Plant Breeding in the 21st Century

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The Australian field pea and lentil breeding programs are working to incorporate a range of cutting-edge technologies to improve breeding outcomes. These technologies include advances in statistical design and analysis, genomic selection, accelerated single seed descent (aSSD), high throughput phenotyping and improving genetic diversity. This paper will give an overview of how these technologies can have an impact on responses to selection pressure within the breeding program. This response has been captured in the “Breeders Equation”, which states:

The response to selection = (σ_g x i x r) / L

Where σ_g = genetic variation, i = selection intensity, r = selection accuracy and L = generation length.

Trial design theory has evolved rapidly in recent years and innovations such as pedigree analysis, partial replication, and more recently, bespoke designs, significantly improve accuracy of yield trials. Genomic selection can have a profound impact on the breeder’s equation through increasing selection intensity, selection accuracy and aid in the incorporation of genetic diversity, whilst dramatically reducing the generation cycle. The Australian Grains Genebank is continually evaluating diverse germplasm and as this facility is co-located with lentil and field pea breeding programs, the breeders can observe this diversity as it is first entering Australia or while undergoing routine seed replenishment. aSSD facilitates the production of F_6 progeny from a cross within a single year, and although it is limited to relatively small populations, the effective population size can be dramatically increased if accompanied by trait and/or molecular selection processes being applied throughout generation advancement. Finally, high throughput phenotyping has the potential to characterize a range of traits within breeding germplasm to improve accuracy through the elimination of subjective biases and increase selection intensity by screening larger numbers of lines. Remotely sensed indices are also being developed to capture variation in photosynthetic ability and other production parameters that have previously been unavailable on such large scales. The combination of the above listed technologies can increase the response to selection in the breeder’s equation by 200-fold over conventional breeding programs.

To maximise the benefit of these technologies, breeders need to define specific crop ideotypes that will reduce input costs for growers, increase the market value of the product or increase yield potential and stability. Examples of where this has occurred in the past will be highlighted, as well as outlining opportunities for future breeding targets in a range of areas. Application of modern breeding technologies will allow us to develop tailor-made varieties much quicker than ever before.