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Original Article

Extracts of *Lomandra hystrix* Labill. Aerial Parts Lack Antibacterial Activity and are Non-toxic *in vitro*

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ABSTRACT

Introduction: The development of bacterial strains that are resistant to multiple antibiotics has made the discovery of new antibiotics a priority for medical research. Examination of plants for new antimicrobial agents is an attractive prospect and numerous recent studies have screened plants for antibacterial activity. Despite this, many plant species are yet to be tested for antibacterial activity. *Lomandra hystrix* Labill. is a perennial rhizomatus herb of the family Asparagaceae that grows widely throughout eastern Australia The antibacterial properties of this plant are yet to be studied against human pathogens. **Methods:** The ability of extracts prepared from *L. hystrix* aerial parts to inhibit the growth of a panel of bacterial pathogens was investigated by disc diffusion assay. Toxicity was examined using the Artemia franciscana nauplii bioassay. **Results:** *L. hystrix* methanolic and aqueous extracts were ineffective at inhibiting the growth of panels of gram-positive and gram-negative bacteria. The extracts were non-toxic or of low toxicity in the *Artemia nauplii* bioassay following 24 hr exposure. **Conclusion:** The *L. hystrix* extracts lacked growth inhibitory bioactivity against a panel of pathogenic bacteria and were non-toxic in the *Artemia nauplii* assay. However, these extracts may have other therapeutic properties and testing against protozoa, fungi, virus and tumour cells is required.

Key words: Asparagaceae, Green mat-rush, Antibiotic resistance, Antibacterial activity, Traditional medicine, Medicinal plants, Toxicity.

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INTRODUCTION

In recent years, the development of bacterial pathogens that are either extremely (XDR) or totally drug resistant (TDR) to common clinically used antibiotics[1] has resulted in the need to develop new antibiotic chemotherapies. There are now limited therapeutic options for many diseases caused by bacterial pathogens and the situation is expected to worsen in the future as bacteria exchange resistance genes via conjugation. Indeed, the development of alternative antibacterial treatment modalities has become crucial and is considered by the World Health Organisation (WHO) to be one of the most serious challenges facing medical science.[2] For a number of reasons reviewed elsewhere,[1] it is unlikely that the previous methods of antibiotic discovery/development will be as successful in the future and new treatment modalities are urgently required. Traditional medicines and herbal remedies have great potential for antimicrobial drug development and there has recently been a substantial increase in interest in this field.[3-14]

Despite the potential of plants to provide us with useful pharmaceutical agents, the field is still relatively poorly studied. Only an estimated 5-10 % of the approximately 300, 000-500, 000 plant species worldwide have been screened for 1 or more bioactivities.[15] *Lamandra hystrix* Labill. (commonly known as green mat-rush' creek mat-rush; synonyms *Lomandra longifolia* subsp. *hystrix* R.Br., *Xerotes hystrix* (Labill.) R.Br.; Figure 1) is a robust tufted perennial rhizomatus herb that grows throughout the eastern states of Australia. It has flat, strap-like flat leaves (up to 100cm long and 2cm wide) and whorled flower clusters (Figures 1b) that contain white to yellow cylindrical flowers (Figure 1c). Little evidence is available about the use of *Lamandra hystrix* medicinally.[16] We were also unable to find any studies examining the antibacterial activity of this species against any bacterial species. Similarly, there is a lack of information on the phytochemical composition of this species. This study was undertaken to screen extracts prepared using *L. hystrix* aerial parts for the ability to inhibit the growth of a panel of gram-positive and gram-negative bacterial pathogens of importance to human health.

MATERIALS AND METHODS

Collection of plant material and extraction

Lomandra hystric Labill. aerial parts were obtained from and identified by Philip Cameron, senior botanic officer, Mt Cootha Botanical Gardens, Brisbane, Australia. The plant material was thoroughly washed in deionised water and dried in a Sunbeam food dehydrator dried within 4 hours of collection. The dried plant material was subsequently ground to a coarse powder using a coffee grinder. Individual 1g masses of the dried plant material was extracted extensively in 50mL methanol (Ajax Fine Chemicals Australia, AR grade) or deionised water for 24h at 4°C with gentle shaking. The extracts were filtered through filter paper (Whatman No. 54) under vacuum followed by drying by rotary evaporation. The resultant pellet was dissolved in 5mL deionised water (containing 1% DMSO) and passed through 0.22µm filter (Sarstedt) and stored at 4°C until use.

