4 PhD scholarships in Plant and Crop Physiology

University of Tasmania, Australia/University of Copenhagen, Denmark

Four PhD scholarships are available to work on a range of projects related to the physiology of crop plants, including halophytes, and mechanisms of their adaptation to salinity and drought stresses. The successful candidates will be co-supervised by A/Professor Sergey Shabala (University of Tasmania) and Prof Sven-Erik Jacobsen (University of Copenhagen) and are expected to spend approximately half of their candidature working at each of the institutions.

Global food production will need to increase by approximately 40% by 2050 to match the projected population growth. At the same time, most suitable land has already been cultivated, implying a need for either expansion into new areas to meet the above target, or a dramatic increase in crop production on existing cultivated lands. Given the fact that approximately 7% of the world's total land area is already saline, and another 15% is 'perennial desert' or 'drylands' which can only be made more productive by irrigation, the use of halophytes may be an attractive solution to meet the above goal. Halophytes have evolved in saline habitats and are an untapped source of food, fibre and bioenergy. Deepening our understanding of halophytes and saline ecosystems will help combat salinisation, soil erosion, loss of biodiversity and bioproductivity, as well as assist in development of a saline agriculture using brackish water as a replacement or a supplement for diminishing freshwater. The key to implementing all these practices is in a better understanding of the physiology of halophytes.

One of the crops which will be an important part of these PhD programmes is the seed crop quinoa (*Chenopodium quinoa* Willd.) which has been cultivated in the Andean region for several thousand years for the supply of highly nutritious food. It tolerates several of the abiotic factors that constrain crop production in the Andes (Jacobsen and Mujica, 2001; Mujica et al., 2001; Bois et al., 2006; Jacobsen et al., 2006). However, research on the physiological mechanisms for resistance, and the response to actual stress levels conferred by the environment, has only recently been initiated. Initial results have demonstrated that quinoa tolerates drought through growth plasticity and tissue elasticity (Vacher, 1998), and an inherent low osmotic potential (Jensen et al., 2000). Quinoa also avoids the negative effects of drought through its deep, dense root system, reduction of leaf area through leaf dropping, special vesicular bladders, small and thick-walled cells adapted to large losses of water without loss of turgor, and stomatal closure (Jensen et al., 2000; Jacobsen et al., 2003). It is believed that quinoa yields can be stabilized with the help of deficit irrigation by applying only half of the irrigation water as required for full irrigation, replacing evapotranspired water (Geerts et al., 2008). It was recently demonstrated that ABA plays a role, although only minor, in the drought adaptation of quinoa (Jacobsen et al., 2009).

The following research topics are available:

1. Halophyte responses to combined drought and salinity

1.1 Role of ABA in quinoa

Despite osmotic stress is recognised as one of the major factors in salinity tolerance, mechanisms of salt- and osmotic-stress signalling in plants appear to be rather different. We will elucidate such specificity by undertaking a series of experiments at the whole-plant and cellular levels elucidating the role of ABA- and MAPK- dependent and independent pathways in quinoa (*Chenopodium quinoa*) in response to salinity and drought (Jacobsen et al., 2009). The project will utilise a range of whole-plant physiological and biochemical techniques, as well as electrophysiological techniques such as non-invasive ion flux measurements, membrane potential and single-cell pressure probe.

Time allocation between laboratories = 1.5 years in Hobart; 1.5 years in Copenhagen.

1.2 Osmotic adjustment to drought and salinity

This project will elucidate the ionic and molecular basis of cell osmotic adjustment in quinoa leaves and roots, in comparison to glycophyte crop species. The main aim of this work is to understand a cost-efficient way of maintaining cell turgor pressure under adverse environmental conditions. The major emphasis will be on tissue-specificity of osmotic adjustment and a balance between organic and inorganic osmolytes. Techniques to be used: single cell turgor pressure measurements; metabolomics; non-invasive ion flux measurements.

Time allocation: 2.5 years in Australia; 6 months in Copenhagen.

2. Salinity tolerance mechanisms in halophytes

2.1 Role of salt bladders

Salt bladders are highly specialised structures in leaves of halophyte species which are considered to be crucial for plant adaptation to saline environment. Surprisingly, little is known about the identity and control modes of major ion transporters involved in Na^+ flux and redistribution in these tissues. This project will fill this gap by studying electrophysiological and biochemical aspects of ion transport and distribution through salt bladders in halophytes and linking it with plant adaptive responses to salinity. This project will be undertaken in collaboration with Prof Stefano Mancuso (University of Florence). Techniques to be used: SEM imaging; electrophysiology; microsampling; cytosolic dye imaging; biochemistry.

