WESTERN SYDNEY UNIVERSITY

School of Science

Summer Scholarship Research Program 2021

Project Lists

Project 101: Towards 21st century materials: testing and evaluation of novel alkali-alumino-silicate (AAS) resins.

Supervisor(s): Christopher Jones - c.jones@westernsydney.edu.au
Principal Supervisor

Leon Burgess-Dean
Second Supervisor, External Partner, **CalAlSil**

Mariam Darestani - M.Darestani@westernsydney.edu.au
Third Supervisor

Project Description

CalAlSil™ is a Brisbane-based chemical and material technology company committed to the development of sustainable materials for the building and construction industry. Several years ago, the company identified a gap in the market for a sustainable, easily prepared and applied series of ceramic and ceramic-organic hybrid resins. Led by the founder, Dr Burgess-Dean, their work has recently resulted in the invention of the world's first alkali-alumino-silicate (AAS) resin system. These resins and their concretions and composites are applicable replacements for concrete, engineered wood, fired clay, organic polymer fibre composites and light metals and offer a new benchmark for the sustainable materials for the world's economy. An opportunity now exists for a materials engineering or chemistry student to partner with CalAlSil™ to investigate the novel structures and properties of some of these resins.

Project Aims

This project aims to use analytical and imaging techniques to provide a comparison of material and mechanical properties for CalAlSil™'s AAS-organic hybrid resin and composites. The project will produce a detailed evaluation of CalAlSil™'s chemical and structural character and fire properties compared with mechanical strength, fracture toughness and density. The results will provide a summary of the composite polymer's material properties so they can be compared with current fire retarded polymers and polymer concretes. This is an opportunity for a student to gain experience and knowledge in a broad range of advanced characterization techniques, including infrared spectroscopy, calorimetry and electron microscopy and to work across multiple WSU schools. Note: the student will have to sign a non-disclosure form to ensure protection of IP.

Project Methods

CalAlSil™ will provide polymer mixtures based on their proprietary formulations. These will be based on three main composites - CalAlSil™NC AAS/Organic Polymer; CalAlSil™NF AAS/Organic Polymer and E-Type Glass Fibre/CalAlSil™NC AAS/Organic Polymer Composite.

Each of the different formulations will have a series of analytical and material testing performed on them, namely:

- TG/DTA/DSC
- FTIR
- Powdered XRD

- SEM microscopy including EDX Mapping for Si, Al, Ca, Na.
- Density measurements using a pycnometer.
- Porosity measurements of each hybrid polymer resin and resin-glass fibre composite.
- Tensile Strength Tests on polymer blend.
- 4-point-bend tests for Bend Strength determination.
- Fire tests using cone calorimeter to measure heat release rate.
- Limiting oxygen index (LOI) for each hybrid polymer.

Testing will be undertaken using equipment in the School of Science, the School of Engineering and the Advanced Materials Characterization Facility.

Opportunity for Skill Development

The student will gain skills in basic analytical techniques and analysis and will get exposure to more advanced material characterisation techniques.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

This project will be best suited to a Science student majoring in Chemistry or an Engineering student with an interest in materials. However, any STEM student will have a basic skill set to contribute successfully to the project.

Project 102: Bio-beetle-bins' for the sustainable management of dog excrement in urban landscapes

Supervisor(s): Clarissa House - C.House@westernsydney.edu.au
Principal Supervisor

Ricky Spencer - R.Spencer@westernsydney.edu.au
Second Supervisor

Project Description

Australia has a population of 24 million and a staggering 85% of these people live in urban areas. With the increase in human populations there is an increase in the number of companion animals with an estimated 9 million companion dogs in Australia in 2018. Despite the positive benefits of dog ownership, the issue of removing dog excrement is problematic. The removal of excrement from public spaces by their owners is socially expected but is an unsatisfactory solution when faeces is entombed in plastic that persists in landfill and pollutes our environment. The use of dung beetles to remove cow dung has been highly successful and several enterprises continue to supply populations of dung beetles to agriculturalists. In 2018 to 2020 we investigated the potential of seven species of dung beetles to use dog excrement compared to cow dung for dung burial and reproduction in a laboratory setting. We found that four of the tested species buried substantial amounts of dog excrement.

Importantly, species that buried dog faeces also produced offspring. These results suggest that at least some of the species that we tested have the potential as biological agents to reduce the amount of dog excrement that end up in landfill or contaminate our water ways.

Project Aims

The overall aim of this proposal is to extend our laboratory trials to test the effectiveness of four beetle species (Onthophagus taurus, Onthophagus gazella, Onthophagus australis and Onitis alexis) to bury dog excrement and reproduce in-situ i.e. a dog park.