Qualitative Phytochemical Studies

Phytochemical analysis of the *L. hystrix* extracts for the presence of saponins, phenolic compounds, flavonoids, phytosteroids, triterpenoids, cardiac glycosides, anthraquinones, tannins and alkaloids was conducted using standard assays.[17-19]

Antibacterial screening

Test micro-organisms

All media was purchased from Oxoid Ltd., Australia. The reference strains of *E. coli* (ATCC157293), *Klebsiella pneumoniae* (ATCC31488), *Proteus mirabilis* (ATCC21721) and *Streptococcus pyogenes* (ATCC19615) were purchased from American Tissue Culture Collection (ATCC), USA. Clinical isolate microbial strains of *Aeromonas hydrophilia*, *Alcaligenes feacalis*, *Bacillus cereus, Citrobacter freundii*, *Pseudomonas fluorescens*, *Salmonella newport, Serratia marcescens, Shigella sonneii, Staphylococcus aureus* and *Staphylococcus epidermidis* strains were obtained from Ms

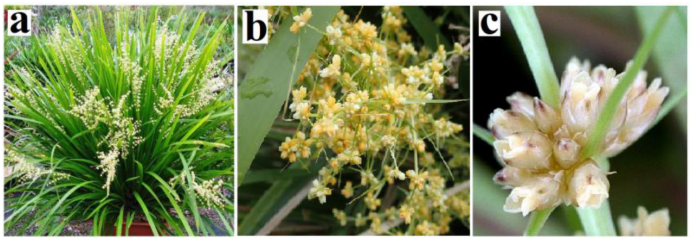

Figure 1: *L. hystrix* (a) whole plant, (b) inflourescence and (c) close up of flowers.

Michelle Mendell and Ms Jane Gifkins, Griffith University. All stock cultures were subcultured and maintained in nutrient broth at 4°C.

Evaluation of antimicrobial activity

Antimicrobial activity of the *L. hystrix* extracts was determined using a modified disc diffusion assay.[20-23] Briefly, 100µL of the each bacterial suspension in log phase was spread onto individual nutrient agar plates and the extracts were tested for antibacterial activity using 6mm sterilised filter paper discs. The discs were each infused with 10µL of the individual plant extract, allowed to dry and placed onto the inoculated plates. The plates were allowed to stand at 4°C for 2hr before incubation at 37°C for 24hr. The diameters of the zones of inhibition (ZOIs) were measured to the closest whole millimetre. Each assay was performed three times in triplicate (n=9). Mean values (± SEM) are reported in this study. Standard discs of ampicillin (10µg) and chloramphenicol (10µg) were obtained from Oxoid Ltd., Australia and were used as positive controls to compare antibacterial activity. Filter paper discs infused with 10µL of distilled water were used as a negative control.

Artemia franciscana nauplii toxicity screening

Toxicity was tested using an adapted *Artemia franciscana* nauplii lethality assay.[24-26] Briefly, *A. franciscana* nauplii were incubated in the presence of the extracts, reference toxin (1mg/mL potassium dichromate) or artificial seawater (negative control) at 25±1°C under artificial light. All treatments were performed three times, each with internal triplicates (n=9). The number of dead were counted in each well at 24hr, 48hr and 72hr. At the completion of the 72hr exposure period, the remaining live nauplii were sacrificed by acidification of the seawater and the total number of nauplii in each well were counted and used to calculate the % mortality per well. LC_{50} values were calculated for each treatment using probit analysis.

Statistical analysis

Data are expressed as the mean ± SEM of three independent experiments with internal triplicates (n=9). One way ANOVA was used to calculate statistical significance between control and treated groups, with a P value < 0.01 considered statistically significant.

RESULTS

Liquid extraction yields and qualitative phytochemical screening

Extraction of 1g of dried and powdered *L. hystrix* plant material with methanol and water yielded 287 and 225mg of extracted material respectively (Table 1). The extracts were resuspended in 10mL of deionised water (containing 1% DMSO), resulting in the extract concentrations shown in Table 1. Qualitative phytochemical screening studies showed that both extracts had similar phytochemical profiles. Both contained moderate to high levels of phenolic compounds, flavonoids, tannins and saponins. Lower levels of triterpenoids were also detected in both extracts. Low levels of alkaloids were also detected in the methanolic extract, but were below the detection threshold in the aqueous extract. Cardiac glycosides and anthraquinones were completely absent or below the detection thresholds for both extracts in these assays.

