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Journal Title: Australian journal of Ecology
Volume: 23
Issue: 5
Month/Year: 1998
Pages: 492-496

Article Author: Garkaklis MJ, Bradley JS, Wooller RD
Article Title: The effects of woylie (Betongia penicillata) foraging on soil water repellency and water infiltration in heavy textured soils

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Australian Journal of Ecology (1998) **23**, 492–496

Short note

The effects of Woylie (*Bettongia penicillata*) foraging on soil water repellency and water infiltration in heavy textured soils in southwestern Australia

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Abstract In the wheatbelt region of Western Australia, brush-tailed bettongs or woylies, *Bettongia penicillata*, occur in remnant woodlands that have highly water repellent soils. As these marsupials dig for the fruiting bodies of hypogeous fungi they disturb the soil surface. The effect of these diggings was evaluated by laboratory and *in situ* assessments of soil water repellency. The undisturbed woodland soil surface showed severe water repellence whereas diggings had low water repellence, and appear to act as preferential water infiltration paths after autumn rainfall events. This indicates that *Bettongia penicillata* has an impact on the non-wetting property of soils in this region.

Key words: *Bettongia penicillata*, soil water repellency, water infiltration, woodland soils.

INTRODUCTION

Hydrophobic organic compounds derived from decomposing plant material and litter, fungal hyphae and microorganisms can make soils non-wetting or water repellent (Bond 1964; Roberts & Carbon 1972; DeBano & Rice 1973; King 1981; Ma'shum *et al.* 1988). This property is common to many soils in the southern part of Australia (McGhie & Posner 1980), particularly sandy soils in areas of South Australia and southwestern Australia (Bond 1969; King 1981; Ma'shum & Farmer 1985; Harper & Gilkes 1994). Water repellence causes a reduced infiltration rate of water (DeBano 1969), which coalesces on contact with the soil surface (King 1981; Dekker & Ritsema 1994), resulting in an uneven infiltration pattern into soils (Burcar *et al.* 1994; Harper & Gilkes 1994; Ritsema & Dekker 1994).

The non-wetting property of soils often occurs as a crust-like surface feature, with a thin intensely repellent layer acting as a barrier to an underlying wettable soil (DeBano & Rice 1973). Any disturbance to this water-repellent, surface layer would provide a site of wettable soil through which water could infiltrate. This study examines the effect that digging, associated with the foraging activity of the brush-tailed bettong or woylie (*Bettongia penicillata* Gray 1837), has on a heavy-textured, water repellent soil in south-western Australia. The potoroos and bettongs, including *B. penicillata*, are small kangaroo-like marsupials in the family Potoroidae (Strahan 1983; Start *et al.* 1995). Like several other bettong species, *B. penicillata* feed extensively on the hypogeous fruiting bodies of ectomycorrhizal fungi (Christensen 1980; Lamont *et al.* 1985; Malajczuk *et al.* 1987; Taylor 1992; Claridge & May 1994; Johnson 1994, 1997). During feeding they make a large number of small diggings that disturb the soil surface.

METHODS

This study was in Dryandra Woodland (32–48′S, 116°54′E), 200 km southeast of Perth, in the wheatbelt region of Western Australia. The vegetation associations included a *Eucalyptus wandoo* woodland on mid to lower slopes, with lateritic woodlands of *E. accedens*, *E. wandoo*, *E. calophylla* and *E. marginata* on the upper slopes and plateaux (Coates 1993). This region experiences a Mediterranean climate and lies between the 500 mm and 600 mm rainfall isohyets (Coates 1993).

Soil water repellency was determined from soil samples collected in the field and assessed both in the laboratory and *in situ*. Laboratory determinations were made using the Molarity of Ethanol Droplet (MED) technique of King (1981), in which water repellency was expressed as the molarity of aqueous ethanol solution required to facilitate droplet penetration into the soil sample within 10 s. The severity of soil water repellency was classified as very low (MED < 0.1 molar ethanol solution), low (0.1–1.0), moderate (1.2–2.2),

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Accepted for publication May 1998.

severe (2.4–3.0) or very severe (MED > 3.0 molar ethanol solution), following King (1981). The very low category indicates that a pure water droplet was absorbed immediately upon contact with the soil. *In situ* determinations of soil water repellency used the same classification and a modified version of the MED technique in which droplets of ethanol solution were delivered directly to the soil surface after litter and plant debris had been gently removed from it. The two methods were used to allow for a broad comparison of non-wetting in Dryandra soils with other studies that employed the laboratory MED technique, while *in situ* measurements provided a measure of soil water repellency in the vicinity of the digging without further disturbance of the soil in the digging itself.