Project Methods

We propose to determine a) the number of beetles that are required for rapid burial of dog excrement and b) whether pairs of beetle species can bury larger volumes of excrement in a shortest time. (a) The population size (i.e. medium population, N = 100 and large population, N = 200) of the four species will be manipulated and placed in experimental, 'EnsoPet Poo Composters' with a litre of dog excrement. At the same time, we will set up control, replicate 'EnsoPet Poo Composters', seeded with commercial enzyme and a 1 litre of dog excrement. This experimental treatment and 'control' will be replicated four times. After 2 weeks, the bins will be removed and the mass of dung remaining on the surface of the soil will be measured. In the experimental, composters that were seeded with beetle species, these sites will be covered with permeable covers and left for another 6 to 8 weeks to provide sufficient time for the dung beetle larvae to grow, pupate and emerge as adult beetles. At ~5 weeks, these sites will be baited with excrement traps to attract any adult beetles that emerge from the soil. The numbers of beetles that eclose (i.e. hatch) will be recorded and released. The results of the study will be analysed to determine the effectiveness of the experimental, beetle species to bury dog excrement compared to the control, 'EnsoPet Poo Composter, seeded with enzyme alone. Next, the

number of dung beetle offspring to eclose from the experimental, composters will be quantified to determine the species that have the greatest potential to provide a continuous supply of beetles to seed a bespoke 'bio beetle bin'. (b) Pairs of dung beetle species will be selected to bury dog excrement in 'EnsoPet Poo Composters'. The criteria for selection of dung beetle species and numbers will be based on the results of (a). Two of the most productive dung beetle species will be placed together in equal proportions in 'EnsoPet Poo Composters' and provided 1 litre of dog excrement. As a control, each species will be set-up individually in 'EnsoPet Poo Composters' and provided a 1 litre of dog excrement. The remaining methods are the same as for (a)

Opportunity for Skill Development

The student will develop their problem solving and organisational skills and further their skills in working under a tight deadline. The candidate will also develop expertise in experimental design and numeracy (i.e. understanding of statistics and the use of IBM SPSS statistic package or R if applicable) and written communication. If the research is executed to a professional standard there is the potential to submit the work to a scientific journal (For example, 'People and Nature') and therefore the student will be exposed to the rigors of scientific writing to a professional standard and the peer review process.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

We are seeking a student who is self-motivated and can use their initiative. They must be capable of working with a team and independently and be proficient in communicating the findings of their research and any issues that may arise in a professional manner.

Project 103: A potential revolution in the treatment of glioblastoma: Does cyclic peptide c2 cross the blood-brain barrier?

Supervisor(s): David Harman - d.harman@westernsydney.edu.au
Principal Supervisor

Alex Hunter
Second Supervisor, External Partner, **Filamon Pty Ltd**

Shadma Fatima - Shadma.fatima@inghaminstitute.org.au
Third Supervisor

Project Description

Glioblastoma multiforme is an aggressive cancer of the brain and spinal cord which has a very poor prognosis. Only 40% survival is expected in the first year following diagnosis and 17% in the second year. Current treatments consist of surgical removal of tumours, followed by a combination of radiotherapy and six months oral chemotherapy. Temozolomide (TMZ) is the most common oral alkylating agent used to treat glioblastoma, however, at least 50% of TMZ treated patients do not respond positively.

C2 is a novel cyclic peptide drug, developed to inhibit an enzyme called phospholipase A2, has shown great promise in the treatment of advanced prostate cancer and entered human clinical trial at Liverpool Hospital in 2018. In experiments conducted this year, it was demonstrated that c2 kills cultured glioblastoma cells much more effectively than TMZ. Work is continuing to elucidate the way in which c2 works, but there is already evidence to indicate that it interacts with the protein vimentin whose primary function is to maintain cellular integrity. There is therefore great interest in whether c2 might be an effective treatment for glioblastoma, and consequently offer patients with the illness the hope of a cure.

One vital experiment which is now required is to determine whether c2 gets into the brain, whether it crosses the blood-brain barrier – a system of blood vessels which keep toxins out while allowing nutrients in. To accomplish this, a small number of wild type rats will be treated intraperitoneally with 100 mg/kg of c2. The rodents will then be humanely euthanised and their brains removed. Part of the brain will be sectioned for analysis by MALDI imaging in order to visualise how the c2 is distributed in the brain. The remainder of the brain will be homogenised and extracted to measure how much c2 it contains. A small amount of data (see figures below) have established that some c2 does get into the brain, but nothing is known about its distribution.

