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Conservation of Plant Genetic Resources - A Continuing Saga

Farrer Memorial Oration, 1985

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NSW DEPARTMENT OF
PRIMARY INDUSTRIES

FARRER MEMORIAL ORATION 1985

Conservation of Plant Genetic Resources - A Continuing Saga

C.M. FRANCIS*

Introduction

William James Farrer (1845-1906)

William James Farrer truly deserves his title as the father of Australia's wheat industry. The introduction and general cultivation of Farrer's first wheats in 1901-1903 demonstrated to the world's wheat buyers the potential of Australia as a major wheat producing country, and that we could produce wheat which could compete on the world's markets with Canadian, American and Indian wheats, something not previously possible with the soft English wheats introduced by the first settlers.

Farrer's greatness was not only due to his instinctive plant breeding powess, but also because of his appreciation of the agronomic problems that the farmers faced. He was a practical agronomist and farmer as well as a wheat breeder and his 'feel for the land' and for the growers problems is a characteristic shared only by the really great breeders. Unfortunately too many of the breeders today do not have sufficient agronomic background lack this insight and fall back into a number crunching game. This, albeit very often effective, is certainly expensive in terms of resources and manpower. William Farrer used very small populations by todays standards but was able not only to combine a degree of rust resistance, with earlier maturity and improved milling quality but the wheat was of a type more readily harvestable with the Australian machinery and adaptable to a wide range of soil types. It was Farrer's training and work as a surveyor in N.S.W. which had developed this practical appreciation of the farming problems of the day. He took this insight into his field testing programme which at the time was unique and of which he was justly proud. He wrote to his colleague G.L. Sutton "in remaining with me you are helping to make the greatest practical advance that has ever been attempted by any Department in Australia. Indeed the principal on which we want to work, that is to carry out the same experiment on different soils and in different climates under the supervision and direction of the one mind, will in time commend itself to all". The validity of this statement is now well established. Widespread testing and the appreciation of the different behaviour of the varieties in different environments and the need for wide adaptation were enormous contributions to the science of crop agronomy at the time.

Farrer was born on April 3, 1845 and he died from a heart attack on April 16, 1906. He had just completed his 61st year. He was born in West Moreland of landed gentry. He was educated at a school called the Christ's Hospital, a bluecoat school and before leaving was one of the Grecians, a name given to senior boys entitled to wear the blue coat and distinguished himself by gaining a gold and silver medal for mathematics. After leaving this school he entered Pembroke College, Cambridge and established himself amongst the 'wranglers', the top mathematicians of the college. He had intended to embark

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upon a career in medicine but developed early symptoms of tuberculosis and decided to move to a drier climate in Australia. He planned to purchase agricultural land and become a station owner but in the interim he decided to speculate in a few mining ventures which left him so short of finance that he was forced to take up surveying. He became a licenced surveyor in the Lands Department in 1875. He resigned however in July 1886 and settled down in his new home 'Lambrigg' near Queanbeyan, not far from Canberra, a beautiful spot on the banks of the Murrumbidgee. It is here he began the role which was to occupy most of the rest of his life. He was particularly impressed by the devastation of rust epidemics he had seen and also that the wheat varieties available were too late in maturity for most of N.S.W. He grew introduced and local selections and their crossbred derivatives on 3 acres of land near his home. He loved the work, left it reluctantly at night and looked forward eagerly to the morning that he might resume it (Guthrie 1922). Some 33 varieties were produced either directly by him or from unfixed lines he produced. For one man to have accomplished so much in but a short part of his life time was a veritable triumph in wheat breeding history.

So much has been written about Farrer, books, and even a film "Strong as the Seed" was produced about his life that little remains unsaid. An exception however is his substantial contribution to the West Australian wheat industry. This was due largely to the direct involvement of Farrer's then assistant, George L. Sutton, later to become the Director of Agriculture in Western Australia. Dr Sutton was one of Farrer's most trusted Research colleagues and there are many of Farrer's letters to Sutton preserved in the Battye Library, Perth. Farrer was said by some to be a 'yeoman of the pen', a progidious writer who typically answered letters within 24 hours of receival. For those that could read his far from copper plate script, there unfolds an enormous amount of wisdom, energy, foresight and devotion. Farrer had joined the N.S.W. Department of Agriculture, N.S.W. in 1898 and in his role as wheat experimentalist had problems convincing research station managers of the importance of his work. An exception was Hawkesbury College where Sutton controlled the experiments. Farrer, as a result of his pertubations with the managers, lobbied the Director of Agriculture, Mr W.S. Campbell, to open a new station at Cowra, to specialise in wheat breeding and agronomy. He recommended it be placed under the direction of G.L. Sutton. At the time, in the early 1900s, Sutton was contemplating a position in Western Australia, a move Farrer discouraged in no uncertain terms. He wrote "Your function here would be unique and far more attractive than the head of an Agricultural College, especially one in what can for the time being can only be a relatively stagnant State. I do not think that you would like Western Australia at all .... If you want to remain at the forefront of progress in Australia, you will have to stay in the East where we want you to remain so much".

