Australia's Search for Greener Pastures:

The Foundations of the Global Genetic Resources Movement, 1926-1980

Derek Byerlee

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Cover photo. Seeds held in the Australian Pasture Genebank, the world's most diverse and significant collection of forages[1]

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Table of Contents

List of Acronyms[1]

Acronym	Name (in English)	Headquarters Location
ALAD	Arid Lands Agricultural Development	Beirut, Lebanon
ANU	Australian National University	Canberra
CBE	Commander of the Order of the British Empire	
CBP	Commonwealth Bureau for Pastures and Field Crops	Aberystwyth, UK
CGIAR	Formerly known as Consultative Group on International Agricultural Research	Washington DC, USA
CIAT	International Center for Tropical Agriculture	Cali, Colombia
CIMMYT	International Maize and Wheat Improvement Center	Texcoco, Mexico
CMG	Companion of the Most Distinguished Order of Saint Michael and Saint George	
CSIR	Council for Scientific and Industrial Research (to 1949)	Melbourne, Australia
CSIRO	Commonwealth Scientific and Industrial Research Organization (from 1949)	Canberra, Australia
EMB	Empire Marketing Board	London, UK
FAO	United Nations Food and Agricultural Organization	Rome, Italy
FRS	Fellow of the Royal Society	
IBP	International Biological Program	London, UK
IBPGR	International Board for Plant Genetics Resources	Rome, Italy
ICARDA	International Center for Agricultural Research on the Dry Areas	Aleppo, Syria
IFPRI	International Food Policy Research Institute	Washington DC, USA
ILCA	International Livestock Center for Africa	Addis Ababa, Ethiopia
IEMVT	Institute for Livestock and Veterinary Research in Tropical Countries	Maisons-Alfort, France
ILRI	International Livestock Research Institute	
IPGRI	International Plant Genetics Resources Institute	Rome, Italy
IRRI	International Rice Research Institute	Los Banos, Philippines
IUBS	International Union of Biological Scientists	Geneva, Switzerland
JAA	Jebel El Akhdar Authority	El Marj, Libya
Mha	Million hectares	
MENA	Middle East and North Africa	
NSW	State of New South Wales	
NZ	New Zealand	
OEEC	Organization for European Economic Cooperation	Paris, France
PVRs	Plant Variety Rights	
QDPI	Queensland Department of Primary Industry	Brisbane
SA	State of South Australia	
TAC	Technical Advisory Committee of CGIAR	Rome, Italy
The Waite	Waite Agricultural Research Institute, University of Adelaide	Adelaide, Australia
UK	United Kingdom	
UM	Section Committee on Use and Management of Biological Resources, IBP	
UNESCO	United Nations Educational, Scientific and Cultural Organization	Paris, France
USA	United States of America	
USDA	United States Department of Agriculture	
WA	State of Western Australia	
WWII	World War Two	

1 Name and headquarters prevailing for much or all the period of this history

Executive Summary

Australia's engagement with plant genetic resources from 1926 to 1980 played a foundational role in the global movement for conservation, exploration, and utilization of genetic diversity in agriculture. This history traces Australia's contributions, from early systematic plant introductions to leadership in international genetic resource conservation efforts.

The Commonwealth Scientific and Industrial Research Organization (CSIRO) led plant collection expeditions after World War II to source new pasture species for both Mediterranean and tropical environments. By the 1960s, Australia had positioned itself as a key player in the global genetic resources' movement, notably through the leadership of CSIRO's Sir Otto Frankel. His advocacy for international cooperation to conserve genetic conservation led to the establishment of the International Board for Plant Genetic Resources (IBPGR) in 1974 under the auspices of CGIAR.

Australia's early plant exploration efforts were shaped by its agricultural dependency on introduced species. The country's institutions, notably the Waite Agricultural Research Institute and CSIRO, first engaged in systematic searches for plant species suited to Australian conditions in the 1940s and 1950s. The influence of British institutions prior to World War II, such as the Empire Marketing Board, the Welsh Plant Breeding Station, and Cambridge University fostered early collaboration by Australian expeditions to collect genetic material.

During the 1960s and 1970s, Australia extended its global leadership by influencing CGIAR centres dedicated to livestock and forages. Emphasizing the importance of legumes in pasture systems, the 'Australian school' shaped programs in regions such as North Africa, South America, and Southeast Asia. Despite these successes, transferring Australian farming systems built around forage legumes to other regions met with challenges, particularly socio-economic barriers. The years 1979 and 1980 were a highpoint in Australian leadership of genetic resources and pasture science as many of the key players assembled for international congresses in Australia to take stock of these efforts.

While this history focuses on the period up to 1980, it notes critical turning points in the 1980s as the discourse around genetic resources shifted from conservation to issues of ownership and access, leading to increased tensions between industrialized and developing countries. At the same time, Australian scientists, who had played a central role in shaping international genetic conservation efforts, faced declining funding and support for its pasture research. The international community moved toward more regulated frameworks for genetic resource sharing, with Australia's role gradually diminishing.

This monograph highlights the critical impact of Australia's scientific leadership in pioneering the global movement for plant genetic resource conservation. Although Australia has been a major beneficiary of these efforts, the long-term sustainability of genetic resource collections remains a challenge. Today, the responsibility falls upon its institutions and scientists to reinvigorate international cooperation and ensure the preservation of these invaluable resources for future generations.

Summary in Verse

For fifty years, Australia took its stand,
Preserving seeds with care and steady hand.
Through science, toil, and global partnership,
It shaped the fields where future yields expand.

The legume's root, a model well refined,
Enriched the pastures, strengthened soil and land.
Yet efforts met with limits ill-aligned,
As climates changed beyond what plans had spanned.

When voices turned to ownership and trade,
The call for conservation lost its might.
The funding waned, priorities were swayed,
As staple crops and biotech took light.

Yet echoes of that work still shape today,
A lesson clear for those who would defend:
To guard diversity in seed and clay,
Lest all we built shall falter in the end.

Shaun Coffey,

CEO, Crawford Fund

1. Introduction

On 18th September 1967, 112 delegates from 27 countries and 6 international organizations assembled at the United Nations Food and Agriculture Organization (FAO) in Rome to discuss the exploration, utilisation, and conservation of plant genetic resources. The meeting, widely regarded as a historic milestone in galvanizing international collective action to save landraces and wild relatives of crops from extinction, had been initiated and organized by Sir Otto Frankel, recently retired from the Executive of the Commonwealth Scientific and Industrial Organization (CSIRO) of Australia and Erna Bennett, a leading scientist on genetic resources at FAO. The chair of the meeting elected by the delegates was William Hartley, formerly head of CSIRO's Plant Introduction Section who had more than a decade of experience in presiding over international meetings on genetic resources. Not only did the meeting spur a sense of global urgency on the need to conserve genetic resources but it brought together the best scientific knowledge and practice to get the job done.

For the next seven years, Frankel and his colleagues worked with missionary zeal to set up an international network of genebanks to collect and conserve genetic resources for food and agriculture. Eventually this resulted in the creation of the International Board for Plant Genetic Resources (IBPGR) as part of CGIAR, then known as the Consultative Group on International Agricultural Research. After a slow start, IBPGR succeeded in facilitating the collection and conservation of genetic resources of many major food crops. In addition, Australian scientists played a lead role in designing the three CGIAR centers with livestock and forage programs, drawing on their global reputation for research on improved pastures and on the genetic resource collections they had systematically assembled for nearly 50 years.

How did Australian scientists come to play such an outsized role in what became known as the global genetic resources' movement? In Australia, more than in any other large country, agriculture was and still is dependent on introduced plants. From the time of European settlement, both public and private actors had introduced new crops and varieties. At the same time, many plants including weeds were introduced accidentally and became naturalized in their new environment as integral components of local farming systems.

The Australian economy was also highly dependent on the livestock industry. For much of its history, Australia "rode on the sheep's back" as the wool industry provided the bulk of export earnings and remained the single most important source of foreign exchange into the 1970s. After 1960, the beef industry concentrated in the tropical north expanded rapidly in response to emerging export markets. The conventional wisdom at the time was that, to realize the potential of the livestock industry, natural pastures would have to be replaced by introduced species responsive to improved soil fertility and grazing pressure, at least in areas with sufficient rainfall to support such intensification.

To systematize introductions CSIRO[2] created a Plant Introduction Section in 1929 soon after its founding. This Section for its first two decades depended entirely on correspondence to exchange seed with contacts around the world. This worked well for cultivated crops such as wheat and to some extent for forage grasses but was highly constrained for forage legumes since few species suited to Australian conditions had been domesticated in countries with similar Mediterranean or tropical climates.

The Plant Introduction Section from its founding recognized the need for plant exploration—that is, scientific expeditions to collect samples of potentially useful cultivars, landraces and wild relatives. However, such expeditions faced cost and logistical challenges especially in countries and territories outside of the British Empire that were priority regions for searching for new pasture species and ecotypes suited to Australian conditions. Indeed, prior to World War II (WWII), only the United States and the Soviet Union with large scientific cadres and generous budgets had institutionalized regular plant collection expeditions. To match those efforts for its equally diverse agricultural conditions, Australia had to rely much more on international cooperation in plant collection to share costs and provide logistics.

This paper traces the early efforts by Australian scientists to explore for new plants to enrich its agriculture arguing that their cooperation with FAO built both Australia's and FAO's reputation in the science and practice of plant exploration and introduction, and laid the foundations for their leadership of the global movement to conserve plant genetic resources from the 1960s. Even as IBPGR took center stage in collecting and conserving genetic resources, Australia continued to be a major player in influencing global research on pastures and related genetic resources. It had built a global reputation on incorporating forage legumes into farming systems to supply nitrogen and enhance livestock nutrition. That status had a major influence on research approaches in the developing world.

The history unfolds in six chapters as follows.

Chapter 2 describes Australia's pre-WWII efforts in systematic plant introduction and collection to search for new species and ecotypes to raise pasture productivity. Chapter 3 then provides a detailed review of Australia's pioneers in plant exploration and the long and sometimes tortuous process of seeking international cooperation for its first collection expeditions in the 1940s and 1950s. The experience and contacts gained through these pioneering efforts paved the way for future expeditions that became routine by 1970. Other authors have listed and briefly described these efforts and their impacts in Australia. [3] I highlight the people and processes rather than the plants, drawing on archival sources. These sources reveal the British imperial roots of the small group of scientists who pioneered plant exploration, and the many obstacles they faced. They also show how Australia sought international cooperation especially with FAO to conduct these expeditions.

From the 1960s, attention turned to conservation of genetic resources in the face of growing recognition of the loss of landraces and wild relatives of potential but unknown value to future generations. As described in Chapter 4 conservation of genetic resources required more than international cooperation to share costs; rather, collective action on a global scale was needed to reach broad agreement on priorities, evaluation, storage strategies and sharing of germplasm and information. Frankel's success in leading this effort was due to his strong partnership with FAO that in turn drew heavily on its earlier collaboration with Australian scientists on forage genetic resources.

Chapter 5 describes how even after conservation of genetic resources became a global priority in the mid-1970s, Australia with its large genetic stocks and long-standing expertise in forage legumes, continued to influence the design of forage programs in CGIAR centers both in the Mediterranean region and in the tropics. This collaboration extended beyond the CGIAR centers to forging close links with forage programs in countries of North Africa, Southeast Asia, and Brazil.

The year 1980 was in many ways a turning point for both pasture development and the global genetic resources movement, briefly summarized in Chapter 6 as a postscript to this history. Australian scientists now faced increasingly complex technical, economic, and environmental challenges to pasture development. On the global stage, the discourse on genetic resources now turned to ownership and control of genetic resources, resulting in an acrimonious debate between the industrialized countries who were privatizing plant breeding and developing countries that freely provided most landraces and wild types for these breeding programs.

Finally, in Chapter 7, I reflect on the benefits of these exchanges noting that, although Australia has undoubtedly been a major beneficiary, impacts were global in catalysing international cooperation to conserve genetic resources. Australian scientists also stimulating a new era of pasture research globally although efforts to transfer Australia's emphasis on forage legumes to other countries met with mixed success. I conclude that while great progress was made in conserving genetic resources, international cooperation to sustain these collections remains a challenge today.

A note on terminology

Many terms and names have changed over the course of this history. I have used them interchangeably. For example:

- **Forages** is a more generic term than **pastures** since it includes cutting to feed to animals (common in many countries) as well as grazing *in situ* by animals (the common situation in Australia). Likewise, **forage science** may be used instead of **pasture science**, or **agrostology** that was in wide use prior to 1960.

- **Tropics** is used as shorthand for both the **tropics and sub-tropics**—that is low elevation areas between 30° north and south of the equator.

- The term **genetic resources** only became widely used after 1967. Previous terms included **gene pools, genetic stocks**, or in a narrower sense, **plant introductions. Plant genetic resources** is used as shorthand for **plant genetic resources for food and agriculture.**

Also, many **organizations have undergone name changes** over the period covered in this history. To avoid confusion, I have used the name prevailing over the longest period. For consistency, I have used the US spelling of **"center"** throughout as used in CGIAR, except where an organization includes **Centre** as part of its name.

2. The Foundations of Systematic Plant Introduction in Australia Before WWII

Examples of early efforts in plant introduction[4]

Before 1900, the botanic gardens set up in the capital cities of each Australian colony led public efforts in plant introductions and some of these introductions resulted in successful improvement of Australian agriculture. One of the most active botanists was Ferdinand von Mueller at the Royal Botanic Gardens in Melbourne who corresponded widely with his counterparts around the world.[5] One of his most frequent contacts was with Algeria which had recently been colonized by the French. The French were impressed with the success of British settlement in southern Australia with a similar climate to Algeria and regularly requested von Mueller to send potentially useful flora and fauna ranging from *Eucalyptus* species (spp.), saltbush (*Atriplex* spp.) and even kangaroos.[6] There were also flows in the other direction and in 1887 von Mueller distributed seed of two 'burrless' medics (*Medicago* spp.) noting that he had "introduced these into Australia where, in the dry hot inland regions, they have surpassed most other fodder herbs."[7] Von Mueller's reach even extended to Queensland where he introduced forages suited to the tropics.[8]

William Farrer, Australia's pioneering wheat breeder, initially acting in his private capacity and then serving the NSW government, introduced hundreds of wheat varieties. Using these introductions as parents, he built one of the largest breeding programs in the world through an extensive network of correspondents in Europe, the USA, Canada, South Africa and India to the extent that he has been described as a "one-man international center."[9] This enabled him to develop Federation, the most widely grown wheat variety in Australia in the early 20th Century, reflecting its resistance to wheat rusts and adaptation to hotter and drier areas.[10]

Arthur Perkins who would serve as the South Australian (SA) Director of Agriculture from 1914 to 1936 was one of the first to personally assemble a collection of seeds in the Mediterranean region specifically for southern Australian conditions. He was recruited as a professor at Roseworthy Agricultural College in SA in 1892 based on his experience with Mediterranean agriculture. A British national, he had grown up in North Africa and had studied at L'École Nationale d'Agriculture in Montpellier in the south of France. Before departing from his position of farm manager in the French protectorate of Tunisia he received a letter on behalf of the SA minister in charge of agriculture requesting that he collect seed to the value of £20 for a wide variety of cereals and forages from the region "grown on the northern and southern shores of the Mediterranean…bearing in mind that the climate [of SA] is similar to the Mediterranean area."[11] The final shipment included 80 species and varieties about half of them forages that were widely distributed to farmers in SA with some success in higher rainfall areas.

In 1902, after a decade in Australia, Perkins recognized the need to collect forages from the dry areas of the Mediterranean region noting:

> **"For situations in which rainfall is deficient and summer heat intense no suitable plants have yet been forthcoming [in SA]… At all events [forage] plants that succeed in Algeria will succeed here and I shall endeavour to secure some."[12]**

In 1910 Perkins, by now with wide responsibilities for crops and livestock research in SA, returned to the Mediterranean region and travelled for one year to six countries or colonies capitalizing on his fluency in French and Arabic. He again collected seed of local crops and forages, and was particularly enthusiastic about one forage legume, Sulla (*Hedysarum coronarium*) that he promoted on his return.[13]

The emerging state departments of agriculture in eastern Australia were also active in introducing pastures suited to the tropics complementing introduction efforts by farmers and seedsmen.[14] NSW may have been the first to appoint a dedicated agrostologist, E. J. Breakwell, in 1914. Not only did Breakwell engage in introductions from abroad, but he also produced a comprehensive guide to pasture species and their origins. His guide notes several grasses that had been purposely introduced by NSW and Queensland experimental farms through correspondence with contacts in the British Empire.[15]

These few examples illustrate that the value of plant introduction was widely appreciated and deliberate introduction of new crops and ecotypes, sometimes through field expeditions, to improve Australian agriculture were common. However, efforts were individual rather than institutional and not sustained. Institutional capacity for systematic plant introduction and collection from overseas was developed only from the 1920s.

The imperial roots of the science of pastures and genetic resources 1926-29

The period 1924 to 1929 was particularly formative for Australian agricultural scientific institutions with the founding of the Council for Scientific and Industrial Research (CSIR, re-organized in 1949 as the CSIRO) and the establishment of the Waite Agricultural Research Institute at the University of Adelaide (hereafter, the Waite). Under the dynamic leadership of A. M. V. Richardson, the Waite in little more than a decade from its founding had 27 professionals with the best expertise in Australia on pastures, soils and agroclimatology, and its research was recognized internationally.[16] Richardson was also a member of Executive Committee of CSIRO and many CSIRO staff were located at the Waite where they conducted research jointly.

The scientific capacity of both CSIRO and the Waite in "agrostology" (as pasture science was then known) owes much to its imperial roots in Britain, especially the Welsh Plant Breeding Station for forages at Aberystwyth. Under the leadership of George (later Sir George) Stapledon, Aberystwyth became a global center of excellence in pasture science employing a holistic or ecological approach from selection and breeding of new pasture cultivars, fertilization, and integration of legumes.[17] Stapledon made a nine-month trip to southern Australia and New Zealand (NZ) in 1926 reporting his perceptive observations in a book.[18] He advocated for an organized effort to cooperate across the Empire in pasture research and breeding programs to exploit intraspecific diversity and wild species. In his keynote speech to the "first"[19] International Grassland Congress, held at Aberystwyth in 1937, he was passionate about the central role of legumes concluding that "no grassland is worthy of the name…unless a legume is at work…find the right legume and then make the conditions suitable for the legume and the battle will be won."[20] This emphasis on pasture legumes at Aberystwyth and the close links of Aberystwyth with CSIRO and the Waite strongly influenced Australian pasture research efforts over the next 50 years.

Richardson of the Waite attended the landmark 1927 Imperial Agricultural Research Conference in London that resolved to build central research institutes to conduct fundamental research for the Empire and to foster scientific cooperation across the Empire. In the same year, the Empire Marketing Board (EMB) was established with part of its remit to provide research grants that would facilitate cooperation on research that would be "applicable sometimes for the whole Empire, but always to more than one of its countries."[21]

Frank L. McDougall, who would achieve fame after the second World War (WWII) as a founder of FAO, was highly influential in setting up the EMB and in managing its research grants. McDougall had emigrated from London to SA to take up a fruit farm in the newly opened irrigated areas on the River Murray. In 1922 he was nominated as a delegate to London for the Australian Dried Fruits Association to negotiate tariff preferences for Australian producers. There he developed a close working relationship with Australia's prime minister, Stanley Bruce that greatly expanded the scope of his activities. McDougall became the prime minister's eyes and ears in London as well as a highly effective lobbyist for Australian economic interests in Britain and the Empire, more generally.[22]

McDougall was a staunch supporter of cooperative research across the Empire noting that "fundamental problems are better tackled jointly." He recognized the priority of pasture research having provided an annex to Stapledon's book on Australia on "The economic importance of Empire pastures."[23] He also observed that Aberystwyth was the "intellectual general headquarters" for pasture research in the Empire.[24] Accordingly, one of the first EMB projects linked Aberystwyth, CSIRO, the Waite, and research institutes in NZ, Palestine, and South Africa to conduct research on pastures. This project spawned three "agrostologists" who studied under Stapledon and would lead pasture research in the UK, Australia and internationally for decades.[25] The first agrostologist hired by the Waite was H. C. (Chris) Trumble who spent a year in the UK under an EMB grant in 1928, mostly at Aberystwyth, greatly enriching his limited experience in pasture research.[26] Trumble later rose to be Professor of Agronomy at the Waite through pathbreaking research to define variations in pasture growth in relation to climate and soils. A review of agricultural achievements in SA concluded that, "Trumble did more than anyone else to identify and promote legumes appropriate to specific environmental factors."[27]

The second agrostologist, John (Jack) Griffiths Davies, a student of Stapledon at Aberystwyth, was appointed under the EMB grant to the Waite in 1928 and for a decade led its pasture research—a period when the Waite built its reputation as a global leader in research on pastures for a Mediterranean climate. J. Davies would later join the CSIRO as chief agrostologist and then build the world's largest and most advanced pasture research program for the tropics based at Brisbane. His older brother, William Davies, also an Aberystwyth graduate, became Imperial Grasslands Investigator at Aberystwyth where the EMB grant supported him to spend 1931-32 in Australia and NZ to review pasture research. In the first meeting of Australian agrostologists in Adelaide in 1932, chaired by Perkins, SA's Director of Agriculture, W. Davies reported on his one-year tour of Australia noted the extraordinary success of sub clover (*Trifolium subterraneum*) as a widely adopted naturalized species in southern Australia. He recommended increased search for legumes for the tropics to replicate the success with sub clover.[28] W. Davies would also become a global leader in pasture science from his UK base.