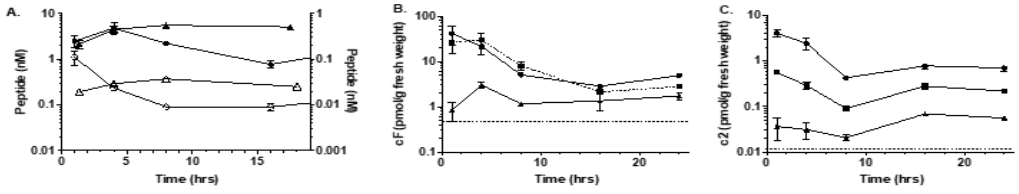

Fig 5.2.1. Pharmacokinetic analysis of cyclic peptides. *Tritiated peptides (5 mg/kg) were administered to BALB/c mice (n=4/time point) for indicated times. Plasma and tissue tritium content was determined by scintillation counting. A. Plasma concentration of cF (closed symbols) and c2 (open symbols) following sc (circles, left y-axis) or oral (triangles, right y axis) administration. Tissue concentrations of cF (B) and c2 (C) were determined in liver (□), kidney (□) and brain (□) following sc administration. Dashed lines indicate estimated background levels of tritium in tissues due to tissue blood content (10% of peak plasma concentration).*

Project Aims

1. Inject rats intraperitoneally with c2 solutions
2. Dose the rats with c2
3. Humanely euthanize rats and harvest the brains
4. Section the brain and analyse a frozen section using MALDI imaging
5. Homogenise portion of the brain, extract c2 and quantify using LC-MS/MS
6. Analyse data, write report, prepare and deliver oral presentation

Project Methods

1. Learn to handle rats according to guidelines
2. Learn to dose rats with drug and to euthanise and extract required tissue samples
3. Be aware of how to section brain with microtome for MALDI imaging
4. Homogenise brain segment and extract c2 drug for LC-MS/MS analysis
5. Gain experience with analysis of data and literature pertinent to project

Opportunity for Skill Development

- Learn to handle rats according to guidelines
- Learn to dose rats with drug and to euthanise and extract required tissue samples
- Be aware of how to section brain with microtome for MALDI imaging
- Homogenise brain segment and extract c2 drug for LC-MS/MS analysis
- Gain experience with analysis of data and literature pertinent to project
- Gain experience in approaches to commercialisation by a startup biotech company

Students are required to have the following skills/meet the following pre-requisite(s) to apply

The most important attribute is an interest in research and an awareness of its potential. Junior researchers with skills in managing animals, with analytical chemistry and with pharmacology would be highly suited, but these attributes are not essential. An interest in early stage drug commercialisation would be beneficial.

Project 104: Traditional Chinese Medicine–metal based drugs

Supervisor(s): Feng Li - feng.li@westernsydney.edu.au
Principal Supervisor

ChunGuang Li - C.Li@westernsydney.edu.au
Second Supervisor

Project Description

Small organic molecules (~ 900 Daltons) and their metal complexes incorporating flat aromatic functional groups, has received very considerable attention over recent years, because of their specific bio-applications in both vitro and vivo, and drug discovery, etc. At the applied level, they are expected to spur the development of a new class of drugs for tumour cells, Alzheimer's disease, Parkinson's disease, and tauopathies, etc. Such compounds may exhibit excellent solubility in water and can rapidly diffuse across cell membranes. It addition, they can act as an effector to reach intracellular sites to bind specific biological macromolecules, such as, protein, DNA and RNA etc. We have synthesised and tested various small molecules for their anti-inflammatory activities, and identified a compound with potent inhibitory effect on proinflammatory modulators and cytokines in RAW264.7 and THP-1 cells, as well as in neuroinflammatory tri-culture cell model (microglia N11, neuron2A, and murine microvascular endothelial cells). For example, we identified a potent compound which inhibited LPS-induced IL-6 production in human THP-1 cells and is more potent than that of Tocilizumab and Nurofen. This compound also concentration-dependently inhibited LPS-induced expression of caspase-3 and p-tau protein in the tri-culture system. The proposed summer project will help further testing and developing this molecule as potential therapeutics, in particular the transition to clinical trials.

Project Aims

This research aimed at discovering and developing potential new drug candidates, though synthesis and testing serious compounds/derivatives in different systems, for treating important chronic diseases, including cancer, Alzheimer's disease, Parkinson's disease and other inflammation related diseases

Project Methods

Ligand and metal complex synthesis. Most ligands and metal complexes will be prepared using both reported methods and newly designed synthetic routes developed in Dr Li's laboratory and some ligands and metal complexes are already available. Crystal growth of metal complexes will be performed through well-known methods, including slow-evaporation, slow diffusion and solvothermal techniques for all of which he is also well experienced. Characterisation (all necessary instruments are located at WSU unless otherwise specified) Organic ligands and, where possible, metal complexes will be characterised by NMR spectroscopy in both the solid and solution state and by Mass spectrometry (Xevo QToF coupled with nanoAcquity UPLC separation technology). HPLC will be used for purification and characterisation of compounds where appropriate A number of techniques including powder X-ray diffraction, cyclic voltammetry, Raman, FT-IR and UV-vis-NIR spectrometry will also be used for the characterisation of the proposed compounds and materials. Structures of crystalline complexes will be determined by X-ray crystallography at the Australian Synchrotron (with my existing CAP grant from Australian Synchrotron). When suitable crystals are

