfall between 200 – 400 mm, which mainly falls in summer (October to March).

The rangeland benchmark sites (representing various degrees of degradation: good, moderate and poor) serve as demonstration plots regarding the resting of veldt and were established in 1999 by DACET. The plots were central to the National Land Care program, the objective of which is to develop and implement integrated approaches to sustainable natural resources management. Prior to the establishment of the permanently fenced plots (110 m x 20 m) the rangelands were continuously grazed by free-roaming cattle and small ruminants which resulted in overgrazing of

the palatable grass species and proliferation of unpalatable grasses and shrubs. The paired, adjacent unenclosed areas are still subject to overgrazing.

Soil samples were collected for mycorrhizal analysis from the permanently fenced plots at Austrey, Eska-Neuham and Tseoge, and from adjacent, unenclosed areas. Collecting was done along existing 100 m transect lines used by other DMP partners. The transects were divided into thirds and soil samples (0-15 cm depth) collected and bulked from 5 locations in each third. Thus there were 3 soil samples from each transect.

Table 1. Site characteristics of veldt field sites (from Moussa et al, in prep)

	Austrey	Eska-Neuham	Tseoge
Latitude/Longitude	S 26°28', E 24°14'	S 26°38' E 23°51'	S 25°57' E 23°31'
Rainfall (mm)	300-400	300-400	200-350
Geology	Kalahari Group	Kalahari Group	Ventersdorp Group
Soil type	Yellow sands (Clovelly form) and red sands (Hutton form), with 3-10% clay, 900-1200 mm deep.	Yellow sands (Clovelly form) and red sands (Hutton form), with 3-10% clay, > 1500 mm deep.	Mispah form, with 4-10% clay shallower (< 250 mm).
Vegetation	Kalahari thornveld and shrub bushveld, described as a generally open savanna of *Acacia haematoxylon* and *Acacia erioloba* (Acocks, 1988; Tainton, 1999). Dominance of Increaser II species characteristic of overgrazed rangeland.		

Representative soil samples were also collected from three home gardens in the village of Austrey (Table 2). Ten samples (0-15 cm depth) from each plot were collected and bulked. All samples of soil collected were air dried and 100 g aliquots of soil were sealed in plastic bags and transported to the UK by air.

Table 2. Site characteristics of the householder's gardens

	Seboana Letlhogile	Seboana Letlhogile	Mildred Magabe	Betty Lolokwane
Crop 2003	Vegetables	Maize	Maize, beans, pumpkin	Maize
Crop 2004	Maize and cowpeas	Maize	No crop, Pen for ~10 goats and 1 donkey	Maize, grazed off by 3 donkeys
Plot size	35 m x 25 m	50 m x 25 m	20 m x 15 m	50 m x 25 m
Fertilizer	25 kg	25 kg	20 kg	20 kg
Perennial vegetation	None	None	2-3 bushes	No shrubs in plot but hedge border

AM spore assessments

AM spores were extracted from a 40 g sub-sample of each soil using a sucrose centrifugation method (Walker et al., 1982). Spores were classified as 'dead' or 'live' according to their appearance; live spores typically with cytoplasm and/or showing no signs of parasitism. Live

spores were examined microscopically to confirm their status and, when possible, identify them. Differences between treatments were examined by 2-way ANOVA (site*grazing). Data were transformed (log n+1) before analysis.

Results

Overall total numbers of spores and numbers of live spores were low, however differences were found between the sites with significantly more spores found in Austrey and Eska-Neuham soils than in Tseoge soils (Table 3).

Table 3. Numbers of AM spores and species in 40 g of soil collected from plots at 3 different sites in Bophirima District, NW Province

	Austrey	Eska-Neuham	Tseoge	*P* value
Total spores	69.8a	68.5a	31.3b	<0.001
Live spores	6.0a	6.0a	1.0b	0.003
Mean no. species	2.17	2.17	1.33	0.165

Overall total numbers of spores across all 3 sites were greater in ungrazed plots compared with grazed plots (Table 4).

Table 4. Number of AM spores and species in 40 g of soil collected from grazed and ungrazed plots in Bophirima District, NW Province

	grazed	ungrazed	*P* value
Total spores	46.7b	66.4a	0.019
Live spores	3.33	5.33	0.649
Mean no. species	1.78	2.0	0.689

Site * grazing interactions showed that increases in spore numbers were more apparent at the Tseoge and Austrey sites, although only soils from Austrey had significantly more live spores in soil from the ungrazed plot compared to the adjacent grazed plot (Table 5).

Table 5. Numbers of AM spores and species in 40 g of soil collected from ungrazed or grazed plots at 3 different sites in Bophirima District, NW Province

	Austrey		Eska-Neuham		Tseoge		*P*
	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	value
Total spores	53.0	86.7	66.7	70.3	20.3	42.3	0.158
Live spores	2.33b	9.67a	5.67ab	6.33ab	2.00bc	0c	0.040
Mean no. species	1.33	3.00	2.33	2.00	1.67	1.00	0.094

In the householder gardens at Austrey, total numbers of spores and live spores were also low and were similar to, or less than, those found in the grazed plots (Table 6).

