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Enhanced soil nutrient concentrations beneath-canopy of savanna trees infected by mistletoes in a southern African savanna

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A B S T R A C T

Mistletoes have a major influence on nutrient dynamics in nutrient-poor ecosystems with potential to contribute to nutrient enrichment beneath tree-dominated patches. We studied the soil nutrient concentrations beneath four tree species with and without mistletoe infections. Effects of species and infection status on soil nutrient concentrations were tested using a general linear model (GLM). Soil nutrient concentrations differed with tree species, infection status and their interaction ($p < 0.05$). The concentrations of nitrogen (N) and phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) were elevated beneath *Sclerocarya birrea* and *Diospyros mespiliformis*, respectively. Soils beneath host trees had higher nutrient concentrations and were slightly alkaline than those beneath non-host trees. The concentration of soil nutrients increased by a factor ranging from 2.25 for N, 2.28 for P, 8.55 for Ca, 3.78 for Mg up to 39 for K. The increase in below-canopy soil fertility with mistletoe infection leads to an increase in the spatial heterogeneity of nutrient availability with potential to alter ecological factors such as species diversity and plant productivity. In conclusion, we suggest that nutrient enrichment in tree-dominated patches and associated increase in resource heterogeneity play an important role in determining ecosystem structure and function in semi-arid savanna.

1. Introduction

Nutrient enrichment in tree-dominated patches is a widely recognized phenomenon, which increase heterogeneity of resource availability in savannas (Belsky, 1994; Belsky et al., 1989; Ludwig et al., 2004; Mlambo et al., 2005; Treydte et al., 2010). Three major mechanisms have been advanced to explain this phenomenon: (1) trees absorb and transport nutrients from tree interspaces towards the plant using their extensive lateral roots, and depositing them beneath the canopy via litterfall and canopy leaching (Scholes, 1990), (2) tree canopy traps nutrient-laden atmospheric dust, which is washed off the leaves by rainfall and drip into the subcanopy area (Bernhard-Reversat, 1982), and (3) animals such as herbivores and birds seeking shade or cover concentrate nutrients beneath the canopy through urine and faecal deposits (Belsky, 1994; Treydte et al., 2010). However, recent research has shown that aerial hemiparasites (hereafter mistletoes) that occur in tree canopies can alter litterfall, decomposition rates, and soil microbial communities beneath the canopies of their hosts (Press, 1998; Watson, 2009). Consequently, mistletoes have potential to alter nutrient cycling rates, and thus may contribute to nutrient enrichment in tree-dominated patches.

Mistletoes are aerial parasitic plants that obtain water, minerals, and nutrients passively from their hosts through a vascular attachment called a haustorium (Kuijt, 1969). The nutrient acquisition pathway enables mistletoes to accumulate greater foliar nutrient concentrations than their hosts (Marshall et al., 1994; Ehleringer and Marshall, 1995). At senescence, the litter of mistletoes remains enriched due to a low nutrient resorption efficiency (March and Watson, 2010; Ndagurwa et al., 2013, 2014a). Such litter decomposes and releases nutrients faster than more recalcitrant litters (Ndagurwa et al., 2014b), and may also stimulate the decomposition of litter of co-occurring species (Quested et al.,

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2002). The enriched litter may also alter soil microbial communities and thus processes in which microbes are involved such as decomposition (Bardgett et al., 2006). In addition, due to a high leaf turnover and extended periods of litterfall, mistletoes increase overall litterfall which results in greater nutrient returns beneath mistletoe-infected trees than beneath uninfected trees (March, 2007; March and Watson, 2010). Collectively, these changes in litter quality, litterfall and decomposition rates are likely to result in an increase in soil nutrient concentrations with mistletoe infection.

We are aware of a few studies (e.g., Ndagurwa et al., 2013, 2014a) that have examined the influence of mistletoes on soil nutrient concentrations in semi-arid savanna, which limits our understanding of their ecological function. We studied soil nutrient concentrations beneath mistletoe-infected and uninfected trees (hereafter host and non-host trees, respectively) in semi-arid savanna. Specifically, we tested the hypothesis that soil nutrient concentrations would be greater beneath host than non-host trees. We suggest that this is due to increased litter quality, litterfall and decomposition rates beneath host trees (March, 2007; March and Watson, 2010; Ndagurwa et al., 2013, 2014a,b).

2. Materials and methods

2.1. Site description

The study was conducted in Nyamandi communal lands (Latitude 19°31′–19°40′S, Longitude 31°22′–31°33′E) in south eastern Zimbabwe. The area is relatively dry, and receives an average rainfall of 450 mm per annum (Department of Meteorological Services, 2011). The mean daily temperature recorded over the last 20 years is 22 °C, with a minimum and maximum temperature of 5 °C and 40 °C, respectively (Department of Meteorological Services, 2011). The vegetation of the area is Miombo and comprise species such *Brachystegia boehmii* Taub., *Brachystegia spiciformis* Benth., *Diospyros mespiliformis*, Hochst. ex A. DC., *Ficus sycomorus* L., *Grewia flavescens* Juss., *Julbernardia globiflora* (Benth.) Troupin, *Pseudolacnostylis maprouneifolia* Pax, *Peltophorum africanum* Sond., *Sclerocarya birrea* Hochst., *Securinega virosa* (Roxb.) Baill., *Strychnos spinosa* Lam, *Terminalia sericea* Burch. ex DC., and some Combretum species.