While Aberystwyth from 1926 to 1929 was providing the base for building pasture science in Australia, three scientists who would play leading roles in the international genetic resources movement were in residence at Cambridge University during 1928-29. First, Robert Orr Whyte, a NZ plant scientist completed his doctoral studies in botany at Cambridge in 1929. Under the guidance of Stapledon, Whyte then established and led what became the Commonwealth Bureau for Pastures and Field Crops (hereafter the CBP) naturally also based at Aberystwyth. The CBP was one of several such Bureaux set up on the recommendation of CSIRO to the 1927 Imperial Conference in London, to exchange scientific information across the Empire in a specific discipline. Under Whyte the CBP became one of the most dynamic Bureaux organizing the 1937 International Grassland Congress at Aberystwyth and producing a wide range of reports including a book on *Grassland Investigations in Australia* in 1940. The Bureaux were also among the first to emphasize the importance of conservation of an "imperial asset"—that is, its genetic resource collections.[29] Whyte would go on to become FAO's leader in genetic resources in a close partnership with CSIRO.

Second, Otto Frankel was spending 1928-29 at Cambridge after working in British-ruled Palestine on another EMB project on animal nutrition under John Boyd Orr, Director of the Rowett Institute in Scotland (and later the first Director General of FAO). Frankel of Jewish heritage had left Austria to complete his studies at the Agricultural University of Berlin in Germany in 1925 but was still seeking a permanent job. At Cambridge Frankel interacted closely with A. E. Watkins on cytological studies of his unique collection of landraces of wheat that had been inspired by Nikolai Vavilov, the famous Russian plant explorer and geneticist.[30] Frankel's year at Cambridge was formative in stimulating his interest in genetic diversity and becoming a life-long admirer of Vavilov.[31] It was also Boyd Orr who recommended Frankel for a position as wheat breeder in NZ, where he worked on breeding, cytology and increasingly on administrative duties before joining the CSIRO in 1951.

Third, William Hartley, described as a "vertically challenged but irrepressibly humorous Yorkshireman" received his post-graduate diploma in agriculture from Cambridge in 1929.[32] On graduation Hartley jumped at the opportunity to move to Canberra to be a founding member of the Plant Introduction Section of CSIRO. He would lead the Section from 1944, providing the scientific foundations for its work, and in the 1950s often liaised with Whyte at FAO to promote global cooperation on genetic resources. Unlike the close-knit group of Trumble and the Davies brothers at Aberystwyth, soon joined by Whyte, there is no evidence that the three scientists at Cambridge in 1929 interacted although given their common interest in the emerging science of cytology as well as their NZ connections, Whyte and Frankel were likely acquainted.

Finally, in 1926 from the southeast coast of the UK, a 16-year-old "farm boy" Colin M. Donald, sailed from England to study at Hawkesbury Agricultural College in NSW. After distinguishing himself at Hawkesbury and the University of Sydney, Donald joined CSIRO based at the Waite before undertaking an extended overseas study leave in 1938-39, again spending much of it at Aberystwyth. On his return to Australia he produced a book on Australian pastures in which he argued for plant collection expeditions to support pasture improvement.[33] Donald went on to replace Trumble as professor of agronomy at the Waite in 1954 and to an illustrious career in Australian agricultural science "contributing more than any other person to the understanding of pastures."[34]

First steps toward overseas plant exploration

The scientific community in Australia was slowly recognizing the potential value of systematic plant introduction and collection expeditions. In 1917, at the first Australian conference on agricultural research chaired yet again by SA's Perkins, George L. Sutton, a long-time assistant and friend of Farrer and then Commissioner of Agriculture in Western Australia (WA) called for organized efforts at plant collection and distribution. He recommended a federal center as in the USA that would "lead to economy of effort and money"[35].

Trumble from the Waite was the first Australian sent to the Mediterranean region and southern Africa to "obtain preliminary information as to the value of these regions for plant exploration …for the discovery of pasture species suitable for the semi-arid regions of the Empire" as well as to identify the best sites for collection and make appropriate contacts for such an expedition.[36] The trip was again arranged by McDougall of the EMB using his wide imperial connections.[37] Frequently noting the "close similarity" of rainfall and temperature data to those of Adelaide, Trumble observed that many native pasture plants in the areas he visited were identical to those naturalized in SA. He also discovered a "new Australia" of Eucalyptus trees and other Australian flora introduced earlier via von Mueller's exchanges that were "very reminiscent of SA." Trumble did not have the time nor resources to systematically collect seeds nor was the season appropriate for seed collection. However, based on his travels, Trumble became a strong advocate for systematic plant collection expeditions in the region concluding from his trip that the advantages of such expeditions to the Empire would be "enormous."[38]

Institutionalizing plant Introduction in Australia

CSIRO's Plant Introduction Section established in the Plant Industry Division in 1929 followed a plea by Richardson of the Waite and a member of CSIRO's Executive to step up introduction of new pasture species and ecotypes for both the southern areas with a Mediterranean climate as well as the northern tropical areas that were then being opened for beef production.[39] To design its plant introduction service, CSIRO had only a handful of institutional models to draw upon that featured a specific mandate for plant introduction, exploration and evaluation. Within the British Empire the Royal Botanic Gardens at Kew had traditionally played this role especially for tropical commodities like rubber.[40] By the 20th century this role was winding down although using EMB grants it was partially revived in the 1930s for some tropical food crops.[41]

The United States Department of Agriculture (USDA) had established a Foreign Seed and Plant Introduction Office in 1898 led by David Fairchild. With his official post of "Agricultural Explorer," Fairchild and his colleagues naturally focused on plant collection, mounting numerous and wide-ranging expeditions over more than four decades that would make him legendary in the world of plant collection and introduction.[42] USDA provided some budgetary support for international collection expeditions, but Fairchild associated with two private philanthropists who had a specific interest in botany and plant collection. They provided generous resources for his extensive world travels including a well-appointed yacht to circumnavigate the globe in the 1920s. Over the next 70 years, the USDA Section would conduct an average of about two expeditions per year drawing on extensive staff resources (about 20 scientists in the 1920s), many of whom gained experience over multiple expeditions.[43] Although USDA distributed its introductions widely, it did not have the means to conserve the collected samples and a large majority were lost (98 percent for clovers).[44] Also, USDA paid little attention to the science of plant introduction and exploration, although some effort was made to define "homoclimes" as the basis for collection and distribution of the collected seed.[45] Nonetheless, the USDA organizational structure of a central office, introduction stations for plant quarantine and observation, evaluation networks and the regular publication of inventories of new introductions strongly influenced the design of the Australian system. Some USDA's forage collections were also useful in Australia (Box 2.1).

Box 2.1. The value of the USDA and Vavilov collections to Australian pastures

Both Fairchild and Vavilov had specific interests in forage legumes. Although Vavilov defined the Mediterranean and West Asian regions as centers of origin for forages, he focused on temperate forages for higher latitudes and, for example, only listed one wild annual *Medicago* spp. from the Mediterranean in his collection.[46] Fairchild had a special interest in Mediterranean forages, including annual medics that were widely grown in southern and western USA at the time. He observed that "ever since my first trip to Algeria [in 1903] to collect bur [*sic*] clovers, there has been a fascination for me in the genus."[47] On his 1903 trip he collected 24 species of annual *Medicago* species as well as 40 *Trifolium* species (clovers).[48] He made further additions on his 1924-1927 trip along with samples of *Rhizobium* root nodules. Some of these made their way to Australia through the frequent exchanges between the USDA and CSIRO. Harbinger, one of the first medics to be widely commercialized in Australia, was a selection from an introduction from USDA in 1941.[49]

The Soviet Union had built an even larger system for plant collection under the famed scientist and plant explorer, Nikolai Vavilov, director of the All-Union Institute of Plant Industry, now commonly known as the Vavilov Institute. The Vavilov Institute conducted over 100 collection expeditions prior to WWII and Vavilov himself led many of them, visiting some 50 countries. However, unlike the USDA system, Vavilov developed an integrated system that included conservation through periodic replanting of his collection that reached 250,000 samples by 1940.[50] Indeed the Institute's scientists achieved further fame in the siege of St Petersburg (then Leningrad) in WWII when in the face of acute starvation they conserved their seeds for science rather than eating them.[51] Vavilov also gained global scientific fame by analysing diversity within crop species and with their wild relatives. He is best known for identifying geographic centers of diversity that he associated with centers of origin. He also systematically applied the disciplines of botany, geography, and ecology to make representative collections.[52] Vavilov's approach to genetic resources inspired the building of a strong scientific base for Australia's plant introduction system.

To set up its plant introduction service in 1929, CSIRO recruited Alexander McTaggart a US-educated NZ soil scientist who was quickly sent to Washington DC to observe the USDA system. He then modelled the Plant Introduction Section based in Canberra on the USDA's system through correspondence, introduction "preferably by exploration," evaluation centers, and wide distribution. Hartley, on his graduation from Cambridge University, soon joined the unit followed in the mid 1930s by John F. Miles a native Queenslander based at a testing site for tropical forages near Rockhampton.

The importance of collection expeditions to augment introductions by correspondence continued to be recognized by Australian scientific leaders especially for pastures. After a decade with no follow up to his 1928 trip to the Mediterranean, Trumble concluded,

> **"It is unbelievable that Australia has not thought it worthwhile to send a well-qualified expedition to these parts [the Mediterranean] for scientific study...it would result in the collection of likely practical value in southern Australia."**[53]

However, the Great Depression from 1930 curtailed expensive exploration trips and the onset of WWII further delayed exploration. During the 1930s, plant introduction and evaluation in Canberra was managed by a staff of two persons, McTaggart and Hartley, with a very limited annual budget of about £2,200 (about $120,000 in today's dollars).[54] The cessation in 1934 of the EMB-Aberystwyth projects that made up one-third of the funding of CSIRO's Division of Plant Industry added to these budgetary woes. Hartley who had long aspired to lead a plant exploration trip resigned in 1938 in frustration and returned to the UK to work in the Kew Gardens. In contrast during the 1930s Depression the Vavilov Institute was able to accelerate collection efforts while USDA scaled back but still managed to field about 20 exploration trips.[55]

Frankel as a wheat breeder in NZ was one of the loudest voices at the time on the need for plant exploration, building on his long-time admiration for Vavilov and a visit he made to Russia in 1935. In 1946 he delivered a lecture in Adelaide calling for international cooperation to facilitate systematic plant collection, introduction, evaluation, and storage.[56] Two years later at a major UN scientific conference on natural resources in Lake Success, USA, and still representing NZ, Frankel chose to focus on genetic resources noting that "without variability there can be no adaptability" and advocating that "all genic [*sic*] resources should be preserved for future generations."[57] He recommended international cooperation for assembling and maintaining plant collections, and organizing and exchanging material, information and personnel including with "primitive countries with the greatest wealth of plant types."[58]

It was also clear that CSIRO's introduction exclusively by correspondence with overseas contacts was producing diminishing returns, at least for pasture legumes. The introductions during the 1930s were narrowly based as the British Empire provided over 40 percent of exchanges and the US one-third.[59] Despite the wide reach of the Empire, only about 10 percent of direct exchanges were with tropical Africa, tropical America and the Mediterranean region, the most likely sources of useful pasture plants for Australia. Nonetheless, several introductions of tropical grasses, including some by state governments and private actors with imperial connections in eastern and southern Africa were released commercially.

Taking stock of a decade of introduction and testing of over 3,000 forage samples since 1930, McTaggart classified 56 as outstanding or useful.[60] However, only about five grasses and two legumes would be released from his selections in the post-War period.[61] Plant introduction by correspondence worked reasonably well for forages in wetter regions of coastal Australia that could use established cultivars from NZ, USA, and UK, and tropical grasses from British Africa. Forage legumes suited for Australia's drier Mediterranean areas and its tropical regions were rarely cultivated in their regions of origin so that introductions were necessarily limited to wild ecotypes and species that had already been collected by others—that is, very few. These regions were mostly located in 'underdeveloped' countries and colonies with few experimental stations and forage research programs that could facilitate collection.

Still forage legumes were widely adopted in southern Australia based on naturalized species and their variants. The adoption of *Trifolium subterraneum* and superphosphate in what came to be known as the 'sub and super revolution' led by SA farmer seedsman, Amos Howard, from the 1920s has been well documented.[62] In the post-War period, rotation of cereals with legume-based pastures—termed ley farming—further extended the revolution into dryland farming areas with a typical dry Mediterranean climate.[63] Trumble himself had been instrumental in identifying and commercializing barrel medic, *Medicago truncatula,* that took off in SA's mostly alkaline soils immediately after the War.[64] Selection of better adapted cultivars and pathbreaking research by the CSIRO and the Waite to identify and ameliorate soil micro-nutrient deficiencies contributed greatly to expansion of legume-based pastures. By the 1960s, there was an estimated 20 Mha of improved pastures in southern Australia.[65] However, these were still narrowly based on a handful of mostly naturalized species and variants and overseas expeditions offered the opportunity to further extend the area under improved pastures as well as to increase pasture productivity in already established areas.

This was not the case for legumes in the tropics where only the naturalized Townsville "lucerne" (*Stylosanthes humilis)* from tropical America was deemed to have wide potential.[66] Townsville stylo as it came to be called together with two other *Stylosanthes* spp. introduced prior to the War, had spread on a significant but still small area compared to legumes in southern Australia. The potential payoffs to collection expeditions for tropical legumes were expected to be huge.

3. Pioneering Plant Exploration after WWII

In the post-War period, the Plant Introduction Section, now under the leadership of Hartley who had returned to CSIRO from the UK, renewed its efforts to mount expeditions for plant exploration. The major priority was to follow up Trumble's 1928 trip to the Mediterranean region. Although Hartley himself led the first expedition to South America in 1947, the Mediterranean expeditions that soon followed were directly linked to the pre-War imperial roots of Australian pasture science.

Exploring in the Mediterranean region

Immediately after the War, Whyte from the CBP at Aberystwyth provided a strong push to the Australians to mount an expedition in the Mediterranean region. He had recently conducted extensive surveys of Mediterranean forages in the British protectorates of Cyprus and Palestine and interacted with Trumble on the potential value of collection expeditions.[67] Invoking Vavilov's concept of the Mediterranean region as a "primary center of origination" for forages, Whyte highlighted the potential value to Australian pastures of what he called "gene hunting expeditions."[68]

Prominently citing Whyte, Hartley prepared a detailed proposal in early 1950 for plant collection in the Mediterranean to be carried out by Donald, CSIRO's up-and-coming Mediterranean forage specialist who had transferred from the Waite to Canberra.[69] Despite the strong justification, the proposal was rejected by Bert T. Dickson, Chief of the Plant Industry Division, who argued that it needed "considerable preparation and organization" and "it is not possible for Donald to be away for six months."[70] Given that the cost estimated at £4,000 was only 1.5 percent of the Division's increasingly generous budget, the rejection likely also reflected the strained relations between Dickson and J. Davies, who had also moved from the Waite to head up CSIRO's Agrostology Section as part of the Division of Plant Industry in Canberra.[71]

Not to be thwarted, the two Davies brothers in Canberra and the UK found a way to circumvent CSIRO's bureaucracy to organize the planned collection expedition through the Organization for European Economic Cooperation (OEEC).[72] The OEEC had been set up to foster European integration and reconstruction after WWII with funding from the US in what became known as the Marshall Plan. The OEEC Grasslands Working Party was chaired by W. Davies, Director of the UK Grasslands Research Institute who we formerly met as Imperial Grasslands Investigator at Aberystwyth during his tour of Australia. W. Davies in correspondence with J. Davies and Donald in CSIRO organized a three-month OEEC survey mission on forages in the Mediterranean region during the spring of 1951. This was designed to set the stage for a CSIRO collection expedition immediately afterwards in the summer when seed could be collected.[73] The initial survey would provide contacts, logistical details, and "maps and information on geology, soils vegetation, livestock distribution etc." to inform the collectors.[74]

Not surprisingly, the OEEC survey team had strong Aberystwyth and Antipodean links. The team was led by W. Davies and included his longtime Aberystwyth colleague Whyte who had recently resigned from the CBP and was in the process of moving to FAO to lead its work on pastures.[75] Besides Donald, it included a South African, J. K. Rowland, who had participated in the pre-War EMB-Aberystwyth pastures project and in a survey of pastures in Libya.[76] Two US pasture specialists including the senior forage scientist of USDA, Olaf S. Aamodt, were added to the team, no doubt in a nod to US financing of most OEEC activities. Trumble who had moved to FAO as a pasture specialist also expected to join the team but decided to return to his professorship at the Waite.[77]

Despite the OEEC support, Donald still had to overcome considerable bureaucratic hurdles since Australia was not a member of OEEC.[78] Given that Donald's costs were to be paid by OEEC and the survey period was for only three months, Dickson grudgingly approved Donald's participation in the survey part of the plan but not the follow-up collection trip, even though it had high level support of the CSIRO

Executive.[79] However, Dickson was about to retire in a few weeks and only when Donald was already on the road for the OEEC survey, was the collection trip finally approved by J. Davies himself, after he became acting Division Chief on Dickson's retirement. In addition, to cover the maximum number of countries, CSIRO then added a second scientist, John F. Miles, to the collection part of the trip, since as described later he was already planning to visit tropical Africa.

The OEEC survey team visited eight countries and colonial territories and presented their findings in 1951 in Rome. Their report stressed the importance of replacing extensive area of fallow after cereals with pastures to reduce grazing pressure in the neighbouring rangelands. They concluded that "the most adverse features of the farming system is the almost complete lack of integration of crop and livestock husbandry."[81] Noting the very similar climatic conditions to southern Australia, Donald drew attention to the emerging success in Australia in incorporating pasture legumes into the cereal crop rotation and their potential use in the region.[82]

Not only did the trip expose Donald to a wide range of issues in pasture management in the region, but it enabled him to make contacts and arrange logistics for the follow-on collection trip to most of the same countries, timed to maximize seed availability in the early summer. The OEEC report also provided legitimacy to the collection expedition by recommending that collection, evaluation, and exchange of pasture germplasm become a priority in the region. Together Donald and Miles visited 13 countries and collected 1,300 seed samples with the primary focus on sub clover and annual medics.

After Frankel arrived in November 1951 as the new Chief of the Plant Industry Division (replacing Dickson), CSIRO support for plant exploration was assured. In addition, Richard G. Casey was Minister in Charge of CSIRO—he had previously been British Prime Minister W. Churchill's Minister-Resident in the Middle East in WWII and was well versed in the potential value of Mediterranean pastures to Australia.[83] Indeed, it was Casey, then based in London who had facilitated Trumble's travels in Morocco in 1928.[84] The initiation of pasture breeding programs also stimulated demand for further collection and with the rapid rise in CSIRO's budget in the 1950s, funds were no longer a significant constraint on plant exploration.

Colin Donald (left) and John Miles at the OEEC meeting in Rome, 1951[80]

The second Mediterranean expedition arose from a trip Frankel took to the International Congress on Genetics in Bellagio, Italy, in 1953, with a stop in FAO. FAO at the time was "top heavy" with forage scientists and keen to mount collection trips to support its forages program in the Mediterranean region, now under the leadership of Whyte (Chapter 4). Accordingly, Whyte at FAO and Donald in CSIRO negotiated a joint collection expedition focusing on grasses in North Africa to complement the Donald-Miles emphasis on legumes. The expedition was led by CSIRO's Cedric A. Neal-Smith who had carried out research with Donald on diversity in Australian ecotypes of sub clover before also moving from the Waite to the CSIRO, Canberra.[85] FAO not only paid Neal-Smith's salary for the trip but he could draw on FAO's wide network of recently established country offices to provide contacts and trip logistics. Neal-Smith travelled 25,000 km in 9 countries over 9 months using a 2-stage process of first visiting each country to plan the collection and then returning at the best time for seed collection. Overall, this was a much more systematic effort than the 1951 expedition and, unlike the Donald-Miles expedition, he also collected *Rhizobium* spp., the bacteria that allows legumes to fix nitrogen.

Beyond the benefits to Australia, the 1954 expedition had several lasting influences on the international genetic resources movement. First, in Libya Neal-Smith was accompanied by the resident FAO agronomist, Peter Oram from the UK, who would become a key player in designing new CGIAR centers and programs two decades later. Second, Frankel on his 1953 trip also visited Ledyard S. Stebbins, an "eminent American botanist and evolutionist" at the University of California, Davis.[86] Stebbins had recently published his book *Variation and evolution of plants,* which would become a classic in plant science. Learning that Stebbins was going to be in Algeria in mid-1954 collecting pasture grasses for dryland California, Frankel arranged for joint exploration with the FAO-CSIRO team in Algeria. It was Stebbins who engaged Frankel in genetic resource conservation on a global scale a decade later. Third, recognizing the potential value of the collection for the region, Whyte required that a complete duplicate of the collection be made available to the countries in the region, setting a standard for future expeditions on sharing collections with the host countries. Finally, Neal-Smith concluded from his trip that "that there is a danger that much of the valuable plant [genetic] resources may be lost due to increasing cultivation and overgrazing."[87] This was an early recognition by CSIRO of the dangers of genetic erosion that Frankel would so effectively articulate in the 1960s.