Six soil samples were collected at random during April 1995 from each of three parallel 400 m long transects, also placed at random, within a survey area of ~1.2 km^2. Surface soils were collected from 10 cm × 10 cm areas to a depth of 1 cm. Seven of the samples were from *E. wandoo* woodland and 11 from lateritic woodland. The samples were air dried and lightly sieved to remove material greater than 2 mm diameter. Five determinations of MED were conducted on each sample, then averaged.

The *in situ* measurements were made at a *B. penicillata* digging closest to each sample point on 24–28 April 1995 and on 17–18 April 1996. Different diggings were selected in each year. Although *B. penicillata* diggings vary in size, they have a similar shape (Fig. 1). They are characterized by a steep wall (7 and 8 in Fig. 1), formed as the animal digs downward, a shallow wall formed as the animal pushes soil beneath it (4 and 5), and a spoil heap of material formed as soil is ejected from the digging to the rear of the animal (2 and 3 in Fig. 1). This digging process results in a disturbance area, including the spoil heap, which is roughly elliptical when observed from above. The *in situ* measurements of water repellency at digging sites were made along the long axis of the digging, to include the spoil heap. Five *in situ* MED measurements were made at 2.5 cm intervals along this axis, and the depth below or above the soil surface at each point was recorded. These measurements were extended 10 cm in each direction beyond the digging to obtain water repellency values for the surrounding undisturbed soils. Since each digging had different dimensions, water repellency values are reported only at distinct points along the diggings that are common to each (Fig. 1).

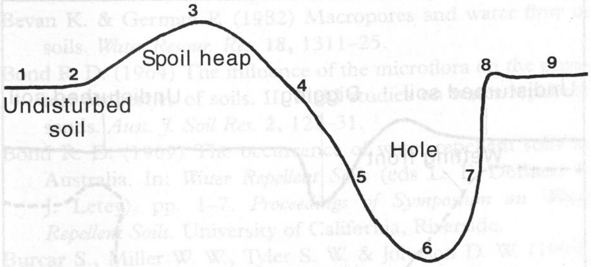

Fig. 1. Schematic representation of a typical *Bettongia penicillata* digging showing points common to all diggings at which mean *in situ* water repellence is reported. 1, Soil surface; 2, start of digging spoil; 3, spoil heap mid-point; 4, back-lip of digging; 5, back-wall mid-point; 6, bottom of digging; 7, front-wall mid-point; 8, front-lip of digging; 9, soil surface.

Levene's test for homogeneity of variance (Kinnear & Gray 1994) showed a highly significant ($P < 0.005$) heterogeneity of variance between MED values at the sampling points, indicating that non-parametric procedures were appropriate (Zar 1984). A Kruskal–Wallis Analysis of Variance test was used (Kinnear & Gray 1994). Non-parametric Tukey-type multiple comparisons (Zar 1984), using the calculated mean ranks were used in *a posteriori* analyses.

Water infiltration patterns in the soil were examined on 11 May 1995 after the first substantial winter rainfall. The soil profile was exposed through the long axis of 12 additional diggings to a depth of ~45 cm, and into undisturbed soils adjacent to each digging. Soil water content was determined from subsoil samples directly beneath the digging and in the undisturbed area. Sub-soil colour in these two zones was also noted and the soil profiles were photographed. Samples were weighed and dried at 60°C to a constant weight. Water contents were expressed as the percentage difference between fresh and oven dried weights. Comparison of the subsoil water contents in the zones below the diggings with those in adjacent areas of undisturbed soil showed a large spread of values and a low Pearson correlation coefficient ($r = 0.11$) between them. Therefore, the non-parametric Sign Test was used to test the means between these groups (Zar 1984).

RESULTS

Of the soil water repellence values determined in the laboratory, two-thirds were very severe or severe. The mean MED values for the *E. wandoo* and lateritic woodland soils were 2.4 ± 0.5 and 2.6 ± 0.4, respectively. Thus, soil water repellency was apparent over the entire sampling area, with most soils highly water repellent. Measurement of *in situ* water repellence revealed the same pattern for each digging (Fig. 2). Undisturbed woodland soils averaged MED values greater than 2.0 in both years (Fig. 2). At the edge of a digging spoil, water repellency fell sharply from severe to low and remained low throughout the entire disturbed region, albeit with a slight increase in water repellence at the bottom of the hole (Fig. 2). Non-parametric ANOVA analysis, using a Kruskal–Wallis test corrected for ties, indicated that differences in the mean *in situ* MED values were highly significant ($\chi^2 = 93.68$, d.f. = 8 in

1995 and $\chi^2 = 93.96$, d.f. = 8 in 1996; $P < 0.00005$). Non-parametric multiple comparisons showed that the undisturbed woodland soil MED values were significantly higher than those for the disturbed soils in the diggings ($P < 0.025$ for the bottom of the hole; $P < 0.001$ for all other sampling points).

