

Farrer and Further

Farrer Memorial Oration, 1999

This is a copy of the 1999 Farrer Memorial Oration, presented by Dr W J Peacock.

The Farrer Memorial Trust was established in 1911 to perpetuate the memory of William James Farrer and to encourage and inspire agricultural scientists. Initially it awarded scholarships for 'study or research in agricultural problems'. Later it included the delivery of an annual oration and the presentation of the Farrer Memorial Medal to a distinguished agricultural scientist for service rendered in the fields of research, education or administration.

For more information see the Trust website at

www.dpi.nsw.gov.au/farrer-memorial-trust

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THE 1999 FARRER MEMORIAL ORATION

FARRER AND FURTHER

Dr W J Peacock, CSIRO Plant Industry, Canberra

Thank you very much for this honour. I am very pleased to receive the medal and proud to be a contributor to Australia's agriculture.

Pleased, too, because this event caused me to read about Farrer and to read Farrer's papers. Farrer wrote a paper in 1898 on his ideas and his work in wheat breeding which I think was quite remarkable. What amazed me was that before the rediscovery of Mendel's work on the inheritance of characters, Farrer had a clear understanding of the principles of genetics. He based his breeding program on crosses between different genotypes. He recognised the genetic uniformity of the first generation following the cross and that the second or 'variable' generation provided him with the segregants on which he could base his program of selection for desired characteristics.

Farrer also had the good judgement and courage to trust in his experimental results and his careful observations rather than always to agree with dogmas stated by the more prominent scientists and agriculturists of the day. He based his wheat breeding on an underlying fabric of scientific method.

My study of William James Farrer's writings showed me the magnitude of the inputs this man had on wheat improvement programs in this country. It also emphasised to me that

the William James you awarded the medal to this year needs to be humble as well as pleased.

In the minds of Australians in most walks of life wheat in Australia is linked, and properly so, to Farrer. Farrer is especially significant to us here in Canberra because his property "Lambrigg" is juxtaposed to our suburbia. His name is significant to the New South Wales Department of Agriculture because the Department had the good judgement to employ and support Farrer.

With his experience in farming, Farrer saw in his travels as a surveyor that the wheat varieties available to growers in the 1880s and 1890s needed to be improved in many characteristics so that they would better fit Australian conditions. Most of the key traits identified by Farrer have been substantially improved in the last several decades of wheat breeding but they still remain valid objectives to this day. I will discuss a small number of these traits and I hope will show you that we now have one or two advantages over Farrer. He recognised the genetic or inheritable nature of the characteristics he struggled to improve but he was not able to define, isolate and work with the genes themselves as we can today. Our abilities to do this are now beginning to have profound influences on our wheat improvement programs, both in our conventional breeding programs and in what will become transgenic wheat improvement programs. Farrer was a visionary but I doubt whether he ever dreamt that we would be able to work from gene back to phenotype rather than using the phenotype to infer the gene.

Farrer saw major crop failures as he travelled around the country and these were attributable to rust epidemics. In his opinion the later season stem rust was more

damaging than leaf rust, his view diverging from that of his superior – Farrer’s observations were correct! Farrer never actually achieved his goal of producing varieties with effective in-built rust resistance but he did produce varieties which largely escaped the rust challenge, especially in the drier regions of the wheat area. His varieties suffered minimal damage from rust because they were early maturing.

In general, early maturity is correlated with early heading (or early flowering). We in CSIRO Plant Industry have made some exciting discoveries in understanding the genetic control of flowering. In the past two years we have identified a key flowering control gene (FLF) in our laboratory plant, Arabidopsis. This gene controls the difference between winter Arabidopsis and spring Arabidopsis and experimental evidence suggests that the same gene controls the difference between winter wheat and spring wheat.

We have been able to understand the mechanism of control – the molecular pathway of control of flowering time. The FLF protein is a repressor of flowering – it prevents the plant from switching from vegetative growth to the reproductive stage. If we increase the amount of this protein in the plant, flowering is delayed. If we decrease the amount of this protein in the plant, flowering is advanced.

Exposure of germinating seed to low temperature, fertilisation, stops the FLF gene from making protein and the plant flowers at the appropriate time in spring. We have identified other control genes which result in intermediate flowering times. It is highly likely that Farrer achieved early maturity in his wheat by selecting gene activities in this pathway. We can expect to be able to make deliberate calculated changes in flowering time in wheat in the future by specific changes in these genes.