Despite his daunting opinion of the prospects in West Australia, his contribution to the wheat industry of Western Australia was enormous. Not only did 'Federation' released in N.S.W. in 1901 become the major wheat in Western Australia but numerous other Farrer derivatives were subsequently introduced when Sutton moved to Western Australia in 1910. From second generation (F_2) rows at Cowra, Sutton bought with him wheats which were to make profound impact on the Australian wheat farming scene some sixty years after the release of his most famous variety 'Federation'. From one of the Cowra station populations was selected the variety 'Nabawa' which was by 1928 the widest grown variety in Australia. Nabawa in turn was used by E.J. Limbourne in a cross with 'Gluyas' Early' to produce the variety 'Bencubbin' which replaced Nabawa as Australia's most widely grown wheat and remained so for no less than 19 years; a record unlikely to be surpassed. Bencubbin was largely replaced by a selection from it made by Dr A.J. Millington. This selection the variety 'Bungulla' continued with Bencubbin as the leading wheats in Western Australia from 1949-1957. It was not until the advent of the Sydney University rust resistant cross breds 'Gabo' in 1959 and a few years later 'Gamenya', that the direct influence of Farrer varieties in Western Australia began to wane (Millington 1979).

That the direct Farrer influence remained for more than 60 years, reflected the wide adaption of his crossbreds, how well he had carried out his program in the first place, and perhaps a narrower than desirable genetic base on which many earlier Australian plant breeders operated (Frankel 1954). In fact since the Farrer variety 'Federation' bred 85 years ago genetic yields in Western Australia have increased only slowly. This rate of increase about 5 kg/ha/year (M. Perry Pers. Comm) reflects no doubt the token effort Western Australia has made toward wheat breeding. Until the 1970s there was only one wheat breeder, and then usually attempting to breed other species part time. An obsession with breadmaking quality, as an esential criterion for new varieties, has not helped progress in yield selection. Farrer had similar battles with flour millers as some of the breeders of today, but Farrer won!

William James Farrer is thus worthy of a special salute from Western Australia. Farrer's appreciation that the English wheats were not the only wheats available and of the value of variability available in wheat and of the principles of its recombination were matched by a part contemporary in Russia on whom the main theme of this paper is based.

N.I. Vavilov (1887-1943)

Not long before the end of Farrer's life, a man was born in Russia who was to make yet another enormous contribution to the wheat industries of the world. His name was Nikolai Ivanovich Vavilov. Of wealthy parents, his was an academic family. His brother Sergei was a physicist and became President of the Academy of Sciences of the USSR. Nikolai however chose agriculture and graduated from the Agricultural Academy at Petrosov, Moscow and went on to continue his education at Cambridge University. He became a close friend of William Bateson, one of the pioneer classical geneticists of the day and later worked at the John Innes Horticultural Institute. After his return to Russia at the start of the first war, he commenced his classical work on the origin of cultivated plants. This monumental study was published in 1926 "The Centres of Origin of Cultivated Plants". In his famous book he synthesised a mass of botanical literature published by the early botanists and developed the principal of 'centres of origin'. In these centres he hypothesised must reside the greatest concentration of genetic diversity of cultivated plants (Figure 1). He and his collaborators were to back this treatise with more than 60 plant collection trips. He crossed the near inaccessible Hindu Kush, was the first European to study the mountain outskirts of Afghanistan (the Kafiristan) and in 1926 crossed Ethiopia in a small caravan. In all he bought 50,000 varieties of wild plants and 31,000 wheat specimens to the USSR (Popovsky 1978).

The Russian revolution (1917) provided unlimited opportunities in a time of dramatic change for anybody with the energy and intellect of Vavilov. At the age of 24 he became Professor at the University of Saratov. He was placed in charge of the Bureau of Applied Botany at Leningrad in 1920 and within a few years developed it into one of the largest and most active agricultural research institutes in the world. Scientists from elsewhere in Russia and the world joined Vavilov's rapidly growing staff of collaborators and in a few years the All Union Institute of Applied Botany and New Crop Development, as this bureau came to be called, became the centre of a Federation of Agricultural Research Institutes located all over the USSR from the polar circle to the sub tropics. In 1934 the combined staff of the association of institutes, with Vavilov as the head, numbered some 20,000 people. Honours came from all directions, in the late 1920's he was elected a member of the Academy of Sciences and President of the All Union Geographical Society and Director of the Genetics Institute of the Academy (Leppik 1969).

