Agronomy as applied ecology-or why we shouldn't lose sight of the big picture when marking the white pegs. A chickpea example.

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Abstract

Agronomy is concerned with identifying practical solutions to agricultural constraints. Often this involves subjecting a range of genotypes to particular treatments, selecting the best combinations and moving on. The problem with this focused approach is that the results pertain to the specific (ie a subset of genotypes and environments), rather than the general (representative of the crop and target environment as a whole), and as result it can be difficult to apply the knowledge widely. Agronomic interventions usually aim to change the crop environment to improve productivity. An understanding of crop evolution to specific environments is a good starting point for this type of research. This is illustrated by the case of chickpea as an Australian cool season grain legume.

In Australia chickpea is grown as winter-annual and is subject to biotic (Ascochyta blight) and abiotic stresses (cold and subsequent terminal drought) which reduce yield and yield stability. Early phenology is required to avoid terminal drought and heat stress throughout most Australian cool-season environments. However, early flowering exposes chickpea to temperatures too low to set pods, resulting in unproductive cycles of flowering and subsequent abortion. Chilling tolerance is rare in chickpea because of its early evolution as a spring-sown Mediterranean crop, and subsequent dissemination to warm-winter environments in South Asia and East Africa. However, climatic analysis of global chickpea environments has demonstrated the diversity of habitats in which the crop is grown, and will be used to evaluate chilling tolerance in germplasm from areas with low temperatures during flowering. An alternative approach is to evaluate the wild relatives which have maintained a Mediterranean winter-annual lifecycle. Preliminary results show improved chilling tolerance in lines of *Cicer judaicum* and *C. pinnatifidum*, neither of which can be crossed with chickpea at present. More collection of wild relatives in the primary genepool of chickpea is required to advance this work because there are <30 original accessions of *C. reticulatum* (n=18) and *C. echinospermum* (n=10) in the world collection.

Key Words

Agro-climatic habitat characterization, chickpea, chilling tolerance, annual wild Cicer species.

Introduction

Because agronomy is concerned with finding practical solutions to real-world problems the research can be prone to a narrow focus which makes it difficult to apply the knowledge widely. This situation is well illustrated by the use of genotype by environment (G?E) studies to identify high yielding or highly responsive cultivars, and has recently reviewed in chickpea (Berger et al. 2006). The typical approach of such studies is to calculate genotype means, Finlay-Wilkinson (1963) response coefficients or Eberhart and Russell (1966) stability parameters, and then recommend particular varieties on this basis. With few exceptions environments are uncharacterized, and no attempt made to explain high responsiveness or deviations from linearity among the genotypes from the point of view of environment or genotype biology. As a result it remains unclear to what the genotypes are responding, and why some genotypes fail to respond to these stimuli. While this approach allows breeders to choose the best material in the particular subset of genotypes evaluated, it does little to further understanding of adaptation in chickpea, and makes it impossible to extrapolate the results to other genotypes and different sites. This type of criticism, where research is focused on the particular, and cannot be extrapolated to the general can be levelled at a great deal of agronomic research. The solution to this problem is to consider the biology underlying the central issue as much as possible when designing experiments. This is illustrated below by considering the problem of poor adaptation of chickpea to Australian cool-season agriculture.

Chickpea constraints as a winter annual

Chickpea is grown as a winter annual throughout Australia, despite the fact that it evolved as a spring-sown Mediterranean crop and subsequently spread into warm sub-tropical regions, losing many of the winter-hardy traits found in its wild progenitor in the process (Abbo et al. 2003; Abbo et al. 2003; Berger et al. 2005; Berger and Turner 2006). Poor adaptation as a winter crop is manifested by susceptibility to *Ascochyta* blight (a disease of cool, humid conditions), and an inability to set pods at low temperatures. While *Ascochyta* pressure varies seasonally depending on rainfall, a lack of chilling tolerance constrains performance annually in southern Australia. Under field conditions, chickpea delays pod set at mean temperatures below 16?C, and ceases podding altogether below 12?C (Berger et al. 2004; Berger et al. 2005). Therefore, relative to better-adapted cool-season legumes such as lupins or faba bean, podding is delayed in chickpea, exposing the crop to terminal drought throughout much of the pod-filling phase, irrespective of when flowering commenced. The outcome is low and variable yield. While the causal mechanism is known (low temperature inhibition of pollen tube growth, (Clarke and Siddique 2004)), to date there has been no systematic search for cold tolerance, and consequently breeding programs are stalling due to a lack of resistant parental material.