[INSERT SLIDE 1]

Although Farrer did not identify and use gene-based rust resistance, his successors have managed to do this to great effect in Australia. Our wheats carry genes giving resistance to leaf rust, stem rust and stripe rust. Many of these genes have been introduced from wild grass species by special breeding technologies. Jeff Ellis and colleagues have now isolated actual rust resistance genes and are beginning to understand the molecular interactions that occur between the pathogen and the host when the rust fungus begins its invasion of the plant. Resistance genes to virus, bacteria and other pathogens have some common features with the rust resistance gene. Will we be able, using gene technologies, to design effective resistance genes against new strains of rust as they appear? The prospects are promising.

We are learning to recognise the parts of the protein produced by the resistance gene that are responsible for the specificity of resistance to rust strains. Already we have been able to build synthetic rust resistance genes. Remember that resistance genes against other pathogens and pests have similar structural features to the rust resistance gene. This is the case, for example, with a gene conferring resistance to cereal cyst nematode. The DNA sequence of this gene provides a DNA marker making it easy for the breeder to follow the resistance gene in a breeding program, saving much time and effort. Marker directed breeding is the first of the new wave of powerful technologies which will increase both the efficiency and the efficacy of wheat breeding.

[INSERT SLIDE 2]

One of Farrer's most successful varieties, Federation, had as one of its favourable characteristics, shorter stature than the other varieties that were current. In the shorter stem plants more of the products of photosynthesis are put into the grain rather than into the stem thus giving increased yield. Although Farrer knew about the use of dwarf wheats in Japan, it was many years before the dwarfing genes were crossed into Australian varieties. Now, all of our varieties have one of two dwarfing genes. These have been extremely beneficial for Australia's wheat production but they have some features which need to be improved.

The shorter stems of our semi-dwarf wheats are fine, but the varieties also have short coleoptile. This feature is not ideal for our modern methods of wheat cropping. When a farmer plants the seed a little deeper to make the most of soil moisture or when he uses reduced tillage management and there is stubble mulch on the soil surface, our wheats often show poor establishment. The coleoptile is just not long enough!

By introducing a different dwarfing gene, Richard Richards and his colleagues have overcome this problem. The new dwarfing gene results in short stature in the mature plant but it has long coleoptile. This leads to striking improvement in crop establishment. For example, in Hartog, one of our high performing prime hard wheats, the replacement of the existing dwarfing gene with the new gene can result in dramatically improved establishment.

[INSERT SLIDE 3]

Farrer also recognised that the early growth of wheat was important and could be very instructive to the breeder. The objective of early vigorous growth is now being followed in several breeding programs. We are using DNA markers to achieve this breeding objective. Basically, a larger embryo provides the wheat seedling with a better start in its early development resulting in better ground cover and larger leaves. It is a bit like normal term and premature term babies I guess. DNA markers for the larger embryo character and for thin, wide leaves are making it possible to efficiently incorporate these characters into our near-future varieties. Our research data show substantial increases in yield in many of our test sites.

Farrer's ideas for better wheats extended beyond the farm gate. He realised that it was necessary to have good milling qualities. He championed hard wheats and he favoured strong doughs for baking. Gains have been made in grain quality features in our wheats and these have been the basis of highly successful international marketing strategies. But it has been a difficult task for breeders.

There are a large number of grain proteins and they all contribute to a greater or lesser extent to the properties of dough important in bread making, noodle making and for other uses. Plant breeders have mostly not been able to focus on single proteins with particular properties. Now, we can isolate any protein gene and insert it into a bacterium or yeast production system so that we have large enough quantities of the single protein to use it in experiments exploring its effects on dough quality. By specific modification of these genes and their proteins, we can identify the regions of the molecules responsible for certain properties.

For example, the positions of cysteine residues in the protein can vary the polymer chain length in the network of molecules making up the dough. This can have marked influences on mixing time, dough strength and other important characteristics.

[INSERT SLIDE 4]

There are increasing markets for Australian wheat if we are able to produce wheats designed especially for the various market opportunities. Starch, the other major constituent of the grain, can also be varied with gene technologies. At present, wheat starch is fairly uniform across all varieties and we use starches from other species of plants to mix with wheat starch to give it different properties. For example, in Wonder White bread the starch which provides the soluble residual fiber so valuable to the health of our colons is a high amylose maize starch. Now it will be possible to alter wheat starch itself so that it will have a variety of properties.

One important example of starch properties in our current work is that Japanese buyers clearly preferred some Western Australian cultivars because they produced Udon noodles with a superior mouth feel to the varieties from Eastern Australia. We now know that this property was the result of the absence of one particular starch enzyme gene. With our new technologies we can build varieties to meet this market requirement. In the future wheat starches will have many roles in the food industry and in other industries as well. Chemical processing of starches will be reduced - the plant will do the processing for us.

