A COMPARISON OF CANEFIELD SOIL TYPES ON ROOT HERBIVORE PERFORMANCE AND FEEDING

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Introduction

Soil nutrients and quality are important factors, not only for plant growth but also for belowground herbivore performance (Barnett and Johnson, 2013; Erb and Lu, 2013), and can be a driving factor for grassland communities (Russell, 1973). Indeed, for many managed grassland and grass crop systems, the application of nutrient fertilisers is common practice to ensure maximum growth and yield. However, fertilisers are often applied without any characterisation of base soil nutrient concentrations or availability. Therefore, fertiliser application could often be unnecessary and can potentially be both economically and ecologically damaging (Stevens et al., 2004; Tilman, 1999).

The larvae of the greyback cane beetle (*Dermolepida albohirtum* (Waterhouse)), known as canegrubs, are found across the state of Queensland. These insects feed on the roots of native grasses, previously causing damage to floodplains, grasslands and forest understories (Allsopp, 2010). However, with the introduction of sugarcane (*Saccharum* spp. hybrids) to Australia, these insects switched hosts to become economically significant pests of the sugar industry. Sugarcane is a grass crop grown across eastern Queensland and far north New South Wales, Australia. The economic significance of sugarcane and the canegrub provided a good model grass species to test the impacts of soil nutrient variations on plant growth and insect performance.

This research assesses the soil nutrients of two sugarcane field soils (soil A and soil B) located in the Gordonvale region of Queensland, Australia. These soils are anecdotally known to vary in quality and in persistence of canegrub populations, yet the soils remained uncharacterised. We focus on several key soil nutrients known to play an important role in plant growth and insect performance (e.g. nitrogen, carbon, silicon). We assess the impacts of the different soil nutrient concentrations on plant growth and canegrub performance.

Methods

Soil and soil analyses

Two different soils (soil A and soil B) were excavated from agricultural sugarcane fields located within the Gordonvale region of tropical north Queensland, Australia, located in the southern side of Cairns. Soil A site sits at 22.7 m a.s.l. elevation (17°03'48.8"S, 145°46'45.9"E), soil B site is located west of this, at 19m a.s.l. elevation (17°04'47.5"S, 145°50'37.7"E). This region experiences a tropical climate with high rainfall (mean 422.5 ml/month) between December and March. Soils at both sites are light loam soils with relatively low organic matter (1–3%) that are anecdotally known to differ in plant quality production and infestation of canegrubs. Fertilisers had not been applied to either site for at least 12 months. Prior to use, the bulk soil was sterilised by gamma-irradiation to minimise any microbial effects and thoroughly homogenized. A 250 g sample of each soil type was sent for nutrient analysis to the Environmental Analysis Laboratory (Southern Cross University), Lismore, Australia (see Table 1). Methods mentioned in Table 1 for soil nutrient analysis are fully described in Rayment and Lyons (2011).

Plant growth conditions

Forty sugarcane (*Saccharum* species hybrids: Poaceae) plants of Q138, a commonly grown variety within Australia, were grown from single-eye cuttings. Plants were germinated in trays of gamma-irradiated potting mix (Richgro© All Purpose Potting Mix), receiving tap water ad libitum for three weeks in a shade house. All plants were then transferred to 10 L pots with either soil A or soil B. Pots were randomly distributed on benches within a shade house and received natural light throughout. Mean day and night temperatures throughout the growth period were 26.5 °C and 16.2 °C respectively. All pots received water ad libitum. Every two weeks all pots were randomly re-arranged within the shade house to reduce any spatial effects.

Plants were grown for 26 weeks before being harvested. After this time all plants were removed from their pots and the plant material was placed in a 40°C oven for 48 hours, and then weighed for biomass.

Feeding assays

To assess the impacts of the two soil types on the growth and food utilisation by canegrubs, we conducted feeding trials using an approach adapted from Massey and Hartley (2009). Individual third instar larvae were starved for 24 hours and weighed before being placed in a Petri dish (14 cm diameter) with a known mass of fresh sugarcane root material, taken from the harvested sugarcane plants. Larvae were allowed to feed for 24 hours, after which time they were starved for a further 12 hours to ensure all frass had passed, before being reweighed. Values of water content, derived from root samples from the same plants, were used when converting fresh mass of roots to dry mass, to account for any evaporative water loss during of the experiment. Food utilisation indices were calculated according to Slansky (1985):

- Relative growth rate (RGR), calculates body mass growth relative to initial body mass, calculated as: mass gained (g)/initial mass (g)/time (days)
- Efficiency of conversion of ingested food (ECI) estimates the percentage of food ingested that is converted to body mass, calculated as: mass gained (mg change in fresh body mass)/food ingested (mg change in dry mass) × 100

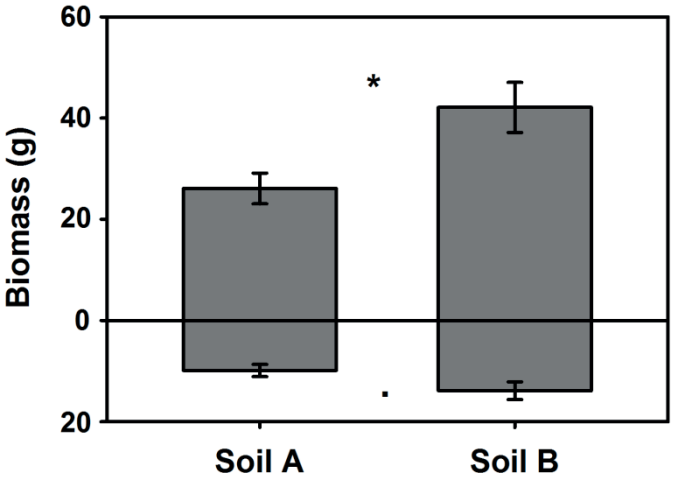
→ Efficiency of conversion of digested food (ECD) estimates the percentage of assimilated food converted into body mass, which is calculated as: mass gained (mg change in fresh body mass)/ food ingested (mg change in dry mass) – frass mass (mg dry mass) × 100

Results and Discussion

Soil A had a higher C:N ratio by 74% and also had 36% higher phosphorus concentrations compared with soil B. Soil B had higher concentrations of several important nutrients (Table 1). This included 235% higher total calcium, 68% higher total potassium and 60% higher total silicon. Soil B also had 78% higher plant available silicon, compared to Soil A.