Donald moved from CSIRO to the Waite in 1954 and with Whyte facilitated a joint FAO collection expedition by David Symon of the Waite to the countries on the eastern Mediterranean. Donald himself opportunistically collected samples of forages on a consultancy visit to Argentina in 1958 for the British Bovril company, one of the many cases where Australian scientists used travel for other purposes to enrich Australia's forage genetic resources.[88] Finally in 1958 Eric T. Bailey of the CSIRO plant introduction station in WA mounted an expedition to Chile, a country with a Mediterranean climate, facilitated by the Rockefeller Foundation. This built on recent exchange visits between Frankel and the Foundation that would fund CSIRO's research on nitrogen fixation by legumes.[89]

Collecting for tropical pastures

The potential for development of improved legume-based pastures in northern Australia had been recognized prior to WWII, as highlighted by W. Davies in his tour of the north in 1931. The spontaneous spread of Townsville stylo was widely recognized before WWII and in the immediate post-War period CSIRO demonstrated its value in greatly improving productivity in the beef cattle industry.[90] Although resources for tropical pasture research were minimal, CSIRO's John F. Miles had conducted extensive testing of introduced forages from 1936.[91] However, after the War Australia's interest in developing its vast and sparsely populated areas in the north for defence purposes focused attention on realizing its potential for beef production for both the domestic market and emerging export markets. Both Hartley and Miles had called for additional searches for suitable legumes for tropical pasture development and both pioneered plant exploration for the tropics in the post-War period.[92]

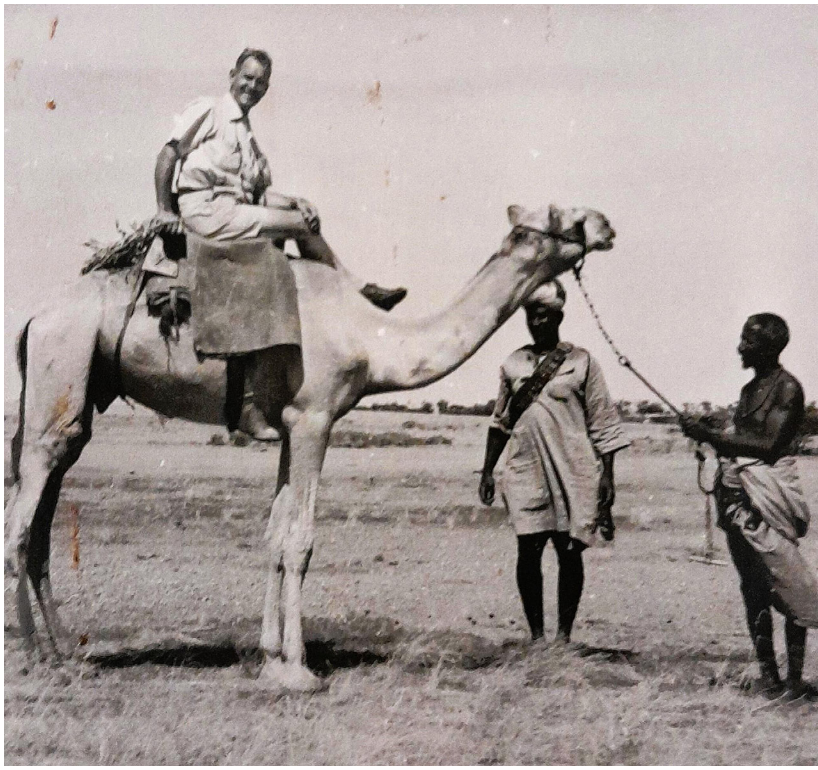
Learning of a USDA expedition to collect *Arachis* species and ecotypes for US peanut improvement, Hartley asked to join the expedition via the Commonwealth Agricultural Bureaux.[93] After a successful British Empire Potato expedition to Latin America in 1938-39, the Bureaux had agreed to coordinate funding, implementation of collection expeditions, and distribution of the samples within the Commonwealth.[94] In the face of an acute world scarcity of vegetable oils immediately after WWII, Britain had a strong interest in oilseeds and had invested heavily in the infamous Tanganyika Groundnut Scheme.[95] Australia had a similar interest given that the British and Queensland governments were investing in large-scale state farming of peanuts at Peak Downs, Queensland, with equally disastrous results.[96] However, Hartley's major interest was clearly in *Arachis* and other legumes for tropical pastures. The press learning of the expedition enthused that "millions of acres in Queensland and the Northern Territory will be made capable of sustaining a vastly increased cattle population."[97]

Coordination with USDA and the Bureaux was simple in 1947 given that Whyte then headed the CBP and Trumble was Australia's official correspondent for the Bureaux. The CBP was also finalizing one of its more successful books, *Grasslands of Latin America,* by

Gladys M. Roseveare, a scientific assistant to Whyte who employed her multilingual talents to compile nearly 900 references in 8 languages.[98] The book provided Hartley valuable background information on taxonomy, vegetation complexes, species distribution and climate data for him to identify tropical American climate analogues in Australia. Further, the US leader of the expedition James L. Stephens was an experienced 'agricultural explorer' having participated in a USDA expedition in 1936 for dryland forages to Russia's Far East (coordinated with Vavilov himself) and northern China.[99] Over six months, the Stephens-Hartley expedition visited southern Brazil, northern Argentina, Paraguay, and Uruguay, focusing on the legume genus, *Arachis,* but also *Stylosanthes* and *Desmodium,* as well as the grass genus, *Paspalum*.

In 1951, Miles was granted a study leave that he used to travel extensively in sub-Saharan Africa, a region rich in diversity of grasses suitable for grazing.[100] The record of Miles trip to Africa is scanty but it covered some 14 countries and colonies from Sierra Leone to Sudan to South Africa over a nine-month period, largely in the British Commonwealth but including also the Belgian Congo and Ethiopia.[101] This trip was again likely coordinated through the CBP that had extensive contacts in the region. Miles obtained many of his samples from research stations but in Southern Africa, he made extensive field collections on a road and camping trip of about 10,000 km with his family over a six-month period.[102] In total he was able to send home 1670 samples including some for commercial crops such as cotton, sorghum, and rice.[103] Combining his Mediterranean and sub-Saharan African trips, Miles visited some 30 countries and colonies over an 18-month period, rivalling Vavilov himself in his coverage and endurance.

These pioneering trips enabled CSIRO to build up extensive knowledge and contacts in the most important regions of diversity for tropical forages that provided a base for future collections.[105] Interest in tropical pastures surged in the post-War period under the CSIRO leadership of Ian Clunies Ross, a strong advocate of the potential of the cattle industry in the tropics to develop new export markets.[106] This vision was enthusiastically echoed by J. Davies, who moved to Brisbane in 1952 with a vision of "sweeping plains of highly productive pastures" in northern Australia. He was soon joined by other senior scientists from Canberra, including the legume breeder,



John Miles in Sudan 1951[104]

E. Mark Hutton, who like Davies had begun his career on pasture research in SA, and D. N. Norris, a legume microbiologist. Davies vigorously promoted the Aberystwyth fundamentals of pasture development—find the right species especially of legumes, amend soil nutrient deficiencies and evaluate the resultant pasture in terms of animal production.[107] Davies soon aspired to head his own Tropical Pastures Division, not least because of the antagonistic relationship that quickly developed with Frankel, his chief in the Plant Industry Division. Frankel strongly opposed the new division until he was finally overruled by the CSIRO Executive in 1959.[108] Davies "had a remarkable talent for planning and organizing research" and under his leadership the new Division quickly grew to become a global center for tropical pasture science.[109]

Building the science of plant introduction and exploration

From the outset, the Plant Introduction Section had emphasized science to make plant introduction more efficient and productive. Prior to the War, McTaggart had undertaken a valuable survey of Australia's grasslands and produced a typology with a detailed map to guide plant introduction.[110] After the War, the scientific leaders were Hartley and Frankel, both inspired by the writings of Vavilov.[111] Although Frankel assumed a heavy administrative load in CSIRO, he continued to write about crop diversity and adaptation.[112] During this period, he also sketched out the key elements of the science of the collection and conservation of genetic resources, choosing that as his topic for an address to an international symposium on plant breeding and genetics in New Delhi in 1957.[113]

Meanwhile Hartley focused on the emerging science of phytogeography, employing data on climate, soils, vegetation, and flora to improve the chances of successful plant introductions by better targeting of regions for exploration and selecting appropriate sites for testing in Australia. Using extensive floristic data from diverse regions, he developed a quantitative "agrostological index" of the relative frequency of grass species of different tribes.[114] Hartley was also intrigued by the work of M.Y. Nuttonson to compile large-scale data sets on climatology together with phenological data from crop variety testing across countries.[115] Nuttonson, a Jewish émigré from Russia, had studied under Vavilov before moving to Israel and the USA. During the 1950s he was engaged by the government of Israel to compile an encyclopaedic volume on crops, varieties and agricultural practices in southern Australia that might be useful in similar agroclimatic analogues in Israel.[116]

The scientific focus was evident in the first Australian meeting on plant introduction held in Canberra in 1953 that brought together all the actors from the original explorer, Trumble, Donald, Hartley, Miles, and Neal-Smith, with Frankel himself joining for the entire five days.[117] The meeting recognized that an explicit objective of the Plant Introduction Section was to conduct "research to establish scientific principles to aid plant introduction."[118] This scientific focus translated into more carefully prioritized collections that set the standard for an integrated system that combined introduction, evaluation, and information exchange built into the design of the Section. This emphasis on research contrasted to the USDA system that saw itself as a service to other scientists. Further contrasting with USDA and akin to the Vavilov Institute, CSIRO conserved its collections initially through regular regeneration of seeds, so many are available in genebanks today.[119]

International cooperation in the South Pacific

In the 1950s, Australia led one of the first efforts at international cooperation on genetic resources. The South Pacific Commission had been set up after WWII to promote cooperation among the six Western countries governing colonies and protectorates in the Pacific—Australia, Britain, France, Netherlands, NZ, and the USA. The US member of the Commission, Knowles A. Ryerson, formerly in charge of the USDA's plant introduction service (succeeding Fairchild), ensured that the Commission's agricultural activities were built around introduction and evaluation of economic crops and tropical pastures and exploring the diversity of major food crops in the region, such as breadfruit, sweet potatoes, and taro. Australia through CSIRO's Hartley took the lead in this collaboration, chairing a meeting of scientists (nearly all colonial officials) from across the region in 1955 to set priorities. Hartley continued as a technical adviser to the Commission throughout the 1950s.[120] With limited resources, the results were modest, but it did re-enforce Australia's support of the principle of international cooperation to achieve economies of scale for activities related to genetic resources. It also set up the CSIRO to provide similar leadership globally through the FAO (Chapter 4).

Mainstreaming plant exploration in the 1960s and 1970s

Once evaluated under field conditions in Australia, the collections soon proved the value of such expeditions, greatly increasing the diversity of species and ecotypes then available. The Donald-Miles 1951 expedition around the Mediterranean was particularly productive with seven released cultivars based on selections or breeding from the collection.[121] Another five grasses cultivars were selected from the Neal-Smith 1954 expedition. The two tropical expeditions by Hartley and Miles also yielded three new legume and two grass cultivars.[122]

The experience and contacts of the pioneering expeditions of the 1950s and the strong faith in science, accompanied by the rapid rise in funding for agricultural research during the 1950s, enabled plant collection to become routine in the 1960s and 1970s (Figure 3.1).[123] Indeed, Clunies Ross, the dynamic CSIRO executive chair during 1949-59, was featured in 1973 on Australia's first $50 currency note against a background of exotic pasture plants.

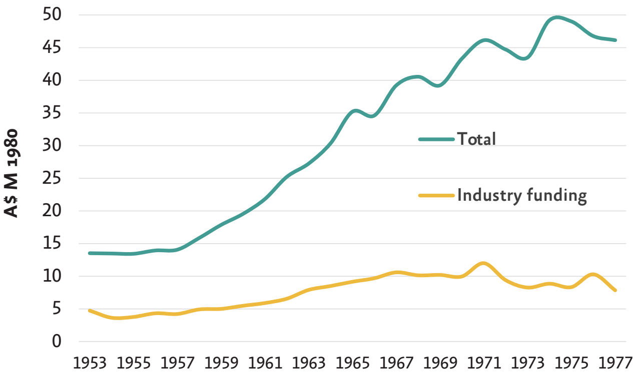
After Donald moved to the Waite, CSIRO left collection of Mediterranean pastures to the States, especially Eric Crawford[124] of the SA Department of Agriculture and Clive Francis of the WA Department of Agriculture, who in the 1960s initiated what would become the Australian Medicago Genetic Resources Centre and the Australian Trifolium Genetic Resources Centre, respectively. These soon became the world's largest collections of Mediterranean forage legumes. At least 20 more significant collections were mounted around the Mediterranean region from 1960 to 1979.[125]

After 1960, CSIRO focused on collection of tropical pastures led by R. (Ron) J. Williams in Brisbane who set up the Australian Tropical Forages Genetic Resources Center initially as part of the CSIRO Plant Introduction Section. Williams who would lead plant introduction initiatives for the tropics for the next two decades, had worked under Hartley in Canberra from 1953 and shared Hartley's scientific interests in taxonomy and ecology as a basis for collection and testing.[127] The Queensland Departments of Primary Industry (QDPI), the University of Queensland and the NSW Department of Agriculture also became active in exploration for tropical pastures. In total, at least 18 more significant collection expeditions were conducted from 1960-79 with a continuing priority to tropical America and a second priority to tropical Africa. By the early 1980s, the tropical pastures genebank was the world's second largest repository for tropical legumes, after Brazil.[128]

Over time, collection methods and coverage became more systematic and scientific, building on the experience of the 1950s pioneers. In the CSIRO, collection intensified in the 1960s with no fewer than four expeditions in tropical America in 1965. This coincided with the 9th International Grassland Congress meeting in Brazil, the first time the Congress was held in the tropics. These expeditions included a seven-month expedition by Williams focused on Brazil and supported by the Beef Cattle Industry Research Fund—a trend towards industry funding of overseas collections that would continue in the following decades. This expedition resulted in the release of the successful cultivar, *Stylosanthesis scabra* cv. Seca. Norris, the legume microbiologist based in Brisbane, also moved with his family to Brazil in 1964-65 to combine collection of legumes with the first major collection of *Rhizobium* spp. for the tropics.

Clunies Ross and exotic pastures on the first $A50 note 1973

Figure 3.1 Trends in real expenditures by CSIRO on research for broadacre agriculture[126]

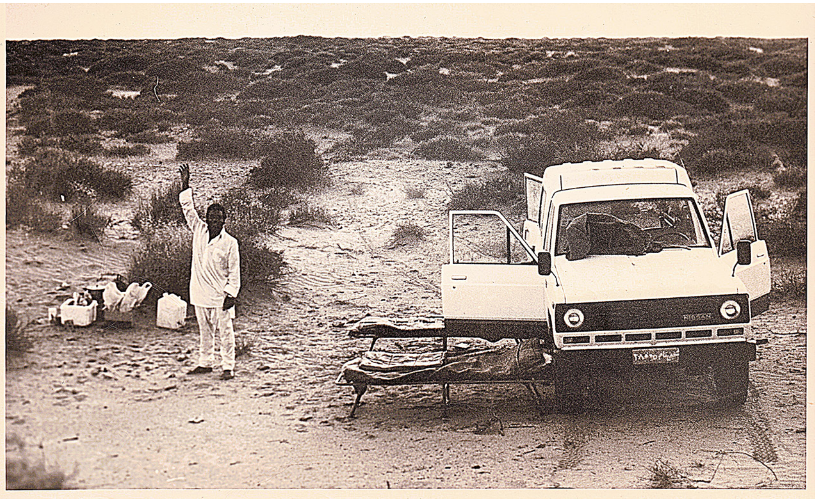


Two Australian pioneers in genetic resources—William Hartley (left) with Ron Williams[129]

In the late 1970s, Robert (Bob) Reid from CSIRO mounted perhaps the most ambitious expedition when he moved with his family to Mexico and over 15 months in 1978/79 criss-crossed the country multiple times to capture the seasonality of seed harvesting of different species and ecotypes of *Leucaena* spp. as well as the genus, *Desmanthus*.[130] He also collected extensive site data including soil samples. Notably, CSIRO signed a contract with the Mexican national agricultural research institute to provide logistics and technical advice for the project.

In the Mediterranean region, the Libyan Agricultural Research Center, FAO and the WA Departments of Agricultures collaborated from 1979 to 1981 on an in-depth collection of annual *Medicago* spp., financed by the Government of Libya. Gustave Gintzburger, a French FAO range ecologist in Libya and then an employee of the WA Department of Primary Industry, trained teams of Libyan collectors to make carefully designed transects across diverse ecologies. He also managed a novel accelerated evaluation of the collection of over 2,000 samples in Libya in the northern hemisphere winter and in WA in the southern winter.[131]

Finally, Francis of the WA Department of Agriculture was one of the most intrepid of the Australian explorers focusing on *Trifolium* spp. and *Medicago* spp. from the Mediterranean region but also forages and grain legumes from West Asia. From 1973, Francis participated in around 30 plant collection expeditions resulting in a total of about 14,000 samples and over 20 cultivar releases from the collections.[133] He was particularly recognized for forming close partnerships with local scientists many of whom subsequently visited Australia. Both Francis and Reid were honoured by the prestigious Vavilov Memorial Medal from Russia's Vavilov Institute.



3.5 Collecting annual medics in Libya 1978 in collaboration with WA Dept of Agriculture[132]

Although the need for international cooperation declined as Australian scientists built local contacts and experience, Australia's scientific organizations remained in close contact with FAO to coordinate collection. This was naturally most pronounced in the Mediterranean region where FAO was conducting parallel pasture programs (Chapter 4). A few of the collections for tropical pastures were also coordinated through FAO, especially in Africa. The spirit of international cooperation was evident when, prior to his 1965 expedition to Brazil, Williams wrote to FAO offering to consider specific requests on behalf of other interested parties and to freely share seed samples he collected.[134]

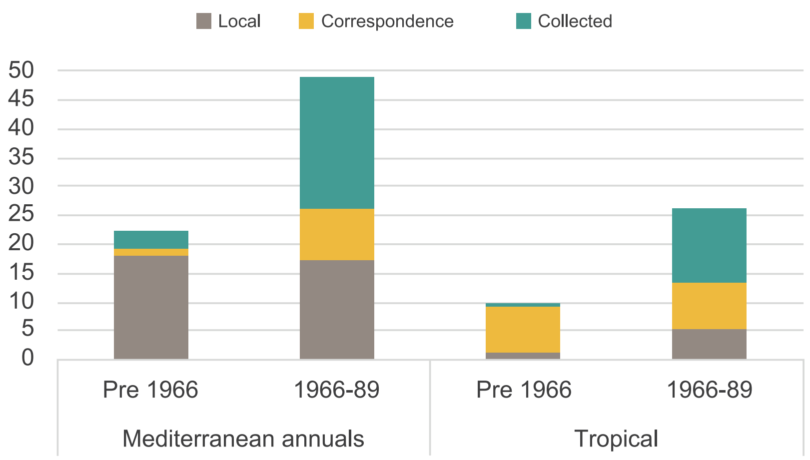
By the simple and surely inadequate metric of the number of cultivars released, the impact of Australian exploration for legumes is seen in Figure 3.2. Before 1966, over 80 percent of annual Mediterranean legumes were derived from selections from naturalized local ecotypes, but during 1966-89, cultivars based on collections accounted for half of releases, either as direct selections or through breeding. For tropical legumes, the few releases before 1966 were mostly based on introductions via correspondence but during 1966-89, half of releases originated from field collections. In both cases, the rate of release sharply accelerated with access to greater diversity of genetic resources and increased funding for evaluation and breeding. The origin of released cultivars is also impressive, with about 14 different countries supplying Mediterranean legumes (overwhelmingly from around the Mediterranean Basin) and 14 countries providing tropical legumes (with a concentration in tropical America, especially Brazil). These new pasture legumes enabled their adoption in new agroecological niches, as well as improving the productivity and stability of pastures in established areas.

Finally, while collections greatly assisted the release of new forage legumes, their impact on release of grass cultivars was marginal. As discussed at the beginning

Veteran WA plant explorer, Clive Francis in Armenia collecting with Prof. Eleonora Gabrielian[137]

of this chapter, some grasses had been introduced in southern and northern Australia even before CSIRO was established. Grasses for high rainfall and cooler climates could also draw on commercial releases in similar temperate environments, especially NZ. After WWII, the establishment of grassland research stations in the British territories of eastern and southern Africa facilitated a new wave of introductions of tropical grasses. Accordingly, releases of grass cultivars depended much more on correspondence even after 1966 and field collections of grasses resulted in few releases, with most resulting from the first expeditions to the Mediterranean in 1951 and 1954.[136]

Figure 3.2 Number of Australian registered cultivars of pasture legumes by source of germplasm and period of release to 1989[135]



4. The Genetic Resources Movement, FAO, and IBPGR[138]

From forages to FAO's global responsibility for genetic resources 1951-1961

FAO had from its beginnings recognized its role in the "genetic stocks" of major food staples.[139] Arising from meetings initiated by the UK-based Commonwealth Bureau for Genetics and Plant Breeding (a sister of CBP), with USDA and FAO in 1948, the director of the Bureau moved to FAO to initiate a world catalogue of genetic stocks beginning with wheat.[140] Breeders around the world were asked to provide lists of varieties and their characteristics in a standard format and agreed to supply small samples of seed on request to other breeders. The success of this venture was limited by the willingness of breeders to contribute information and seed and the narrow focus on released varieties, with little attention to landraces and wild relatives. FAO also set up a seed laboratory that received and distributed about 20,000 seed samples annually in the 1950s, mainly of released varieties, to supply its regional programs on crop improvement for cereals and forages.[141]

While the genetic stocks catalogues and seed exchanges promoted plant introduction for the major cereals, FAO work on plant exploration mostly related to forages. This partly reflected the unusually powerful position of forage agronomists who occupied top positions in FAO in the 1950s, from the director general to the chief of plant production.[142] However, the major driver was Whyte who, together with W. Davies of the OEEC, set up the FAO Working Party on Mediterranean Pastures and Fodder Development in 1952, consisting initially of nine countries and colonial territories bordering the Mediterranean Sea.[143]

The Working Party that met biannually was a direct follow up of the OEEC survey in 1951 (Chapter 3). Inspired by Donald's presentation at the OEEC meeting on Australian dryland farming in a similar Mediterranean climate, the major objective of the Working Party was to integrate livestock with cereals in dryland farming by substituting sown legume pastures for fallow to improve soil fertility and provide livestock nutrition—that is to "fit the shepherd and his flock into a new system."[144] Although orchestrated by Whyte, USDA's Aamodt from the OEEC survey team was a technical adviser throughout the 1950s, and CSIRO scientists also participated in two of the early meetings.