With the benefit of an education in classical Mendelian genetics Vavilov appreciated and taught that new varieties of economic plants could be created by combining together valuable genes. Such genes are scattered in the existing varieties and in their primitive progenitors especially at the centres of origin. These centres contain of the greatest diversity in terms of numbers of varieties and it was towards these that Vavilov moved to develop his collections of crop plants. Vavilov had incredible working ability and a analogy must be made to Farrer and probably to almost all the great scientists. Their energy, their drive, and perhaps ego sustained an enormous work output. Vavilov needed only between 4 and 6 hours of sleep per day and liked to start work at 4 a.m. On field trips these habits made coexistence a little difficult for some of his scientific co-operators. Nevertheless his collaborators contributed greatly to the program and by 1940 the Leningrad collection numbered more than 250,000 accessions including 36,000 wheat entries. The collection was stored in one of the country abodes of the Tzars in the Leningrad suburb of Pushkin. Miraculously, and to the great pride of the keepers of the collection, not one grain was lost during the siege of Leningrad (1941-44). It survived the war, vermin and the starving Russian population, despite the penetration of German troops to within but a kilometre of the seed stores.

One of Vavilov's greatest triumphs was the congress of Genetics, Plants and Animal Breeding held in Leningrad in 1929 under his presidency. Some 1,400 scientists attended and amongst the 348 papers was paper on the physiology of cereals. It had as a junior author T.D. Lysenko, a figure who was very soon to became familiar not only to biologists but to newspaper readers throughout the USSR. He was hailed as the discoverer of vernalisation, a process whereby winter wheats could be made to head in the spring. Although the phenomenon had been discovered earlier in the United States Lysenko gave it a name. A master of the art of publicity. It was claimed vernalization would herald a new era in Soviet agriclture by allowing the cultivation of better crops in the summer. By employing high yielding winter varieties one could effectively produce new varieties in only a year or two by unlocking the yield potential of the winter wheats thus greatly shortcutting the traditional crossbreeding techniques because, said Lysenko, such changes were heritable. Lysenko's debut was welcomed by Vavilov who in fact proposed facilities for testing Lysenko's ideas. Lysenko took charge of the Plant Breeding Institute at Odessa and he and his followers produced stream of papers, magazines, articles and speeches. A man of energy clearly rivalling that of Vavilov himself, Lysenko was greatly influenced by the work of the Russian plant breeder, I.V. Michurin, (1863-1935). His successful empirical work in horticulture usually involved grafting techniques. He supported this with theoretical views which were anti Mendelian (Caspari and Marchak 1965). Michurin believed (as Darwin did) that 'heredity' is in some fashion diffused throughout the organism and can be modified by many types of environmental influences. Michurin noted buds from grafts of one fruit species onto another often acquired characters from both parents, supporting thus the concept of diffusion of heritable material. These points of view were adopted by Lysenko and perpetrated as the Lysenko-Michurinist doctrine which was used to explain many of the results of traditional plant breeding as well as providing a theoretical basis for.

Lysenko's work on vernalization and temperature controlled phasic development of cereals. By 1935 with the aid of Marxist philosopher I.I. Present, Lysenko had tied his theories of phasic development to Marx's theories of development of society and convinced the socialist government to embark on a gigantic, and largely unsuccessful, application of vernalization to agriculture. Cohen (1977). They contended that Vavilov, in basing his work on Mendelian genetic principles, has caused inexcusable delays in the successful outcome of breeding programmes. At this time, around 1935, it was a pretty serious matter to be accused of having slowed down the development of agricultural production in the USSR (Dobzhansky 1949).

To consider these charges, a new congress on genetics was convened in Moscow in 1936 presided by A.I. Muralov, a Government nominee. The published transactions showed a very well organised group led by Lysenko and Present. Geneticists, amongst them, the famous American, H.J. Muller tried to stem the tide against genetics. Vavilov himself made several speeches but many Russian scientists began to 'sit on the fence' in the dispute aware of the dangers to their positions, as it was known that Lysenko by this time had greatly impressed the Soviet bureaucracy, most notably Joseph Stalin, with his work at the Odessa Institute. Indeed the 1936 Genetics Congress turned on the whole against Vavilov just as the 1929 congress had been one of his greatest triumphs (Dobzhansky 1949). Of course, no matter what else may be said about their intentions, those that assembled at the 1936 Genetics Congress, including most of Lysenko's followers undoubtedly sincerely desired the betterment rather than the deterioration of Soviet agriculture, a most unfortunate irony.

Lysenko and his followers continued their efforts to grasp the leadership of the Lenin All Union Agricultural Academy from Vavilov. After the 1936 meeting there was an open season for fault finding with Vavilov's research and organising ability. Dozens of hitherto unknown authors suddenly discovered that Vavilov's theories of the centres of origin and of homologous series were totally unfounded. Worse than that, those theories had led Vavilov to "dissipate his efforts toward sending expeditions to foreign countries" instead of confining himself to the studies of local varieties in the USSR which would have achieved far greater practical results. Vavilov was accused of causing plant breeders to reply solely on the method of sexual hybridisation practiced by 'bourgois geneticists' instead of the methods of vegetative hybridisation proposed by the famed Russian fruit breeder Michurin, whose results were widely adopted and interpreted by Lysenko as supporting his theories. Vavilov's worst sin, which negated all his research and practical activities was his interpretation of Darwinism in terms Mendelian genetics. Amazingly, Lysenko set up Darwin as an incontrovertable authority in the opposition to genetics, in claiming Darwin's "survival of the fittest" depended on the whole plant adapting to the environment. This adaption was heritable and not to recombination and selection amongst small genetic changes or gene mutations. Lysenko in fact totally denied the existence of genes and gene theory in one of the wierdest chapters in the incredible story of Lysenko's rise to power. The fact that genetics is a foundation of modern Darwinism proved to be no obstacle to the Lysenko/Present campaign.

