Farrer Memorial Oration 2001

Author:

The award of the 2001 Farrer Medal to me by the Farrer Memorial Trust is a deeply appreciated and humbling honour.

I see this award as not just recognition of my efforts, but more significantly as an acknowledgment of the considerable efforts of all the breeding team members over many years. I, also, wish to acknowledge publicly the intellectual stimulation, practical guidance and administrative support that the breeding program continues to receive from scientific colleagues, management, farm staff and industry people both within and outside NSW Agriculture. I would like to acknowledge particularly the substantial assistance and co-operation afforded the program by numerous durum growers over many years, through their willing and generous donation of land, technical advice, expert experience, funding support, enthusiasm and sincere friendship. All these close interactions are essential to the success of the program.

Before considering my topic of 'Durum Wheat in Australia – Past, Present and Future', I wish to reflect on the plant breeding career of the man we honour today, William Farrer. I feel that it is fitting to make some brief observations from a present day wheat breeder's perspective, especially as this year marks the centenary of one of Farrer's most significant contributions, the release of the very popular variety, Federation. Federation remained Australia's leading variety for 25 years, a record probably not repeated since.

It is abundantly clear, from the records, that Farrer was, without doubt, a genius. A self-taught biologist, practical agronomist, farmer and most importantly, an instinctive plant breeder.

While travelling the colony of NSW as a licensed surveyor in the Lands Department, he witnessed the devastation of rust epidemics and the moisture stress imposed on late maturing European varieties during the summer grain filling period. He determined to purchase a block of land, Lambrigg (near Tharwa, in the ACT) and breed adapted varieties commencing in 1886.

Over the next 20 years, 33 varieties were released either directly by him or from unfixed lines he produced. This is an enormous accomplishment in such a short time, especially by modern standards.

Farrer had a particularly incisive mind for plant breeding. He conceived and rapidly developed all the essential elements of a successful conventional wheat breeding program. These elements are:

- recognise a few key achievable breeding objectives and concentrate on them;
- obtain suitable germplasm from world-wide contacts which has the genetic potential to achieve the set objectives;

- undertake a planned crossing program to combine the desirable genes for the selected economic traits in the shortest possible time;
- generate selection populations that can be managed with modest resources;
- test these progeny lines in planned field and laboratory trials for agronomic, disease resistance and quality traits;
- test regionally on farms for wide adaptation to different production environments;
- undertake full commercial processing trials before releasing varieties;
- exchange ideas, germplasm and data internationally;
- collaborate with scientists from related disciplines; cereal chemists, plant pathologists;
- focus on germplasm development and research relevant to the breeding objectives, and integrate this study directly into the varietal breeding;
- have an irrepressible and single-minded determination to carry through a course of action once decided on and not be deflected by side-issues.

In 1898, his obvious success and skills were recognised when the New South Wales Colonial Director of Agriculture, W.S. Campbell recommended that he be appointed to the NSW Department of Agriculture, as a wheat breeder.
Farrer's incredible gift for biological observation and interpretation provided him with an understanding of the inheritance of economically important traits. He was unaware of Gregor Mendel's publications on the theory of inheritance until 1905, the year before his death.

It is quite probable that Farrer was the leading wheat breeder in the world at the time, an incredible feat given his limited means and circumstances. A very humble man, he would not have agreed with this assessment. All he wanted from his labours was to provide farmers with better varieties so that they and the Australian industry would prosper. By sharing his materials and experiences freely with colleagues, his plant breeding practices undoubtedly raised the standard of world wheat breeding and in turn global production. Surely here is a NSW Agriculture staff member we should learn from and be inspired by his tenacity to succeed.

Historical perspective of Australian Durum breeding

William Farrer was Australia's first durum wheat breeder. After hearing from M.A. Carleton, in the US, a very helpful and long term breeding colleague, that a durum industry based on Russian varieties had been successfully established in the mid-west states, Farrer felt that it would be profitable to attempt the same in Australia.

Farrer, 'believed that these wheats could be of great value to Australia, for the reason that, on the one hand, some varieties produce payable yields in localities where the climate is too dry for bread wheats; and, on the other, because there are varieties which are so resistant of rust as to be able to withstand the rusty conditions of our coastal climate, and produce crops of gain in places where rust appears to have made impossible the cultivation of bread wheats'.

W.S. Campbell appears to have taken a keen interest in Farrer's work and gave official support and encouragement to Farrer's durum initiative.

