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EDITORIAL

Editorial: special issue GROW "plant desiccation stress"

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Desiccation tolerance implies the ability of a plant or plant part to come into equilibrium with atmospheric relative humidity and to survive in this state for ecologically significant periods. Thus the definition of desiccation tolerance is usually cited as the ability to survive drying to, or below, the absolute water content of 0.1 g H_2O g^{-1} dry mass ($g\ g^{-1}$), this being equivalent to air-dryness at 50% relative humidity and 20°C and corresponding to a water potential of ≤ -100 MPa (Vertucci and Farrant 1995). It has long been known that the seeds (termed orthodox) of many species are desiccation tolerant (DT) but vegetative tissues of most plants are highly sensitive to even small amounts of water loss. Relatively recently it was reported in the literature that there are some species in which the vegetative tissues are DT, these being termed "resurrection plants" (see e.g. Gaff 1971, 1977) and that the seeds of some species are desiccation sensitive (DS), these termed "recalcitrant" (see e.g. Chin and Roberts 1980). Since those early reports, research on vegetative DT and seed DS has steadily grown, undoubtedly driven in part by the potential applied benefits. Understanding of the mechanisms whereby vegetative tissues tolerate extreme water deficit can lead to the development of drought tolerant crops, the benefits of which are improved food security in drought prone developing countries. Indeed with the prediction that the effects of global climate change is likely to lead to increased frequency and duration of droughts (FAO 2008) and that this in turn could lead to complete abandonment of cropping in many countries by 2050 (Thornton et al. 2009), such research has important implications for our future. DS in seeds precludes their long term (and in some species, even short-term) storage, the effects of which are lack of stock for planting of crops and inability to conserve germplasm for the maintenance of plant biodiversity. Typically for ex situ conservation purposes seeds are stored in seed banks in which they are maintained in the desiccated state at temperatures of −18°C (conventional storage) or in the vapour of liquid nitrogen at −120 to −150°C (cryogenic storage). Orthodox seeds have been maintained viable under such conditions for more than 30 years, with predictions of considerably longer life spans (Walters et al. 2005). DS seeds are killed if dried and suffer lethal ice crystal damage if stored hydrated under such low temperature conditions. Thus research in which methods for long term storage of such seeds has also become an important imperative.

While applied research directed specifically toward the production of drought tolerant crops and methodology for improved storage longevity of recalcitrant seeds is ongoing (see for e.g. Thomson 2006; Walters et al. 2008) by far the majority of research reported in recent literature is fundamental in nature and this is reflected in the papers in this Special Issue of Plant Growth Regulation. Typically such studies pose specific research questions and are conducted using discipline specific approaches on a single species, but often reflect some common questions and strategies associated with research into desiccation tolerance. Papers within this issue report on stresses associated with water deficit, such as the mechanical stress of plasmolysis (Koster et al. 2010), oxidative stresses, including those associated with light (Aidar et al. 2010; Proctor 2010; Kamies et al. 2010; Colville and Kranner 2010) and the protective responses generated in response to those stresses, or take a more global approach of searching for genes