From the beginning, the Working Party evaluated both local and introduced ecotypes of pasture species, with Australian cultivars prominent in the latter group. FAO's interest in sponsoring the 1954 FAO/CSIRO expedition in the Mediterranean region reflected its desire to obtain local species and ecotypes (mostly wild types) that could be tested in a uniform nursery distributed to member countries. National scientists and FAO agronomists continued to collect additional ecotypes, including CSIRO scientist E. T. Bailey, who had collected in Chile in 1958 and was on an FAO assignment in Jordan.[145]

How to integrate crop and livestock production was a topic of continuing discussion at the Working Party meetings. FAO's Oram, who had participated in the 1954 FAO/CSIRO collection in Libya, surveyed forage research in the region and designed a series of experiments with grain and forage legumes, including many Australian cultivars, to compare rotational options.[146] Other FAO experts, including some from Australia, also contributed with more in-depth country studies of forages, within the overarching aim of substituting productive pastures for fallow. Participants in the Working Party meetings often noted the potential conflict in land use, since livestock management was in the hands of specialized herders, often nomadic, who under customary law enjoyed open grazing rights on any land that was not under crop, including cropland in the fallow phase. Oram summed up this complication as "shepherds with no land and cultivators with no animals" and that "management may well prove the nemesis of sown pastures in the Mediterranean."[147] These discussions would dominate research on forages in the region over the next three decades, with Australian scientists and projects in the forefront (Chapter 5).

Whyte also helped set up other Working Parties on grazing and fodder resources in the Near East and on Pasture and Fodder Development in Tropical America. Both included collection of local forages and distribution of forage nurseries, especially the Near East group. FAO also had Working Parties for the staples wheat, rice and maize. These largely tested existing varieties, but the Working Party on Hybrid Maize for Europe undertook the collection of maize landraces that were rapidly being displaced by hybrids.[148]

Beyond the field-based work on genetic resources of forages, Whyte organized a first effort to assess the state of scientific and practical knowledge on plant introduction and exploration. He did this through a series of meetings in 1956, beginning with a two-day meeting in London attended by scientists from Australia, France, Netherlands, and Sweden, UK, and the USA. Reflecting the close collaboration of FAO with CSIRO, Whyte asked Hartley to chair the meeting. Australia already saw itself in the lead in the science of plant introduction, as Hartley "came away with the impression—perhaps unduly smug—that we have not a great deal to learn from Europe."[149]

The 7th International Grasslands Congress held in 1956 in NZ was an opportunity for further discussion of approaches to plant introduction. En route to the Congress, Whyte convened a meeting in CSIRO Canberra with Frankel, Hartley, Neal-Smith and others to review the state of the art with respect to plant exploration and introduction. This set the stage for Hartley and Donald to propose to the Congress in NZ that forage scientists place a high priority on genetic resources, especially through exploration, and that FAO take the lead in fostering international collaboration. This recommendation paved the way for the 1959 FAO Conference (FAO's governing body) to assume a leadership role in the international coordination of plant exploration, introduction and information exchange.

Building on the deliberations of these various meetings, in 1958 Whyte published *Plant Exploration, Collection and Introduction*.[150] This book was a landmark, bringing together for the first time existing knowledge on plant exploration and introduction as well as related scientific approaches and practical methods. Not surprisingly, Whyte drew heavily on the experience with forages and extensively cites Australian authors. He called for systematic priority setting and targeting and international and regional collaboration to pool efforts of countries within a Vavilov center of genetic diversity to collect and share genetic resources. In a companion article, Whyte also highlighted the importance of conserving genetic resources, noting that "time is running out and the valuable genotypic material will not be there for much longer."[151] To meet this urgency he called for an international fund to aid conservation.

The *Plant Introduction Newsletter* launched by Whyte in 1957 was another innovative step, becoming an essential tool in the exchange of seeds and information and facilitating international collaboration on plant introduction and exploration.[152] The Newsletter would continue as a reference point for the plant genetic resources community for the next 50 years, albeit with editorship passing from FAO to IBPGR when it was created. Whyte also built on his long experience in CBP in assembling reference books to guide plant exploration and introduction. In 1954 he coauthored *Legumes in Agriculture* with Trumble, a book that despite its title focused exclusively on forages. This was followed by another reference book on grasses, making Whyte perhaps the most published author in FAO at the time.[153]

The climax of these extensive FAO efforts in the 1950s was the first international meeting on plant introduction and exploration timed to coincide with FAO's declaration of 1961 as World Seed Year. Whyte and Hartley led the 1961 meeting with Whyte as the main organizer and Hartley as the chair. Described later by Frankel as a "trail blazer"[154] the 1961 meeting brought together 58 delegates from 28 countries including 12 developing countries, although neither India nor China (then represented in the UN by Taiwan) attended. Reflecting the expertise of Whyte and Hartley much of the discussion centered on forages but an attempt was made to bring in the experience of major food crops, notably potatoes and maize.

The attention to potatoes was due to participation of J. (Jack) G. Hawkes, a professor at the University of Birmingham who had undertaken several potato exploration trips including the 1939 British Empire Potato expedition in the Andes when he worked with the Commonwealth Bureau for Plant Breeding and Genetics. Hawkes was destined to be a major player in the genetic resources movement emerging under FAO.

The participation of F. G. Brieger from the University of Sao Paulo in Brazil ensured attention to maize. Brieger had collected indigenous maize varieties in Latin America as part of a project initiated by the Rockefeller Foundation and then managed by a committee of the US National Academy of Sciences. By 1960, this committee had sponsored the collection and description of 10,000 maize samples stored at three locations, including the University of Sao Paulo.[155] The collection succeeded in conserving many landraces that were being threatened by the rapid diffusion of new maize varieties and hybrids in several countries.[156]

The 1961 conference was the first to highlight the rapid and irreversible loss of landraces and wild relatives due to introduction of new varieties, land degradation, and the expansion of cropland into pastures. The conference also emphasized the role of science in making plant exploration and conservation more efficient and effective. Led by Hartley, it endorsed a "genecological approach" in field collection to capture diversity by recognizing the interaction between intraspecific variability and the environment as part of crop adaptation and evolution. Both *in situ* and *ex situ* conservation were discussed although the state of knowledge on the feasibility of long-term *ex situ* storage of seed was still very incomplete. Recognizing the emerging science and practice related to genetic resource conservation, the conference called for the appointment of an FAO Panel of Experts on Plant Introduction and Exploration to provide outside scientific advice.

The urgent need for international collaboration on all aspects of plant introduction, exploration, and conservation was stressed, citing the FAO/CSIRO 1954 Mediterranean expedition as an excellent example of such cooperation. The meeting accordingly recommended that "FAO, through its Member Countries, promote the establishment of international and national exploration stations in or near gene centers [of diversity]." Thus began the discussion over more than a decade on how to organize such collective action and the need for an international agency to coordinate.

While the 1961 conference was a major milestone in founding the genetic resources movement, there was little follow up. Whyte, reportedly passed over for promotion, moved to the FAO office in India, where he remained engaged in forages but was no longer leading FAO efforts on genetic resources. He had played a critical role for a decade in elevating the discourse on international cooperation in genetic resources and his departure left a vacuum in Rome.

FAO's work in genetic resources also shifted from Rome to the Crop Research and Plant Introduction Center at Izmir, Türkiye. This Center had been proposed by the 1961 conference as one of three centers for plant exploration in diversity "hotspots," with a focus on forages. From the beginning there was a tension between the Izmir Center's role as a national research institute and its international role in facilitating exploration and conservation in one of the world's richest centers of genetic diversity.[157] However, it was agreed that "the chief interest in plant exploration came from outside the region."[158] As an example, the Izmir center became an important partner for Australian forage collections with no less than three Australian scientists mounting joint expeditions in Türkiye on forages in 1967 alone.[159]

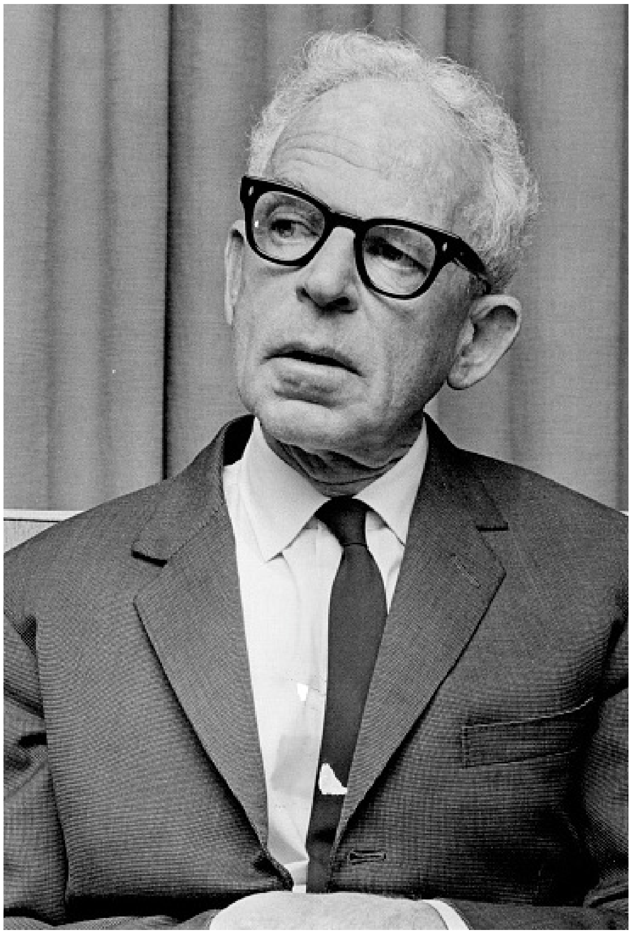
Frankel and FAO shine a spotlight on genetic erosion

The decisive phase in global collective action on the conservation of crop genetic resources began in 1964 and for the next decade would be dominated by Frankel, by now a member of the Executive of CSIRO. By any measure Frankel, only two years from retirement, had led a distinguished scientific career. At CSIRO he had taken over a Division with "flagging morale" in 1951 and built it into a world class scientific group by attracting the best scientists and giving them freedom to conduct "fundamental research."[160] Yet he was destined for his greatest career achievement after his formal retirement. As his biographer succinctly noted, Frankel was a "geneticist by training, plant breeder by occupation, cytologist by inclination, and genetic conservationist by acclaim."[161] He had also developed his signature traits as a "strong and somewhat fierce personality" that would be exhibited in his emerging new career in genetic resources.[162]

Frankel's keen interest in crop evolution and diversity and in international cooperation on what he termed "genic resources" has already been noted in Chapter 3, although it was never a mainstream topic of his research. When approached by Stebbins, the then Secretary General of the International Union for Biological Sciences (IUBS) to lead a sub-Committee of the International Biological Program (IBP) on Plant Gene Pools, Frankel readily agreed. A long-time colleague and friend of Frankel, Stebbins had participated in the FAO/CSIRO forage collection in Algeria and was well aware of Frankel's interest in genetic resources. Indeed, in their joint appearance at an international symposium in India in 1957, Frankel had outlined his priorities for genetic resources and called for international cooperation. Further, Frankel himself was looking for new pastures—in 1962, he had completed his signature achievement of building Australia's first phytotron, opened by Australian Prime Minister Robert Menzies and accompanied by an international symposium jointly organized through IUBS where Stebbins was at the helm.

The IBP was characteristic of the "big science" initiatives of the post-War period. Its stated objective was to increase investment in basic science to feed a spiralling world population, but it also sought to tap rising funding for big science for the cause of biology. Frankel not only led the sub-Committee on Gene Pools but filled other leadership positions in IBP as vice president of the overall IBP steering group, a member of the Section Committee on Use and Management of Biological Resources (commonly known as UM) that included the gene pools study, as well as chair of the IBP national committee for Australia.[164] Indeed by his own account, he shaped the overall UM research agenda and elevated the work on gene pools during an IBP meeting in Paris in 1964.[165]

Two other Australian members of the UM committee were Donald and Keith W. Finlay, professors at the Waite. Finlay was one of the first to employ computers in plant breeding and had achieved fame through a 1963 article describing a simple statistical method for analysing varietal adaptation across environments; one of the most cited articles in plant breeding of that era.[166] Finlay coordinated a second IBP project of UM on Biology and Adaptation but also participated in the Gene Pools study. He would also play a key role in the 1970s in exporting Australian forage technology to the Mediterranean basin (Chapter 5).



Otto Frankel in Sydney en route to the landmark FAO/IBP 1967 conference on genetic resources[163]

M. S. Swaminathan, head of genetics and soon to be director of the Indian Institute of Agricultural Research, was another member of the UM Committee of IBP who would also lead the genetic resources movement. Swaminathan had completed his doctoral studies at Cambridge University and like Frankel had combined seminal basic research (cytogenetics and radiation biology) with applied plant breeding. He had gained an appreciation for the value of biodiversity by tapping wild relatives for potato breeding, but his major fame was just emerging through his close collaboration with Norman Borlaug of the International Maize and Wheat Improvement Center (CIMMYT) in bringing the Green Revolution in wheat to India.

The IBP was mostly a club of rich countries since its funding was to be provided by participating countries themselves. Frankel recognized that IBP working alone would have limited influence given that

Erna Bennett after she left FAO and moved to Australia in the early 1980s[167]

biodiversity hotspots for most crops were in poorer countries. He quickly saw that a partnership with FAO could provide contacts, logistics, and legitimacy for undertaking the IBP study. He was also well connected to B. R. Sen, Director General of FAO, having attended the 1959 FAO Conference where he became a champion of Sen's Freedom from Hunger Campaign, which advocated community action to address world hunger. Frankel chaired the Australia committee as well as the research committee of the Campaign. In the latter capacity he had addressed the first World Food Summit in 1963, where his most memorable line was that "science is not a luxury of the rich but a necessity of the poor."[168] He was also well aware of FAO's interests in international cooperation on plant exploration and introduction through CSIRO's close cooperation on forages.

Sen expressed interest in the IBP partnership and asked Frankel to review FAO work in genetic resources. During a two-month visit to FAO in 1966, Sen finally constituted the FAO Panel of Experts on Plant Exploration and Introduction (hereafter, the FAO Panel) as recommended in the 1961 FAO meeting. The IBP committee on gene pools was merged with the FAO Panel with Frankel as Panel chair. Frankel's main operational contact in FAO for the partnership was Jose Vallega, the Argentinian Director of FAO's Plant Production and Protection Division and a fellow wheat geneticist who had experience in exploration for indigenous crops in South America.[169]

During the early interactions with FAO, the joint FAO/IBP initiative was re-oriented from collecting genetic resources to support plant breeding programs to conservation of "primitive races" and wild relatives to guard against their loss in the field. The extinction of potentially valuable genetic resources had been noted by scientists as far back as 1936 and was a major theme of the 1961 FAO meeting.[170] Frankel recalled that his decision to re-orient to genetic conservation was critically influenced by his discussions in 1966 with Hermann Kuckuck, who had been his student colleague at the Agricultural University of Berlin in the 1920s. Kuckuck had undertaken probably the largest collection at the time of over 10,000 seed samples of wheat landraces during his two-year stay under FAO auspices in Iran in the early 1950s. Since then, he had observed the alarming loss of landraces to introduced "modern varieties" in Iran and most recently in Ethiopia.[171]

Although he did not admit it, Frankel must also have been strongly influenced by Erna Bennett, a British Irish consultant to FAO's Izmir Center on plant exploration. After struggling as a pioneering woman scientist in a man's world, she eventually made her name at the Scottish Plant Breeding Station through a highly acclaimed review of about 400 published articles in *Plant introduction and genetic conservation: Genecological aspects of an urgent problem*.[172] A forthright and often controversial figure, she was highly critical of plant breeders' focus on uniformity that "seeks to eliminate rather than conserve variability" and said diversity was being lost in the centers of diversity, noting that "gene [*sic*] erosion is a dangerous and alarming feature of present-day exploitation of genetic resources." A notable legacy of her review was that she coined (or at least popularized) the terms, "gene (later genetic) erosion", "genetic resources", and "genetic conservation" that became part of the scientific lexicon that we still use today.

As chair of the FAO Panel, Frankel undoubtedly played the leading role in selecting the other Panel members. As at CSIRO, he sought the world's leading scientists but with a focus on those who also had field experience in plant exploration. Two of them would be involved throughout the life of the Panel as pillars of the emerging genetic resources movement. One was Hawkes, already introduced as a participant in the 1961 FAO meeting on genetic resources. From his position at the University of Birmingham, he would shortly establish a unique postgraduate degree in genetic resources that greatly augmented capacity in developing countries.

A second Panel member, Jack R. Harlan, was the son of H. V. Harlan, a noted USDA plant explorer who was among the first to draw attention to the extinction of landraces.[173] J. Harlan had trained under Stebbins as a forage geneticist but, after field exploration in Türkiye that collected over 10,000 samples of cereals and forages, had broadened his interests to crop domestication, evolution and adaptation.[174] Like his father he had sounded the alarm on genetic erosion from his position at the highly regarded Crop Evolution Laboratory that he set up at the University of Illinois.[175] Aside from John Creech, head of plant introduction in USDA who participated in most Panel meetings, other Panel members attended only one meeting due to time and other constraints.[176]

Bennett transferred from the Izmir center to FAO Rome in 1967 to organize with the FAO Panel the 1967 FAO/IBP Technical Meeting on the Exploration, Utilization, and Conservation of Plant Genetic Resources. It is widely agreed that this meeting turned the corner on showing the urgency of genetic resource conservation, as well as documenting the state of art on conservation science and methods. Notably, CSIRO's Hartley was again elected chair, drawing on his deep expertise in genetic resources, recognized with the recent award in the US of the prestigious Frank N. Meyer Medal for genetic resources—the first and only Australian to receive the award.[177]

Bennett meticulously prepared and indexed a report of the conference, including the detailed record of participants' interventions that reveals the dynamics of an international meeting in the early post-colonial period.[178] The 100 or so participants came from 16 developed countries (including 6 from Australia), 2 Eastern European countries, and 6 international organizations, including the founding CGIAR centers, CIMMYT and the International Rice Research Institute (IRRI). Only nine developing countries were represented, a gap that Hartley himself lamented.[179] Of the 43 background documents prepared for the conference, only 3 were authored by scientists from developing countries (India and Argentina).

Given the lack of effective representation of developing countries, it is not surprising that Swaminathan provided their only major voice. FAO Panel members, notably Frankel, and FAO staff, notably Bennett, dominated the proceedings (Figure 4.1). Compared to the 1961 meeting and the earlier work by FAO, the focus had clearly shifted away from

Figure 4.1. The 1967 FAO/IBP Technical Meeting—Number of pages where a specific delegate commented [180]

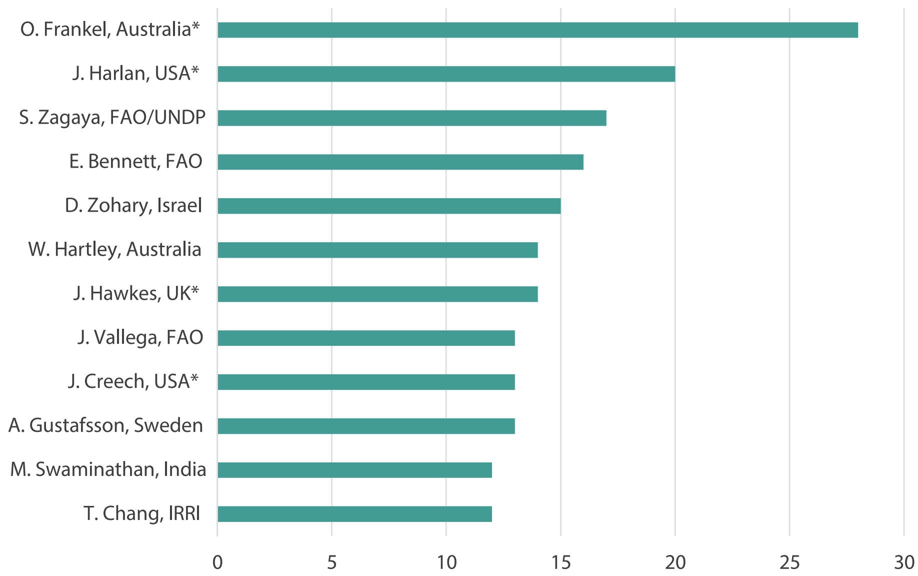
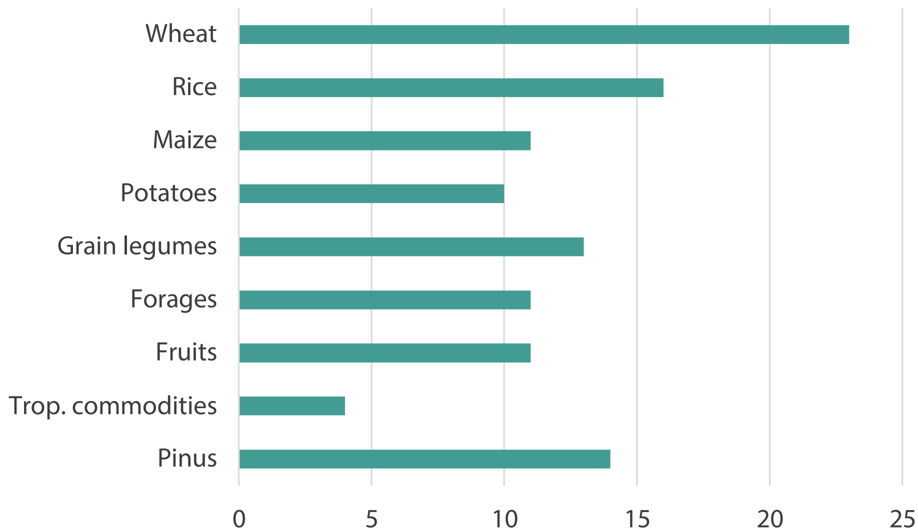


Figure 4.2. The 1967 FAO/IBP Technical Meeting--Number of pages where a specific crop type was mentioned[181]



forages to the major food staples wheat, rice, maize, and potatoes, with forestry also receiving attention (Figure 4.2). In the Malthusian race between food production and population that dominated the global discourse in the 1960s, there was broad agreement that investment in research on food staples especially through support to the emerging international centers was the priority, and this extended to genetic resources. The 1967 conference also moved 'downstream' from plant exploration to give much-needed attention to long-term storage and information and documentation of genetic resources.