Table 1: The mass of dried extracted material, the concentration after resuspension in deionised water and qualitative phytochemical screenings of the *L. hystrix* extracts.

			Methanolic extract	Aqueous extract
	Mass of extracted material (mg)		325	270
	Concentration of resuspended extract (mg/mL)		32.5	27
Qualitative Phytochemical Tests	Phenols	Total phenols	+++	+++
		Water soluble phenols	++	++
		Insoluble phenols	+	+
	Saponins	Froth persistence	+++	++
		Emulsion test	+	+
	Cardiac glycosides	Keller-Kiliani Test	-	-
	Triterpenoids	Salkowski Test	+	+
	Phytosterols	Acetic Anhydride Test	++	++
	Alkaloids	Meyer's Test	+	-
		Wagner's Test	+	-
		Draggendoff's Test	-	-
	Flavonoids	Kumar Test	+++	++
	Tannins	Ferric Chloride Test	++	++
		Lead Acetate Test	+	+
	Anthraquinones	Free	-	-
		Combined	-	-

+++ indicates a large response; ++ indicates a moderate response; + indicates a minor response; - indicates no response in the assay.

Antibacterial activity

To determine the growth inhibitory activity of the *L. hystrix* extracts, aliquots (10µL) of each were screened individually by disc diffusion assay. The *L. hystrix* extracts were ineffective at inhibiting the growth of all gram-negative (Figure 2) and nearly all gram-positive (Figure 3) bacterial species tested. Indeed, only *B. cereus* was susceptible to the methanolic *L. hystrix* extract, and even then, the ZOI (7mm) indicated only relatively low inhibitory activity. In contrast, both positive control antibiotics (ampicillin and chloramphenicol) were effective growth inhibitors, with ZOI's of up to 14.3mm (chloramphenicol against *E. coli*). We were therefore unable to determine the MIC values for either extract against any bacteria.

Quantification of toxicity

The toxicity of the *L. hystrix* extracts was initially tested at 2mg/mL in the *A. franciscana* nauplii bioassay (Figure 4). The mortality in the presence of both extracts was not significantly different to that of the untreated control at 24h and thus both extracts were deemed to be non-toxic. Extracts with 24hr LC_{50} values >1000µg/mL have previously been defined as non-toxic.[24] In contrast, the potassium dichromate positive control induced substantial mortality within 4hr (results not shown), with 100% mortality induction seen by 24hr. The mortality increased

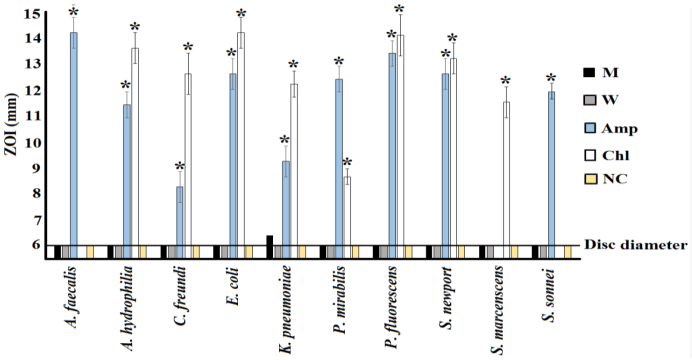

Figure 2: Growth inhibitory activity of *L. hystrix* extracts and reference antibiotics against gram-negative bacterial species measured as ZOIs (mm) ± SEM. Ampicillin (Amp) and chloramphenicol (Chl) standard discs (10µg) were used as positive controls. M = methanolic extract; W = aqueous extract; NC = negative control. All assays were completed three times, each with internal triplicates (*n*=9) and the results are expressed as mean zones of inhibition (mm) ± SEM.