2.2. Study plants

Mistletoes and trees were surveyed in a semi-arid mixed farming communal land in December 2013. Four dominant species i.e. *D. mespiliformis*, Hochst. ex A. DC., *F. sycomorus* L., *S. birrea* (A. Rich.) Hochst., and *Strychnos spinosa* Lam. were chosen for the study. For each species, we randomly identified trees with (host) and without (non-host) adult mistletoes ($n = 6$ in each category or $n = 12$ for each species). The mistletoe species and number were also recorded for each tree. Five mistletoe species i.e., *Agelanthus subulatus* (Engl.) Polhill & Wiens (Loranthaceae), *Erianthemum dregei* (Eckl. & Zeyh.) Tiegh. (Loranthaceae), *Erianthemum ngamicum* (Sprague) Danser (Loranthaceae), *Viscum verrucosum* Harv. (Viscaceae) were identified in infected trees. *S. birrea* was infected by *A. subulatus*, *E. dregei*, and *E. ngamicum* whilst *D. mespiliformis* and *Ficus sycomorous* were infected by *V. verrucosum*, and *S. spinosa* was infected by *E. dregei*.

2.3. Soil sampling and chemical analyses

Soil samples were collected at 0–10 cm depth beneath host and non-host *D. mespiliformis*, *F. sycomorus*, *S. birrea*, and *S. spinosa* trees ($n = 6$ in each species) in December 2013. At each tree, soil cores were collected in four cardinal directions (N, E, S, W) midway between canopy edge and tree bole (Mlambo et al., 2005; Ndagurwa et al., 2013, 2014a). Samples within each tree were bulked, mixed thoroughly and a composite sample was drawn for analysis. Before air drying, the soils were passed through a 2-mm mesh sieve to discard fine roots and rocks >2 mm in size. Soil samples were analysed for mineral nutrients, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Total nitrogen was determined by the Kjeldahl method, available P was estimated by colorimetry using the ascorbic acid–molybdate method, and K, Ca, and Mg were quantified by atomic absorption spectroscopy (Anderson and Ingram, 1993).

2.4. Statistical analysis

All data were tested for normality before analysis. We used one-way analysis of variance (ANOVA), followed by Tukey's HSD-test ($p < 0.05$), to analyse the difference in the number of mistletoes among the four tree species (*D. mespiliformis*, *F. sycomorus*, *S. birrea*, and *S. spinosa*). The effect of species (*D. mespiliformis*, *F. sycomorus*, *S. birrea*, and *S. spinosa*, S), infection status (Host/Non-host, St), and their interaction on soil nutrient concentrations was tested using a general linear model (GLM) with simple contrast. An independent *t*-test was used to compare soil nutrient concentrations between host and non-host trees. The effects were considered to be significant at probability less than 0.05. All statistical tests were conducted in SPSS 16 for Windows (SPSS Inc., 2007, Chicago, IL U.S.A).

3. Results

Mistletoe infection intensity significantly differed ($F_{3, 16} = 6.58$, $p = 0.004$) among the tree species, with the highest number of mistletoes in *D. mespiliformis* and *S. birrea* and the least in *S. spinosa* (Fig. 1). *D. mespiliformis*, *F. sycomorus*, and *S. birrea* had more than twice the number of mistletoes in *S. spinosa* (Fig. 1). The soil pH significantly varied with infection status and its interaction with species (Table 1), being higher beneath host than non-host trees (Table 3). Soil nutrient concentrations significantly varied with species, status, and their interaction (Table 1). Soil N concentration

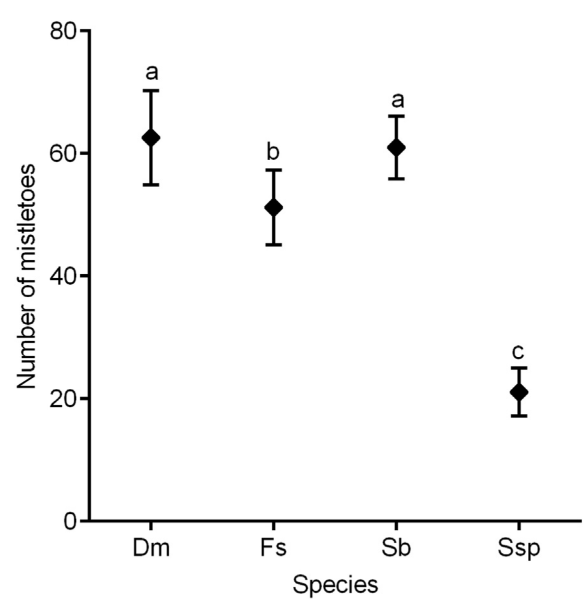

Fig. 1. Mean (±SE) number of mistletoes in *D. mespiliformis* (Dm), *F. sycomorus* (Fs), *S. birrea*, (Sb) and *S. spinosa* (Ssp) trees in a southern African savanna. Different letters (a, b, c) denote significant differences at $p < 0.05$ based on Tukey test; error bars show the standard error of the mean.