The real impact of the conference came from Frankel and Bennett's decision to develop the papers into a 600-page IBP book they co-edited, *Genetic resources in plants; Their exploration and conservation*, published in 1970 by Cambridge University Press and dedicated to Vavilov. Not only did this receive much greater notice in scientific circles than a dry FAO report, but the detailed editing and review of the chapters turned it into a state-of-art assessment of the science and policy of genetic resources conservation. Stebbins in his review in the journal, *Science,* clearly proud of his creation, lauded its "exceptional value...and invaluable encyclopedia of methods."[182] These accolades reflected several milestones achieved by the conference. First, the book embraced a holistic strategy that went well beyond exploration and introduction to include conservation, evaluation and documentation of collections. Second, it elevated the scientific discourse and practice by embracing a range of disciplines from botany, genetics, ecology, to crop evolution. For example, Bennett urged a move from "easy going empiricism to systematic exploration...using phytogeographic methods" and provided detailed guidelines on how to do it. Finlay from the Waite emphasized standardization of information about accessions of genebanks to facilitate their exchange and utilization and for the first time, computerization of that information.

Third and most importantly, the conference provided a sense of urgency to preserve landraces and wild gene pools threatened with extinction. This would require international coordination at the highest level with "FAO in the best position to perform the role of the world's trustee and banker for its genetic wealth."[183] Recognizing that some countries may not wish to share their genetic resources, Frankel talked of a "world genebank as an association of regional and national institutions operating under international agreement and supported by a central clearing house under the UN."[184] The shift in focus from mission-oriented collection for specific crops and traits to a broader conservation objective favoured a regional approach designed around centers of diversity for a range of crops and their wild relatives, echoing FAO's recommendations from the 1950s.[185]

Finally, the conference placed highest priority on *ex situ* conservation of landraces although recognizing a role for *in situ* conservation for wild relatives. Frankel and others saw *in situ* conservation of landraces as impractical and indeed unethical given the need for small farmers to employ new varieties to raises their productivity and incomes. Not all participants agreed, and Bennett and Kuckuck argued forcefully for a role for in situ conservation of landraces to maintain the dynamics of continued evolution under farmers' management. This debate would continue during the life of the Panel and become a major area of disagreement between Frankel and Bennett.

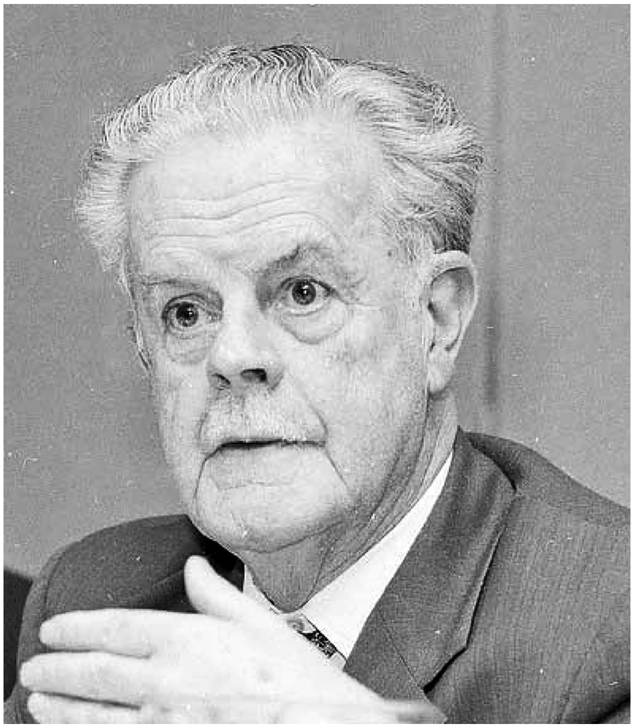
FAO moved quickly to implement the recommendations by forming a Crop Ecology and Genetic Resources Unit later renamed the Genetic Resources Unit. However, few of the other conference recommendations were implemented. Even the Plant Introduction Newsletter as the main means for keeping FAO on the map was suspended for two years in the early 1970s. Bennett, passed over for leadership of the Genetic Resources Unit, did yeoman work to collect landraces of wheat and other food staples in Afghanistan and the Mediterranean, but few other collections were carried out beyond continued joint work with Australia on forages. FAO's slow progress reflected a lack of human resources, funding, and leadership in the Genetic Resources Unit.

Frankel, however, soldiered on by calling four Panel meetings over 1969-74 that continued to promote a network of international, regional and national collection and conservation centers.[186] In addition, working with the Genetic Resources Unit he surveyed the state of conservation in centers of diversity to identify threatened crops and regions and thereby establish global priorities for collection and conservation of genetic resources.[187] While not implemented it did provide the initial plan for collection expeditions when they finally got underway in the late 1970s. By their own admission, the Panel did lots of planning but took little action.[188]

The Panel, especially Frankel, Harlan and Hawkes, kept the urgency of conservation in the news through a strong communication effort, publishing in high profile journals and participating in international and regional conferences.[189] Frankel attended the Paris conference organized by the United Nations Educational, Scientific and Cultural Organization (UNESCO) on the use and conservation of resources in 1968, which recommended support for the initiative. More importantly, he was invited to address the first UN Conference on the Human Environment in Stockholm in 1972. This conference echoed FAO's recommendations on genetic resources conservation, placing FAO firmly in a leadership role for *ex situ* and UNESCO for *in situ* conservation. The cause of conservation was further elevated by the award of the Meyer Medal individually to Bennett, Creech, Harlan, and Hawkes in the following years, on the heels of the award to Hartley.

The endorsement of the Stockholm conference and the emerging interest by CGIAR in funding *ex situ* conservation stimulated the third FAO Technical Meeting on Genetic Resources in 1973. Chaired by Frankel himself, this meeting was much smaller with only nine developing counties present and India notably absent. However, the Soviet Union, not then a member of FAO, did send observers from the Vavilov Institute, still a premier center for genetic resources conservation. As in 1967, a book edited by Frankel and Hawkes was published under the auspices of IBP.[190] The book focused on the practical side of genetic resources conservation and received only lukewarm praise. However, it did advance the science in two key areas. The most discussed and widely cited chapter suggested an approach to optimal field sampling strategies for genetic conservation, co-authored by D (Don). R. Marshall and A. (Tony) H. D Brown of the CSIRO. A chapter by E. H. Roberts of Reading University in the UK drew on over a decade of his research to convincingly demonstrate the scientific and economic feasibility of long-term storage for *ex situ* conservation of seeds of most species and provided confidence to stepping up investments in genebanks.

The 1973 conference continued to promote an international network of genebanks built around regional centers of diversity to be coordinated by FAO. FAO's Director General Addeke Boema observed that "the international movement to promote collective action has now started." However, the center of gravity of the movement was already shifting to CGIAR.



Sir John Crawford, first Chair of CGIAR's TAC[191]

Frankel, Crawford, and the saga of the CGIAR Genes Board

CGIAR was formally established in 1971 and arguably the most influential player in ensuring its operational success in its early years was another intellectual giant of Australian and international agriculture, Sir John (Jack) G. Crawford, at the time vice chancellor of Australian National University (ANU). An economist, Crawford had developed a close relationship with the World Bank by preparing the agricultural chapters of a major report on Indian development in 1965. By 1969 he was interacting with Robert McNamara, the new president of the Bank, and in 1970 he attended the second of a series of meetings in Bellagio, Italy, which, on the initiative of McNamara, founded CGIAR. As a champion of agricultural research and with his deep expertise, global connections and renown skills in chairing meetings, Crawford was a logical choice to chair the Technical Advisory Committee of CGIAR. TAC, as it came to be known, exerted enormous influence in CGIAR's first two decades in vetting and designing new centers and programs.[192]

TAC was made up by 12 eminent scientists with half selected from developing countries. Its membership included expertise in genetic resources through Swaminathan, who had participated in the first FAO meeting on genetic resources, and Dieter Bommer, a German forage specialist who was supporting the development of genebanks in Germany, and in Brazil for tropical forages. TAC's Secretariat was based in FAO and Crawford's "right hand man" in Rome was Peter Oram, Executive Secretary of TAC who had started his career with FAO by supporting its work on Mediterranean pastures throughout the 1950s (including the 1954 FAO/CSIRO expedition).

Crawford was a friend of Frankel who had been a member of the ANU Council and who had his office almost across the road at the CSIRO in Canberra.[193] When not engaged in their frequent overseas travel, they could and did meet informally but formal interaction took place in a series of meetings on genetic resources from 1971 to 1974, leading to the creation of the International Board for Plant Genetic Resources as the eighth "Center" of the CGIAR System.

Genetic resources were a tangential topic in the Bellagio meetings to design the CGIAR System.[194] FAO had expressed interest based on its history of championing plant exploration and introduction. As already noted, the Rockefeller Foundation also had an interest from the 1940s in collecting indigenous maize varieties that resulted in a large collection now stored by the Mexican research institute at Chapingo near CIMMYT.[195] Genetic resources were also a priority for IRRI, established at the initiative of the Foundation in 1960, which quickly moved to obtain duplicates of other collections including that of the FAO-sponsored International Rice Commission. In the 1970s creation of international centers for other major food crops generated increasing demand for genetic resources to support their breeding programs.

The CGIAR Centers were understandably most interested in utilizing genetic resources to improve the productivity and stability of major food crops. The need to inject more genetic diversity into major crops was heightened by the 1971 epidemic of Southern Corn Leaf Blight that attacked genetically uniform maize hybrids across the US Corn Belt.[196] At the same time, there was broad consensus in FAO and the global scientific community on the need and urgency for FAO to mount a global effort to conserve threatened landraces, as charged by the 1972 UN Conference in Stockholm.

After four years of articulating the priorities and advancing the science of genetic resources, Frankel and other members of the FAO Panel were understandably frustrated by FAO inaction on the ground.[197] With the startup of CGIAR, Frankel seized the opportunity to table a paper on genetic resources at the very first meeting of TAC in 1971. Crawford as chair was initially sceptical of CGIAR's role in building "museums" for genetic resources but did agree to request a proposal from FAO.[198]

The FAO proposal presented at the second meeting of TAC recommended 11 genetic resource centers in regions of major crop diversity following Vavilov but was vague on details of governance and organizational design. The proposal had obviously been prepared without consulting its own Expert Panel and Frankel was harsh in his criticisms—lack of urgency, lack of involvement of the CGIAR centers, lack of capacity in FAO commensurate with the proposal, and the need to also tap existing scientific and storage capacity in developed countries.[199] Given these deficiencies, TAC through its member Swaminathan referred the issue to a working group that met at Beltsville near Washington, DC, in 1972. The working group was chaired by Frankel and dominated by members of the FAO Panel but also included representatives from Costa Rica, Ethiopia, India, Türkiye, and the USSR, as well as IRRI and CIMMYT. This so-called Beltsville report re-enforced the urgency of conserving genetic resources as well as the high potential economic payoffs, citing the Australian experience with collection and introducing forage legumes as an example.[200] The proposal called for a global network of international, regional and national centers to be coordinated by a committee of nine scientists and supported by an enlarged FAO Genetic Resources Unit. The role of the FAO Panel was not defined although it soon became clear that it expected to provide the core of the coordinating committee of scientists.

The 1972 CGIAR meeting requested TAC to scale back the proposal from nine to three regional centers and to work out the details of the arrangement with FAO. In March 1973, the FAO Panel concluded that "the new international network will require a high level of coordination which is the clear responsibility of FAO. The Panel offers its continuing assistance in this endeavour."[201] The final TAC proposal recommended to CGIAR in 1973 and seemingly revised largely by Oram, the TAC Executive Secretary at FAO, was explicit that the coordinating committee would indeed be the FAO Panel.[202]

This would be the first time that CGIAR was being asked to consider an organizational model based on a network coordinated by an existing international agency, rather than the standard autonomous international center model.[203] Aware of the strong views of some donors on "FAO politics" and FAO's limited staff capacity, Crawford was clearly uncomfortable with turning over control to the FAO Panel and FAO's Genetic Resources Unit. However, he had been outflanked by Frankel, who had just appointed the two TAC members with expertise in genetic resources, Swaminathan and Bommer, to the FAO Panel. Accordingly, in his 1973 presentation to members of CGIAR, Crawford noted that other options for linking the coordinating committee to FAO might be considered.[204]

Crawford's decision to defer the "FAO matter" to CGIAR would prove consequential. Led by its founding chair, Richard H. Demuth, CGIAR launched a process that turned out to be surely an all-time low point in the quality of the organization's governance. Demuth was Director of Development Services in the World Bank and a lawyer by training. He appointed a sub-Committee on Genetic Resources consisting of one representative of FAO and one from TAC (Bommer) and then invited CGIAR members (that is, the donors) to participate according to their interest. No participants were invited from the developing world, which would be the focus of collection and conservation activities. Demuth himself chaired the sub-Committee, giving it a high profile. Seven donors chose to be members of the sub-Committee and historian Helen Ann Curry has highlighted the influential role of the Rockefeller Foundation representative in key decisions.[205]

The sub-Committee recommended the establishment of an International Board for Plant Genetic Resources of 14 members, made up of donors and scientists with at least 4 from developing countries.[206] In CGIAR tradition, it was to be known by its acronym IBPGR but, given the discordance of this acronym, it was often referred to as the Genes Board. Contrary to the TAC recommendation, the terms of reference for the Board marginalized the FAO Panel, noting only that "recommendations of the Panel would be conveyed to the Board."[207] FAO itself would have only one vote on the Board but, as in previous proposals, the secretariat to implement Board decisions would be provided by FAO's Genetic Resources Unit. Frankel's own discussion with Hugh Bunting from the UK, a key member of the sub-Committee, revealed that this design reflected the sub-Committee's "distrust of FAO and its Panel."[208]

The most infamous act followed when the sub-Committee converted itself into a nominating committee to appoint members of the new Board, still with Demuth as chair. Not only did the sub-Committee exclude FAO Panel members from being nominated but, led by Bunting, they nominated six members of the sub-Committee (that is, themselves) for the new Board, including Demuth who was stepping down as CGIAR chair, to be IBPGR chair.[209] These six members plus the six others they nominated met for the first time in late 1974 to inaugurate the Board.[210] However, the highly donor-driven and irregular process of creating IBPGR sowed the seed of distrust in the global North-South debate in the 1980s over ownership and control of genetic resources, accompanied by a demand by developing countries for a greater role for FAO (Chapter 6).

Frankel was understandably outraged by these developments, as he was reportedly expecting to be the Board's inaugural chair.[211] After meeting with Crawford in Canberra he sent him a letter that frankly laid out his misgivings. He noted the global recognition and extensive experience of the Panel members and the fact that the Panel "literally wrote the entire Beltsville report… without them, the Board would scarcely have been thought of." At the same time, he criticized the lack of expertise of the Board members in genetic resources, singling out Bunting who "without any justification" attached priority to the genetic resources of peanuts. In short, "the Board has a good deal to gain from enlisting the Panel as an advisory group and nothing to lose."[212]

The FAO Panel, still with Frankel as chair, met for the sixth and last time in December 1974. It re-affirmed its willingness to play a scientific advisory role to the new IBPGR and re-iterated the value of doing so, given the wide experience of the Panel and its work over nearly a decade. Very likely in response to his missive to Crawford, Frankel was invited to attend the second Board meeting of IBPGR and report on the work of the Panel. The Board did eventually base its plans on the recommendations of the Panel, especially the priorities and methods outlined by the Panel. However, it did not request ongoing advisory input from the Panel, preferring to set up advisory groups for each major crop building on an ongoing initiative of the Rockefeller Foundation. Ironically, the first external review of IBPGR in 1980 recommended the appointment of a Strategic Advisory Committee—a role that the FAO Panel was expecting to provide from the beginning.[213]

With the ending of the International Biological Program in 1974 and without a role in the new CGIAR-IBPGR architecture for genetic resources, the FAO Panel faded away. After a frenetic decade of travel and meetings, Frankel now 75 years old retired from a formal role in the international genetic resources movement, although he would continue to speak out on the urgency of genetic resources conservation and contribute to the science of doing so for another two decades, co-authoring three more books and numerous articles. And despite the troubled birth of IBPGR and the sidelining of Frankel and the FAO Panel, IBPGR did eventually implement much of the vision provided by the Panel. In its first decade, under the executive leadership of J. Trevor Williams, a close colleague of Hawkes at the University of Birmingham, IBPGR developed a global network that mounted 300 collection missions in 88 countries, adding 100,000 samples to the world's genebanks. It also defined crop descriptors for documenting collections and supported capacity development for genebanks through training and funding.[214] Reviewing the progress of IBPGR for CGIAR in 1985, Hawkes concluded that "the impacts have been extraordinarily good, and IBPGR has unquestionably rescued the major part of the world's germplasm resources, which would otherwise have disappeared completely."[215]

Despite Australia's high interest in plant exploration and introduction, its role in building FAO's capacity and legitimacy in genetic resources and its leadership in proposing the global network for genetic resources conservation, it only began funding IBPGR in 1978. Crawford and Frankel's experience in the Genes Board saga likely influenced Australia's wait-and-see attitude to extending its support.


Photo: Shutterstock

5. Exporting the 'Australian School' —Forage Research in CGIAR

Australia builds its global reputation in forage legumes

By the 1960s, Australia had developed a global reputation in legume-based pastures for livestock production and integrating pasture rotations into crop-livestock systems in what some termed the 'Australian school' (although it originated in Aberystwyth).[216] Several factors contributed to this focus. First, while most industrialized countries took advantage of declining prices of nitrogen fertiliser in the post-WWII period to quickly adopt nitrogen fertiliser in their broadacre agriculture, nitrogen prices in Australia were high—about double that in the USA—due to the small market, lack of a cheap feedstock for domestic manufacturing, high import protection to its industrial sector, and low protection to agricultural producers. Second, most areas sown to crops and improved pastures in Australia experienced periodic droughts, increasing the risks that use of nitrogen fertiliser would not pay. Third, superphosphate that is critical to successful integration of legumes into pastures in Australia's phosphate-deficient soils was heavily subsidized from 1930 specifically for pasture development.[217] Finally, in the post-War period, record prices for wool and special tax incentives for pasture development provided a tail wind for investment in sown pastures.

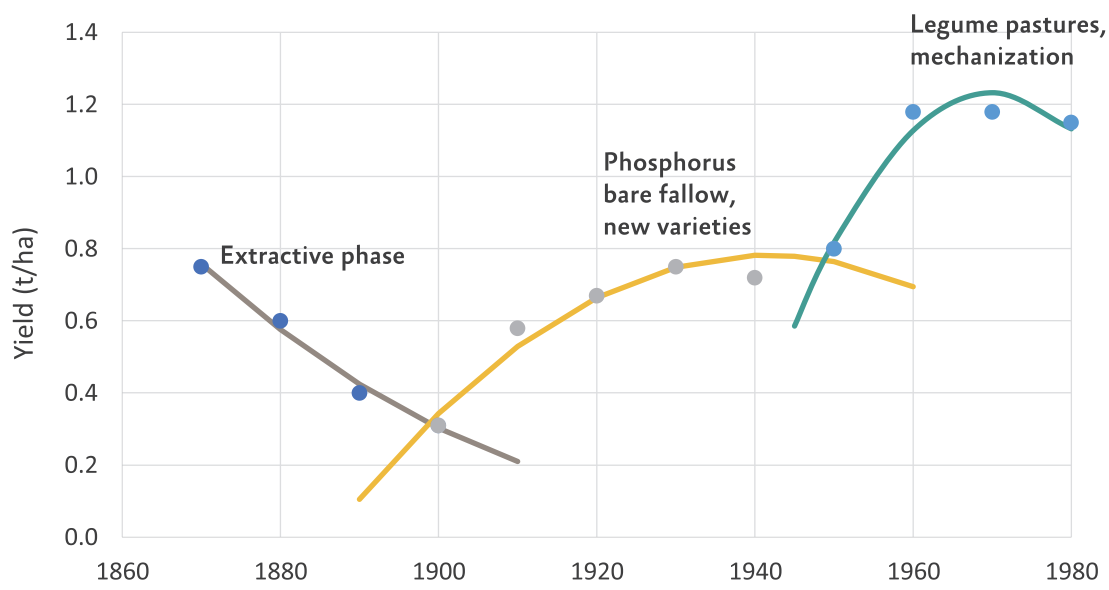
Australia's successes with Mediterranean pastures became well known internationally, above all through publications by Trumble and Whyte during the 1950s after Trumble's sojourn at FAO.[218] Donald at the Waite also highlighted Australia's breakthrough at The International Grassland Congress in 1956 in NZ, including a film, *Two Blades of Grass*. By 1961, Donald had published his iconic "opera house curve" that depicted the impact of forage legumes on Australian wheat yields in the post-War period (Figure 5.1). He also attributed half of the increase in Australia's wool production in the post-War period to adoption of legume pastures, noting that "use of fertilized leguminous pastures stands as the greatest factor of favourable environmental change in our agriculture."[219] In 1971, the lead article of a widely circulated FAO publication promoted the Australian dryland farming system as a solution to the growing grain and meat deficit in the Near East.[220]

Pasture research in northern Australia started much later and only about 1 Mha of legumes were sown in the tropics by 1970 against an estimated potential at the time of about 40 Mha (later reduced to 22 Mha).[222] Still Australian scientists were promoting a global role for the Australian school in the tropics. Australia's progress with tropical pastures was presented in successive International Grassland Congresses starting with J. Davies in 1960 as a striking example of "making deserts fertile" with suitable pastures and soil nutrition.[223] The first Congress held in the tropics in Brazil in 1965 was attended by 19 delegates from Australia, with Davies again promoting the role of legumes in developing pastures in the tropics.

The 1970 Congress held at Surfers Paradise, Queensland, allowed Australia to present its achievements in pasture research to a global audience of over 800 delegates from 51 countries. This was planned to be the pinnacle of Davies's career, as he was expected to preside over the meeting. Unfortunately, he died in 1969 just one year after his elder brother W. Davies in the UK, bringing an end to a remarkable four decades of leadership of the two Davies in global pasture research. Delegates received a book on *Australian Grasslands*, dedicated to J. Davies, which provided a comprehensive overview of pasture research in Australia.

