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Foreword

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Developing saline agriculture: moving from traits and genes to systems

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Abstract. The availability of adapted plants is one of the foundations to the development and implementation of saline agricultural systems. Such plants may be domesticated halophytes or genetically improved crops. However, not all saltland and saline water will be used or useful. Tools for saltland capability assessment will assist researchers in the development of worthwhile targets for plant improvement. Furthermore, saltland can be affected by a wider range of stresses than salinity alone. Developed plants need to be adapted to the range of stresses that occur on saltland.

Additional keywords: crops, halophytes, land capability assessment, salinity, saltland, waterlogging.

Why is saline agriculture important?

The term 'saline agriculture' refers to the use of plants and livestock in soils or with water affected by salinity to the benefit of farmers and the wider community (Qureshi and Barrett-Lennard 1998). The imperative to develop plants capable of growing in saline agricultural systems is growing. The world's population is expected to increase to more than 9 billion by the year 2050, which will increase the pressure for agricultural production from saline wasteland. Furthermore, climate change over the next century is expected to decrease annual precipitation in subtropical regions. As a consequence, in presently irrigated areas we can expect that good quality water will be increasingly reserved for drinking and urban use, and farmers may need to turn to the use of brackish and saline water for irrigation. In the light of these challenges, how can we develop useful plants for saline agriculture? The following considerations apply to naturally saline land, and also to the use of brackish and saline water for irrigation.

Saltland capability assessment

Higher plants can be found growing in natural habitats with salt in the soil solution up to 2.5 M NaCl. However, the productive potential of saltland and its usefulness in saline agriculture may be low over most of this range. Tools for saltland capability assessment should be developed and placed into the hands of farmers so that they target plants to the most appropriate parts of the saline landscape (Bennett *et al*. 2009). However, such tools may also assist saline agriculturalists in selecting their targets in the development of better adapted saltland plants. Severely affected landscapes will have a productive potential too low to justify the development of plants for their use and these landscapes should be set aside. However, moderately affected landscapes might have sufficient capability to justify some investment and slightly affected landscapes would have sufficient capability to justify more substantial investment in plant-development and adoption.

Domesticating halophytes

Databases that list more than 1800 halophytic species of potential value are now available (e.g. www.ussl.ars.usda.gov/pls/caliche/Halophyte.query). However, halophytes appear to be entering into agricultural systems mostly as sources of forage rather than as crops. This is hardly surprising as the qualities that plants need as forages are relatively easy to reach: for the maintenance of a small ruminant animal like a sheep forages need to be non-toxic, supply at least ~8 MJ kg^{-1} of digestible energy, contain reasonable concentrations of protein and not add too much salt to the diet (Barrett-Lennard *et al*. 2003). One of the key lessons from the Australian experience in this area has been the recognition of the importance of plant mixtures. While it has been difficult to find single halophytic species that fulfil all grazing animal requirements, mixtures of species (e.g. *Atriplex nummularia* Lindl. with herbaceous under-storey species like *Medicago polymorpha* L. and annual grasses) can be highly effective as forages on moderately saline land.

Breeding new crops for saltland

Crop species have a wide range of tolerances to salinity (reviewed by Steppuhn *et al*. 2005). For example, we know that barley cultivars (*Hordeum vulgare* L.) are generally more salt tolerant than spring wheats (*Triticum aestivum* L.), which are in turn more salt tolerant than durum wheats (*Triticum turgidum* L. ssp. *durum*

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(Desf.) Husn.). Crop success in saline environments is associated with a range of physiological traits governed by an unknown number of genes.

One of the most important questions for plant research is: how can we most rapidly improve grain production from saltland? This is a very different question to: how can we increase plant salt tolerance? The former takes a more rounded view of the range of stresses that occur on saltland, while the latter assumes that we know that the problem in the field is indeed 'salinity'. Thinking about the problem in this way encourages lateral thinking. Saltland is often affected by stresses other than salinity; boron and other toxicities, waterlogging and inundation by seawater can also be important. Given this, should plant breeders focus on improving plant tolerance to salinity in isolation, or to the range of associated stresses and their interactions in target environments? The importance of this can be illustrated using an Australian example. Many Australian barley cultivars have low tolerance to boron toxicity, but high tolerance to salinity, whereas in Australian wheat cultivars the reverse is true. Given this, we believe that it will probably be easier to improve grain yield on saltland by inserting a small number of genes for B-tolerance into barley than by inserting an unknown but presumably larger number of genes for salt tolerance into wheat.

A second 'lateral-thinking' solution for improved production on saltland exists for many environments with transient salinity (i.e. salinity that varies during the growing season). A recent investigation of annual pasture plants on saltland in a Mediterranean environment showed that successful genotypes delayed their germination until after soils had been leached by winter rainfall, and they ripened rapidly before the salinity of the soil solution increased again in late spring and summer (Nichols *et al*. 2009). Perhaps in soils with transient salinity we might also find it useful to select cereal cultivars with a short growing season, sowing these about a month after the early winter rains have leached the upper soil profile of salt.

In conclusion, it is important to recognise that plant improvement is only part of the solution to the use of saltland. Better germplasm must be linked to the appropriate management of soils and cropping practices. Quantitative modelling approaches may help identify and prioritise strategies for both the short- and long-term improvement of productivity from saltland.

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