Table 6. Numbers of AM spores and species in soil from Austrey householder gardens in Bophirima District, NW Province

	S. Letlhogile maize/cowpea	S. Letlhogile maize	M. Magabe no crop	B. Lolokwane maize
Total spores	54	33	39	35
Live spores	0	1	4	0
Mean no. species	-	1	1	-

No changes in AM diversity were found between the different soils (Table 3). As numbers of live, identifiable spores were so low, most samples yielded only 1-2 species with a maximum of 4 in any 1 sample. As a result, it was unlikely that any effects of site or grazing on AM diversity or species composition would be apparent from this data. The occurrence of AM species found in each plot is shown in Table 7.

Table 7. AM species recorded in soils from ungrazed or grazed plots at 3 different sites in in Bophirima District, NW Province

Site	Plot	Species present
Austrey	ungrazed	*Glomus fasciculatum, Gigaspora albida, Glomus* sp. 1, *Glomus* sp. 2, *Acaulospora mellea, A. gedanensis,*
	grazed	*Gigaspora albida, Glomus fasciculatum*
	gardens	*Acaulospora gedanensis, Glomus* sp.1
Eska-Neuham	ungrazed	*Gigaspora albida, Glomus fasciculatum, G. clarum, Acaulospora mellea*
	grazed	*Gigaspora albida, Glomus etunicatum, G. geosporum, Acaulospora longula*
Tseoge	ungrazed	*Scutellospora gregaria*
	grazed	*Scutellospora gregaria, Acaulospora scrobiculata, Glomus clarum, Gigaspora albida*

Discussion

Generally, numbers of spores, and in particular numbers of live spores, present in the plots were low compared to other studies in natural grassland and pasture where numbers of AM propagules usually range between 200-1500 per 100 g soil (Sieverding, 1991). However, it is well known that large seasonal and spatial variation occurs in the numbers and distribution of AM spores in the soil, and that assessments of spore populations often poorly reflect the numbers of AM propagules present in the soil. Seasonal variation may partly explain the low spore numbers found here, as samples were taken at the end of the dry season. However, the time of sampling was appropriate as it assessed the AM spores present in the soils at the beginning of the growing season when mycorrhizal infection is most important for plant development. Spatial variation (clumped distribution of spores) is often a problem when assessing AM spore populations, but this effect should have been minimised by the sampling strategy employed. Bioassay experiments should be employed if time allows, as they assess the viability of all types of AM propagules (i.e. hyphal fragments, infected root fragments and spores), and are a more accurate means of determining the MIP of soils (Brundrett, 1991).

Grazing has significantly reduced the number of AM spores in the soils at Austrey. The reduction in the variety and growth of plants which act as reservoirs for AM fungi and the negative impact of animal manuring have both been correlated with low AM spore numbers (Sieverding, 1991). Overall numbers of spores at the Tseoge site were significantly lower than the other sites, which may be explained by the sparser vegetation found here and the lower rainfall (a longer dry season?).

Fertilizer applications have been shown to significantly affect levels of AM fungi in agricultural soils, depending on the nature and amount of fertilizer and the background fertility of the treated soil (Jensen & Jacobsen, 1980). This may explain

the comparatively low numbers of AM spores in the soils from the householders' gardens. Otherwise, the result is unexpected, as many studies have shown that cropping and tillage increases AM spore production, while numbers decline when soil is left fallow (Thompson, 1987). It was also surprising that no differences in spore numbers were found between these garden soils as cropping sequences can make significant impacts on mycorrhizal populations (Johnson et al., 1991).

Sieverding (1991) proposed that AM propagule densities of below 900 per 100 g soil would limit the growth of crop plants. The results of this small scale study suggest that soils in the Bophirima District are deficient in numbers of AM propagules, and that any measures taken to increase the numbers of AM propagules in these soils will significantly improve crop yields.

References

Acocks, J.P.H., 1988. Veld types of South Africa. Memoirs of the Botanical survey of South Africa no 57, 146 pp

Brundrett, MC., 1991. Mycorrhizas in natural ecosystems. In: Macfayden, A., Begon, M., Fitter, AH. (eds.), Advances in Ecological Research. Academic Press, London, pp.171-313.

Jensen, A. & Jacobsen, I., 1980. The occurrence of VA mycorrhiza in barley and wheat grown in some Danish soils with different fertilizer treatments. Plant Soil, 55: 403-414.

Johnson, NC., Pflegler, FL., Crookston, RK., Simmons, SR. & Copeland, PJ., 1991. VA mycorrhizas respond to corn and soybean cropping history. New Phytol., 117: 657-663.

Moussa, A. S., Rensburg, L., Kellner, K. & Bationo, A., (in prep). Changes in soil biochemical properties in relation to grazing in communal managed rangelands in the western Bophirima District, South Africa

Sieverding, E., 1991. Vesicular-arbuscular mycorrhiza management in tropical ecosystems. Eschborn., Germany, 371 pp.

Tainton, N.M., 1999. Veld management in South Africa. University of Natal Press. Pietermaritzburg. 472 pp

Thompson, JP., 1987. Decline of VA mycorrhizae in long fallow disorder of field crops and its expression in phosphorus deficiency of sunflower. Aust. J. Agric. Res., 38: 847-867.

Van der Heijden, MGA., Boller, T., Wiemken, A. & Sanders, IR., 1998. Different arbuscular mycorrhizal fungal species are potential determinants of plant community structure. Ecology 79: 2082-2091.

Walker, C., Mize, CW. & McNabb, HS., 1982. Populations of endogonaceous fungi at two locations in Central Iowa. Can. J. Bot., 60: 2518-2529.