Farrer had the innate gift of a truly effective plant breeder. He realised that if it were possible to conduct quality tests in early generations of breeding, quality objectives would be achieved more quickly and more effectively. The trouble is that early generation testing means that the testing has to be done with very few wheat grains. Micro-scale tests are needed.

We have developed instruments for micro-scale milling, dough mixing, strength testing and baking. These machines are now helping our breeders to carry out earlier and more accurate quality tests and hence increasing the accuracy of their selection. These micro technologies are ideally suited for the entry of gene technology into wheat breeding. These Leprechaun loaves were baked in thimbles!

[INSERT SLIDE 5]

I want to talk about one other observation that Farrer made. He realised that the varieties of his day were not ideally adapted to the soils and other aspects of the Australian environment. Most of our soils are deficient in phosphorus and plants need phosphorus to grow. Australian cropping is synonymous with the use of phosphorus fertilisers but the efficiency of use of the added nutrients is poor; generally only about 15% of the added phosphorus finishes up in the plant. Much of the remaining phosphorus accumulates in the soil as phytate, an organic phosphorus compound. This form of phosphorus cannot be accessed by the plant. Currently there is about \$9 billion worth of phosphorus tightly bound in the soils of the agricultural belt in Australia.

Wheat needs phosphorus to grow vigorously and to produce good yields. So too does Arabidopsis but phytate P is not available to the questing roots of these plants. Alan Richardson in our CSIRO Division has made one adjustment to the genetic makeup of Arabidopsis which I believe will also be able to be made to wheat and other crops. The addition of a single gene coding for the enzyme phytase may make a large contribution to our cropping efficiency. Alan isolated the gene from a soil bacterium able to access phytate P and made it into a plant gene with built-in instructions for the root cells to secrete the enzyme into the surrounding growth medium. The results in these experiments are spectacular! It provides a good result for the plant and if we are able to apply it to wheat in our cropping areas it will be a good result for the farmer, to the soil environment and to the wheat industry as a whole.

[INSERT SLIDE 6]

Farrer was certainly a man of vision and with a commitment transcending the wellbeing of the Australian wheat industry – he wanted to achieve food security for the expanding population of the world. The need to increase food production from a non-expanding arable hectareage remains a challenge today. We need to double food production over the next 30 years and moreover to achieve this with a sustainable production system. Australia needs to respond to global needs with expanding production and although much will be achieved with conventional breeding and improved farm management, gene technology and transgenic breeding will undoubtedly play increasingly important roles.

Difficulties never entering Farrer's mind are now becoming prominent in plant improvement programs. With the development of gene technologies, patents and intellectual property positions have become part of agribusiness. How can Australia maintain an active, and hopefully expanding, role in global crop trading when the giant multinational companies are investing billion of dollars to achieve commanding positions over enabling technologies? We need to be able to achieve a situation where our farmers and industries have freedom to operate nationally and internationally with both conventional and transgenic crops. One strategy we have initiated is to form an alliance between researchers, investors and marketers in a bid to generate an entity establishing a powerful intellectual property position for our industries, an entity which will be able to trade on appropriate terms with the large international companies.