unable to be obtained, Density Functional Theory (DFT) and Molecular Modeling calculations will be carried out using Cerius II and Gaussian09 software. DNA binding and cleavage studies DNA binding will be investigated using UV-vis and CD (circular dichroism) spectroscopy, but for some systems, ITC (Isothermal titration calorimetry), NMR titration, magnetic susceptibility measurements and fluorescence studies will also be employed. Mass spectrometry and SEM will be used to characterise the DNA complexes and as a rapid screening method to indicate receptor selectivity. The bioactivity of these compounds will be studied in different cells lines, including RAW264.7 and THP-1 cells, as well as in neuroinflammatory tri-culture cell model as mentioned above. In addition, MCF-7 and MDA-MB-231 breast cancer cell lines will also be used. These cell lines are routinely used in CIB's laboratory. Briefly, cells will be cultured in standard cell culture media and maintained at 37°C under 5% CO2. Compounds will be tested in a range of concentrations in 24-96 well plates with exposure for 24 hr for cell viability/cytotoxicity, and 72 hours for cell proliferation studies, determined by MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay as previously established in our laboratory. In drug delivery studies, cancer cells will be treated with standard drugs (e.g., 5-fluorouracil) or spin transition coordination cages (may use STCC for short) with loaded and released forms to determine the differences in cell cytotoxicity by these compounds as determined by MTT assay.

Opportunity for Skill Development

The research programme will provide significant training opportunities for undergraduate students in pursuing for Masters or HDR studies in a wide range of skills encompassing supramolecular and nanomaterials synthesis, compound and device characterisation and physical measurements using a variety of techniques which are required for employment in Australia's growing new advanced materials and nanotechnology industries. As a continuing project, all results obtained by students will be submitted for publication in appropriate high-quality journals of international repute such as those the Nature Publishing Group, Science, the Royal Society of Chemistry and the American Chemical Society, which will also increase the reputation of both the School and WSU. In addition, this project will offer the great opportunities to establish strategic collaborations with other leading researchers who have complementary strengths across industry, research institutions and other disciplines. Based on our previous work and publications, this research project can be easy to complete within 8 weeks for perhaps one publication in the respect with our experience of supervision.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

3rd year students are required to conduct this project, especially for the students who have completed science research project or advanced science research project in chemistry or biochemistry and are ready for master's studies.

Project 105: Real time water quality monitoring heavy metal ions for greenhouses.

Supervisor(s): Feng Li - feng.li@westernsydney.edu.au
Principal Supervisor

Jason Reynolds - J.Reynolds@westernsydney.edu.au
Second Supervisor

Project Description

Monitoring of key water quality parameters for irrigation waters is imperative to optimal plant growth. Technologies that can provide real-time monitoring of salt (as electrical conductivity), pH, and some nutrients (N and P) are well established. The ability to detect and measure key trace elements is more challenging. The development of chemosensors by our research team has demonstrated that individual chemical elements can be detected and quantified at detection limits that rival ICP-MS. We have demonstrated this capability in environmental waters and soils. We require some initial pilot experiment in the existing analysis with a focus on copper system from greenhouse. This in turn would produce a prototype that would be tested under real-world conditions to monitor copper. In parallel with this work would be development of new chemosensors for additional target elements as advised from key stakeholders.

Project Aims

Our proposal is to expand this capability to greenhouse irrigation systems. We envision a system that can monitor water quality without need to send samples to a laboratory. A system that can provide data in real time using only small volumes of water. To achieve this chemosensors (existing and newly tailored) will be coupled to spectrophotometers and auto samplers to provide immediate data on trace elements in irrigation waters. We propose to initially monitor copper as we have proven capability with this element. Then we will expand to additional elements in discussion with key stakeholders and end users.

Project Methods

A few sensors/probes will be used as received from my research group. However, most sensors/probes containing optical functional units will be prepared using both reported methods and newly designed synthetic routes. Some of them are functionalised by amino groups. The proposed compounds and materials will be characterised by NMR, UV-vis, Fluorescence spectroscopy, ESI-Mass, powder X-ray diffraction (PXRD), cyclic voltammetry (CV), Raman, FT-IR and UV-vis-NIR spectrometry, thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). During the COVID-19, the student needs to pre-screen of individuals prior to working in laboratory and maintain physical distance, good hygiene, ventilation and cleaning regime, etc. If you feel unwell/illness with symptoms of fever or respiratory, please do not to come to work and you are encouraged to seek medical advice and COVID-19 testing.