Despite a substantial durum breeding effort, Farrer did not succeed in convincing Australian farmers to grow durum wheat commercially.

While durum wheat displayed certain production advantages over other cereals, the Australian market was not ready for durum grain at this time.

Archer Russell, in his biography of Farrer, suggested that the huge success of Farrer's breadwheats, in particular Federation, a high-yielding, quick maturing variety of good quality, considerably lessened the interest in Farrer's durums.

Twenty-eight years elapsed after Farrer's death before the NSW Department of Agriculture breeders, Steven Macindoe, followed by Ted Matheson and Bill Single, championed the durum breeding cause.

A small-scale durum breeding program was commenced in 1934 by the NSW Department of Agriculture at the New England Experiment Farm, Glen Innes.

Discontinued during the war years, the program recommenced in 1948, followed by its transfer to the Agricultural Research Centre, Tamworth in 1958.

Dural, the first Australian pasta quality durum variety was released in 1955, in response to a growing but small demand for durum pasta in cans.

The next durum released, Duramba, in 1968 was Australia's first semi-dwarf wheat. Since 1968, a modest number of varieties have been released by NSW Agriculture from Tamworth:

Durati	1977
Kamilaroi	1982

Yallaroi	1987
Wollaroi	1993
Tamaroi	1997
Gundaroi	1998

The later varieties now completely dominate Australian production from Queensland, New South Wales, South Australia to Western Australia.

A new variety should be released to growers next year, mainly for cultivation in the northern region. This variety will provide higher grain protein levels (~1%) without any yield depression, together with near immunity for yellow leaf spot and higher yellow pigment levels in the grain endosperm. Other features of the variety are similar to those of Wollaroi.

Recent trends in Australian Durum program

The dietary styles of post war European immigrants have had a significant impact on Australian eating habits. Australians born since the war have become increasingly more adventurous in their diet. A rapidly increasing number of Australians have now recognised the preparation convenience, health features and pure culinary delight of good quality pasta in their diet.

In response, the domestic demand for durum based high quality pasta rose significantly, especially during the mid-eighties.

Importers of Italian products sensing this demand captured an ever-increasing share of the higher quality sector of the Australian market (up to approximately 85%). Australian pasta manufacturers reacted by changing from breadwheat semolina to the superior durum semolina as their principal pasta ingredient. The timely release and rapid acceptance of Kamilaroi provided Australian millers and pasta makers with a grain quality at least equal to the Italian equivalents.

Domestic grain requirements of about 100,000 tonnes per year has given Australian producers a firm foundation on which to expand plantings to capitalise on significant export opportunities.

Since 1994, Australia has been a consistent exporter of grain to a range of markets, including Italy, Spain, Morocco, Libya, Algeria, South Africa and Ecuador.
The quality of the Australian durum number one grade (ADR1) is now widely recognised as one of the best in the world, being on a par with 'US desert durums' from Arizona and usually ahead of comparable Canadian grades.

As a consequence, Australia DR1 is now keenly sought by Italian mills. Italian purchases represent about 70% of total export sales.

A recent Canadian Wheat Board report 'Grain trade forecast to 2008-9', projected Australia's share of global durum trade would reach 850,000 tonnes by 2008, the largest international growth of any nation. The Australian Wheat Board (AWB) agrees with this forecast except to suggest that this production figure should be reached at an earlier date. This anticipated volume represents 12% of the world trade just behind the US (1 million tonnes) and the EU (865,000 tonnes).

Australian exports could feasibly rise above 1 million tonnes. The AWB believes that a consistent production at about this level could be marketed without difficulty.
Given that New South Wales and South Australian harvests remain consistent at about 750,000 tonnes and 250,000 tonnes respectively, together with increased production in Queensland and Western Australia to about 100,000 tonnes, an export out-turn in the order of 1 million tonnes is achievable, within the next five years.

As it is anticipated that US production and consumption trends will not change dramatically, Australia would then move to the number two exporting nation in the world. This is a significant change given that Australian durum production did not rate a mention on world production statistics five years ago.

Farrer's dream of a significant Australian durum industry has now been realised, albeit nearly 80 years later.

Current Durum wheat breeding research

The Australian durum industry faces a number of challenges in the near future. Durum wheat continues to enjoy a price premium over the comparable breadwheat grades. Given that durum does not require significant additional on-farm inputs, farmers across Australia are keen to consider durum in their farming enterprise, to improve their net farm financial returns.