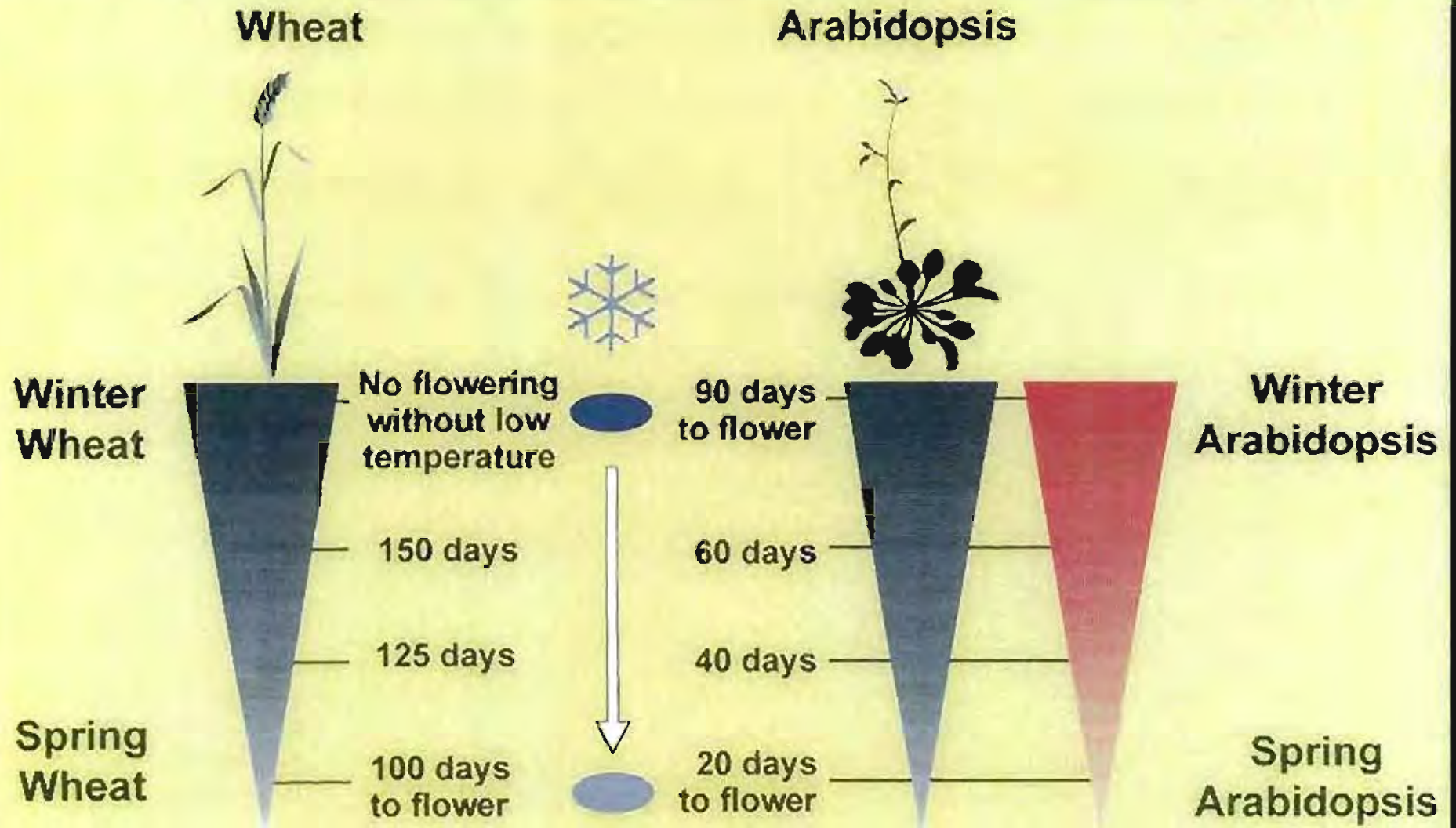
[INSERT SLIDE 7]

Graingene is the entity – it brings the Grains Research and Development Corporation, AWB Limited and CSIRO together. It is a joint venture which has the profitability and sustainability of the Australian wheat industry (and of the other cropping industries) as its central credo.

I believe Farrer would have approved!

September 1999

FLOWERING TIME IN WHEAT



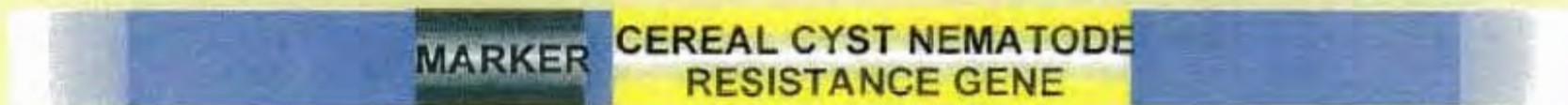
DNA MARKER ASSISTED BREEDING



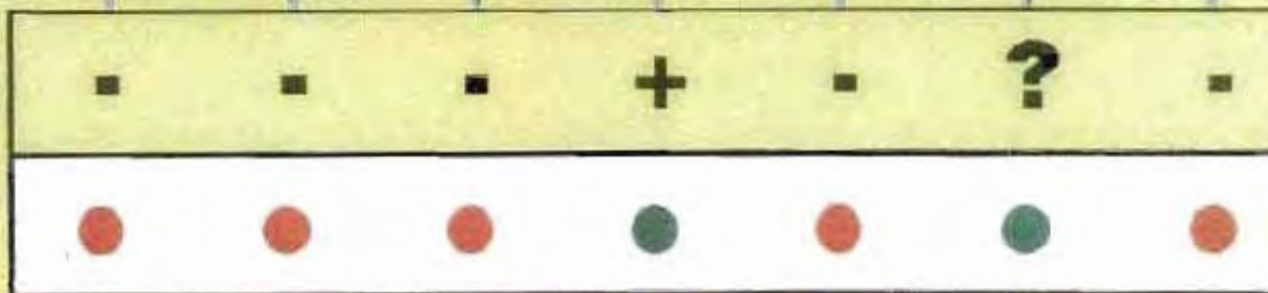
PRESENT IN PLANTS WITH RESISTANCE TO NEMATODES