Opportunity for Skill Development

The research programme will provide significant training opportunities for undergraduate students in pursuing for Masters or HDR studies in a wide range of skills encompassing supramolecular and nanomaterials synthesis, compound and device characterisation and physical measurements using a variety of techniques which are required for employment in Australia's growing new advanced materials and nanotechnology industries. As a continuing project, all results obtained by students will be submitted for publication in appropriate high-quality journals of international repute such as those the Nature Publishing Group, Science, the Royal Society of Chemistry and the American Chemical Society, which will also increase the reputation of both the School and WSU. In addition, this project will offer the great opportunities to establish strategic collaborations with other

leading researchers who have complementary strengths across industry, research institutions and other disciplines. Based on our previous work and publications, this research project can be easy to complete within 8 weeks for perhaps one publication in the respect with our experience of supervision.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

3rd year students are required to conduct this project, especially for the students who have completed science research project or advanced science research project in chemistry or biochemistry and are ready for master's studies.

Project 106: Circular economies and soil health

Supervisor(s): Jason Reynolds - j.reynolds@westernsydney.edu.au
Principal Supervisor

Lyndall Pickering
Second Supervisor, External Partner, **Sydney Water**

Jeff Powell - Jeff.powell@westernsydney.edu.au
Third Supervisor

Project Description

The urbanisation of western Sydney presents challenges to how communities will source food and interact with the environment on catchment-level scales. With climate modelling indicating a warmer and drier western Sydney region, the application of recycled materials to land areas may be of benefit to blue and green landscape management, agriculture, and horticulture. Field and lab-based investigation of recycled materials and soil interactions are required to ensure future land management is appropriate for maximising nutrient capture in soil and minimising losses due to leaching, runoff and greenhouse gas. This project will generate impact through benefits to landscape productivity and resource sustainability within the western Parkland City. This project fits under two existing Sydney Water projects:

1. Recycled water and soil interactions: supporting a cool green city through regenerative agriculture, high quality recreational areas, and a healthy blue green grid.
2. Biosolids and Western Sydney Soils: Circular economies and soil health: Stage 2 of supporting a cool green city through regenerative agriculture, high quality recreational areas, and a healthy blue green grid.

Project Aims

This project seeks to investigate the potential for improved blue and green space management using recycled materials in the rapidly urbanising Western Sydney region. An investigation into different soil landscapes and their interaction with recycled materials will provide information on how soils behave in response to the use of recycled materials. This information can then be used when planning the application of recycled water to new locations. Outcomes of this work will be a greater understanding of

i. How soil systems respond to recycled water for improved carbon storage and nutrient cycling and
ii. How western Sydney landscapes can be managed to confer greater benefits to society. And provide a detailed understanding of
    a. How mycorrhizal fungi, rhizobia, and other microbial associates change in response to recycled water application and
    b. How the soil microbiome can be manipulated for greater benefits to western Sydney.

Project Methods

This Scholarship proposal fits within the exiting funded project works. The Summer Scholarship will be directly involved in: 1. Field sampling and analysis of soils and waters Soils and recycled water: understanding existing sites - Soil taxonomy: Classification across sites with profile samples collected and tested at WSU for pH, texture, colour, biodiversity, bulk density, physical properties (including available water capacity), and potential contaminants. - Nutrient and carbon accrual: Using data from soil taxonomy and analytical work soil carbon partitions and soil nutrient levels will be quantified. This will be used to illustrate soil nutrient and carbon increases in response to irrigation and the potential for soils to increase nutrient levels. Nutrient testing will include, phosphorous, nitrogen, and carbon along with a broad elemental analysis. Contaminant analysis will include - Environmental microbiome: Identification of dominant microbial species and investigate differences between irrigated and non-irrigated locations. Traditional microbiological techniques only isolate and culture a small proportion of the microorganisms in soil samples which provides incomplete information about total soil biodiversity With cultivation-independent metagenomic approaches proposed in this work, the analysis of soil microbial communities makes it possible to capture the genomic information of even low-abundance populations and to reveal the multiple activities in soil. It is a useful tool to help us understand the soil microbiome and can provide information on the biogeochemical interactions of the soil-recycled waterplant system in relation to nutrient and contaminant cycling. 2. Greenhouse based lysimeter studies Recycled materials and soil cores: manipulating inputs and outputs - Soil cores preparation: Intact soil cores will be collected at dimensions of 0.2m wide and 0.3m deep which incorporates the active root zone, majority of soil carbon storage, and majority of the soil biodiversity. These cores will be held in PVC pipes in upright positions and maintained under greenhouse conditions. - Recycled water application: Interactions of recycled water with soil cores collected from the site will be explored by adding set volumes of recycled water at set intervals. Collection trays underneath the soil cores will collect drainage water. This work will be undertaken at WSU greenhouse facilities. - Lysimeter soil and water: The soil lysimeters, drainage water, and input water will be analysed to understand physical, chemical and biological changes. Testing will include pH/EC/DO/pe, nutrients (N,P), DOC, DIC, alkalinity, elemental suite (ICPMS), antibiotic (e.g. ciprofloxacin), medicinal (e.g. pseudoephedrine), illicit (e.g. cocaine and benzoylecgonine), and emerging contaminants (e.g. PFAS suite).