Unfortunately current durum varieties are not adapted to all wheat growing soils and locations. Factors such as soil moisture, salinity, trace element toxicities and deficiencies, soil acidity and certain soil-borne diseases place restrictions on where durum can be grown.

The National program is involved in a number of rather interesting and economically important collaborative research projects aimed at improving Australian durums to suit a wider range of environments.

I would now like to discuss briefly a number of these projects, to give you a flavour of the problems farmers face, possible solutions, research progress and the shape of future varieties.

Salt Tolerance

We are all very much aware of the creeping and serious problem that soil salinity represents. About 7% of Australian arable soils are saline.
The National Land and Water Resources Audit predicts that by the year 2050, as many as 17 million hectares are at risk of salinisation, representing a third of Australia's agricultural land.

One strategy to ameliorate dryland salinity is to sow deep-rooted perennial species that can lower the water table sufficiently to allow for subsequent cropping. After the water table is lowered, following rainfall infiltration will wash most of the salt to lower soil levels. Such a practice will rely on a high level of salt tolerance, not only in the de-watering perennial, but also in the more shallow rooted annual crops that follow, as some salt will be left in the root zone when the water table is lowered.

Cultivated durum wheat is salt-sensitive, a factor that restricts its expansion into areas with sodic or saline soils, especially in southern and western Australia.
In a collaborative project with Dr Rana Munns, CSIRO Plant Industry, we have concentrated on a trait that lowers the uptake of sodium ions (Na^+) from the soil to the roots, but enhances the accumulation of nutrient ions such as potassium (K^+).

On screening a carefully selected collection of durum wheats from the Australian Winter Cereals Collection, Tamworth, for this trait, three landrace accessions were found to restrict their Na^+ accumulation. The salt tolerance displayed by these accessions is at least the equal of that found in the most tolerant breadwheats. Subsequent genetic studies have suggested that the Na^+ exclusion trait is controlled by two genes, that can be manipulated in a breeding context. When appropriate molecular (DNA) markers are available, these markers will ease breeding manipulation, appreciably.

The first salt tolerant durum varieties are expected to undergo small-scale field trials next year with a potential release date in 2006.

The Na^+ exclusion genes in durum are probably not the same as those in breadwheat. By a simple inter-specific cross/hybridisation between appropriate durum and breadwheat parents, it may be possible to further improve the salt tolerance of breadwheat, through combining the two sets of genes.

We would like to think that salt tolerant wheats will produce acceptable grain yields on mildly transient saline soils, provide an economic return to the grower and an incentive to continue with salinity reclamation. Salt tolerant crops are not a solution to the salinity problem but one component in the reclamation process.

Water Use Efficiency

Better water use efficiency is paramount to improving productivity in Australian dryland cropping systems.

In another collaborative project with CSIRO Plant Industry involving Drs Tony Condon and Greg Rebetzke, two key traits to better water usage in durum wheat are being researched. These traits are:

- good crop establishment at the optimal sowing time to promote growth when temperatures are cool and evaporative demand is low, and
- high transpiration efficiency once the crop leaf canopy has established and evaporative demand is rising during the pre- and post-flowing phases.

I shall discuss the first trait today.

Crop establishment

The plant dwarfing genes currently deployed in our high yielding durum varieties impose a major limitation on the consistent establishment of a vigorous crop at the optimal sowing time. Farmers are often chasing receding sowing moisture and are frequently forced to stop sowing because the present semi-dwarf varieties cannot elongate their coleoptiles sufficiently to give effective establishment.

The coleoptile is the sheath that extends from the seed to the soil surface which protects the first leaf as it elongates.

Delayed sowing has a large impact on yield because crops are forced to flower and fill grain under unfavourable conditions of high temperature and low water availability. Yield losses can be about 0.1t/ha for each week sowing is delayed beyond early June.
The current dwarfing genes reduce plant height, to avoid lodging near maturity, by making the plant insensitive to the plant's 'elongation' hormone, gibberellic acid. These genes also act to reduce the length of the coleoptile, to a maximum of about 7cm. The coleoptile needs to reach the soil surface to allow plant establishment. For the seed to germinate it must be planted in moist soil. As the soil dries, the moist soil becomes covered with increasing depths of dry soil. The farmer therefore must plant his seed to greater depths. However current varieties are restricted to a maximum depth of 7cm.