ABSENT IN PLANTS SUSCEPTIBLE TO NEMATODES



NEMATODE
BIO ASSAY
- several months
DNA **SEQUENCE**
+or_
1 day



NEW DWARFING GENES

Deep sowing

Conservation farming
(stubble retention,
direct drilling)

Current
short coleoptile,
dwarf wheats

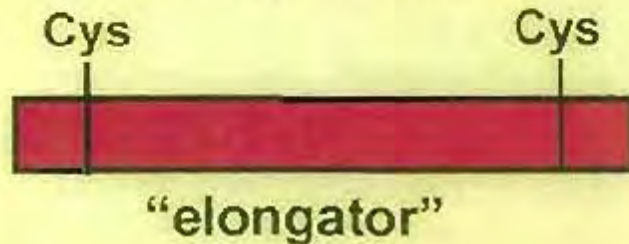


New
long coleoptile,
dwarf wheats




DOUGH QUALITY CAN BE ADJUSTED

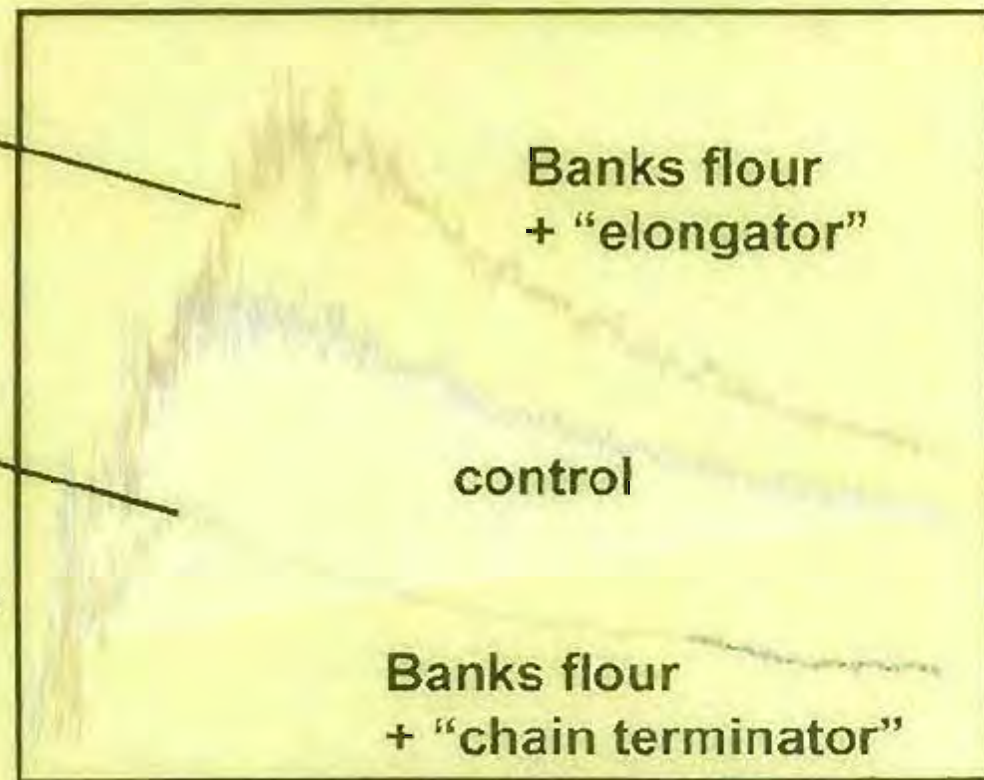
engineered glutenin
subunit protein



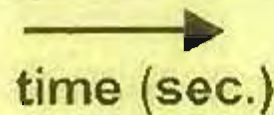
resistance



Result in Mixograph



time (sec.)



MICRO SCALE TESTING



UNLOCKING PHOSPHORUS FOR PLANT GROWTH

Phosphorus as Phytate



Control plants



+ Phytase gene

Graingene



ASSOCIATES

Australian $\left\{ \begin{array}{l} \text{Research} \\ \text{Commercial} \end{array} \right.$

Multinationals