Opportunity for Skill Development

Skill sets in soil classification and site assessment are highly valued in the job sector at present. These skills will be provided throughout this project to the student. This coupled with advanced analytical techniques in soil chemistry and soil microbiology provide a leading edge to any student transitioning to paid work opportunities or looking to branch into higher degree research.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Students need to have completed undergraduate level studies in first year chemistry and biology. Knowledge and/or experience in soils is highly valued.

Project 107: Deciphering trichome function in tomato

Supervisor(s): Jay Bose - J.Bose@westernsydney.edu.au
Principal Supervisor

Zhonghua Chen - Z.Chen@westernsydney.edu.au
Second Supervisor

Project Description

The tomato (Solanum lycopersicum) plants canopy is covered by the tiny hair-like structures called trichomes. The main function of trichomes is suggested to protect plants against herbivorous insect invasion. But some pieces of evidence suggest these trichomes may have a role in low temperature, drought, and salt tolerance. As a summer scholarship student, you will use tomato plants with altered trichome density and structure to investigate the roles of trichomes during low temperature, drought and salt stress. You will assess growth and use the scanning electron microscope (SEM) and/or transmission electron microscopy (TEM) to reveal changes in glandular and non-glandular trichome distribution under a given stress. Also, prepare plant samples for subsequent metabolomics studies.

Project Aims

1. Assess the growth and development of tomato trichome mutants under low temperature, drought, and salt stress.
2. Quantify changes in trichome density and morphology under low temperature, drought, and salt stress.
3. Prepare samples for metabolomics analysis.

Project Methods

1. Standard plant phenotyping experiments in the controlled environment glasshouses.
2. Photosynthetic measurements using standard procedures and equipment
3. Imaging trichomes using a scanning electron microscope (SEM) and/or transmission electron microscopy (TEM).
4. Image analysis to quantify trichome density.

Opportunity for Skill Development

The summer scholarship student will acquire skills in

- Growing and phenotyping tomato plants in state-of-the-art glasshouse facilities.
- Photosynthetic measurements.
- Imaging and image analysis techniques.
- Scientific research: developing hypothesis, planning and conducting experiments, data collection and analysis, review and report writing

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Students from Agriculture or Horticulture majors preferred with a strong desire to continue their career in research and development.

Project 108: Bringing out the big guns: the evolution of antipredator defences in termites

Supervisor(s): Kate Umbers - K.Umbers@westernsydney.edu.au
Principal Supervisor

Markus Riegler - M.Riegler@westernsydney.edu.au
Second Supervisor

Project Description

Animal weapons are extremely diverse in form and function, ranging from spikes and armour to more sophisticated chemical weapons and biological equivalents to guns. Animal weaponry has been a source of fascination for decades and yet many questions are yet to be explored, including whether there is an interaction between weapon types and defensive behaviours. Whilst the morphology of weapons has been well studied in some groups, we are yet to fully understand how behavioural aspects of defence have co-evolved and how they vary across the landscape. The Termitidae (~2000 species), are the largest, most advanced family of termites. This group possesses a diverse range of sophisticated mechanical defences, including mandibles for biting, crushing, snapping, or slashing. Some groups also possess complex defensive glands that produce secretions. These secretions exhibit several defensive functions including being an irritant, toxic and capable of causing immobilisation, incapacitation and even death of enemies. It is in the Termitidae that we see the highest degree of soldier modifications. Why has such a diversity of weaponry evolved? The exceptional diversity in their defensive weaponry makes termites perfect for understanding the co-evolution of weaponry, behaviour, body size, and ecology. This study will delve into the behavioural ecology of an ecologically and economically important Australian nasute termite species. By investigating how nasute soldiers react to potential threats, we will increase our understanding of the functional role of termite weaponry, as well as gain novel insights into what selective forces have driven the evolution of nasute weaponry.

Project Aims

Specifically, this study will address three aims:

- Observe the defensive behavior of Nasutitermes exitiosus in response to predators
- Experimentally determine what triggers Nasutitermes exitiosus to eject its defensive secretion
- Investigate whether predator characteristics (i.e., species, body size, abundance) influence a termite's proclivity to perform defensive behaviours.

Project Methods

To determine what causes Nasutitermes exitiosus soldiers to expel their defensive secretion, behavioural experiments involving the use of live predator trials will be conducted. In order to accurately represent naturally occurring situations, this study will consist of three different treatments:

1. Individual ant vs individual soldier termite
2. Individual ant vs several termites that equal the same biomass as the ant
3. Individual ant vs vastly more soldiers that outweigh the ant in terms of biomass.