Time allocation: 2 years in Hobart; 6 months in Florence; 6 months in Copenhagen.

2.2 Stomata control and development in salinity tolerance

Stomata functioning is central to optimising the balance between CO_2 assimilation and transpirational water losses and, hence, to crop production under saline conditions. Stomata are produced in the leaf epidermis through a series of cell divisions which are controlled by position-dependent patterning and the regulation between proliferation and cell specification. Preliminary results have shown that some halophytes decrease the density of stomata under saline conditions, which is the opposite of what is found in other crops and is presumably responsible for superior salinity tolerance in halophytes. This project will investigate the ionic and molecular basis of this important phenomenon. Techniques to be used: cell electrophysiology; molecular biology; imaging.

Time allocations: 2 years in Hobart; 1 year in Copenhagen

3. Signalling and salt tolerance in halophytes

3.1 Reactive Oxygen Species (ROS) signalling

Reactive Oxygen Species (ROS) signalling and production has been repeatedly named by many researchers as a universal component of plant adaptive responses to literally every known abiotic and biotic stress. In this project, the ionic basis of ROS signalling and its relation to the Programmed Cell Death will be studied, comparing halophytes and glycophytes species contrasting in their salt tolerance: quinoa – tolerant; sugar beet – moderately tolerate; beans – sensitive. Techniques to be used: biochemical assay of antioxidant activity and ROS production; microscopy (DNA laddering); ion fluxes; patch-clamp electrophysiology.

Time allocation: 2.5 years in Hobart; 6 months in Copenhagen.

3.2 Cytokinins in drought tolerance

Over the last couple of years, cytokinins have emerged as potent regulators of plant drought tolerance. Several recent papers have reported a dramatic increase in plant drought tolerance as a result of overexpression of genes involved in cytokinin biosynthesis and signalling. The underlying ionic mechanisms mediating this increase remain elusive. Recently Shabala et al. (2009) suggested that cytokinines' regulation of plasma membrane K^+-permeable channels may be a possible explanation to the above phenomena. This project will build upon the above findings providing a comprehensive electrophysiological and molecular assessment of cytokinin control over the activity of major PM transporters involved in plant osmotic adjustment. Techniques to be used: non-invasive ion flux measurements; patch-clamp; single-cell turgor measurements; molecular biology.

Time allocation: 2.5 years in Hobart; 6 months in Copenhagen.

4. Multiple stresses in quinoa

The project will support the development of "climate proof" food crops that better utilize agricultural areas affected by erratic rainfalls, drought and other stresses. The long-term aim will be the stabilisation of yield capacity in cultivars adapted to combinations of abiotic stresses, under a Mediterranean climate of cold, humid winters, and hot, dry summers. Tolerance to cold at emergence and flowering will enable breeders of winter crops to aim for earlier flowering, securing a longer period of grain-filling before heat and aridity of late spring, thereby avoiding some of the adverse effects of terminal drought. We will study the connection between cold, drought and soil salinity, which often may develop together with irrigation, especially when using inadequate amounts or poor quality water. We will study osmolytes and proteins specifically involved in stress tolerance. The effect of ABA is related to abiotic stress responses, such as adaptation to dehydration and soil salinity, and low temperature acclimation, so ABA will be a key component involved. Abiotic stresses trigger the production of ABA and other compounds, which in turn causes stomatal closure and may induce expression of stress-related genes.

Time allocation: 0.5 years in Hobart; 2.5 years in Copenhagen

The successful applicant should hold a First Class or Upper 2A Honours, Postgraduate Diploma or Masters degree (or equivalent), must have an undergraduate degree in plant physiology or related disciplines and be willing to learn cutting edge electrophysiological and microscopy techniques. The applicant must be an Australian Citizen or Permanent Resident. For further information regarding the position please contact: A/Prof Sergey Shabala; email Sergey.Shabala@utas.edu.au.

Applicants are requested to submit an application in writing together with their CV, a copy of their academic transcript and the names and contact details for two referees (including at least one university referee). Please send applications to A/Prof Sergey Shabala, School of Agricultural Science, University of Tasmania, Private Bag 54, Hobart, Tas 7001, Australia.