CHICKPEA IN AUSTRALIA: OUR DEBT TO VISIONARIES AND TOILERS PAST AND PRESENT

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Today's Australian chickpea industry has benefited from a legion of contributors: breeders, researchers, marketers, processors, advisors and, in particular, farmers whose resilience and inventiveness are boundless. It is on behalf of all of them that I humbly accept this award. The breeding program I had the privilege to lead has also been a collegiate enterprise. I gratefully acknowledge the guidance, support and friendship of many skilled technical staff and other colleagues, both within NSW DPI and interstate, over nearly forty years.

My appointment as chickpea breeder preceded the industry by some years. For four decades I have watched it evolve from close quarters, observed in equal measure its advances and setbacks. It is from this 'insider's perspective that I give my version of its history, and of the breeding program supporting it. I have deliberately inserted the words 'visionary' and 'toiler' in the title of my presentation. These words also applied to Farrer. His vision for a better Australian wheat industry is a given; much less appreciated was the long grinding hours spent in crossing, notetaking and other activities at Lambrigg. Likewise, there has been no shortage of vision and toil in the rise of our chickpea industry. Fittingly, then, this is also the opportunity to acknowledge the seminal contributions of some (of many) key players.

Chickpea has a wide footprint in Australia. Both desi and kabuli types are grown, however desi types account for more than 90% of the total area. Moreover, nearly 90% of the crop area is in Qld and northern NSW. Desi production in the north-eastern region will therefore be my focus.

William Farrer

In keeping with tradition, I would like to reflect on the life and work of William Farrer. His achievements provided both model and inspiration for a succession of Australian crop breeding programs, and chickpea is no exception.

Much can be gleaned about the personal and professional attributes of William Farrer. The evidence is there in the first-hand accounts from close colleagues, his occasional publications (for example in the Agricultural Gazette of NSW), his extensive correspondence, and of course his prodigious breeding achievements. I will concentrate on some of the qualities that I believe were not only key to his own success, but can serve as example and inspiration to future breeders and researchers alike.

Farrer had a powerful drive to serve his fellow man. For 11 years from 1875 he was a registered surveyor plying his trade under contract to the NSW Lands Department. This work took him across large swathes of southern and central NSW, from Cooma to Dubbo and further west beyond Warren. There he would surely have witnessed many crop failures in the fledgling wheat industry, from moisture stress at one extreme and stem rust at the other. I suspect that his intrinsic altruism and empathy were further honed by this exposure. It should also be noted that his sudden change in career path was self-funded for thirteen years; not until his appointment as Wheat Experimentalist for the Department of Agriculture in 1898 was he remunerated, and then at the princely sum of £350 per annum.

The impacts of Farrer's work are staggeringly large. His varieties were significantly higher yielding than their forbears, had better quality and often had better disease resistance; their earlier maturity enabled wheat to be grown in lower rainfall environments, leading to a fourfold increase in wheat area; and they were often the foundation of future successful varieties, both in Australia and overseas (e.g. the Pacific Coast of the USA). It is difficult to imagine any agricultural project since that could boast such a huge benefit: cost ratio, no matter how heroic the assumptions.

Farrer also had a strong instinct for collaboration, no doubt intensified by his physical isolation at Lambrigg. The list of international correspondents (for example Blount, Galloway and Carleton in the USA, Biffen in the United Kingdom and Vilmorin in France) reads like a 'Who's Who' of world plant breeding in the late nineteenth and early twentieth centuries; the list of interstate correspondents is similarly impressive. No doubt they acted as a valuable sounding board for his developing ideas, many of them hatched before the 'rediscovery' of Mendel's laws in 1900 but also based on the writings of distant cousin Charles Darwin. Just as important were his close associations with the pathologist Nathan Cobb, occasional spat notwithstanding, and in particular the chemist Frederick Guthrie. It was the cooperation with Guthrie that enabled much of the progress in milling yield and baking quality to be realised.

Farrer's relationship with international and interstate colleagues also provided a conduit for the crucial two-way exchange of genetic material. As with all Australian crop breeding programs, Farrer's was totally reliant on germplasm from overseas. He introduced material, including other graminaceous species, from a diversity of sources, consistent with his intuition that this was a prerequisite for heritable progress. Farrer was cognizant of his debt to the international community, and was unstinting in his supply of breeding material and professional advice alike. His philosophy is well encapsulated in an extract from a letter to Dr Carleton, the USA wheat breeder: '… and I suggest to you that this is an aim which you, too, might with great advantage to your country, and *to the larger country of which both you and I are citizens*…' (my italics).

Public plant breeding programs have served Australia well. We can only hope that old fashioned concepts like altruism, empathy, collaboration and germplasm exchange will persist with the inexorable drift to private plant breeding.