At each mound, treatments will consist of two replicates (n=120) being conducted in a randomised order. It is expected that a different species of ant will be used for each set of treatments (i.e., 2 species of ants will be used at each mound) in order to test whether soldiers alter their behaviour based on predator characteristics.

All field sites are in NSW and ACT and if required due to border closures, field sties in the ACT can be dropped and replaced by sites in NSW

Opportunity for Skill Development

The student will gain skills in field work, measuring ecological traits, identifying ants and termites, conducting behavioural experiments in the field, understanding of experimental design.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Students must be willing to work full days in the field, must have a reasonable level of physical fitness, and must be reasonably patient – behavioural field work can be slow going.

Project 109: Developing a novel inhibitor to target a key protein involved in the pathway of ageing

Supervisor(s): Roland Gamsjaeger - r.gamsjaeger@westernsydney.edu.au
Principal Supervisor

Derek Richard
Second Supervisor, External Partner, **CARPE VITAE Pharmaceuticals PTY LTD**

Liza Cubeddu - l.cubeddu@westernsydney.edu.au
Third Supervisor

Project Description

Ageing ultimately manifests itself as chronic diseases that place a huge burden on society, causing impaired mobility through osteoarthritis and osteoporosis, loss of cognition through Alzheimer's and vascular dementia, and illnesses such as cardiovascular disease, type 2 diabetes and cancer. These diseases are very costly to treat and manage, and hugely impact the quality of life of the affected individuals and their families. CARPE VITAE Pharmaceuticals have identified a pathway of ageing that can be reversed by targeting the function of a single protein, Barrier-to autointegration factor (Banf1), a small non-specific DNA binding protein that is conserved amongst multicellular eukaryotes. Our collaborator, Derek Richard and colleagues have identified that Banf1 functions by blocking the activity of a key DNA repair protein, Poly [ADP-ribose] polymerase 1 (PARP1). Using molecular simulations, we have identified a druggable site on Banf1. The drug DEK01 binds to Banf1 preventing it from inhibiting PARP1 activity. This results in enhanced DNA repair and genetic stability, improved mitochondrial health and positive changes in several other ageing-related pathways (for details see below). DEK01, or any derivatives might thus function to prevent cellular degeneration, a process that drives the ageing process. This project is an ongoing collaboration and part of an existing partnership grant with CARPE. As part of this summer project the summer student will assist in the NMR analysis of a derivative of DEK01.

Project Aims

1. Recombinant bacterial (Escherichia coli) expression and purification of Banf1 protein
2. Structural characterisation of Banf1 using NMR HSQC experiments
3. Analyse Banf1-binding to one derivative of the DEK01 drug by NMR spectroscopy

Project Methods

The Banf1 DNA construct provided by CARP Pharmaceuticals will be transformed into E. coli BL21 cells. The student under the supervision of the applicants or any HDR students will then use standard methods available in our lab (cell cultures, Ni/NTA beads and size exclusion chromatography) to express and purify Banf1 (Aim 1). We have already complete resonance assignments of Banf1 at this point and the student will use these to in combination with HSQC experiments (600/800 MHz spectrometers based at the University of Sydney) to determine drug binding to Banf1 (Aims 2 and 3).

Opportunity for Skill Development

- Student will develop a wide range of laboratory skills using cutting edge equipment.
- Student will learn how to work independently and as part of a team.
- Skills relevant to further research studies such as Masters, PhD will be acquired.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

- Student is expected to be pro-active and diligent.
- Student is required to have basic molecular biology and protein knowledge.
- Student should have completed Functional Proteins and Genes as well as Molecular Biology.
- A final year student is desirable due to the high-level equipment being used and the potential to carry out further research studies (Masters).

Project 110: Investigating the effectiveness of beta-cyclocitric acid as a promising drought tolerance treatment through its impacts on tomato fruit production and fruit quality.

Supervisor(s): Ryan McQuinn - R.mcquinn@westernsydney.edu.au
Principal Supervisor

Project Description

The current state of climate change is heavily impacting life on earth at extreme levels (e.g. increased frequency and severity of bushfires and droughts) and increasingly hindering agricultural production around globe. In that respect, a major obstacle faced by farmers is the unpredictability of precipitation timing and volume through a given growing season and the accelerated depletion of water resources in times of extreme drought. Remarkably, plants have mechanisms in place to fend off or tolerate such abiotic stresses through the synthesis of chemical signals in response to abiotic stresses which in turn regulates the plant's development in ways that enable it to survive in unfavourable growing conditions.

