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NOTE AND RECORD

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Variation in soil content of faecal pellets of a tropical millipede, *Doratogonus uncinatus* (Attems, 1914) (Diplopoda, Spirostreptida, Spirostreptidae)

Tarombera Mwabvu

School of Biology and Environmental Sciences, University of Mpumalanga, Mbombela, South Africa

Correspondence
Tarombera Mwabvu
Email: tarombera.mwabvu@ump.ac.za

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1 | INTRODUCTION

Millipedes feed on a wide range of food items (Dangerfield, 1993; Ord & Dangerfield, 2001). Besides feeding on decomposing plant material, millipedes ingest mineral soil (Kadamannaya & Sridhar, 2009; Ramanathan & Alagesan, 2012), their own faecal material (Dangerfield, 1994; Mwabvu, 1998), flowers, fruits, mammalian faeces and dead invertebrates (Dangerfield, 1993). According to Hashimoto, Kaneko, Ito, and Toyota (2004), mineral soil constitutes approximately 60% by weight of ingested food in the Japanese train millipede, *Parafontaria laminata*. Furthermore, Mwabvu (1996) reported that field faecal pellets of *Doratogonus uncinatus* (Attems, 1914) contained 52% soil by weight. Hashimoto et al. (2004), Dangerfield (1993) and Ord and Dangerfield (2001) suggested that soil in millipede diet might be critical in digesting organic material in the gut. However, David (2014) reported that ingested soil is probably important for constructing moulting chambers and protecting eggs of millipedes.

Southern African millipedes emerge from the soil at the onset of the summer rainfall season between November and March. They are surface active, primarily to feed and mate (Dangerfield & Telford, 1991). Whether or not soil content in millipede diet varies within the rainfall season is worth investigating because it has implications for decomposition of organic matter. As such, given that soil availability is unlimited unlike organic material, the proportion of soil in faecal pellets of a tropical millipede, *D. uncinatus*, during a summer rainfall season was investigated. It was hypothesized that soil content of faecal pellets will peak at the beginning and end of the wet season.

Surface-active *D. uncinatus* specimens were collected by hand every fortnight before 10.00 hours during the rainfall season (November 2000–March 2001). Sampling was along a 100-m transect for 10 min at each site on each sampling day at Mazowe (17°31′S, 30°59′E) and Mount Pleasant (17°30′S, 30°57′E), Zimbabwe. On average, 30 millipedes were collected on each sampling day at each site and taken to the laboratory. When fewer than 10 millipedes were encountered after 10 min of searching, the millipedes were not taken to the laboratory because not enough faecal pellets would have been generated. The millipedes collected on each sampling day from each site were kept separate in plastic pots (diameter 15 cm, depth 20 cm) at 25°C without food or water for 2 hr during which faecal pellets that were produced were collected. After generating the faecal pellets, the millipedes were returned to their respective sites. The faecal pellet samples were dried at 60°C for 24 hr, weighed and then ashed at 650°C in a muffle furnace for 24 hr. After ashing, the pellets were weighed again to determine the proportion of mineral particles and organic matter.

Unpaired two-sample *t* test was used to compare soil content in the faecal pellets at each site and between sites.

Soil content of faecal pellets fluctuated between 16% and 58% of the pellet weight (Table 1). Soil in the pellets decreased to below 20% during the peak rainfall period (January), before increasing to 50% at the end of the season (Figure 1). Differences between the soil content in pellets from the mid-rainfall season and the beginning of the season were significant ($p < .05$) (Figure 2).

Environmental factors, such as soil moisture, have a strong influence on the quality and availability of organic material when millipedes are surface active. Therefore, as food litter became scarce or unsuitable, individuals trying to extract organic particles probably ingest more soil. This may explain the high soil content in faecal pellets at the beginning of the rainfall season (Figure 1) when organic matter is relatively dry, undecomposed and difficult to digest. Sakwa (1974), who reported that millipedes prefer to feed on softer

TABLE 1 Proportion (%) of soil in faecal pellets from two sites (Mazowe and Mount Pleasant)

	n	Mean ± *SD*
S1a	25	21.80 ± 8.62
S1b	26	19.81 ± 6.65
S2a	25	58.56 ± 10.78
S2b	26	54.73 ± 11.13
S3a	23	27.52 ± 12.60
S3b	24	34.21 ± 10.11
S4a	26	17.00 ± 9.84
S4b	27	25.19 ± 8.70
S5a	25	16.91 ± 6.80
S5b	26	17.96 ± 9.02
S6a	24	34.11 ± 9.51
S6b	22	35.77 ± 11.05
S7a	28	47.13 ± 9.91
S7b	32	46.69 ± 10.99
S8a	30	49.12 ± 14.16
S8b	30	47.70 ± 15.04

S, Sample, a, Mazowe, b, Mount Pleasant.