Chickpea – A Long Gestation Period

Numerous brief reports in the Agricultural Gazette of NSW (e.g. Turner, 1891) attest to an early interest in chickpea. The enthusiasm was not maintained, however, and there is some suggestion that *Helicoverpa spp.* might have been at least partially responsible. The next published reference was by Cameron (1961) who included chickpea in soil conservation trials in NSW in 1958/9. Again, there was no follow-up. However, two decades earlier, at the University of Adelaide's Waite Agricultural Research Institute, Albert Pugsley was beginning to revive its possibilities. He was a lecturer there, and his strategy for obtaining information on a subject was to set his students an essay. By the late 1940s clearly some of his students had convinced him of chickpea's potential. It wasn't long before the fields of the Waite Institute were hosting observation rows of material sourced from India.

Soon after (1953) Pugsley left the Waite Institute to become the inaugural director of the Wagga Wheat (later Agricultural) Research Institute. There the demands from wheat breeding and administration saw chickpea lie dormant in his mind for more than a decade. However, from 1965, there is evidence he was redeveloping an interest: entries from Plant Introduction Review show him introducing germplasm from various overseas collections including the USA, Israel, India and, critically, the Soviet Union, Cold War notwithstanding. (CSIRO scientists were also involved in limited germplasm introduction during this time).

Humble Beginnings

In 1972 Pugsley was gifted the ideal person to begin turning his vision for chickpea into a reality. Eric Corbin had previously cut his agronomic teeth on wheat nutrition in central-western NSW, and moved to Wagga to initiate a program on 'alternative' crops. This new program had its genesis in wheat quotas, first imposed in 1969, and mounting concerns about declining soil nitrogen fertility.

The chickpea 'program' at Wagga effectively began in early 1972 when Corbin tested a modest set of introductions. Following the harvest he arranged for a subset of 16 lines to be evaluated Australia-wide. Significantly, many of the sites selected (e.g. Horsham, Perth, Kununurra, Emerald and Warwick) later became focal points for future evaluation and/or industry development. Chickpea was then considered an option for the drier areas of the wheatbelt, and primarily as a protein source for stockfeed (Corbin, 1975). Fortuitously for the Australian industry, a combination of factors in India (stagnant local production, an emerging middle class and lowering of import barriers) led to the emergence of a more lucrative, human consumption market.

The momentum at Wagga increased in 1973. A pivotal event was Pugsley's attendance at the SABRAO conference in New Delhi, and subsequent discussions with scientists at the Indian Agricultural Research Institute (IARI). His travel report gave one objective of his trip '…to discuss with research leaders the germplasm resources with special reference to *Triticum*, *Brassica* and *Cicer*, and to negotiate the importation into Australia of material that might be useful in breeding programs.' It is highly likely that the chickpea plots he saw at IARI left a lasting impression. The breeding program at Wagga commenced within a year.

Harvestability

An expanded evaluation in 1973 confirmed the crop's potential. It also highlighted the first of three major production problems the industry was to face: poor harvestability. Most of the early introductions were short-statured and therefore poorly suited to mechanised harvesting. (Even today most of the world's chickpea crop is hand harvested).

Fortunately, one line (K368) from the Vavilov Institute provided an ideal plant type. It was extremely tall (up to 1 m) with erect growth habit and sturdy, lodging resistant branches. Almost predictably, there was a catch: it had late maturity, very low yield and poor seed quality. Fortuitously K368's favourable plant type showed Mendelian inheritance. It was readily recovered in the first locally bred variety Amethyst (released in 1987) and subsequently in varieties that have dominated chickpea production in the north-east.

Phytophthora root rot

Commercial chickpea production began in Australia in1979. This was based initially on the desi variety Tyson which was jointly released by Queensland Department of Primary

Industries and CSIRO (Beech and Brinsmead, 1980). Tyson had its origin as the Indian variety C235; it was subsequently reselected to remove a significant proportion of iron inefficient off-types.

The first year of commercial production quickly revealed a serious, and unexpected, disease: Phytophthora root rot. The first identification was made in a crop of Tyson west of Toowoomba in July 1979 where 70% of plants were affected (Brinsmead *et al*., 1985). In subsequent years diseased crops became commonplace in southern Qld and northern NSW. The causal organism *Phytophthora medicaginis* is also pathogenic to lucerne and annual *Medicago* species. Both the wide distribution of these species in the north-east and the longevity of soil-borne inoculum make Phytophthora an important disease threat. Significantly, Phytophthora in chickpea is nothing more than a curiosity elsewhere in the world. It was, therefore, our problem to solve, and a breeding solution was the only viable option. Phytophthora was to become the second major industry and breeding problem.

Bob Brinsmead, based at Hermitage Research Station, Warwick, played a leading role in the development of resistant varieties. He screened the available collection in field nurseries from 1981 and identified a number of partially resistant accessions. One in particular, the Tajikistani landrace CPI 56564, consistently showed reduced mortality (Brinsmead *et al*., 1985). It has since been used extensively as a resistance source.