Recently, a novel metabolite synthesized in plants, beta-cyclocitric acid (B-CCA), was discovered and shown to provide drought tolerance in plants for up to seven days when applied prior to drought conditions. B-CCA is an apocarotenoid derived from the breakdown of the human health promoting carotenoid beta-carotene (provides the orange pigment in carrots and is the precursor to vitamin A) in plants. In the plant, beta-carotene is susceptible to non-enzymatic cleavage by reactive oxygen species over-accumulating during times of abiotic / environmental stress, the resulting apocarotenoids of which provide resistance to the specific stress in the form of transcriptional reprogramming. B-CCA's ability to elicit a strong tolerance to drought stress in various plant species underpins its strong potential as an effective strategy to provide drought tolerance at times of water scarcity. This would enable farmers to produce their crops sustainably while preserving their water resources in times of need. Before B-CCA can be applied in agricultural practices it is imperative to investigate B-CCA's overall effects on crop production, to ensure that the application of B-CCA improves crop yield and quality, while preserving water resources under unfavourable environmental conditions, with minimal or no deleterious effects on overall plant development. Using tomato as a model system for horticultural fruit crops, this proposed project will examine how B-CCA treatment of tomato plants through their lifecycle impacts fruit production and overall plant performance under well-watered and recurring drought conditions.

Project Aims

Aim 1: Given other known apocarotenoids regulate multiple aspects of plant development, we plan to assess whether and how B-CCA effects tomato fruit development and ripening under well-watered conditions.

Aim 2: Investigate B-CCA as an effective drought tolerance treatment in horticultural fruit crop production through the analysis of fruit yield, quality, and nutrition in tomato as a model system during drought conditions.

Project Methods

A common wildtype cultivar of tomato, Solanum lycopersicum cv Ailsa Craig, will be grown in glasshouses at S35 on Western Sydney University's Hawkesbury Campus, Richmond NSW. All tomato plants will be grown under natural light conditions consisting of a 16-h day/8-hr night cycle. The growth media will consist of normal soil mix available on site with slow release osmocote fertilizer. The experiment will be arranged in a complete randomised block design with block 1 under well-watered conditions and block 2 under a recurring drought regime throughout the plant's lifecycle. The recurring drought condition will begin once the plant is transplanted into the final pot size at the point the fourth leaf has emerged. This will consist of applying 1L of water every 5-10 days, thereby allowing the pots to dry out and the plant to experience severe drought conditions. The number of days between watering may vary depending on the growth stage of the plants and be adjusted accordingly to ensure the plant survives. Within each block, plants will be subjected to one of two conditions: water (and fertilizer as needed) only, control; and 1.5mM B-CCA in water (and fertilizer as needed), treatment. Each application of water/fertilizer and B-CCA/fertilizer will be recorded along with the overall condition of the plant.

Due to the time constraints on the scholarship the successful applicant will focus on B-CCA's effects on tomato fruit development and ripening. All other parameters will be investigated prior to the successful applicants start on 30 November 2021. Anthesis flowers will be tagged prior to this date and the successful applicant will identify the initiation of ripening by the first sign of colour change at the blossom end of the fruit (i.e. breaker stage). Ethylene will be measured by gas chromatography in fruit at the mature green (MG), breaker stage (BR) and 1, 3, 5, 7, and 10 days post breaker (1DPB, 3DPB, 5DPB, 7DPB, 10DPB). For accurate ethylene measurements (nl/g/hr), fruit weight (g) will also be recorded along with fruit diameter (mm). Subsequently, the same fruit will be analysed for fruit firmness with a fruit firmness penetrometer, fruit colour with the colorimeter and sugar content (Brixo /TSS) with a refractometer. Additional fruit will be harvested at 7DPB (full red ripe), the pericarp of which will be snap frozen in liquid N2 and stored in -80oC freezer. These samples will undergo chemical extraction of carotenoids and ascorbate to be quantified by high pressure liquid chromatography (HPLC) and UV spectrophotometer, respectively. If time allows, fruit will be harvest at 7DPB and analysed for fruit firmness and fruit weight over a time course to examine the fruit shelf-life.

Opportunity for Skill Development

The proposed project will provide the student with an opportunity to aid in the application of a very promising strategy to improve crop tolerance to drought conditions. Further, this project will introduce the student to a unique approach to enable sustainable water usage by farmers when water resources are limited due to an impending drought. The student's research provides the initial steps to what I hope to be a larger project to develop a precision agriculture strategy for Australian farmers, minimizing their water usage based on data collected on water resource availability and weather forecasting.

As a part of this project, the student will explore fruit ripening physiology and biochemistry as it pertains to fruit quality, flavour, and nutrition attributes desired by the consumer. Additionally, the student will become familiar with how the increasingly unpredictable climates of the future will negatively impact horticultural crop production. The student will be working hands on with tomatoes, a horticulturally relevant crop in Australia. Given tomato is an excellent model system for climacteric fruit ripening the experience gained by the student is easily translated to other climacteric fruit crops grown in Australia.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Pre-requisites for this project include the successful completion of unit 300804, Feeding the Planet; 301096, Horticultural Production Systems; and 301389, Agriculture, Food and Health. This should provide the basic background knowledge to excel in the proposed project.