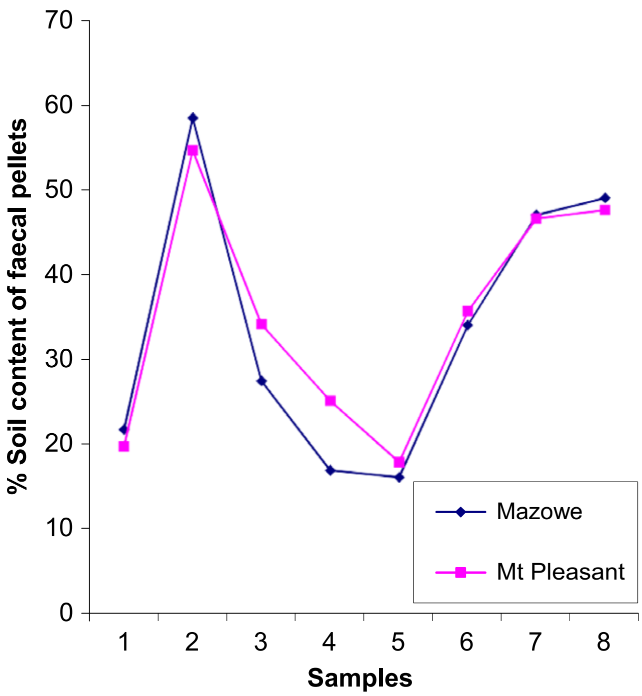

FIGURE 1 Soil content of millipede faecal pellets at Mazowe and Mount Pleasant

	S8b	S8a	S7b	S7a	S6b	S6a	S5b	S5a	S4b	S4a	S3b	S3a	S2b	S2a	S1b
S1a	**	**	**	**	**	**	ns	ns	ns	ns	**	**	**	**	ns
S1b	**	**	**	**	**	**	ns	ns	ns	ns	ns	ns	**	**	
S2a	**	**	**	**	**	**	**	ns	**	**	**	**	ns		
S2b	**	**	**	**	**	**	**	ns	**	**	**	**			
S3a	ns	ns	ns	ns	ns	ns	**	**	ns	**	ns				
S3b	ns	ns	ns	ns	ns	ns	ns	ns	**	**					
S4a	**	**	**	**	ns	ns	ns	ns	ns						
S4b	**	**	**	**	ns	ns	**	**							
S5a	**	**	**	**	**	**	ns								
S5b	**	**	**	**	ns	ns									
S6a	ns	ns	ns	ns	ns										
S6b	ns	ns	ns	ns											
S7a	ns	ns	ns												
S7b	ns	ns													

S = Sample; a = Mazowe; b = Mount Pleasant
ns = not significant, ** = significant

FIGURE 2 Pairwise comparisons of soil proportion (%) in faecal pellets at Mazowe and Mount Pleasant

decomposing plant litter, which has lower content of tannins and polyphenols after microbial action, supported this view.

The peak rainfall period in January saw a decrease in soil content in faecal pellets probably because plant litter became more palatable and softer as a result of increased moisture (Sakwa, 1974) and microbial activity (David, 2014). This is consistent with Kheirallah's (1979) observation of a positive correlation between plant litter palatability and the age of the litter. Additionally, availability of wider range of potential food items may have resulted in reduced ingestion of soil.

Availability of food litter and the quality of potential food material expectedly decrease towards the end of the rainfall season because of microbial decomposition and leaching of soluble nutrients. In addition, moisture levels decreased as rainfall became infrequent and low towards the end of the season. As such, soil content of millipede faecal pellets increased. Eventually, millipedes burrow into the soil to aestivate as environmental conditions become unfavourable and food becomes scarce. The results of this study demonstrated that changes in soil content of faecal pellets occur during surface activity in response to fluctuating availability of food. As such, a season may have several peaks when soil content in faecal pellets is high. Therefore, nutrient release from millipede faecal pellets in tropical ecosystems could vary depending on the soil content in the pellets.

An alternative explanation for the fluctuation in soil content of pellets may be the need for calcium carbonate for the production of the exoskeleton in millipedes (Dangerfield, 1993), rather than the need for soil as roughage or as a source of organic particles. This is corroborated by the sharp increase in soil content of faecal pellets (Figure 1) at the beginning (when millipedes emerge from the soil) and at the end of the wet season when millipedes prepare for aestivation. Thus, the preference for soil by millipedes as reported by Hashimoto et al. (2004) may be influenced by nondigestive requirements.

Given that millipedes are major detritivores in tropical ecosystems, it is useful to determine implications of soil content on microbial activity and nutrient release from faecal pellets. Given their large size, biomass and the large numbers of faecal pellets that they produce (Dangerfield & Milner, 1996), the ecological role of millipedes in tropical ecosystems is probably underestimated.

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ORCID

Tarombera Mwabvu http://orcid.org/0000-0002-8947-7811

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