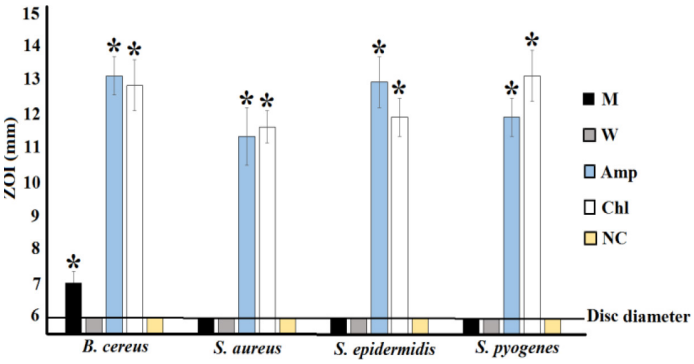

Figure 3: Growth inhibitory activity of *L. hystrix* extracts and reference antibiotics against gram-positive bacterial species measured as ZOIs (mm) ± SEM. Ampicillin (Amp) and chloramphenicol (Chl) standard discs (10µg) were used as positive controls. M = methanolic extract; W = aqueous extract; NC = negative control. All assays were completed three times, each with internal triplicates (*n*=9) and the results are expressed as mean zones of inhibition (mm) ± SEM.

following exposure to the *P. australis* extracts at 48hr and was further increased following 72hr exposure.

DISCUSSION

Due to recent increases in bacterial resistance to many antibiotics, the development of new antibiotic chemotherapies is a high priority for medical science.[1,2] A concurrent decrease in the discovery of new antibiotic medicines by conventional strategies has increased interest in evaluating plants as antibiotic chemotherapies.[27] As *L. hystrix* has not been rigorously tested for any therapeutic activity, it was deemed a viable target for antibacterial screening. Interestingly, the *L. hystrix* methanolic and aqueous extracts were inactive against all gram-positive and gram-negative bacteria tested. However, it is noteworthy that a single assay technique was used to screen for antibacterial activity in this study. We chose to use the disc diffusion assay as it is rapid and it has previously been widely utilised in other studies. Therefore, comparisons between studies are relatively simple.

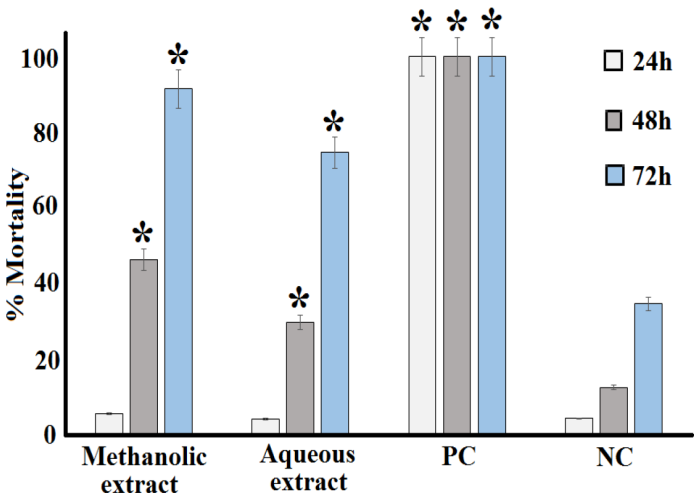

Figure 4: The lethality of the *L. hystrix* leaf extracts, potassium dichromate control (1000µg/mL) and seawater (negative control) following 24, 48 and 72 hr of exposure. All bioassays were performed three times in triplicate (*n*=9) and are expressed as mean ± SEM. * indicates results that are significantly different to the untreated (seawater) control at the equivalent exposure time ($P<0.01$).

As the disc diffusion method is reliant on the diffusion of a molecule through the aqueous environment of an agar gel, this assay may be affected by the solubility of the extract compounds in the aqueous environment. Polar compounds that are highly soluble in water would be expected to diffuse easily in the gel, whereas less soluble compounds would not diffuse as readily and thus will be concentrated around the disc. For this reason, whilst this is a handy assay for screening aqueous extracts, this technique may not be ideal for nonpolar compounds (e.g. when screening essential oils and their components). For examining nonpolar mixtures, other techniques such as liquid dilution assays are preferred. Interestingly, the phytochemical screening studies presented herein reports the presence of saponins (which are relatively nonpolar) within the menthanolic and aqueous extracts. It is therefore possible that these compounds may not contribute significantly to the potential antibacterial activity of these extracts as they remain at or near the discs and are unable to diffuse through the solid agar media. Thus, the growth inhibitory activity of the *L. hystrix* extracts may have been significantly under estimated using this assay. Liquid dilution studies may have been better suited to screen the *L. hystrix* extracts for activity and future studies will use these techniques to re-examine the extracts for antibacterial activity.