The final days of N.I. Vavilov

In 1939 the 7th International Congress of Genetics was held in Scotland. Vavilov, although invited to become President, did not attend giving but short notice and no explanation. Clearly all was not well. The same year another "Conference on Genetics and Selection" was held in Moscow where problems of the 1936 Conference were examined again and Lysenko and his followers greatly expanded their previous claims of the theoretical and practical efficiency of their system. Vavilov was interrupted and heckled from the floor stacked with Lysenko's followers. Lysenko used his position as Stalin's favourite to defeat Vavilov and after the 1939 genetics conference at Moscow a cloud of silence enveloped Vavilov. The reasons for it were chilling.

The true facts became known only some 35 years after Vavilov's death when a commission was formed to investigate the facts behind the disappearance of Vavilov from the scientific scene. The commission, with the support of the Soviet Academy of Sciences, comprised Soviet science writer Mark Popovsky, Vavilov's son Uri and Professor N. Maisuria, a professor of plant culture.

Vavilov was arrested on August 6, 1940 on a Botanical expedition in the Western Ukraine. In the ten volume 'Judicial processes of N.I. Vavilov' (No. 1500) preserved in the K.G.B. archives numerous supporters of Lysenko had made denounciations to the Secret Police (OGPU-NKVD) accusing Vavilov of Scientific sabotage and of malicious disagreement with Lysenko. The Secret police preferred not to publicise Lysenko's role in his downfall but they prepared charges about the participation of the great biologist in foreign intelligence services and about his work as a saboteur of the Soviet economy. In the Judicial papers however, there was no outside evidence connecting Vavilov to foreign intelligence services or sabotage. However his chief interrogator, Senior Lieutenant Alexei Khvat, was able to obtain appropriate confessions in the course of some 400 interrogations lasting 1700 hours using beatings and torture.

Vavilov's trial took place in July 1941 just after the start of the Soviet-German war. It lasted five minutes without lawyer or witnesses and the charge sheet was already prepared. Although Vavilov denied all the accusations no one listened. Under articles 58-1a, 58-9, 58-11 of Russian Federal Republic criminal code, the military board of the supreme court sentenced Vavilov to suffer the highest form of punishment, death by firing squad and confiscation of all his private properties. The sentence was final and no right of appeal. He was taken to Butyrsky goal on July 26, 1941 for the sentence. At this point there was a cloudy area and it was not known why he was not shot that summer. Two of his close colleagues and friends, the geneticist Georgy Karpechenko and the bean culture expert Leonid Govorov were both executed at that time. It was thought that they may have been intending make use of the scientist at one of the Scientific Institutes as was done with the famous aircraft designer Andrei Tupolev. Such a plan did not eventuate however and on October 16, he ended up in Saratov prison No. 1 near the Volga river. The best information about these months was contained Vavilov's own letters addressed to Laventia Beria, the ruthless and all powerful head of the secret police. In a letter dated April 25, 1942 he wrote that he had been in a condemned cell for six months each night expecting to be shot, with no exercise, books or papers. The cell was simply a narrow slit without any window or ventilation. The food was terrible. He asked Beria for the opportunity to help the warring country either as a selectionist, teacher or agronomist. At the beginning of July 1942 a merciful reply came back that the firing squad was to be replaced by 20 years in a prison camp. If he had in fact been transferred that summer to an agricultural camp where food was available he may well have survived, but through forgetfulness or a cruel twist of fate he was not transferred.

One other attempt was made on Vavilov's behalf during those fateful months. Members of the British Royal Society such as William Bateson and Cyril Darlington were great admirers of Vavilov they elected him a Fellow of the Royal Society and through the embassy sent the appropriate documents into

Russia for signature and retrieval. This was the first attempt by the scientific community to find out about his fate and if possible to help him. The documents were received by an officer of the Secret police Andrei Chernov and the President of the Soviety Academy of Sciences Vladimir Komorov. The President was very embarrassed by the situation because no one knew where Vavilov was. Not only were there millions already in the camps of the 'Gulag Archipelago' but there were also the turmoil of war, the German attack on Moscow and the drafting of many of the police and security forces into the front line of defence against the Germans. To this confusion was added the hundreds of thousands of the so called army 'deserters' thrown into the camps without proper documentation. The Russians attempted a trick by getting his brother Sergei, also an Acadamecian, to sign the forms but the British Embassy uncovered the subterfuge and returned them. Beria reacted to this news in the Autumn of 1942 by organising a search for the imprisoned Vavilov under a general Victor Illin. They planned deception first issuing a statement that he was not under arrest at all. Of course it was no simple matter to find him in the wartime confusion and unfortunately they did not receive an answer to their enquiries until Spring 1943 when Vavilov was already dead.