It fell to Hutton, the incoming chief of the Tropical Pastures Division, to preside, assisted by vice president, Donald. In his presidential address, Hutton chose as his topic Australia's success with plant introduction, now amounting to 30,000 accessions and especially the pay offs to the post-War collection expeditions for both

Figure 5.1. A version of the Donald wheat-yield curve for Australia, 1860-1980[221]



Mediterranean and tropical pastures. Hutton has been identified as doing "the most to convince the rest of the world that tropical pastures warranted serious study."[224]

Australia's old friends overseas, W. Davies in the UK, and Whyte, now at the University of Hong Kong, had also published books on tropical pastures that prominently featured Australia's achievements in both the science and on the ground.[225] Although both had established their reputation in temperate and Mediterranean pastures, they too were caught up in the excitement of applying the experience in Australia to other tropical regions to increase livestock production and protein food supply. In the 1960s and early 1970s, protein rather than calorie scarcity was considered the leading cause of world hunger.[226]

A major vehicle for exporting the Australian school was through the design of new CGIAR centers. As CGIAR rapidly expanded in the 1970s, Australian scientists and science had an outsized role in creating 5 of the original 13 Centers (pre-1980). As already seen in Chapter 4, Frankel interacting closely with Crawford as chair of TAC were the main drivers in establishing IBPGR. Crawford, given his long experience in food and agricultural policy, also worked closely with the International Development Research Center of Canada to create the International Food Policy Research Institute in 1975 and was its founding Board chair, although IFPRI did not join CGIAR until 1980.[227] The other three Centers that Australia was involved in founding to 1980 were all concerned with forages and livestock production, the International Center for Tropical Agriculture in Colombia (CIAT) in 1967, the International Livestock Centre for Africa (ILCA) in 1974, and the International Center for Agricultural Research on the Dry Areas (ICARDA) in 1977. The design of all three centers drew heavily on Australian science and scientists. Beyond CGIAR, Australia also developed bilateral cooperation around livestock and pasture research in several countries of Southeast Asia from the early 1970s (Box 5.1).

Box 5.1. Australia and Pasture Development in Southeast Asia

Independently of CGIAR, Australia from the early 1970s mounted livestock programmes in Southeast Asia, a region of high geopolitical priority to Australia's official development aid. The largest such project was led by CSIRO to develop the Centre for Animal Research & Development at Bogor, Indonesia. Other projects were also mounted in Malaysia and Thailand, and all included a forage component. Recognizing that the CGIAR forage programs at the time did not cover Asia, there was even a call for a new international center on tropical pasture research to serve the region, to be supported by Australia.[228] In a more modest effort, CSIRO's Tropical Pastures Division did establish an Australian-Southeast Asian and Pacific Forage Research Network in 1984. At this time, Australian scientific cooperation on forage research in the region also became a priority of the newly created Australian Centre for International Agricultural Research (ACIAR). Several ACIAR research projects were then carried out in cooperation with CIAT, a centre that was already making extensive collections of tropical forages in the region.[229] The early Australian projects in the region also "groomed" future leaders in CGIAR including Peter Kerridge, who would lead CIAT's forage program, and Lindsay Falvey, who later chaired the board of the International Livestock Research Institute (ILRI) (a merger of the two international livestock centers in Africa).

CIAT—Educating the US Foundations on tropical pastures

CIAT, the third center set up by the US Foundations after IRRI and CIMMYT, grew out of a call by US President J. F. Kennedy for a regional center in Latin America as part of the Alliance for Progress, his signature initiative for the region. The call for this Center echoed the motives for Australia's northern development—that is, huge tracts of land with low population density in lowland tropical America, especially the savannas, which could be converted to agriculture to contribute to world food supply.

The initial design of this Center in 1966, entrusted to a team of the US National Academy of Sciences led by the noted Malthusian author of *Famine 1975!*, William Paddock, was rejected by the Alliance as too US-centric in terms of funding, location, and staffing and out of step with the principle of true partnership espoused by the Alliance.[230] A second team chaired by J. George Harrar, president of the Rockefeller Foundation, and including F. F. (Frosty) Hill, vice president of the Ford Foundation, then recommended the creation of CIAT in Colombia, following the same autonomous international center model employed for IRRI and CIMMYT.[231] However, rather than their crop-oriented approach, CIAT research was designed around improved production systems that would integrate crops, livestock and soil management.

Cattle production was an obvious priority in the humid tropics and Latin America was already a large beef producer. However, most research on pastures had followed the US model of finding suitable grasses and applying heavy doses of nitrogen fertiliser. USDA's senior agronomist for tropical pastures concluded that this approach was more productive than a grass-legume mixture.[232] Only Hawaii, facing high costs of transport for fertiliser, seems to have invested in research on forage legumes.[233] Indeed, later studies revealed that legumes made up less than 30 percent of genetic resource collections for tropical pastures in the southern USA, compared to over 80 percent in Australia.[234]

The challenge of developing beef systems in tropical America's infertile savannas had many parallels with Australia's quest to develop its northern beef industry. Given its growing reputation, the US Foundations turned to Australia to inform the design of CIAT. In 1967, after meeting with J. Davies, chief of CSIRO's Tropical Pastures Division, Hill, who was the most senior agriculturist in the Ford Foundation, toured northern Australia for a month interacting with scientists and producers in Queensland and the Northern Territory. In his 45-page trip report he was clearly impressed with the team of more than 60 scientists working on various aspects of pasture improvement and beef development in the tropics, describing them as "highly competent" with a good balance of fundamental and applied research and strong interdisciplinary coordination and team spirit. He saw the CSIRO's Tropical Pastures Division "alongside IRRI and CIMMYT as an organization of greatest importance to food production in developing countries."[235] He also envisaged the Division as a natural partner for CIAT that could provide CIAT germplasm from its extensive forage collections and breeding programs as well as undertake fundamental research to support CIAT in areas such as nitrogen fixation by tropical legumes. Hill vigorously promoted these links to Australia in the design meetings for CIAT.[236]

The following year, as CIAT was being set up, the Rockefeller Foundation requested Loy Crowder, a professor of forages at Cornell University, to propose a detailed design for the CIAT beef and pasture research program. Crowder, who had previously worked in the Foundation's Colombia program, also visited northern Australia to observe its research on pastures and beef production. In his design proposal, Crowder not only emphasized the central role of improved pastures for beef production but based on his Australian visit he also became a convert to the Australian school of legume pastures.[237] He did, however, note the significant investment costs and management skills required for successful integration of legumes in tropical America even for medium- to large-scale beef farms that were CIAT's focus at the time. Crowder's visit was quickly followed in the same year by further exchange visits between CIAT and CSIRO with an emphasis on livestock management.[238]

CIAT's beef program quickly grew to be its largest, reaching 24 scientists by 1979 even as it narrowed its focus to pasture improvement and was renamed the Tropical Pastures Program. Given its foundations, Australian scientists were prominent in the program from the beginning, including seasoned pasture specialist, Bela (Bert) Grof, with experience in collecting forage legumes in tropical America for the QDPI, and several younger scientists hired over the next two decades.[239] By 1976 Australia was providing significant support to CIAT's research budget reflecting not so much Australia's geopolitical interests but a common research interest in tropical pastures and their associated genetic resources.

The identification of suitable pasture legumes was a priority from the beginning. Initially CIAT had access to Australian cultivars and CSIRO also donated 800 of its legume accessions collected mostly from tropical America to CIAT.[240] However, the paradox of depending on Australia for cultivars of species originating in tropical America and the specific focus of CIAT on acid soils soon led CIAT to start its own collection expeditions. These were initially led by Grof and then by the indefatigable German scientist Rainer Schultze-Kraft and his team who mounted 28 expeditions from 1976 to 1985, often supported by IBPGR and sometimes conducted jointly with Australian scientists. Soon the CIAT collection was larger than CSIRO's although the two collections remained complementary in terms of agroclimatic emphasis.

Crowder returned to CIAT in 1973 to review the livestock program, joined by Hutton, Chief of CSIRO's Tropical Pastures Division. Hutton was also a member of a CGIAR external review of CIAT in 1977 and then shortly after he retired from CSIRO, he joined CIAT as a visiting scientist to lead its forage legume breeding. Another member of the external review team was John Dillon, an eminent professor of farm management at the University of New England, NSW. He then joined CIAT's Board in 1982 launching his influential role in CGIAR on boards of five centers (chairing three of them) and numerous other CGIAR reviews. By the late 1970s, CIAT and CSIRO were developing joint research activities around genetic resources and common disease problems, notably anthracnose resistance in *Stylosanthes* spp.

Evaluating a collection of Stylosanthes spp. at CIAT. Much of this work was collaborative with CSIRO[241]

In 1985 Grof, still with CIAT, moved to Brazil to support research on pasture improvement and joined Hutton who was a consultant on forage legume breeding over several years to Embrapa, the leading Brazilian research organization. Although Brazil extensively adopted improved pastures mostly based on *Brachiaria* spp. from Africa, supported by the work of Grof, adoption of legumes was low. These disappointing results reflect the complexity of managing pastures to ensure persistence of legumes (especially anthracnose disease in *Stylosanthese* spp.), as well as the high transport cost in the interior for use of phosphate fertiliser and to export beef.[242]

ILCA—Tribe, Crawford and the French tropical research establishment

The importance of cattle to the livelihoods and cultures of many African societies and the perceived acute malnutrition due to protein deficiency motivated the search for an international center or centers on African livestock from the mid-1960s.[243] The Rockefeller Foundation that was then in the throes of "international institute fever"[244] bifurcated this effort between a narrowly-focused Center for livestock health to undertake basic research on two important diseases of cattle in East Africa and a center for integrated research on livestock production systems that aimed to cover all of sub-Saharan Africa. The first center was set up with little controversy as the International Laboratory for Research on Animal Diseases in 1973.[245]

The design of a center for research on livestock production systems was a much greater challenge. One issue was how one center could address the highly diverse livestock systems across sub-Saharan Africa. Second, the design had to deal with the political legacy of colonial rule. Both the British and French had built centralized research institutes on specific commodities across their colonial territories. While the British had devolved these to their former colonies at independence, the French centralized tropical institutes that were all headquartered in France continued after independence in agreement with their former colonies. The French were sceptical of the US Foundation focus on creating new international research centers claiming that they already had similar institutions in place that could be adapted to serve the needs of all sub-Saharan Africa. However, the French faced considerable budgetary pressure to support their large tropical research infrastructure and were looking for new funding sources such as the US Foundations and other CGIAR donors.[246]

By the time of the Bellagio meetings of 1969 and 1970 that resulted in CGIAR, there were already at least three proposals on the table for an African livestock center—from the Rockefeller Foundation, the Ford Foundation in East Africa, and USAID in West Africa, as well as the established French *Institut d'Elevage et de Medicine Veterinaire des Pays Tropicaux* (IEMVT or the Institute for Livestock and Veterinary Medicine in Tropical Countries). Naturally, these proposed different institutional models varying from the centralized international center model of the Rockefeller Foundation to a network approach building on existing institutions and coordinated by a small central unit, favoured by the French.

As follow up to the Bellagio meetings, the Rockefeller Foundation sponsored a design mission to further explore the possibility of an international livestock production center in Africa. This task force was selected to be inclusive of French expertise, notably Jean Pagot, the director of IEMVT. There was some consensus that the center would be built around livestock production systems and operate quite downstream in the research continuum. However, the task force was divided on the need for a strong central research station and substations for major ecologies, its degree of autonomy, and how it would work with existing research organizations. In terms of location, the task force recommended the headquarters be in Nigeria, an anglophone country. In open disagreement, Pagot filed a minority view advocating that the proposed center should be integrated into existing capacities, such as IEMVT.[247]

From Bellagio the discussion of the livestock institute shifted in 1971 to the TAC of CGIAR, under its chair, Crawford.[248] However, TAC discussion of the Rockefeller report was complicated by the fact that Pagot was also a founding member of TAC. Given Pagot's minority views on the Rockefeller report, TAC was unable to make a recommendation and Crawford decided to create a new task force. He turned to Derek Tribe, a livestock scientist and Dean of the Faculty of Agriculture at the University of Melbourne, who had previously worked with FAO on the year-long

East African Livestock Survey.[249] TAC was careful to include Maurice Thome, Pagot's deputy at IEMVT, in the four-person team, although it conspicuously excluded anyone from Africa. Tribe also enlisted the Australian former director of livestock in FAO, K. V. L. Kesteven, as a consultant to the team.

Tribe and his team had to navigate a delicate balancing act between the proponents of the "standard" CGIAR center model and competing proposals coming from the French supported by the francophone countries of West Africa. As Crawford was advised "the train is on the track but it is not going to be easy to keep it there."[250] Accordingly, the energetic Tribe and his colleagues invested heavily in consultation, visiting 40 research institutes and 26 countries over a period of nearly a year.[251] Above all, Tribe was careful to keep Pagot informed through direct communication and via his team member, Thome, always under the watchful eye of Crawford himself.

Signing the agreement establishing ILCA, Addis Ababa, 1974. Derek Tribe (far left standing) and Jean Pagot (fourth from right standing)[254]

The Tribe task force recommended that the new center be designed around livestock systems using multidisciplinary teams spanning livestock production, ecology, economics and other social scientists. It would not include 'basic research' but would link to established centers of excellence such as IEMVT on animal health and CSIRO on forages.[252] Importantly, it recommended a highly decentralized model where the major part of the research would be conducted by existing national and regional institutes—that is, ILCA's "essential role should be complementary, cooperative and catalytic."[253] With this revised *modus operandi* TAC gave the green light for the establishment of ILCA to be located in Ethiopia, a country neutral to the anglophone-francophone divide. However, it was a delicate compromise—the French were still not happy and suggested it be called an "effort" [*sic*] rather than a "center" while Crawford and some donors worried about the proposal's lack of emphasis on research.

Although ILCA was founded in 1974, the saga with the main actors, Tribe, Crawford, and Pagot, continued over the next few years. The World Bank engaged Tribe to help set up the center and select the Board with the understanding that Tribe himself would play a leading role on the Board. Pagot was selected as a Board member, and then the Board selected him as the first director general of ILCA, likely in a further effort to gain French support and expertise after the long debate about the appropriate organizational format for the center. However, within two years, staff morale was low due to Pagot's autocratic management style as well as the unfolding Marxist revolution and unrest in Ethiopia. Senior ILCA managers in a meeting with Tribe threatened to resign *en masse* unless Pagot departed. After years of carefully cultivating relations with Pagot and the French establishment, Tribe had the unenviable task of persuading the Board to ask Pagot to resign, which it did at the end of 1976.[255] Tribe as a member of the Board's executive committee took over for some months as interim director general. After this shaky beginning, TAC appointed a sub-Committee to make a quick review of ILCA, headed by Crawford himself. Demonstrating his keen interest in ILCA, especially its unique organizational model, Crawford also returned in 1982 (after stepping down as TAC chair) to lead the first in-depth external review of ILCA. In many ways Tribe and Crawford were the parents of ILCA.[256]

The Tribe report had focused on the search for an appropriate organizational model and was light on technical detail of the actual research programs and indeed what role, if any, ILCA would have in research. Given Crawford's strong belief that CGIAR should conduct research rather than development, the two early reviews of ILCA that he led, recommended that

ILCA build its capacity in research. In particular, the reviews recommended research on forage legumes, especially in crop-livestock systems. The livestock systems programs underway at ILCA were already grappling with forage issues, including testing of local and introduced species, particularly the Ethiopian Highlands Program led by Frank Anderson, an Australian agricultural economist.[257] ILCA eventually established a forage program in 1982 with emphasis on collecting, evaluating and conserving forage legumes from Africa. To initiate the collection, ILCA received a donation of tropical forage collections from CSIRO and CIAT, some of which had originated in Africa.

Regeneration of the forage genebank on the ILCA campus. Trifolium quartinianum, a native of Ethiopia, in the foreground[258]

Beyond genetic resources, ILCA's forage research program took off vigorously in 1985 with the appointment of John C. Tothill, a senior scientist in CSIRO's Tropical Pasture's Division to lead the program. Like the other CGIAR programs, ILCA under Tothill's leadership prioritized the incorporation of forage legumes into smallholder farming systems but compared to the other CGIAR programs ILCA demonstrated considerable flexibility in adapting legumes to local socio-economic and institutional constraints. The programme accordingly explored diversified research approaches to incorporating legumes such as alley cropping, multipurpose trees, dual purpose grain and forage legumes, and fodder banks, as well as crop-forage rotations.[259] This produced modest initial results but then, as described in Chapter 6, the role of forage legumes in Africa became the subject of considerable debate.[260]

ICARDA—Transferring the Australian dryland farming model

The International Center for Research on Dry Areas (ICARDA) was founded in 1977 near Aleppo, Syria as the lead CGIAR center for research in Middle East and North Africa (MENA). ICARDA in turn built on ongoing efforts by FAO and the Ford Foundation involving Australian pasture scientists in the region. Chapter 4 has already described the extensive FAO pasture network in the region dating from the 1950s. The Ford Foundation from 1967 had created its Arid Lands Agricultural Development (ALAD) program based in Lebanon but recognized that a "permanent central institute will be required."[261]

The head of the ALAD program, Hugh Walker, visited Australia in 1967 along with Hill to review pasture research.[262] While Hill focused on tropical pastures, Walker's interest was naturally in dryland cereal-pasture systems of southern Australia. The design of the ALAD program reflected the results of this visit with the livestock component explicitly modelled on the Australian dryland farming system that integrated forage legumes in rotation with cereals to replace extensive fallows.[263] ALAD also brought in at least four livestock and forage scientists from Australian including Helen Newton Turner, CSIRO's foremost authority on quantitative genetics to advise on sheep breeding. Turner would shortly become the first woman to win the coveted Farrer Medal, where her oration emphasised conservation of the genetic diversity of animals as a complement to Frankel and FAO's emphasis until then on plants.[264]

Despite the ALAD-Australia connection, it was CIMMYT with the support of the Ford Foundation that initiated testing of the Australian dryland system in North Africa in 1971. Finlay from the Waite (Chapter 4) invited Borlaug to deliver the keynote address to the International Wheat Genetics Symposium in Canberra in 1968. There Borlaug expressed his admiration for the Australian dryland farming system "hoping to see the day when the knowledge and skills you have developed…are transplanted back to North Africa and the Middle East where they are so badly needed."[265] Borlaug recommended that CIMMYT hire Finlay which it did as its Director for Basic Research in 1969.[266] With his background in breeding for dryland cereals in Australia, Finlay became actively engaged in CIMMYT's nascent programs in North Africa and asked John B. Doolette, a senior agronomist in the SA Department of Agriculture to review the potential for the Australian dryland farming system in North Africa. Doolette enthusiastically supported a research program to evaluate forage legumes in place of fallow and in 1971 he moved to Tunisia with CIMMYT to implement the program based on annual medic cultivars from Australia (although originating in MENA). Finlay also contracted another colleague from the Waite, Edward (Ted) Carter, a pasture agronomist who had worked closely with Donald, to review the potential for medics in Algeria. In his report, Carter noted that "it was soon obvious to me that there were striking ecological similarities between Algeria and southern Australia and that Australia had a great deal to offer in…the science and technology related to cereal and livestock production and integration."[267] CIMMYT then recruited a second agronomist, again from SA, to introduce the dryland farming system to Algeria.[268]

These programs soon demonstrated the technical potential of using a rotation of medic varieties directly imported from Australia to substitute for use of nitrogen fertiliser in wheat, although no livestock component was included.[269] By 1975 with an oil price shock and a nearly ten-fold increase in the price of nitrogen fertilisers, CIMMYT was ready to showcase its efforts. A glossy CIMMYT report, *Return of the Medic,* highlighted the rapid progress and concluded that "the cereal-legume rotation is a bold stroke… that could improve the lives of millions." Indeed, the main constraint was lack of sheep to graze the newly established pastures, with Doolette noting that income from sheep would be "the cream on the jam."[270]

A conference sponsored by the Ford Foundation, CIMMYT and FAO in 1975 in Tunisia gave special attention to the unfolding promise of the new farming system. The presentations led by Doolette unanimously endorsed the potential of the dryland farming system.[271] A Ford Foundation delegate, not coincidentally another Australian agronomist, quantified the huge potential of sowing medics in the region, concluding that "the rotation could be introduced with a minimum of adaptive work and with maximum results."[272]

FAO continued to be an enthusiastic partner in introducing the Australian farming system building on the foundations laid by Whyte in the 1950s. TAC's Peter Oram, who had worked on pastures in the region in the 1950s, continued to champion the system. At the first meeting of TAC, he pointed to the mounting food deficit in MENA and to the fact that this was the only region without a planned CGIAR center. CGIAR was also eager to fill this gap with the expectation that it could attract funding from those MENA countries that were growing wealthy from the 1970s oil boom. Indeed, the Ford Foundation's ALAD team had already put together a detailed proposal for such as center.[273]

In 1973, TAC commissioned a team to explore the feasibility of an international center for the region under the leadership of Dunstan Skilbeck from Wye College, UK, who had experience in the region. TAC chair Crawford was familiar with the Mediterranean 'agroclimatic analogue' with dryland farming areas of southern Australia and employed Carter from the Waite as a member of the team.[274] Oram in turn recruited his FAO colleague Ibrahim Abu-Sharr, who had worked with him on forage legumes in Libya, to the team. Given this line-up of expertise, it is not surprising that their report recommended the establishment of an international center with a top priority to develop integrated crop-livestock systems. Application of the "Australian model" by introducing forage legumes to replace fallow was seen as "offering the greatest potential to increased income from rainfed areas."[275]

Despite the strong TAC recommendation to establish ICARDA, it took four more years of discussion of location and funding to accomplish this. The original design called for a headquarter station in Lebanon with an extension across the border to a substation in Syria. 'Satellite stations' in Algeria and Iran were soon proposed, not only to serve the diversity of the region but to entice funding from these two gas and oil rich states. Crawford, who was leading a large World Bank team on agricultural policy in Iran, was asked to take on the delicate discussion with Iran for an ICARDA sub-center in Iran with the implicit *quid pro quo* of Iranian funding to CGIAR.[276] Iran did provide modest support to CGIAR from 1976 but with the outbreak of civil unrest in 1978 both the funding and the plans for a sub-center in Iran fizzled out. Fighting in Lebanon too forced the decision to relocate ICARDA's headquarters near Aleppo in Syria.[277]

As ICARDA was being set up in 1977, it brought Carter back again for an extensive survey across the region on research priorities on legumes. Describing visits to some ten countries over a three-month period, his report largely ignored food legumes and, drawing on the experience of the CIMMYT and Australian and FAO programs that had been initiated in several countries, strongly promoted research on dryland farming with forage legumes.[278] He carefully quantified the potential in terms of 23 Mha of farmland suited to the cereal-pasture legume rotation that could produce 86 million *additional* sheep and 1.4 million tons of nitrogen for the following cereal crop. As in his previous visits, his report heavily emphasized the technical side although vaguely noting that to address "uncontrolled grazing and uncontrolled cultivation" would require a "delicate blend of political, social, economic and technical expertise."[279] ICARDA was impressed by the numbers and integration of crops and livestock through forage legumes was at the core of ICARDA's research in its first decade. Indeed, Doolette transferred from CIMMYT in Tunisia to ICARDA to start the work.