Diffusion of molecules within an agar gel is also affected by the size of the molecules. The movement of large, complex phytochemicals (e.g. complex tannins) through agar gels by diffusion would also be retarded and may provide a false idea of the efficacy of an extract. As many tannins have well described antibiotic properties, screening for growth inhibition using agar diffusion techniques may give a distorted view of its inhibitory potential for extracts rich in these compounds.

The findings reported herein also indicate that the extracts examined were non-toxic (24 hr LC_{50} >1000µg/mL) in the *Artemia* nauplii bioassay. Whilst toxicity was assessed in this study with the test organism *A. franciscana*, toxicity towards *A. franciscana* has previously been shown to correlate well with toxicity towards human cells for many toxins.[24] However, further studies are required to determine whether this is also true for the *L. hystrix* extracts examined in these studies.

CONCLUSION

Methanolic and aqueous *L. hystrix* extracts lacked antibacterial activity in the disc diffusion assay against a panel of human pathogenic bacteria. The extracts were non-toxic towards *Artemia* nauplii.

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CONFLICT OF INTEREST

The authors report no conflicts of interest.

ABBREVIATIONS

DMSO: Dimethyl sulfoxide; **LC_{50}:** The concentration required to achieve 50 % mortality; **MIC:** minimum inhibitory concentration; **ZOI:** zone of inhibition.

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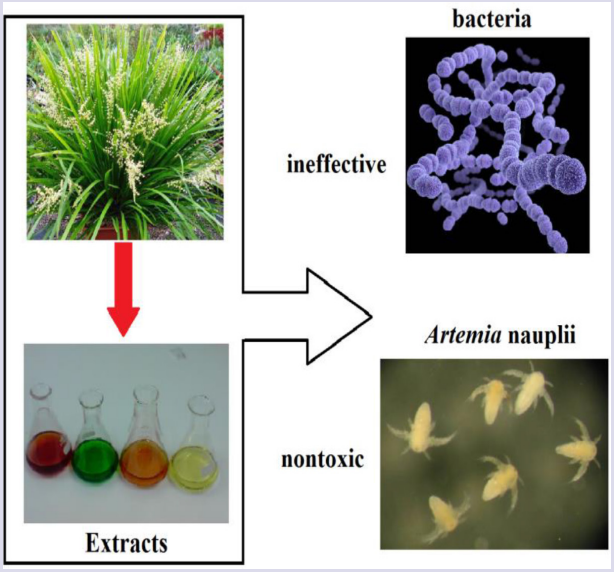
PICTORIAL ABSTRACT



SUMMARY

- *Lomandra hystrix* aerial part extracts were screened for the ability to block the growth of a panel of human bacterial pathogens.
- Low or no inhibitory activity was evident against the bacterial species tested
- Toxicity of the *P. australis* extracts was determined using the *Artemia* nauplii toxicity bioassay.
- Both the methanolic and aqueous extracts were non-toxic.

About Authors

Ms Getmore Chikowe completed at BSc at Griffith University in life sciences. Following graduation, she undertook a research project in Dr Ian Cock's laboratory in the School of Natural Sciences at Griffith University. The project examined the growth inhibitory properties of a variety of Australian native plants against an extensive panel of bacterial pathogens.

Dr Ian Cock leads a research team in the Environmental Futures Research Institute and the School of Natural Sciences at Griffith University, Australia. His research involves bioactivity and phytochemical studies into a variety of plant species of both Australian and international origin, including Aloe vera, South Asian and South American tropical fruits, as well as Australia plants including Scaevola spinescens, Pittosporum phylliraeoides, Terminalia ferdinandiana (Kakadu plum), Australian Acacias, Syzygiums, Petalostigmas and Xanthorrhoea johnsonii (grass trees). This range of projects has resulted in nearly 250 publications in a variety of peer-reviewed journals.

Ms Lindiwe Mpala completed at BSc at Griffith University in life sciences. Following graduation, she undertook a research project in Dr Ian Cock's laboratory in the School of Natural Sciences at Griffith University. The project examined the growth inhibitory properties of a variety of Australian native plants against an extensive panel of bacterial pathogens.

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