Finding chilling tolerance in chickpea

Chilling tolerance is rare in chickpea because of its unique evolutionary history (Abbo et al. 2003). There are almost 29,000 accessions of chickpea in ICRISAT and ICARDA alone (SINGER 2006). Screening this number of genotypes is an onerous task which is probably technically infeasible. However, if the problem is approached as an exercise in applied ecology, a simpler solution presents itself. By characterizing the world’s chickpea growing habitats it is possible to select areas where the crop experiences low temperatures during flowering. It is assumed that these conditions will select for reproductive chilling tolerance and thereby reduce the germplasm numbers that need to be screened. Moreover, by selecting material from contrasting environments (warm versus cold, wet versus dry etc.) the focus of the work is raised from the specific to the general, and it becomes possible to extend the results to answer questions about how chickpea adapts to different climatic stresses. The task of characterizing chickpea habitats has begun. The global distribution has been mapped and climates defined by extracting data from high resolution interpolated climate grids (Berger and Turner 2006). The next step is to prepare phenological rules for the global distribution so that seasons can be defined in time, and the appropriate data extracted for the flowering phase. This work is ongoing.

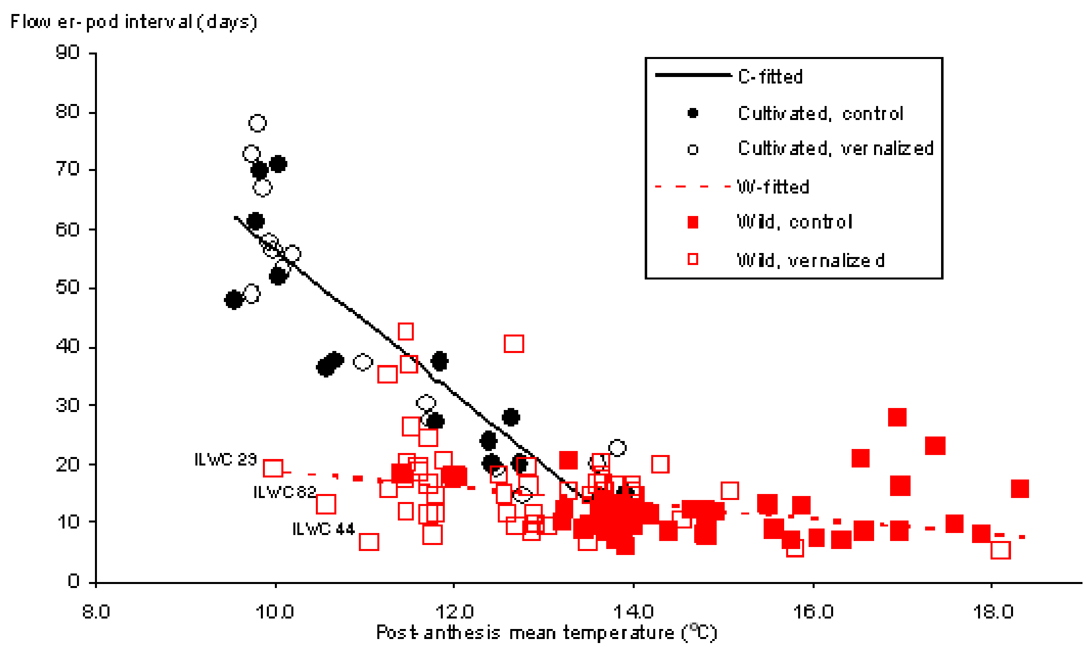

Fig. 1: Reproductive chilling sensitivity of chickpea and it's annual wild relatives in a field trial at Mt. Barker (WA), estimated by regressing the interval between flowering and podding against temperature averaged over the 1st 20 days after flowering (modified from Berger et al (2005)).

Finding chilling tolerance in the annual wild relatives of chickpea

An alternative approach is to consider the evolutionary history of the crop and its wild relatives. While chickpea lost many of its winter-hardy traits, presumably as a result of the shift to spring-sowing in the Early Bronze Age (Abbo et al. 2003; Berger and Turner 2006) its wild relatives have retained the winter-annual lifecycle, and may be a useful source of chilling tolerance. Preliminary evaluation of much of the world's meagre collection of germplasm gathered from the wild has demonstrated that wild relatives are far less sensitive to low temperatures at flowering than the cultigen (Fig. 1). Unfortunately the most chilling tolerant accessions (ILWC 29, 44, 82) are not in the primary gene pool of chickpea, and cannot be introgressed at present. However, given that the world's annual wild *Cicer* collection is extremely limited (1-34 original accessions/species, (Berger et al. 2003)), evaluation of species potential is extremely preliminary at this stage. More collection is urgently required, particularly in the primary gene pool (*C. reticulatum* and *C. echinospermum*), targeting areas experiencing low temperatures during podset. Evaluation of the 163 accessions subsampled from the originally collected material (2-49 per species, (Berger et al. 2003)) is also an important priority and is currently underway.

Conclusions

The aim of this paper is to stimulate agronomists to consider the underlying biology of the problems their research is addressing. The poor adaptation of chickpea as a winter-annual in Australian farming systems is given as an example of how this can be done. Field evaluation over the next 2-3 seasons will establish the validity or otherwise of this approach.

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