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and gene products up regulated in response to stress (Abdalla et al. 2010). In addition to furthering our understanding of stresses and associated protection these works add important information to the field. Koster et al. (2010) quantify the extent of dehydration tolerance in the moss *Physcomitrella patens*, a species that is gaining importance as a model organism for functional genomics studies of bryophyte responses to abiotic stresses. Aidar et al. (2010) confirm that *Pleruostima purpruea* is indeed a resurrection plant that displays poikilochlorophyllous protection mechanisms to minimise oxidative stresses associated with photosynthesis during desiccation. Proctor (2010) utilizes chlorophyll-fluorescence parameters to compare and quantify recovery responses in a range of bryophytes and pteridophytes and proposes that this tool can give insight into factors influencing recovery time and rate. Kamies et al. (2010) describe the successful use of aeroponics to study antioxidant responses of roots of the resurrection plant *Xerophyta viscosa* to desiccation. There are few studies reported on roots of resurrection plants largely due to the problems associated with adherence of soil and associated microbes which cannot be removed from dry roots without altering tissue water content. This novel approach is likely to open the door for many future studies on root tissues of such plants. Colville and Kranner (2010) provide an excellent review of responses of desiccation tolerant plants and seeds to oxidative stress, showing that such organisms are robust models for the study of protein redox regulation. Abdalla et al. (2010) have identified nuclear proteins significantly up-regulated during drying of the resurrection plant *Xerophyta viscosa*, these data confirming that DT is indeed characterised and controlled by a multiple gene response. A comprehensive review of research conducted over the past 17 odd years on the resurrection grass *Sporobolus stapfianus*, put into context of how this information can be utilized for devising strategies for improved tolerance of water deficit as well as enhancing growth rates and biomass production in future applied studies is provided in the paper of Blomstedt et al. (2010). Such work, which is essentially taking a systems biology approach to the understanding of plant desiccation tolerance, is what is sorely needed for the advancement of this field. Due to lack of funding, extensive and varied technological requirements and/or adequate personnel with requisite expertise, such endeavours are often not possible. Researchers from the University of Cape Town, South Africa are following such an approach on species from the genus *Xerophyta*, and two papers within this issue (Kamies et al. 2010; Abdalla et al. 2010) bear testimony of some of their endeavours. In Myers et al. (2010), the authors examine the role of desiccation and other environmental cues involved in regulation of flowering in *X. humilis*; this work being an example of some of the ecological research being undertaken by the group.

The final papers contribute towards the theme of this Special Issue in a slightly different way. Vieira et al. (2010) explore use of exogenous treatments to facilitate re-establishment of desiccation tolerance in germinating seedlings of the orthodox seeds of *Tabebuia impetiginosa*. Re-establishment of desiccation tolerance in germinated seedlings has been an approach used to gain insight into the molecular mechanisms of desiccation tolerance—since this strategy enables elimination of genes and gene products involved in non-desiccation associated seed maturation events (e.g. Buitink et al. 2003, 2006). Vieira et al. (2010) found that rather than re-establishment of DT, their protocols promoted production of adventitious roots permitting seedling survival under water limiting conditions—an alternative survival strategy shown by plants growing in regions of high abiotic stresses. Desiccation tolerance is acquired during the mid- to late stages of seed maturation in orthodox seeds but developmental studies on recalcitrant seeds show that this is not achieved prior to, nor after shedding (e.g. the reviews by Farrant et al. 1993; Finch-Savage 1996). Such studies are in the minority and it is not yet known whether this is universally the case, whether there is partial or truncated attainment of DT in some species. The paper by Woodenberg et al. (2010) examines embryological development of the recalcitrant seeds of the cycad *Encephalartos natalensis*. While this paper concentrates on reserve accumulation and the unusual pattern of cellularization in the megagameophyte tissue, is it part of a larger study that is likely to give additional insight into what is important for development of desiccation tolerance in orthodox seeds by their absence in *E. natalensis*. Furthermore, *E. natalensis* is an extant species of what is considered a primitive genus and the study of their seed developmental characteristics might provide an answer to the question frequently asked by researchers in this field: Is recalcitrance a primitive condition or has DT been lost in such seeds?

Taken together, the papers in this Special Issue have provided confirmatory evidence to purported mechanisms of desiccation tolerance and sensitivity, have introduced new DT models for future studies and have allowed a review of DT from comprehensive studies on at least one such model plant. Piecemeal though such work might be, it all contributes towards, and is essential to, the gaining of a comprehensive understanding of stresses associated with severe water deficit and the nature of protection instituted to alleviate these stresses. This ultimately being required, in my opinion, to make informed choices for use in the production of drought tolerant crops and improved storability of seeds.

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