He died at 7 a.m. January 26, 1943. He was just 55 years old and the prison papers indicated dystrophy and oedema and the pathologists anatomical examination of the body, revealed nourishment was sharply reduced and the subcutaneous cells were missing ... the man who had given his country millions of tonnes of wheat had died of starvation (Popovsky 1978).

Trofim Denisovich Lysenko - His era ends

By 1948 all Lysenko's most formidable rivals were either dead, in the Gulag Archipelago, or simply dismissed from their posts. Major positions in all the leading scientific or breeding institutes were staffed with Lysenko's supporters, and at a special congress in 1948 the ideals of Lysenko-Michurinist biology were ratified unanimously by the congress. Text books containing earlier Mendelian genetics were withdrawn and rewritten in terms of Lysenko's theories of inheritance of environmentally acquired characters. This 'black' period in Soviet genetics lasted in effect some 20 years. However, with the death of Stalin in 1953 criticisms of Lysenkoist theories began to surface in the scientific literature. Although Lysenko initially retained a substantial power base he lost his position as President of the Agricultural Academy whilst retaining the Directorship of the Genetics Institute on which he had replaced Vavilov. However with the fall of Khrushochev so ended the Lysenko era. In 1965 the Director of the Academy of Science announced the removal of Lysenko as Director of the Genetics Institute and added, "His theories were to be submitted for free discussion and normal verification". Thus a sad and instructive story came to an end requiring yet again the rewriting of the text books. Thus, though the impetus in the start of the Lysenko era had been for a revolution in agricultural production when to this potent brew was added an extraordinarily ambitious and ruthless scientific adventurer like Lyssenko, the results were to set Soviet agriculture back decades (Caspari and Marshak 1965)

Lysenko's fall occurred in a non Stalin era and unlike most of his less fortunate opponents he was allowed to continue working as a provincial agronomist at a reasonably obscure collective farm near Gorki. He retained his position there until his death in November 1976 (White 1976). Part of his work was to supervise the production of seed potatoes using the principles and techniques which he had 30 years earlier used as one of the cornerstones of his theories of the inheritance of a acquired characters.

Soviet biologists, in particular Vavilov's former colleagues rapidly regained their positions and control of the All Union Institute of Plant Industry. In 1965 it was renamed the N.I. Vavilov Institute of Plnt Industry. Vavilov's theories and teachings were revived and the Institute and its fabulous collection restored to its former status.

The Australian Role in Plant Genetic Resources

The well co-ordinated, documented and freely accessible collection of the Vavilov Institute, superbly staffed and funded, contrasts sharply with the haphazard system used in Australia whereby the breeders themselves usually maintain their own germplasm. Although the Australian wheat collection and associated activities are reasonably well co-ordinated, in most crops this is not so. This results in duplication, wasted effort, and often, an irretrievable loss of germplasm, problems which the Vavilov Institute had long overcome (Marshall, Francis and McIntosh 1977). Australia's lack of communication and co-ordination between the various importing agencies has been a serious deficiency in Australian Plant Introduction System. Agriculture has been a traditional State function with CSIRO an independant group. This has led not only to duplication in collections but also international co-operators getting several requests for the same material from different States.

There have been initiatives by F.A.O. and its agency IBPGR (International Board of Plant Genetic Resources) to sponsor a global network of genetic resources. This worthy ideal is one not without problems as discussed later. In Australia, Marshall (1976), though warmly supportive of such an initiative, made it clear that "First, we need to develop our own national network of genetic resource centres which will conserve germplasm of our most important crop and pasture species and second, we need to tie this network as closely as possible with the proposed F.A.O. international network in order to ensure access to germplasm which we do not conserve outselves."

Dr D. Marshall's words were translated into action in his preparation of a proposal for the formation of an expert panel on genetic resources to discuss the network theme. This plan was presented and adopted at the meeting of Plant Production Committee in 1977.

Despite the promising start and the agreement in principle amongst the States, the Australian effort has been far from an exercise in decisive decision making. The network plan has taken some seven years to commence and will take at least a further 5 years to complete.

Two working groups were established to develop a suitable proposal for the Commonwealth. The first, chaired by Mr R.H. Taylor and formed at the request of the Standing Committee on Agriculture (January 1977) recommended that a network of germplasm centres be established in Australia. After accepting this recommendation in principle, Standing Committee (January 1979) then approved the formation of a second group chaired by Dr R.D. Brock to further develop the plan. The proposal of this group, to establish eight plant genetic resource centres over a five-year period (Table 1) was accepted by Australian Agricultural Council (in August 1980).