Alternative ‘gibberellic acid-sensitive’ dwarfing genes are available that reduce plant height similarly to the currently used dwarfing genes, but, more importantly, allow for much longer coleoptile lengths (about 15cm). Longer coleoptiles will greatly improve the flexibility in sowing depth and timeliness, resulting in much better crop establishment under stubble-retention minimum-tillage agronomic practices.

The ‘gibberellic acid-sensitive’ genes can be readily manipulated in a breeding program, by applying simple growth measurement tests to breeding progenies.

The existing dwarfing genes are currently being replaced in advanced breeding lines, by a backcrossing procedure, with the expectation that new semi-dwarf varieties will be available in about 2006.

Disease Resistance

The two most intractable diseases in Australian durum cultivation are Crown Rot (causal fungus *Fusarium graminearum*) and Fusarium Head Blight (*Fusarium pseudograminearum*). Despite the investment of considerable time and effort by researchers both in Australia and overseas, plant genetic resistance solutions to these diseases have proved difficult to locate. However, all this effort is now starting to yield exciting results.

Effective genetic resistance has recently been found in durum and breadwheats to both diseases. Fusarium Head Blight causes the grain to shrivel or die and its contamination with compounds highly toxic to mammals, including man. Pathological manipulation of these diseases is rather difficult, hence the conventional disease screening of breeding materials that segregate for resistance genes, can be very time and resource consuming. Fortunately molecular markers closely linked to the resistance genes, particularly in respect to Fusarium Head Blight, are significantly assisting the accurate, reliable and cost-effective selection for resistance.

Here we have an example of an international and national collaboration, between publicly funded groups in the US, Austria, Mexico (CIMMYT) and across Australian agencies. Australian research and breeding will increase substantially in the near future given significant investments by NSW Agriculture and the Grains Research and Development Corporation. In view of the current researcher enthusiasm, dedication and willingness to share knowledge and materials around the world, there is a strong prospect that one or both diseases will be well managed by genetic resistance in the next five to 10 years, here in Australia.

By combining genetic resistance with crop rotations involving non-host species, both diseases should no longer present a threat to growers, especially those in the northern wheat belt. The long and patient wait by growers for a more satisfactory control strategy should be nearing an end.

Other Traits

The breeding program is involved in a number of other projects located in Australia and overseas, but time constraints do not allow more than a cursory glance here. Additional traits under consideration include:

- new durable rust resistances
- transpiration efficiency
- black point avoidance
- grain protein and starch composition and the relationship to product quality
- possible new products derived from durum
- molecular markers specific to durum breeding
- resistances to the exotic pests and diseases – Russian wheat aphid, hessian fly and saw fly, and durum specific leaf rust.

The Future Direction of Australian Durum Wheat Breeding

Before concluding this Oration, I wish to share with you some thoughts and concerns on the future direction of Australian wheat breeding.

Firstly, as a preface, let us consider the big picture.

Australians are members of a very fortunate community. We are endowed with abundant rural resources from which to produce much more than our domestic food needs. We are learning how to manage these resources in a sustainable manner. Our governments are prepared to make hard decisions that ensure that progress towards sustainability continues.

In contrast, many overseas nations are not able to provide their food needs from within their borders. Many nations by necessity are pushing their productive resources in clearly unsustainable ways. Salinity, pollution, soil erosion, acidification and urban spread are reducing the productive area, significantly.

On the other side of the supply-demand equation, some 80 to 100 million additional mouths are added to the global population each year. This is equivalent to four to five times the Australian population.

Worldwide, we have a shrinking arable land area coupled with a rapidly growing food requirement. Production per unit area has a finite limit.

Clearly, this situation cannot continue for much longer.

In future, Australian agriculture will have an increasing role in the world food supply.

Wheat is the biggest source of food for the global population, just ahead of rice. The quantity and nutritional quality of this grain has an enormous impact on human wellbeing. Wheat breeders and researchers the world over have a tremendous responsibility, especially those of us in the more affluent nations, to ensure the sustained productivity of this important crop.

That responsibility does not stop within our region, or even the nation, but extends globally.

To feed the ever-increasing world population, one important way forward is to maximise productivity gains on an international basis. This effort cannot be impeded in any way. Food is our most important material need. Human wellbeing and world social stability and security are dependent on a sustained and adequate supply of basic food. Science makes the best progress when the exchange of ideas, data and materials is free and rapid, and not constrained by legal, political or economic restrictions.
As breeders and allied researchers, we have an unquestionable obligation to share our germplasm and the intellectual property embodied in this germplasm.
Now let us turn to the new breeding structure.