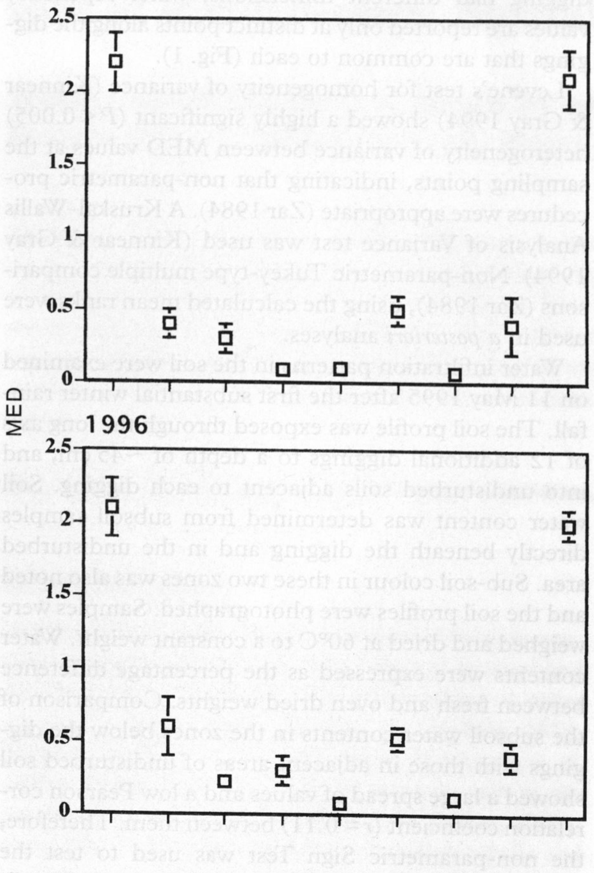

Fig. 2. Schematic representation of depth in *Bettongia penicillata* diggings and the corresponding mean Molarity of Ethanol Droplet measure of water repellence (±SE) in 1995 and 1996.

After heavy rainfall, distinct colour differences were clearly visible in the soil profiles near diggings, indicating preferential water infiltration via *B. penicillata* diggings (Fig. 3). Sub-soil water content was significantly greater in the darker soils (15.0% ± 0.5%) below each digging, compared with the paler soils (9.6% ± 0.3%) in the undisturbed zones ($P = 0.0063$) (Fig. 3).

DISCUSSION

The variable nature of soil water repellency in Dryandra Woodland is typical of other water repellent soils. Discontinuities in water repellency that give rise to an uneven water infiltration pattern have been recorded in North America (Burcar *et al.* 1994; Dekker & Ritsema 1994). At Dryandra, additional discontinuities appear to result from the diggings made by *B. penicillata*, which create water absorbent sites within the surface of a predominantly water repellent landscape.

From a two dimensional perspective, this type of disturbance appears to create a water absorbent site that includes both the spoil heap and the actual digging, but the undisturbed soil surface covered by spoil is likely to remain highly water repellent.

Fig. 3. Water infiltration pattern after rainfall in the vicinity of a *Bettongia penicillata* digging.

General observations of soils in this area indicate that the digging activity by *B. penicillata* is very extensive. However, it is difficult to assess the ecological impact of this digging upon plant water relations and nutrient cycling in woodlands where soils are non-wetting. Uneven water infiltration through large pores in forest soils leads to a channelling of nutrients through these preferential flow paths in North American soils (Bevan & German 1982; Moore *et al.* 1986; Burcar *et al.* 1994). The preferential flow paths created by discontinuities in soil water repellency due to *B. penicillata* digging may provide similar conditions for nutrient channelling. The large-scale disturbance of soils has been found to be an important factor in the regeneration of *Eucalyptus salmonophloia* in Western Australia (Yates *et al.* 1994). Digging by *B. penicillata*, and cultivation by other species like the superb lyrebird (Ashton & Bassett 1997) provide smaller scale disturbance regimes for Australian woodland and forest soils.

Small and large fauna have been recognised as important factors in the development of soil structure and soil characteristics (Grinnell 1923; Kay 1990). Clearly *Bettongia penicillata* does affect soil water repellency but the role of vertebrates in water relations, nutrient cycling and disturbance processes within soil environments that are water repellent remains to be explored.

ACKNOWLEDGEMENTS

We thank the Department of Conservation and Land Management, Western Australia, for access to Dryandra Woodland and Dr Tony Start for comments on a draft of the manuscript. The work was supported by a Murdoch University Research Studentship.

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