Australia provided significant financial support to ICARDA from its beginning. J. (Jim). R. McWilliam, a pasture specialist from the University of New England (and formerly CSIRO), who had worked with Crawford in Iran, was a founding member of ICARDA's board. On completing his term, ICARDA requested him to review the forages program, where he strongly endorsed the focus on forage legumes to integrate crop and livestock production.[280] This emphasis was further re-enforced by the first external review of ICARDA that included Norman Halse, the deputy director of the WA Department of Agriculture and Jock Anderson, a leading Australian agricultural economist from the University of New England. The appointment of SA's senior forage legume scientist, Philip S. Cocks, in 1982 to head ICARDA's forage program cemented the strong focus on forage legumes in line with the Australian school.

Since ICARDA was situated in an important center of diversity for many food crops and forages that was rated as under serious threat from genetic erosion, collection and conservation of genetic resources was high priority from the beginning. Both the Skilbeck and Carter reports had strongly recommended priority to collection and evaluation of genetic resources of forage legumes to meet the diverse needs of the region. ICARDA specialist in genetic resources, Bhal Somaroo, collaborated closely with scientists from Australia in organizing several collection expeditions on forages. In ICARDA's first year of operation it contracted SA's E. Crawford to lead an expedition in Syria, Iraq and Jordan supported by IBPGR. Both SA and WA provided initial donations from their genebanks to ICARDA, but ICARDA's many collection expeditions in the 1980s soon made it the leading repository of forage legumes from the region.[281] ICARDA then became an important source of genetic resources for Australia, initially for forages but soon prioritizing winter cereals and pulses that would provide significant economic benefits to Australian agriculture.[282]

Beyond ICARDA, Australian state governments, farmers, and private companies engaged extensively in promoting dryland farming in MENA motivated by commercial interests. The world food crisis of the early 1970s spotlighted the spiralling grain and meat imports in MENA, while the accompanying oil price spike provided the resources for some countries of the region to ambitiously invest in their agriculture using Australian expertise and technologies. Sales of seed of Mediterranean forage cultivars from Australia was high on the agenda and the Australians also used these projects to continue their collection of genetic resources.[283] I have elsewhere extensively described the activities of SA in MENA (Box 5.2 provides an example)[284] and Norman Halse has reflected on the WA projects that he oversaw in the region.[285]

Box 5.2. A SA Dryland Farming Project in Libya

The project was initiated in 1973 by Bashir Jodeh head of Jebel El Akhdar Authority (JAA) in eastern Libya. With an annual budget of US $300 million (equivalent to the total budget of the government of SA), JAA aimed to develop agriculture in a marginal dryland environment through the settlement of about 2,000 farmers using Australian dryland farming methods. JAA contracted with the South Australian Seedgrowers' Cooperative Ltd (SeedCo) to supply pasture seed and to send an average of eight SA farmers per year to provide short-term training to Libyan farmers. In addition, JAA requested the SA Department of Agriculture to set up a 1,000-ha demonstration farm that was essentially a 'turnkey project' to replicate a large Australian farm. Wheat and medic seed, machinery, and fences as well as sheep, a shearing shed and even shearing instructors were all imported from SA. Sales of pasture seeds and machinery were significant in the early years but with declining oil prices Libyan revenues to fund the project and purchase farm inputs dried up. After early successes and the spending of millions of dollars, the project collapsed in the early 1980s as did a comparable WA project in the west of Libya. Similar SA and WA projects in northern Iraq also failed when they were caught up in civil conflict.

FAO also mounted its own regional and country projects to promote dryland farming methods, in close cooperation with Australian scientists.[286] The largest such effort was in Algeria where FAO employed Australian advisers to carryout adaptive research and training. This was followed by many 'study tours' for scientists from the region to Australia. The most ambitious FAO program (funded by Saudi Arabia) sent some 50 agronomists from the region to Roseworthy Agricultural College in SA from 1976 to 1980 to complete a one-year post-graduate diploma in dryland farming systems.[287] Aided by these exchanges, national leaders emerged who led research on dryland farming incorporating forage legumes across the region. However, by 1980 serious doubts were being raised about the transfer of the Australian model to MENA (next Section).

All roads lead to Australia 1979-80

Australia's leadership role in both Mediterranean and tropical pastures and especially genetic resources was celebrated by two international conferences in 1979 and 1980 in Australia that brought together many of the actors of this and previous chapters. These conferences would also prove to be the highpoint in Australia's leadership of forages and genetic resources.

The first international conference on genetic resources of forages, Townsville

This conference was organized by CSIRO and IBPGR in Townsville in northern Queensland in 1979. Until then, IBPGR had given little attention to forages, focusing instead on the major food crops following the recommendations of the FAO Panel. The conference brought together 120 delegates, nearly half from abroad, and included most of the Australian 'explorers' from the 1960s and 1970s. Frankel who had never showed much interest in forages attended and although he was not on the program was still asking the hard questions of why and how.

The keynote speaker for the conference was Jack Harlan, formerly of the FAO Panel and after publication of his seminal book, *Crops and Man,* was becoming known as America's Vavilov.[288] Harlan laid out the challenge of too many species and too few resources that required systematic priority setting in collecting and conserving forage genetic resources. The edited book of the proceedings published four years later was a comprehensive compendium of the current knowledge base, addressing the taxonomy, diversity and distribution of both grasses and legumes suited to Mediterranean and tropical climates. It also provided the state of the art for the theory and practice of conserving genetic resources along the whole 'supply chain', from collection to evaluation, storage, data management, and utilization. However, the book was largely prepared by Australian authors and fell short in providing guidance on the global status of forage genetic resources conservation.

The summing up was made by Hugh Bunting, who after his dustup with Frankel in establishing IBPGR, was still on the IBPGR Board. Bunting also noted the high level of international participation but the heavy Australian content of the conference. However, he observed that "Australia is in a better position than any other country to contribute directly to the progress of agriculture in poorer countries...particularly in relation to genetic resources [of forages]."[289]

Following the conference, IBPGR constituted its first working group on forages that set global priorities for collection and conservation, chaired by E. (Ted) F. Henzell, the third Chief of CSIRO's Division of Tropical Pastures. This group also initiated a stocktaking of genetic resources that revealed Australia's leading position in conserving Mediterranean and tropical forages.[290] Although IBPGR now gave priority to forages it took another five years to develop a detailed plan for collecting and conserving forage genetic resources.[291] By then both funds and interest in forages were on the decline in Australia and globally (Chapter 6).

The international dryland farming congress, Adelaide

A year later SA hosted a major international congress on dryland farming with a large contingent of delegates from countries in MENA.[292] Delegates were provided an attractive book, *South Australian Farming Systems,* with detailed colour maps and climatological data to illustrate other areas of the world with a similar Mediterranean climate where Australia's cereal-legume systems could be employed. They also watched a film on SA farming, *Food from the Reluctant Earth,* that, like the book, was translated into Arabic and French to reach the delegates from MENA. Finally, and most importantly, overseas delegates were invited to purchase SA expertise, machinery, sheep breeds, and seed of the forages originating in their region. MENA was seen as a vast new market for SA products.[293]

Although not focused on genetic resources or even seed, many of the presenters had been engaged in earlier efforts from the 1950s in collection expeditions and export of the dryland system to MENA. Carter from the Waite who had been so active in advising CIMMYT and creating ICARDA continued to be optimistic about the potential of the Australian dryland system in MENA but Doolette, who had worked for a decade to demonstrate the technical feasibility of the system on the ground was now more cautious noting the need to adapt it to the diversity of farms and tenure regimes.[294] Donald who had retired from the Waite was scheduled as the keynote speaker but due to ill health was replaced by Halse from WA. On the basis of his experience with WA projects in MENA, Halse was quite pessimistic noting technical difficulties including lack of suitable legumes, separation of ownership of land and animals, and lack of effective extension and interaction with farmers.[295]

Prominent among the overseas speakers were current and former FAO officials who unexpectedly for the congress organizers were now critical of SA efforts in MENA. Bommer who had been a key player on TAC and was now Assistant Director General of FAO argued for cooperative arrangements of pastoralist and farmers that required a deeper "understanding of social structures and economic and cultural motivation."[296] Oram, based on his long experience in MENA was quite critical of efforts to directly transfer the system and recommended much more attention to socio-economic issues and more flexible options including grain legumes to better fit traditional practices.[297] G. Perrin Brichambaut, who had also been part of the FAO work on forages in MENA from the 1950s, chastised the commercial orientation of SA projects given the huge benefits SA had reaped from genetic resources of legumes in the recent past.[298]

Overall, the congress sowed doubts about the relevance of the Australian legume school in MENA. Further, the decline in prices of oil and nitrogenous fertilisers was reducing commercial opportunities for Australian technology in MENA. In Australia itself pasture development in the south was facing new technical and economic challenges that required new approaches (Chapter 6).

Australian deposit – inside Svalbard Seed Vault, 2018[299]

6. Postscript: A New Era for Both Pasture Research and Genetic Resources from 1980

The year 1980 was in many ways a turning point for both pasture research and genetic resources. The "golden era" of pasture development in Australia from WWII now confronted a host of technical, economic and environmental challenges that had major implications for research priorities, investment in research, and genetic resources for Mediterranean and tropical pastures. By 1990 these challenges were mirrored in CGIAR forage programs. At the same time, the genetic resources movement began to emphasize issues of ownership and control that led to major disagreements between the industrialized countries, that were privatizing research, and developing countries, that were providing the bulk of landraces and wild relatives for crop breeding programs.

New challenges for pasture research

Only one year after the International Dryland Farming Congress in Adelaide, SA organized a symposium entitled *The medic crisis in cereal-livestock farming systems of South Australia.* Carter, who had done so much to promote the system in MENA, attributed the crisis to the lack of investment in pastures, poor grazing management, increased frequency of cropping, growing damage from insects, increased use of herbicides, and rising acidity in some soils. These problems in turn reflected the system's "reliance on a very narrow suite of legumes and the tendency to manage these as monocultures."[300] They also related to changing economic conditions—declining wool prices had reduced the length of the pasture phase of the cereal-pasture rotation, and introduction of non-legume crops such as canola had increased use of nitrogen fertiliser.[301] These trends ushered in new research priorities to diversify crop rotations and seek both grain legumes and forage legumes more suited to changing soil conditions and pest populations. Collection expeditions to seek new forage legumes in MENA were scaled back but continued to be critical to research on dryland farming.[302]

In MENA, after nearly two decades of efforts by CIMMYT, ICARDA, FAO, SA, WA, and others to transfer the Australian model to MENA and against the early estimate of its potential in the tens of millions of hectares, there were at most 50,000 ha of sown pasture legumes, mainly medics, in North Africa.[303] The end of the 1980s was another period of stocktaking through a series of conferences, the most important being a conference organized by ICARDA and IBPGR, *Introducing ley farming in the Mediterranean Basin*, with participants from 15 countries. Building on the much-expanded research base and the experience in many countries, participants recognized multiple difficulties of transferring the Australian dryland system and questioned the profitability of ley farming with medics over alternative systems.[304] This was a turning point for ICARDA as it began to phase out its work on ley farming, seeking more flexible options that considered food legumes as well as forage legumes and harvesting for grain and green and dry fodder, as well as grazing.[305] The failure to extend the Australian dryland farming system in the region was due to a combination of technical, economic and socio-cultural factors.[306] However, the overwhelming problem was lack of control by farmers over grazing rights of legume pastures due to traditional land tenures. Doolette, who had pioneered the effort in 1971, recalled years later:

> **There would have been better acceptance had we listened to the traditional farming ways and the reasons for these traditions and taken into account the social and political implications.**[307]

In northern Australia, uptake of improved tropical pastures and especially legumes fell far short of the ambitious vision of J. Davies and his colleagues in the 1960s. A comprehensive assessment in 1985 commemorating the 25th anniversary of the Tropical Pastures Division still talked of a tropical pastures revolution.[308] Indeed, the area of improved pastures had more than tripled to 3.5 Mha from 1963 to 1973 with about 1 Mha of that including legumes. However, a disease outbreak (anthracnose on *Stylosanthes* spp.) and a sharp drop in world beef prices after the UK joined the European Common Market, led to a stagnation of investment in pasture improvement over the next decade and then only slow growth in the following decades. Still Henzell, after a lifetime career in tropical pastures, estimated that improved pastures accounted for about 40 percent of the increase in beef production over 1985-2007, with legumes contributing about one-third of that increase—that is, about 10 percent of the total.[309] A more formal but unpublished economic assessment estimated a rate of return to investment in tropical pastures of 6-13 percent, with the highest benefits provided by uptake of Buffel grass.[310] While these figures suggest an overall positive return to investment in tropical pastures, they were well below returns to research in other areas of Australian agriculture. With respect to adoption of legumes, Henzell concluded that this was "a disappointing outcome from the substantial investment in research."[311] This reflected the dependence on one commodity, beef, the isolation and high transport costs of many producers, the significant upfront investments required for pasture establishment, the management control to successfully retain legumes in pastures, and overinvestment in breeding at the expense of other disciplines. The rise of the environmental movement from 1990 further added to these challenges, especially with concerns about purposely introduced pasture species, notably Buffel grass, becoming weeds.[312]

This is the background that led to a precipitous decline from about 125 scientists working on tropical pastures in Australia at a peak in 1975 to about a dozen in the 2000s.[313] CSIRO phased out overseas exploration and forage breeding activities and even QDPI scaled back its investment in pasture research. CSIRO also ceased to support the tropical forages genebank in 2000 passing its accessions to QDPI and then eventually to the Australian Pastures Genebank established in 2014. However, sustainable funding of the genebank continues to be a challenge. CSIRO also sent parts of its collection on legumes to CIAT and on grasses to ILRI.[314]

In CGIAR, budgets for crop and forage research were also sharply curtailed from 1990 as the end of the Cold War reduced funding for foreign assistance and new research priorities on natural resources and the environment took center stage after the Earth Summit in Rio. CIAT's forage program, for example, was cut from a peak of 20 scientists in 1980 to 5 in 1997.[315] The transfer of the Australian model was also being questioned. After decades with little payoffs to breeding of forage legumes, John W. Miles at CIAT (no relation to John F. Miles) despaired that the Australian school had become "something of a dogma."[316] The close association of tropical deforestation with beef production in tropical America added to these woes.

Max Shelton of the University of Queensland surveyed participants in overseas projects and CGIAR centers to better understand the reasons for limited uptake of tropical forage legumes. He noted technical issues such as the unsuitability of Australian cultivars and the lack of germplasm to fit diverse ecological conditions, as well as the need to better understand smallholder farming systems including socio-economic factors. In Africa, James (Jim) Sumberg, formerly with ILCA, ignited a debate on the impacts of the Australian school, tracing the evolution from Whyte and Trumble in FAO nearly fifty years before. Sumberg questioned the focus on tropical legumes as the "mantle of goodness" noting that private land ownership and control of grazing was at the heart of the legume model. [317]

Another paper prepared by Shelton with CGIAR colleagues for the 2005 International Grassland Conference estimated that tropical legumes were planted on some 3 Mha outside of Australia.[318] However, the largest area was a projected (rather than actual) area of dual-purpose cowpeas in Africa, where forage value is secondary to that of grain. Brazil was also a significant adopter of forage legumes, but they still amounted to less than one percent of the area under sown forage grasses.[319] Ross Humphreys, a long time stalwart of Australian pasture science, observed on a visit that "here in Brazil we are amazed at the vast areas now growing selected African grasses, but we grieve at the …relative absence of legumes."[320] The most impressive data were for adoption of *Stylosanthes* and *Sesbania* spp. by smallholders in Southeast Asia and multipurpose tree legumes in Africa. These experiences suggest that introduction of forage legumes continues to hold much potential for sustainable farming but must involve farmers from the beginning to adapt forages to the diversity and complexity of smallholder farming systems.[321]

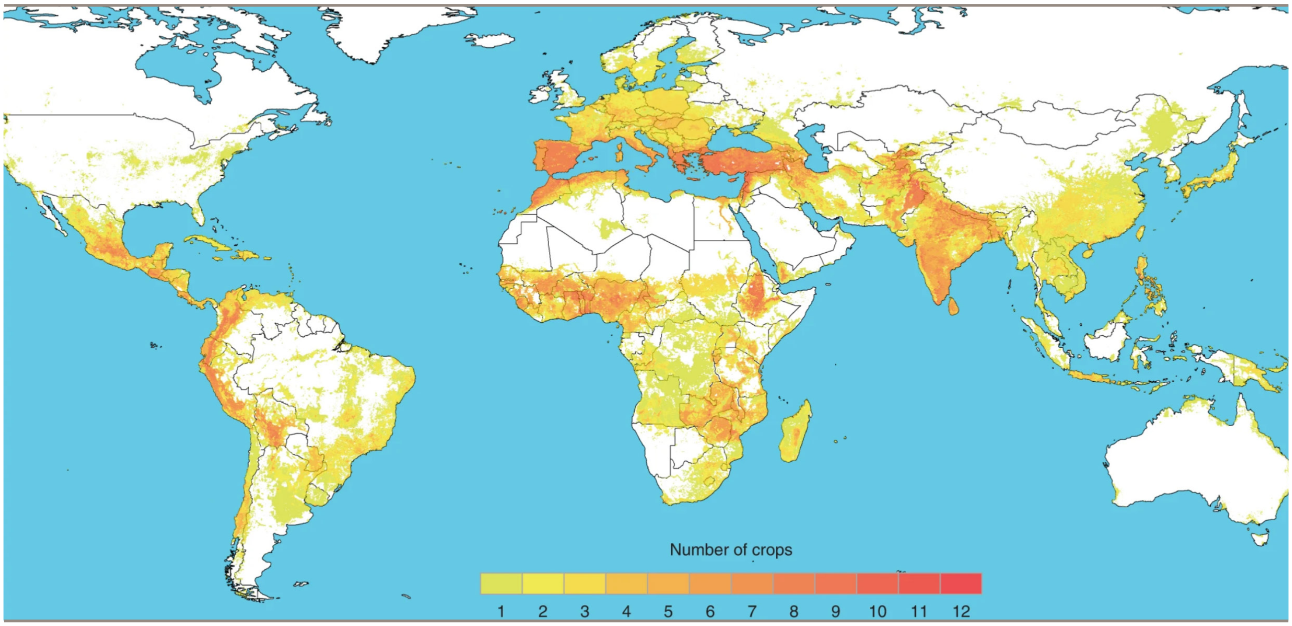
The cut in CGIAR and Australian research budgets also sharply reduced the number of collection expeditions for forages. The momentum on genetic resources conservation built up since the 1967 FAO conference ensured that CGIAR genebanks received relative priority in allocating CGIAR's limited resources, at least for food staples. However, two scientists deeply involved in forage genetic resources, Bruce Pengelly, the long-time curator of the Australian tropical pastures genebank, and Brigitte Maass, formerly of the CIAT genebank, have highlighted the crisis in conserving forage genetic resources due to lack of funding compounded by the large number and diversity of potentially useful species, their limited seed yield, and a decline in their utilization given smaller budgets for forage research.[322] Pengelly summarizes the state of forage "genetic resources as *ex situ* germplasm conservation at risk, changes in land use, climate and world tensions that threaten *in situ* conservation, and reduced expertise across both national and international arenas."[323]

Yet there were bright spots on the knowledge front. In 2005 CSIRO and QDPI in cooperation with CIAT led an effort to produce the Tropical Forages Database as a valuable reference source for 150 species that was updated in 2019. In 2013, CSIRO and CIAT also merged its two scientific journals, *Tropical Grasslands* and *Forrajes Tropicales*, respectively, into an open source, bilingual journal, *Tropical Grasslands-Forrajes Tropicales*, published by CIAT with a managing editor currently from ILRI, that continues to be an important vehicle for dissemination of applied research results.

The changing discourse on genetic resources

Starting in 1979 the global discourse on genetic resources decisively shifted from the conservation ethic of the 1970s to include questions about their ownership and sharing. In part this reflected a new willingness in the post-colonial world for developing countries, the so-called Global South, to speak out on justice and equality in international exchange through trade, aid and other resource transfers. Ironically, the very success of Frankel and his colleagues in raising global awareness on the urgency of conservation of genetic resources contributed to the recognition by developing countries of their potential value, given the concentration of centers of diversity in their countries.

The spark that ignited this debate was a book published in 1979 by a Canadian author and activist, Pat Mooney, *Seeds of the Earth: A public or private resource?*, that in turn drew on discussions in the late 1970s by a coalition of civil society organizations, not least the US-based National Sharecroppers Fund, directed by Cary Fowler. Mooney argued that the growing trend by developed countries to legislate



Richness map of the predicted distributions of landrace groups of 25 major food crops. (Darker colours indicate greater numbers of crop landrace groups)[324] plant variety rights (PVRs) so that plant breeders could protect their inventions was inherently unfair, since breeders could profit from using landraces from the Global South without recognizing the contributions of generations of farmers who had developed them—what soon came to be known as "farmers' rights." Mooney further argued that PVRs and other forms of intellectual property protection would lead to concentration in a seed industry that was becoming integrated with the agrochemical industry. These arguments were based on solid emerging evidence and as it turned out were highly prescient of future trends in the seed industry, at least in high income countries.