Australian wheat breeding is being transformed from eight public programs within State Departments of Agriculture, CSIRO and Universities to three competitive commercial joint ventures or companies. Several private programs are also being established.
I shall now outline my thoughts on several areas of considerable concern.

National and International Collaboration

The success of Australian wheat improvement programs over the past 100 years is in large part due to co-operation between programs, free exchange of germplasm/varieties and data, and strong linkages with colleagues involved in research projects specifically relevant to the breeding objectives. Fora such as the Australian Wheat Breeder's Assemblies have allowed the wide dissemination of public information and ideas.
In the case of the durum program, being the only program in Australia for many years, extensive overseas collaborations have proved essential to maintaining the breeding momentum in Australia.

I wish to review the key benefits of one of these overseas collaborations. The most successful and productive collaboration in which I have been involved is that with the ICARDA/CIMMYT durum program based in Syria. Our programs are now virtually integrated as one. All materials, data and services requested by either group are freely exchanged. Essentially each program has been doubled in size. The germplasm resources of the two programs complement each other very well. There are many mutual benefits, both within and outside breeding. Australian materials are tested widely in the Middle East against a range of abiotic and biotic stresses such as the exotic pests; Russian wheat aphid, hessian fly and the durum specific leaf rust. ICARDA has established a world leading durum wheat specific molecular marker laboratory to develop a range of breeding relevant markers for numerous agronomic, physiological, disease

resistance and quality traits. Australian materials are now being screened by this laboratory. Molecular marker assisted selection will significantly assist the rapid incorporation of genes for traits that are difficult to select by conventional tests.
Farrer went to great lengths to share his materials and knowledge, widely. Clearly, he believed in open exchange. This practice is still most relevant today. We must continue to share freely in any new wheat breeding structure.

Staffing

It has been said that the greatest asset in a research and development program is the talent of the scientific and support staff. It is vital to train, attract and hold good breeding staff that, like Farrer, have an irrepressible and single-minded determination to succeed. Unfortunately, attracting such dedicated people who are prepared to stay in breeding for their working life is becoming extremely difficult given the uncertainties of science funding and relatively low salaries for scientists. Clearly, the career structure and remuneration for breeding staff is in urgent need of review, otherwise excellent breeding programs and opportunities will be lost.

Ownership

Ownership of programs must remain entirely in Australian hands. Growers and industry contract the research and development agencies to conduct R & D on their behalf. Like any progressive business, growers need R & D to remain productive and competitive, however they are individually too small to conduct this work on their own, thus they combine their resources to contract agencies. This principle will remain the same in the future. The new wheat improvement structure must accommodate significant grower involvement, even a proportion of grower ownership. After all, the growers have paid for a significant part of the breeding programs, over many years.

Change of Direction for Durum Wheat Breeding

May I suggest a total rethink of the direction that we are heading with the reorganisation, particularly in relation to durum. Instead of forming separate and probably somewhat isolated durum breeding groups across Australia, we should seriously move towards a joint international consortium of durum programs.
An Australian national durum program does not have all the resources to carry out all the selection tests for all traits, at world's best practice standard. This also applies to all overseas programs, including those in Canada and the US. In addition, it is evident that there is a large degree of complementarity in skills and resources between programs. By pooling our resources, skills and materials at a pre-competitive stage of breeding, worldwide durum productivity must benefit.

Initial discussions and comments between durum breeders on this topic have been very encouraging.

Perhaps this model could form the foundation for similar consortia covering other crops, especially the smaller crops. These crops are less likely to attract commercial breeding interest and public support in individual nations.

The future productivity of the world's principal food source and in particular durum wheat is too important to be compromised by constraining commercial, legal and political interests. An enormous 'public good' benefit is to be derived from a vigorous internationally collaborating breeding investment.

To conclude, Archer Russell made the following observation when concluding his Farrer biography, that 'Farrer wheats, or derivatives of Farrer wheats, have been extensively cultivated in India, Persia, North America, South America, Africa and even in some of the countries of Mediterranean Europe. Indeed, there are few agricultural countries into which his wheats, or his influence, have not penetrated. For Farrer was a world pioneer in plant improvement, and his methods have been studied and applied in practically every country where wheat is grown. Australian and overseas cerealists have built on the Farrer varieties in the production of better wheats. Farrer had faith in man's creative ability; he did not look upon Nature as an unconquerable power, but as a natural order capable of being bent, by co-operation and control, to the will and for the good of mankind'.

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