In 1982 it was agreed to combine the resources of the Wagga (generating segregating populations) and Warwick (selecting resistant lines) programs to breed adapted, resistant varieties. (The Wagga program was relocated to Tamworth in 1986). This was the beginning of a rudimentary 'national program'. The first resistant variety (Barwon) was released in 1991; higher yielding varieties such as Jimbour, Kyabra and PBA HatTrick have since dominated regional production.

Yield losses from Phytophthora have been reduced significantly although current resistance levels are inadequate under high disease pressure. Despite incremental improvements in resistance (e.g. Yorker), the apparent absence of better resistance in the chickpea germplasm suggests an approaching plateau. Fortunately, much superior resistance has been identified amongst accessions of the closely related wild species *Cicer echinospermum* (Knights *et. al*., 2008). Highly resistant backcross lines, in which most of the *C. echinospermum* resistance has been retained, have now progressed to final evaluation stages.

Nikolai Vavilov

At this point it is appropriate to interpose a tribute to the Russian geneticist Nikolai Vavilov, a true giant of twentieth century agricultural science. Vavilov's prodigious germplasm collecting spanned many decades, continents and species, chickpea included. He had much in common with Farrer: both were visionaries; both pushed their bodies to their physical limits; and both were driven by an urge to better the lot of humanity. Both men also battled against the headwinds of scientific orthodoxy and scepticism entrenched in their respective cultures.

Arguably Vavilov's greatest accomplishment was the establishment of an extensive germplasm collection housed in St Petersburg. Miraculously the samples stored there survived the city's famous 28 month siege during the Second World War; in some cases this was to the supreme cost of the collection's starving custodians. Germplasm collected by Vavilov and his successors has endowed agriculture worldwide. For the Australian chickpea industry, two landraces collected from Central Asia in particular have had a profound impact. The influences of both K368 (plant type) and CPI56564 (phytophthora resistance) are largely retained in the varieties that currently dominate production in the north-east.

Ascochyta Blight

The chickpea industry consolidated during the 1990s, despite the vagaries of weather (drought), markets (driven mainly by demand from India) and a range of teething problems including diseases (virus, botrytis grey mould), 'hostile' soils and weeds/herbicide toxicity (Figure 1). More rapid growth in crop area occurred in southern and western regions, underpinned by the release of higher yielding, superior quality varieties: Lasseter (Victoria), Desavic (South Australia) and Sona (Western Australia). However, this trajectory was about to be interrupted by the emergence of a major new, albeit expected, disease.

Ascochyta blight of chickpea (causal agent *Phoma rabiei*; formerly *Ascochyta rabiei*) became the third major industry/breeding challenge. It is unarguably one of the most lethal of plant diseases, having the ability to lay waste to entire crops within weeks of infection. There is evidence that the disease was present in Australian crops from 1991 (Khan *et al*., 1999), although it did not reach epidemic proportions (in south-eastern Australia) until 1998. Ascochyta was observed the following year in Western Australia. The industry was literally decimated in its wake. Subsequent deployment of resistant varieties (initially overseas introductions) did not see a significant return to pre-Ascochyta areas, due in part to other pulse crops filling the vacuum.

Almost counter-intuitively, chickpea production in the north-east expanded in the wake of Ascochyta's arrival. (The disease was widely detected across northern NSW and southern Qld in1998; its incursion into Central Qld occurred about a decade later). Industry survival in the north-east can be partially explained by a less favourable disease environment, compared to south-eastern and western regions, and fewer winter pulse options. Another crucial factor was the rapid deployment of an effective disease management program. The highly coordinated response, in which the NSW and Qld Departments of Primary Industries, Pulse Australia and GRDC all played pivotal roles, involved a large number of research and advisory personnel. Amongst these, two individuals stand out.

Kevin Moore, the Tamworth-based plant pathologist, was immediately tasked with developing a management response for an industry then based entirely on highly susceptible varieties. From 1999 his survey work and trial program helped clarify the epidemiology of Ascochyta and identify highly effective seed dressing and foliar fungicide treatments. This enabled susceptible varieties to 'hold the fort' until the release of more resistant varieties such as PBA HatTrick, PBA Boundary and PBA Seamer. Ongoing research has enabled disease management strategies to be fine-tuned to match the resistance levels of new varieties. Moore did more than research, however. The role that he moulded for himself was that of an extension plant pathologist. His pre-season meetings and field day attendances got the message directly to farmers and their advisors. The credibility that Moore has established over nearly twenty years has been a powerful enabler of change.