In July 1982 Council agreed that the Commonwealth be approached to provide $1.2 million over 5 years for the capital works to develop the centres. At its 116th meeting (Sydney, February 1983) Council considered a submission from Standing Committee proposing a start with three of the centres in 1983/84. Subject to Commonwealth funds being available, Council approved the expenditure of a total of $310,500 for the centres in New South Wales, Western Australia and South Australia. They also approved the establishment of a Management Committee for the genetic resources network to be known as the Plant Genetic Resources Committee. This committee under the chairmanship of Mr N.J. Halse, undertook the further development of funding plans. Despite the recommendation by Australian Agricultural Council that this important project should commence in 1983/84, no funds were allocated for it is in the Commonwealth Government's budget that year.

Plant Production Committee at its meeting (October 1983) expressed serious concern about this situation and proposed that an updated request for funds for the first year of this project should be re-submitted immediately. This was done and the first grant of $357,000 finally approved by Cabinet for the 1984/85 financial year to consolidate existing collection of cereals at Tamworth, N.S.W., Medicago species (Adelaide S.A.) and Trifolium species (Perth, W.A.) under the control of the respective Departments of Agriculture. Thus a major advance in the saga of plant genetic resource conservation was finally achieved.

When they are completed total accessions should total approximately 150,000. Even by the standards of Vavilov Institute the network will be one of the best in the world and will serve current and future plant scientists for generations as a invaluable resource for future improvement of both crop and herbage species.

Genetic resources must be seen not as static collections but as dynamic systems backed by an active screening and at least a preliminary agronomic evaluation of defined priority species. Although the 'squirrel' syndrome of collection and storing anything for a rainy day is understandable, unfortunately such blanket collections, which one never has time to catalogue through lack of resources and time, can in fact be deleterious to the total effort. Collections are best in the hands of experienced agronomists who can make judgements on the species potential. Such a listing of priority species has in fact been defined for the forthcoming Australian temperate pasture collections. Table 2.

Table 1. Australian network of plant genetic resource centres

Collection	Place/organisation
1. Winter cereals (wheat, barley, oats)	Department of Agriculture, N.S.W.
2. Tropical forage plants	CSIRO, Queensland
3. Temperate forage legumes *Medicago* and associated species	Department of Agriculture, South Australia
4. Temperate forage legumes *Trifolium* *Ornithopus* and associated species	Department of Agriculture, Western Australia
5. Tropical crops	Dept of Primary Industries Queensland
6. Temperate field crops (except cereals)	Department of Agriculture, Victoria
7. Sugar (*Saccharum* sp.)	CSR/Bureau of Sugar Experimental Stations
8. Indigenous wild relatives of crop plants	CSIRO, Canberra

Table 2. National genetic resource banks - priorities for temperate pasture species (after Crawford 1984)

Trifolium	Medicago	Other species and genera
T. alexandrinum	*M. aculeata*	*Astragulus*
T. ambiguum	*M. intertexta*	*Hedysarum*
T. balansae	*M. littoralis*	*Lotus*
T. cherleri	*M. murex*	*Onobrychis*
T. fragiferum	*M. orbicularis*	*Ornithopus* sp.
T. hybridum	*M. polymorpha*	*Tetragonolobus*
T. isthmocarpum	*M. rigidula*	*Trigonella*
T. nigrescens	*M. rugosa*	
T. pallidum	*M. sativa*	
T. pratense	*M. scutellata*	
T. purpureum	*M. tornata*	
T. repens	*M. truncatula*	
T. resupinatum	*M. turbinata*	
T. semipilosum		
T. subterraneum		
T. squarrosum		
T. vesiculosum		

Genetic Resources Under Threat

Despite the Australian initiative and the efforts of F.A.O., threats to plant genetic resources are increasing. Whilst the losses due to overgrazing, intensification of cultivation, desertification and of neglect and inadequate storage are obvious, effects of improved varieties, of plant variety rights and of increasing competition for limited funds are less so and deserve discussion.

The industrial nations have been freely taking gene stocks from Third World countries and then selling back new strains developed from them, often at high prices and requiring high inputs of fertilisers and sprays to exploit their high yielding potential. These new commercial strains tend to rapidly replace the indigenous and genetically diverse varieties grown over centuries in many third world countries, so reducing and sometimes wiping out the important genetic base upon which future breeding depends. The growing invovment of multinational seed companies, protected by plant variety rights, in the breeding and promotion of new cultivars has hastened the process.

A classic example is to be found in Turkey where one high yielding variety of sugar beet was introduced as seed by the Germany company KWS. This variety replaced all indigenous races in commercial agriculture. In order to continue their breeding programmes KWS are now having to comb small gardens in Turkey in search of wild sugar beet strains that might hopefully have survived their own onslaught (Blake 1983).

Many third world countries feel they have no say in the use of their own genetic resources, and they even fear that what they have lost may be withheld from them and are beginning to discourage further foreign exploration. Because of Plant Patents, Afghanistan and Libya have already been denied wheat genes that originated from these countries but which are now extinct there. (Blake 1983 Loc. Lit.). Plant patents then are not only a danger to plant genetic resources but a mechanism for the rich countries to get richer and the poor to be exploited.