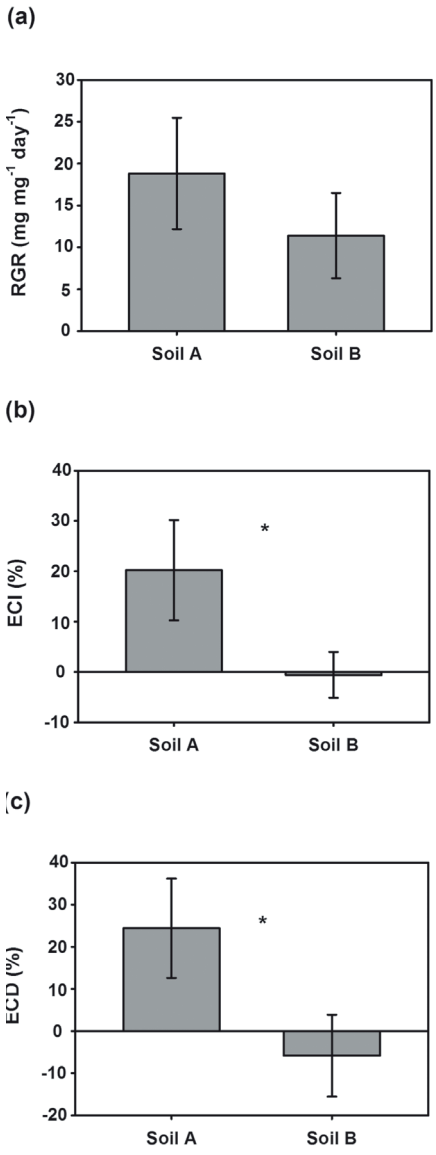
The aboveground plant biomass was significantly higher under soil B compared to soil A ($F_{1,19}$= 7.9, *P* = 0.02), possibly due to higher soil phosphorus and silicon concentrations. Belowground biomass was marginally higher under soil B ($F_{1,19}$= 3.6, *P* = 0.07), again possibly due to higher silicon availability in the soil. This was not unexpected as silicon is known to promote the growth of many grass species (see Ma and Yamaji, 2006 and references therein).

Figure 1.
Aboveground and belowground biomass (g) of sugarcane grown within soil A and soil B. Mean values (±SE) shown. Significant terms indicated by . (P < 0.1), * (P < 0.05).



The relative growth rate of the larvae was not significantly different between the two soil types ($F_{1,19}$= 0.79, *P* = 0.38), however larvae tended to have lower mean growth rates in soil B. This is interesting as soil B typically has higher levels of nutrients such as potassium, calcium and magnesium. Larval efficiency of conversion of ingested food ($F_{1,19}$= 3.59, *P* = 0.04) and digested food ($F_{1,19}$= 3.93, *P* = 0.04) were significantly reduced under soil B compared with soil A. Both the total and available soil silicon were higher in soil B, which potentially explains these reductions in food utilisation efficiency as plant silicon is known to reduce root herbivore performance (Frew et al., 2016).

Figure 2.
(a) Relative growth rate (mg g^{-1}), (b) efficiency of conversion of ingested food (%) and (c) efficiency of conversion of digested food (%) of canegrubs (*D. albohirtum*) feeding on sugarcane roots grown in soil A and soil B. Mean values (±SE) shown. Significant terms indicated by . (P < 0.1), * (P < 0.05).



The results from our study indicate that variations in soil nutrients can potentially impact on plant growth and root herbivore performance. Our data suggests that differences in agricultural field soil silicon are sufficient to potentially promote plant growth while reducing performance of a root feeding insect. As many grasses are high silicon accumulators (Ma and Yamaji, 2006) these findings have implications not only for sugarcane crops, but also for the management of natural and managed grasslands across Australasia that are often damaged by root feeding insects. We suggest that initial tests of soil nutrient concentrations are implemented in managed grasslands and grass crops, prior to fertiliser applications. This way, targeted nutrient fertiliser application can be applied where necessary, avoiding unnecessary costs and damage to the environment.

Table 1.
Results from nutrient analysis of two field soils. Analysis carried out by Environmental Analysis Laboratory, Southern Cross University, Lismore, Australia. LECO IR analyser and total acid extractable techniques give an indicator of a store of nutrients while $CaCl_2$ extractable indicates nutrient availability for plant growth.

Method	Nutrient		Units	Soil A	Soil B
LECO IR Analyser	Carbon	C	%	2.20	1.08
	Nitrogen	N	%	0.11	0.09
	C:N ratio			20	11.5
Total Acid Extractable	Calcium	Ca	mg/kg	348	1,167
	Magnesium	Mg		401	752
	Potassium	K		983	1,653
	Sulfur	S		120	192
	Phosphorus	P		363	266
	Silicon	Si		1,392	2,221
	Aluminium	Al		9,880	13,854
$CaCl_2$ Extractable	Silicon	Si	mg/kg	23	41
	Boron	B		0.17	0.35

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