John Slatter, a Toowoomba-based agronomist with the industry body Pulse Australia, was the second part of an unlikely double act. An old style agronomist and consummate salesman, Slatter had a rare ability to distil the complexities of Ascochyta epidemiology and management into a simple story. He was also adept at leveraging the Ascochyta message to promote other key production points, particularly his hobby horses of deep sowing and sowing seed quality. Together Moore and Slatter played a major role in lifting the skills base of both farmers and their agronomists. Their impact cannot be understated: as attested by chickpea's precipitous decline in southern and western regions, the industry was facing an existential threat.

The National Program

In 1988 all state-based breeding and evaluation programs were merged into a national breeding program, funded by the newly formed Grain Legume Research Council. The most recent iteration is the chickpea sub-program within Pulse Breeding Australia (PBA), funded by GRDC and now in its third funding cycle. It is one of four breeding programs, the others being fababean, lentil and pea.

The PBA structure reflects a drive for efficiency: functions are allocated on the basis of comparative advantage, and duplication is avoided; no room is left to accommodate organisational self-interest. More difficult to quantify is the dividend from cooperation between individuals. To quote Andrew Inglis from his Farrer oration three years ago: collaboration amongst scientists is intrinsic. I believe the success of PBA also derives from a framework (Coordination Group) to enable synergies between different programs, a strong commercialisation focus with program input into selection of the commercial partner, and well resourced disease, herbicide and quality screening components. An involvement in the selection of relevant, GRDC funded postgraduate scholarships is an innovation likely to generate longer term dividends, perhaps even in succession planning. PBA can now boast a slew of new varieties across all the crop's target environments. The model has been a success, underpinned in large part by the cooperative spirit that has existed since Eric Corbin first enlisted the help of interstate researchers in 1972. No doubt the structure and cooperative ethos of PBA would also have earned Farrer's imprimatur.

Concluding Thoughts

To conclude, I will indulge in a brief stocktake of the breeding program, both to show the distance travelled and the challenges and opportunities ahead. Compared to the founding variety Tyson, significant progress has been achieved in the battle against the major regional diseases. Varieties moderately resistant/resistant to Ascochyta are much less reliant on fungicidal protection: foliar fungicides may not be required in the best case scenario; under high disease pressure an early reactive, as well as podding stage, application may be necessary. This contrasts sharply with repeated, mandatory sprays prior to rain events for susceptible varieties. Phytophthora is still observed in most years, however the crippling production losses that plagued the early industry no longer occur. Major progress has also been achieved, in some genotypes somewhat serendipitously, against a third disease, Root-lesion nematode. Recent work (Rodda *et al*., 2016) has shown some of the newer varieties (e.g. PBA HatTrick) to be partially resistant to *Pratylenchus thornei*, the most important regional nematode. This resistance, curtailing multiplication of the pathogen to less than two-fold, is highly comparable to that of breeding lines specifically bred for resistance using the wild species *C. echinospermum* as a resistance source. As such it represents a significant advance in the concept of chickpea as a rotational crop, since wheat is also host to the pathogen.

Diseases remain a potent threat, however, and will continue to be a primary focus of the breeding program. The fungus causing Ascochyta blight is notoriously variable, and the recent appearance of more aggressive isolates will require a constant rear-guard action. For Phytophthora, the much needed boost in resistance from chickpea's wild relative is tantalisingly close at hand. There is also a need for improved resistance to a number of second order diseases: Botrytis grey mould, Sclerotinia and virus. Elsewhere, improved Helicoverpa resistance would arguably reduce the reliance on insecticides, although genetic resources within the cultigen are limited. There are better prospects for enhanced tolerance to herbicides, both in-crop and residual, via chemically induced mutagenesis (L. McMurray, pers. comm.), and for improved reproductive-stage chilling tolerance sourced from the *C. echinospermum* genepool (Berger *et al*. 2012).

Harvestability has been greatly improved: compared to Tyson, crop (and lowest pod) height have increased in the order of 50% and lodging resistance has also improved. Seed quality has seen the largest advance overall: there has been a doubling of seed size without compromise to milling quality or appearance (shape, colour). Australian desis are now a premium product in the Indian sub-continent market, both for direct consumption and milling end uses.

The report card for yield is less flattering, with the annual rate of yield increase at about 0.3%, although not much less than that for local wheat programs. Nonetheless the progress overall has now enabled chickpea to capture more than 30% of the Qld winter crop area, and more than 20% in northern NSW.

It is fitting to conclude with an extract from a letter written by Farrer in 1893, and first quoted by Professor Donald in his 1964 oration: 'I will conclude this letter by expressing my belief that if we can hit upon a leguminous plant that can be economically grown with wheat, the yield of the latter would be so greatly increased that wheat growing would become a highly profitable industry'. Now we can safely say that chickpea has joined a growing list of crop and pasture legumes that bears testament to the prescience of Australia's 'greatest benefactor'.

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Figure 1. Chickpea area (ha) in Australia, 1984-2016