The saga does not end with individual countries however, and the whole international framework of future planning is threatened by self interest. The administration of the world's germ plasm is the responsibility of the International Board for Plant Genetic Resources (IBPGR). The weakness is that this board is responsible to no-one. Although affiliated to FAO, it is funded by the developed nations and is largely controlled by them. Third World countries called a FAO/IBPGR meeting in November 1983 to try and carry three resolutions: (1) To bring international control over the world's plant germplasm resources. (2) To ensure the free interchange of germ plasm. (3) To instigate new means and resources for plant collection and conservation.

However the disaster is that it seems that none of these objectives succeeded beyond an 'agreement to negotiate' stage because of stalling by the major industrial nations without whose co-operation an agreement is totally meaningless. Countries abstaining from voting to achieve the stated objectives in establishing a world heritage included all these in which plant variety rights are championed. New Zealand, the U.K., U.S.A., West Germany, Canada, France, Japan and Switzerland. It must be concluded that political and commercial considerations are against the international heritage concept providing further evidence that commercialism and its sibling in P.V.R. are restrictive to the interchange of genetic materials. Clearly if seed companies hold potentially valuable genetic material they do not wish to pass it on to other countries or organisations until it is developed to the stage where plant patent provisions can be applied.

All countries agree that valuable genetic sources are being lost, by intensification in the Vavilov centres, by commercial pressure, by inadequate conservation and by sheer neglect. The future however looks bleaker if anything as a result of this recent debate and provides a striking demonstration that unless commercial interests are separated from what is a matter of world heritage, we can only expect a continued deterioration of world's vital plant genetic resources

Genetic Engineering

The newly emergent science of plant genetic engineering provides a potentially valuable tool for use by multinational seed companies to produce new varieties more rapidly. Maximum profits are gained from rapid turnover of varieties. For the purpose of PVR patents, a new variety is required only to be distinct. A minimum of genetic change in an adapted variety, but slightly altering its character, should require but a minimum of expensive testing and reselection. That is why the genetic engineering techniques are so attractive to the purveyors of plant variety rights and it is little wonder that they will pay huge sums for the rights to such techniques as CSIRO's much publicised 'jumping gene'. Any technique capable of transferring valuable genetic material from one source but making no unwanted changes in the recipient, would be a formidable method of genetic interchange.

Besides the question of who ultimately might reap the most benefit of genetic engineering research, the prospects of genetic engineering of crop and pasture plants have been dramatized to such an extent that comments like "genetic resource conservation is obsolete", "who needs genetic variation we can create our own" are echoing around the seminar and meeting rooms. Such thinking and promises of "plant breeding in the fast lane" (Anon. 1985) direct valuable funds and resources into an exciting perhaps, but highly speculative fields full of 'Lysenko-like' promises. Proven but more conservative plant breeding and genetic resource conservation can suffer in competition unless rationality returns.

Plant Genetic Resources - Applied Success in Forage Plant Breeding

It is clear that genetic engineering lends itself to making small genetic changes in a well adapted genotype and may well produce a character that is rare or indetectable in its natural environment. What genetic engineering cannot do is bring about new multigene recombinations of characters to build a completely new range of adaption. Classical plant breeding can, and often does, recombine groups of characters into better adapted genotypes. This is not a role of genetic engineering techniques for higher plants, a point that seems to be forgotten if not by the genetic engineers then at least by those who interpret and publicise their progress.

As an example of recombination of characters, embodying the use of classical techniques of plant collection and crossbreeding, a new range of a low oestrogen subterranean clovers have been produced. Some of these have resistance to waterlogging and tolerance of disease. These are the results of the application of various aspects of 'biotechnology'. In this case plant collection techniques, plant biochemistry, animal physiology and traditional breeding. The new clovers belong to the group of clovers related to the white seeded cultivar Yarloop and form a subspecies of *Trifolium subterraneum* called *yanninicum* (Katznelson and Morley, 1965).

During the 1940's and 50's there was a major development of subterranean clover pastures. It came accompanied by a syndrome of rapidly declining fertility amongst the ewes flocks accompanied sometimes by some rather gross symptoms such as a prolapsed uterus. The syndrome, described by Bennetts, Underwood and Shier (1946) seemed particularly related to grazing pastures dominant in the Dwalganup variety of subterranean clover. In the 1950s and early '60s very large areas were sown to a newer variety, 'Yarloop' subterranean clover. This was an attractive looking vigorous clover. Yarloop was also adapted to waterlogged conditions and became very dominant in such situations. Unfortunately it had quite devastating effects on the ewes' and sometimes resulted in lambing percentages as low as 15%. The genetic resource of *yanninicum* varieties in Australia was very limited and in either case it was not known whether or not they would cause the infertility syndrome as the reasons for it were unknown. Work at the University of Western Australia, Institute of Agriculture was to reveal the causal agent, the isoflavone formononetin (Millington, Francis McKeown (1964). This finding was to give plant breeders a specific aim to select varieties or crossbreds low in formononetin.

