Climate variability, climate forecasting, and improved crop design

Dr Roger C Stone[1] and Dr Graeme L. Hammer[2].

1. Queensland Department of Primary Industries and Fisheries, Toowoomba, Australia, and University of Southern Queensland, Toowoomba, Queensland, Australia, 4350.
   Email: Roger.Stone@dpi.qld.gov.au.
2. Queensland Department of Primary Industries and Fisheries, Toowoomba, Australia, and The University of Queensland, St Lucia, Australia 4072.
   Email: graeme.hammer@dpi.qld.gov.au

Improved and better-adapted crops provide a clear pathway to enhanced economic, social, and environmental well-being of rural communities, and, potentially, to improved world food security. Recent developments in plant science, computer science, and climate science, provide us with an unprecedented opportunity to design and implement crops using virtual plant technologies to explore interactions among crop genotypes (G), crop management systems (M), and the crop-growing (climate) environment (E). An important aspect of improved crop adaptation involves developing resilient crops and systems that can cope with climate variability (and potentially, climate change) and such extreme conditions such as drought. The opportunities for incorporation of climate forecasting, particularly at the decadal or near-decadal time scales, into improved plant breeding programs are large.

Crop adaptation can be considered by investigating the interactions among G, M, and E in determining crop 'fitness'. As plants are complex adaptive systems, they can sense their environment and respond to its 'cues' in a way that enhances their individual 'fitness' or ability to survive and reproduce. The sensing mechanisms and the control of the organism's responses via biochemical signalling are contained in the genetic make-up of the individual plant. While fitness occurs at the level of the individual organism, *the specific growing environment* determines the complex of genetic switches and cellular and organ level responses that are triggered. It is in this way that the combination of genetic make-up and growing environment mould the resultant phenotype.

Therefore, the phenotypic characteristics of an individual such as the amount of grain produced result from the interaction of its genes and the environment. The superior phenotype is the fit individual for the specific combination of circumstances, and it is the genes that carry the sensing-signalling-responding process capability to the next generation. The crop system reduces to a set of controllable factors (genotype – G; management – M; and another of uncontrollable factors basics of the CLIMATE and soil – E). Hence we think of crops as the interaction of G, M, and E, or G*M*E. This view is useful in exploring approaches to crop adaptation in situations where all three components are varying.

The concept of an adaptation landscape is useful in visualising this complexity and considering it for desirable combinations. The landscape will look very different for a drought year than for a wet year, for example. Crop modelling provides a means to explore adaptation landscapes *in silico*. The cropping simulation modelling platform, APSIM, has been used successfully to explore crop management scenarios and their modification depending on seasonal climate forecasts. This has led to practical approaches to interaction with farmers and their advisers in relation to management decisions. However, while these approaches have been successful in pursuing problems of M*E, this has been restricted to a very limited G, largely related to genetic variation in crop duration. Recent developments in crop modelling have provided a means to better link with variation in Genotype and with the explosion of knowledge in molecular biology and genetics. There has been substantial enhancement of the capability of APSIM in this regard by the development and incorporation of a generic crop model template. This paper explores the potential capabilities of combining climate science, especially climate forecasting, with environmental knowledge within the G*M*E concept.