As it transpired, all the minute Australian collection of subspecies *yanninicum* were high in formononetin. It was thus that CSIRO mounted a collection trip to the only known centre of diversity in Northern Greece obtained the services of the Israeli scientist, Dr Joseph Kalznelson, for the task. A specialist in mediterranean agriculture and noted botanist and another prodigious worker, he found more than 40 new yanninicum varieties in a collections from Northern Greece and Yugoslavia (Figure 2). Dr Fred Morley, then of CSIRO, was the organiser of the mission and arranged for isoflavone analysis at the University of Western Australia. Amongst them were a number low in formononetin, but they were generally too late in maturity to be direct 'Yarloop' replacements. Thus classical recombination techniques were used here to combine low formononetin with suitable maturity. At the same time it was hoped to maintain the characteristics of waterlogging tolerance as well as sufficient vegetative vigour for the farmers who liked the vigorous growth of Yarloop.

With only modest populations such a recombination was achieved to create the new cultivar Trikkala. Trikkala is now one of Australia's leading cultivars and is recommended in all Southern states. Total seed production has exceeded 3,000 tonnes. The new cultivar is a monument to the principles of plant exploration and its value especially when objectives can be defined.

Another exciting result arising directly from plant genetic resource collection, has been the development of a new range of *Medicago* species with adaption to acid soils. Commercial *Medicago* cultivars, though ideally adapted to the Australian ley farming system, have hitherto been almost exclusively restricted to neutral and alkaline soils. Acid soils in the mediterranean region have been a prime target for West Australian plant collection expeditions and have generally concentrated on *Trifolium*, *Lupinus* and *Ornithopus* species, and this was the prime aim of a plant collection tour to Sardinia (Francis and Gillespie 1981). The ecological studies associated with this tour were however, to reveal that the little known species *M. murex* and to a lesser extent *M. polymorpha*, were very common on acid soils (to pH 5.5) on the island. The adaption of *M. murex* has subsequently been confirmed on a range of soils in this State (D.J. Gillespie private communication). As a follow up subsequent collections have been made by Mr John Howieson, Dr Gus Gintzburger and Dr Efisio Piano, not only of more medics from acid soils of the island, but also of the associated rhizobial populations. As a result of this combined work, new combinations of medic species and rhizobial strain have been developed and the ability of M. polymorpha and M. murex to grow on acid soils hitherto not suited to medics (Howieson and Ewing 1985), promises to enormously expand the pasture options available to Australian farmers in Southern Australia, particularly in areas where frequent cropping is an integral part of the farming system.

The development of the medics and the cultivar Trikkala are examples of more than 50 herbage and forage cultivars released during the past 15 years to have resulted more or less directly from plant collection and introduction. The CSIRO Division of Tropical Crops and Pastures, Queensland and the South and Western Australian Departments of Agriculture have been particularly active in herbage plant introduction. The next decade will see an increase in the utilization and development of these collections, the National Cereals Collection at Tamworth, N.S.W. and other collections in the network. The current scattered programmes of alternative crop development, especially with the legumes Pisum, Lupinus, Vicia have been hampered by the lack of an organised and extensive genetic resource base. Development of the planned facilities at Horsham, Victoria, will represent a major advance.

In Conclusion

The challenge is clear. Genetic resources are under ever increasing pressure in their centres of diversity but on the plus side there are movements in Australia and elsewhere toward funds being set aside at least for the development of storage facilities. The technology of long term storage has greatly improved and with the advent of computers so have our data retrieval systems. Providing Governments and scientific administrators will give a lead in the finance and not be mislead by a short term 'biotechnological promises', then at least a proportion of the worlds genetic stocks will be conserved for our future scientists. It is a great credit that Australia is seen to be taking a lead.

Finally, my gratitude to the Farrer Memorial Trust for the honour of the medal award for 1985. I would particularly like to note that in almost all aspects of my work it has been a team approach. Although there is always room in science for outstanding 'loners', by and large, given the complexities of modern agriculture, team efforts are most likely to make advances at the interfaces of agricultural science. There have been many colleagues involved in my work but I would have to single out three who have had the greatest influence on the course of my career. Firstly Dr John Millington. He has the rare ability to recognise genuinely important practical aspects for agricultural research yet his achievements in the cereal and pasture fields failed to gain full recognition by his own University. Training for agronomic research in Western Australia has suffered as a consequence. My colleague and partner in the varieties like Trikkala and many others and a driving force in the clover breeding programme was Dr John Gladstones. Dr Bryan Quinlivan has ensured a natural predeliction for creativity and did not stray too far from practical reality.

I would also wish to acknowledge also the contribution of the industry funds to our programs. Wheat Industry Research Council and the Australian Wool Corporation have provided support vital to the successful outcome of the projects so far.

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