The second part of Mooney's argument, however, was purely speculative but even so would become part of the dogma surrounding the Green Revolution and genetic resources. He argued that the Green Revolution promoted disease susceptible varieties laying the groundwork for multinational seed corporations to take over the supply of seed and chemicals to farmers in the Global South, so that "global companies have virtual control over the second phase of the Green Revolution."[325] In particular, farmers in the South would have to purchase seed from multinational companies based on genetic resources that they had freely provided to those companies. To support his argument, he cited sales of pasture seeds by Australian companies in Kenya and Libya based on germplasm freely collected by Australian plant explorers in those countries (Chapter 3). In the same year, anthropologist Lucille Brockway published a highly cited book on the "piracy" of seeds by Kew Gardens in the colonial period.[326] She also noted the contemporary example of Australian sales of seed of *Stylosanthes* spp. to Brazil, the original home of the species. Mooney escalated the rhetoric in a follow up book, *Law of the Seed,* in 1983, in which he described CGIAR centers as the "handmaidens of private companies", arguing that their collections of genetic resources as well as IBPGR staff should be placed under the direct control of FAO. Notably, Mooney ignored the fact that food staples grown by small farmers in the developing world, including the Green Revolution crops, rice and wheat, were and remain today of little interest to multinational seed companies.

During the late 1970s, Mooney had been interacting with Erna Bennett of FAO, whose activities were becoming more political. She had led the first strike by FAO employees that successfully recognized their right to organize and negotiate with management on their terms of employment. Given the productive if sometimes tense Frankel-Bennett partnership to mount the landmark 1967 FAO conference on genetic resources, their colleague from the FAO Panel, Hawkes, invited both to speak at a celebration of the University of Birmingham's centennial. Frankel gave his usual succinct summary of the state of genetic resources conservation, while Bennett stressed global injustice and inequality with nary a mention of genetic resources.[327] She was by now a vocal critic of the Green Revolution and its consequences for the poor and the environment, and echoed Mooney and his colleagues in criticizing PVRs that would re-enforce trends toward corporate control of the seed industry in the Global South.[328]

Meanwhile, the Australian government introduced legislation for PVRs in 1979 but the release of Mooney's book and its widespread distribution in Australia in the same year by the Australian Council of Churches guaranteed a contentious debate. Bennett's opposition to PVRs and their perceived consequences for genetic resources attracted national attention when she was interviewed by the Australian Broadcasting Commission.[329] In 1980, she was invited to Canberra to debate along with Frankel the merits of PVRs. Bennett was unable to get permission from FAO to travel so she was replaced by Mooney with whom she was now closely allied. Even so, Bennett would soon resign under protest from FAO and move to Australia, where her focus shifted from genetic resources to social welfare issues and advancing the cause of the Communist Party of Australia.[330]

In the lively debate on PVRs in Canberra, Mooney echoed the arguments in his book on the "gene drain" that robbed farmers of their rightful heritage when genetic resources were sent to the North and used for private profit. Meanwhile Frankel praised the progress in genetic resources conservation led by IBPGR, noting the strong participation of developing countries in this effort including for *ex situ* storage. Frankel also defended the Green Revolution and denied the link with agrochemicals, pointing out that in Australia CIMMYT's wheat varieties were widely adopted without using nitrogen fertiliser since they were grown in rotation with forage legumes. However, Frankel also raised concerns about PVRs and the potential to restrict free exchange of germplasm; it was left to a third participant in the debate, Ross Downes, formerly a CSIRO forage breeder and an aspiring private breeder, to advocate for adoption of PVRs in Australia.

Frankel followed the debate with a scathing rebuttal of Mooney's arguments at a conference in Canada (Mooney's home country), calling his critique of CGIAR efforts on genetic conservation "unadulterated nonsense."[331] However, the PVR debate in Australia would continue for several more years with detailed hearings by a Senate Committee that heard many of the same arguments including Australian sales of seeds to Libya based on their collections in the region.[332] In 1984 the Senate Committee recommended passage of PVR legislation that finally occurred in 1987, making Australia a late comer among developed countries in adopting PVRs.

Against this background FAO organized its fourth technical meeting on genetic resources in 1981 following the 1961, 1967 and 1973 meetings (Chapter 4). The three stalwarts of the former FAO Panel of Experts were all there but in different guises. Harlan was part of the official US delegation while Frankel and Hawkes represented associations of plant breeders for Asia and Europe, respectively. Conspicuously, Australia did not send a delegation to the meeting. Mooney and Fowler were also there as NGO observers, the first time that NGOs had attended an FAO technical meeting on genetic resources.

The most contentious issue on the agenda was the FAO proposal for an international convention on safeguarding and sharing genetic resources, tabled by Assistant Director General Bommer. Demuth, the departing chair of IBPGR, was opposed, arguing there was no need to fix what was not broken. However, other delegates echoed FAO and Mooney's views, noting that many countries were restricting export of their genetic resources given concerns about materials being exploited for private purposes or losing their comparative advantage in a valuable export crop.[333]

The FAO Conference later in 1981 requested a study of such an agreement as well as a proposal for a world genebank under the control of FAO. Leadership of this new phase of the genetic resources movement now passed to the Mexican delegation to FAO during much of the 1980s.[334] The idea of a world genebank was dropped as financially and institutionally impractical, but FAO did move forward to implement an International Undertaking on Plant Genetic Resources as a voluntary agreement to promote safeguarding and free exchange of genetic resources. A decade later, an agreement was also reached between FAO and CGIAR that the CGIAR base genebank collections would be placed under the "auspices of FAO" but remain under the stewardship of the CGIAR centers.[335]

Although Australia did not recognize PVRs until 1987, it joined other developed countries in opposing the International Undertaking as incompatible with PVRs. However, the debate within Australia about the ethics of selling seed to countries from which the original germplasm had been collected was changing. In 1972 Paul Broue, then CSIRO's chief plant introduction officer, urged Australia to prepare to exploit major new markets for seed, noting that "the same countries that initially provided the genetic stocks of our pasture cultivars could now develop into expanding markets for our pasture seed."[336] Officials in SA were already gearing up for an expected large new market.[337] These scientists did not see the irony of Australia's embargo on the export of its merino rams (also originating in the Mediterranean region) during 1929-1982, to protect its wool industry. However, by the early 1980s, there was growing awareness of the sensitivities of seed sales to the originating countries. Francis from WA, who had done so much to collect and conserve forage genetic resources through country partnerships, was particularly outspoken in supporting developing country rights on genetic resources.[338]

FAO set up a Commission on Genetic Resources to monitor the implementation of the International Undertaking and more generally report on the state of genetic resources conservation. With the FAO International Undertaking and the FAO agreement with CGIAR genebanks, the balance of power in governing genetic resources had again shifted back to FAO. The further strengthening of intellectual property through plant patents, the advent of the new biotechnologies that allowed genes to be moved across species and genera, and the UN Convention on Biodiversity in 1992 that recognized sovereign rights over biodiversity, all strengthened the argument for upgrading the Undertaking to a binding international treaty on plant genetic resources. A period of protracted and acrimonious negotiation eventually resulted in the International Treaty on Plant Genetic Resources for Food and Agriculture adopted by the

FAO Conference in 2001 and implemented in 2004. The Treaty promotes free access to genetic resources for most food crops and some forages and since 2009 has included a mechanism (The Benefit Sharing Fund) to provide benefits directly to farmers where crop genetic resources are conserved and managed for food security. Frankel did not register his views on these new developments but surely would have endorsed a greater role for FAO in governing genetic resources, as he had advocated in the 1970s. However, he did not subscribe to the North-South struggle over control of genetic resources and, in his last book published in 1995, did not even acknowledge the noisy debate about ownership and control of genetic resources.[339]

Relations between FAO and IBPGR continued to be tense, reflecting the earlier struggle over the roles of CGIAR and FAO in establishing IBPGR as well as deep-seated personal conflicts.[340] It fell to CSIRO's Max Day, who had earlier replaced Frankel on the CSIRO Executive, to lead the second external review of IBPGR and assess its troubled relationship with FAO, and James (Jim) Peacock, chief of the CSIRO's Division of Plant Industry and chair of the IBPGR Board, to arbitrate these tensions. This resulted in IBPGR shifting out of FAO but still located in Rome. In 1993, the IBPGR under the leadership of Geoffrey Hawtin was transformed into the International Plant Genetics Resources Institute (IPGRI) as a separate autonomous center aligned with the legal status of other CGIAR centers.[341]

The other major issue that became center stage in the 1980s was sustaining the growing number and size of collections of genetic resources resulting from the IBPGR and other initiatives of the 1970s. This led to efforts by IBPGR to prioritize a few "base collections" that would emphasize long-term conservation, an idea that emerged from the FAO Panel.[342] Frankel and his CSIRO colleague, A. D. H. Brown, also promoted the idea of "core collections" as a small subset of a collection that would include most of the biodiversity and that would be a priority for evaluation and associated information, to facilitate efficient utilization of genetic resources by breeders. By the 1990s, attention turned to sustainable funding of genebanks resulting in the creation of the Global Crop Diversity Trust (Crop Trust) in 2004 as an endowment fund. Hawtin was the main architect of the Trust and he and Fowler were the first executive directors of the Trust (Chapter 7).

The importance of safe backups of unique collections of genetic resources also became a critical element of sustainability. This was dramatically demonstrated by the repatriation of 766 diverse Cambodian rice varieties from the IRRI genebank to Cambodia in the late 1980s, following the fall of the Khmer Rouge regime.[343] Many of these landraces had been lost during the genocide and major disruptions in the countryside under the regime. This effort was supported by Australian technical assistance under the Cambodia-IRRI-Australia Project that had been initiated by Swaminathan as director general of IRRI. In the 2000s, Francis of WA, with support from the Australia's Grains Research and Development Corporation, led an effort to evaluate and back up 4,000 accessions of grain legumes at the Vavilov Institute genebank in genebanks in ICARDA and in Australia.[344] At the time, the Vavilov Institute was struggling to support its large collection due to severe budgetary cuts and loss of many of its far-flung research stations after the collapse of the Soviet Union. However, by far the most ambitious effort was the initiative of Fowler and Hawtin to set up the Svalbard Global Seed Vault in the Norwegian Artic in 2008 as a backup for all base collections of most crops.[345] Fittingly, both Hawtin and Fowler were recognised in 2024 when the prestigious World Food Prize was awarded for their global leadership in genetic resources for "preserving and protecting the world's heritage of crop biodiversity and mobilizing this critical resource to defend against threats to global food security."[346]

7. Reflecting on 50 Years of International Cooperation on Genetic Resources

Photo: Shutterstock

The period of 1960-1980 was the high point in the global genetic resources' movement, in terms of conservation of a unique and valuable asset. In many ways, Frankel and Bennett were the man and woman of the moment in spearheading the 1967 IBP/FAO meeting on genetic resources that catalysed the conservation movement as well as a new scientific subdiscipline around genetic resources. The timing was critical, since they were able to seize a narrow window of opportunity; 1967 was also the year that the Green Revolution took off in South Asia and new varieties were reaching tens of millions of farmers across the globe, threatening the loss of landraces.[347] Frankel and Bennett were in turn building on more than a decade of close collaboration between Australian and FAO scientists on forage genetic resources that had established them as world leaders in the emerging science of plant introduction, exploration and conservation.

The IBPGR set up in 1974 was designed to implement the broad recommendations of FAO and its Panel of Experts. Despite a rocky beginning that excluded Frankel and FAO expertise, IBPGR was eventually successful in facilitating hundreds of expeditions, building long-term storage for the new acquisitions, and developing human resource capacity in national systems. By 1990, the collection phase for the major food crops was mostly completed and a recent review of the food crops targeted by CGIAR concluded that *ex situ* collections were "moderately comprehensive" in their coverage of landrace groups, although with considerable variation across crops.[348] However, another recent review found widespread and continuing loss of landrace diversity and wild species *in situ,* concluding that "reversing the trajectory of crop genetic erosion requires profound changes."[349] The global status of genetic resources of forages is much more precarious for both *ex situ* and *in situ* conservation.[350] Long-time ILCA/ILRI genebank curator, Jean Hanson, has noted the relatively low number of forage accessions in the world's genebanks and the special challenges of setting priorities among many potential species for conservation.[351]

Australia's (and FAO's) initial interest in genetic resources was built on forage crops. In the post-War period, Australia developed a world-class system of research on both Mediterranean and tropical forages that depended on the introduction of germplasm from around the world. Australian farmers were the main beneficiaries of these efforts. This was especially so in southern Australia, where legumes were almost universally adopted for pastures in the higher rainfall areas and in much of the drier wheat belt. As observed by a leading scientist from Western Australia, "Australia is umbilically connected to the Mediterranean region for germplasm."[352] Although the tropical pasture revolution never lived up to the initial high expectations, the impacts were significant and even more than in the south, were based on purposefully introduced forage legumes and grasses. Overall, there is little doubt that after a long delay, Australia's significant investments in overseas expeditions for forage genetic resources after WWII paid handsomely in terms of productivity and sustainability of its farming systems.

The 'Australian school' that promoted the centrality of forage legumes in improving both crop and livestock productivity was mainstreamed across CGIAR and in many countries. There is still much debate about the success of that approach. Certainly, efforts to directly transfer Australian forage cultivars and farming systems met with little success especially in commercially oriented ventures as in SA's and WA's dryland farming projects in MENA. Building on the experience over decades and the rich collections of genetic resources now available, there remains much potential to improve smallholder farming systems by introducing forage legumes.

The benefits of Australia's engagement with international genetic resources are clear. The country has significantly improved its pasture systems and contributed to global food security by advocating for sustainable management of plant genetic diversity. The partnerships established during this period facilitated the exchange of knowledge and genetic materials, strengthening global agricultural resilience. Yet much work remains to make the conservation of crop genetic resources more comprehensive and sustainable. Climate change, shifting land-use patterns, and the privatization of plant breeding have reshaped the landscape of genetic resources. The next generation of Australian scientists and policymakers must build upon this legacy, ensuring that plant genetic diversity continues to be a cornerstone of global food security. This history suggest that this requires renewed investment in conservation programs, stronger institutional partnerships, and a commitment to balancing conservation with innovation.

Annex. Brief Biographies of Selected Actors, 1926-1980[353]

Bennett, Erna (1925-2012).
Born Northern Ireland and after graduating in botany from Durham University, she established her global scientific reputation at the Scottish Plant Breeding Station in 1963-65 coining or at least popularizing the terms, genetic resources, genetic erosion and genetic conservation. Worked closely with Frankel on the landmark 1967 second FAO meeting on genetic resources and subsequent book. Undertook pioneering collection expeditions in the Mediterranean basin and the Middle East in the 1970s. Parting ways with Frankel and disillusioned with FAO and CGIAR policies on genetic resources and plant breeding, she resigned from FAO under protest and moved to Australia in 1982 focusing on public education and political advocacy. First women to be awarded the Meyer Medal.

Bommer, Dieter Felix Reinhard (1923-2010).
Forage breeder who studied and worked at Giessen University and Braunschweig-Volkenrode Federal Agricultural Research Centre. Pioneered cooperation on genetic resources in Europe and advised on forage genetic resource collections in Brazil. Member of TAC and key participant in the creation of IBPGR. Appointed Assistant Director General, FAO, 1974-85, overseeing its work on genetic resources.

Bunting, Arthur Hugh (1917-2002).
Raised in South Africa and studied at Oxford University. After an extended career in British colonies of Africa including the infamous East African Groundnut Scheme, became professor of agricultural botany at the University of Reading in 1955. Lead member of the CGIAR sub-committee that created IBPGR clashing with Frankel on the role of FAO in IBPGR. One of the self-appointed founding Board members for IBPGR until 1980.

Carter, Edward Diment (1927-2018).
Studied agriculture at the University of Adelaide. Lecturer in agronomy at the Waite and leading SA agronomist for dryland farming systems. Played a major role in advising CIMMYT's research to introduce forage legumes in rotation with wheat in North Africa, designing the forage research program at ICARDA and training students from MENA in SA.

Crawford, John Grenfell (1910-1994).
After studies at the University of Sydney, became Australia's most distinguished agricultural economist playing multiple roles in national and international research, policy advice, institution building, and higher education over decades. While Vice Chancellor of ANU appointed founding chair of CGIAR's TAC, 1971-76, overseeing the establishment of IBPGR, ILCA and ICARDA (among other centers). Continued to influence ILCA through external reviews to 1982. Crawford Fund established in his honour in 1987. Numerous awards including Knight Bachelor.

Davies, Jack Griffin (1904-1969).
Doctorate from University of Wales, Aberystwyth, under Stapledon, and then led pasture research at the Waite 1927-39. Moved to lead the agrostology section of CSIRO, Canberra, with increasing focus on tropical pastures. Moved to CSIRO Brisbane in 1952 and then established and led the CSIRO Division of Tropical Pastures that grew rapidly to become the premier center for tropical pastures globally. CBE.

Davies, William (1899-1968).
Elder brother of Jack Davies. After studies at the University of Wales, Aberystwyth, under Stapledon, appointed Imperial Grasslands Investigator at Aberystwyth. Spent 1931/32 in Australia and was one of the first to recognize the potential of improved pastures in the tropics. Chaired the OEEC Grasslands Working Party and instigated the OEEC survey of Mediterranean pastures to facilitate the Donald-Miles 1951 pioneering collection of Mediterranean pastures. Continued to support international cooperation on pasture research and to promote the role of Australian pasture science. CBE.

Doolette, John Barton (1928-2015).
Graduate in agriculture from the University of Adelaide and then agronomist SA Dept of Agriculture with a focus on dryland farming systems. In 1971, undertook initial survey of feasibility of wheat-annual medic pasture rotation in Tunisia and then moved to CIMMYT Tunisia to implement the project. Moved to ICARDA in 1977 to initiate its forage research and finished his career in the World Bank with a continuing focus on MENA.

Donald, Colin Malcolm (1910-1985).
Raised on a farm in the UK and then from 1926 studied at Hawkesbury Agricultural College and University of Sydney. Joined CSIRO at the Waite and then moved to Canberra in 1941. Worked closely with Crawford in the Department of War Organization of Industry during WWII. Led the pioneering 1951 collection expedition to the Mediterranean with Miles. Returned to the Waite as professor of agronomy (replacing Trumble) in 1954 and became Australia's most distinguished pasture agronomist. CBE and Farrer Medal.

Finlay, Keith Warren (1924-1980).
After his doctorate at the University of WA, moved to the Waite in 1955 where he became reader in plant breeding. One of the first to use computers in plant breeding he gained international recognition through research on wide adaptation. Active in the IBP program on gene pools with Frankel and then moved to CIMMYT as Director of Basic Research in 1970. Oversaw CIMMYT's efforts to incorporate pasture legumes into North African farming systems.

Francis, Clive McDonald (1940-2013).
After studies at the University of WA became a highly successful pasture legume breeder in the WA Department of Agriculture. From this post and then at the Center for Legumes in Mediterranean Agriculture led WA efforts in plant introduction with emphasis on MENA. During some 30 expeditions from 1973, developed close partnerships with national scientists of the region, at ICARDA, and at the Vavilov Institute. Established the Australian Trifolium Genetic Resources Center. Farrer Medal and Vavilov Medal.

Frankel, Otto Hertzog (1900-1998).
Born in Vienna and completed his doctorate at the Agricultural University of Berlin in 1925. After about one year each on an EMB project in Palestine and at Cambridge University, appointed wheat breeder in NZ in 1929. In 1951, appointed Chief of Division of Plant Industry, Canberra, rising to the CSIRO Executive in 1962. Shortly before his retirement from CSIRO in 1966 joined forces with Stebbins to establish the Gene Pools sub-Committee of the IBP and developed a close partnership with FAO on conservation of genetic resources. Chaired the FAO Panel of Experts on Plant Introduction and Exploration, 1966-74 and co-organized the landmark 1967 FAO Technical Meeting on genetic resources and the subsequent book. A prolific author on variability and adaptability of crops, the science of genetic resources exploration, conservation, and utilization, and conservation of biodiversity more generally. Numerous awards including FRS and Knight Bachelor.

Grof, Bela (1921-2011).
After migrating from Hungary to Queensland in 1949, evaluated and bred tropical legumes and undertook early collection expeditions in South America for the Queensland Dept of Agriculture. Moved to CIAT in 1971 to initiate its work on forage legumes and genetic resources. In 1985, moved to Brazil to continue his work on tropical forages until 1997 with an interim period with CIAT on tropical forages in Southeast Asia.

Halse, Norman James (1929-).
After studies at the University of WA, worked with the WA Dept of Agriculture becoming its Director General in 1984. Oversaw WA Department of Agriculture projects in MENA on introducing dryland farming systems incorporating legume pastures. Participated in the 1982 external review of ICARDA and then became a member of the Board of ICARDA.

Harlan, Jack Rodney (1917-1998).
Son of noted USDA plant explorer H. V. Harlan. Studied forage genetics with Stebbins at the University of California and joined USDA's forage program where he undertook comprehensive plant collections in MENA from 1949. Gained an international reputation in crop domestication and evolution and established the Crop Evolution Laboratory at the University of Illinois in 1966. One of the first to sound the alert on the problem of genetic erosion, he was a pillar of the FAO Panel of Experts from 1966 to 1974. Meyer Medal.

Hartley, William (1906-2000).
A native of Yorkshire he completed a postgraduate diploma in agriculture from Cambridge University. Joined CSIRO's Plant Introduction Section in 1929, then Section head from 1944 to 1961 before becoming CSIRO scientific liaison officer in London and Washington. Pioneered plant exploration in South America in 1947/48, championed international cooperation on genetic resources in the Pacific and FAO, and helped establish scientific foundations of plant collection. Only Australian to receive the Meyer Medal for genetic resources.

Hawkes, John Gregory (1915-2007).
After studies at Cambridge University, he joined the Commonwealth Bureau for Genetics and Plant Breeding where after visiting Vavilov, he participated in extensive field collection for wild potatoes in the Andean region, including the British Empire Potato Expedition in 1938/39. A pillar of the FAO Panel of Experts from 1966 to 1974 he reviewed IBPGR in 1985. In 1968, he initiated the first post-graduate degree course and shorter courses in plant genetic resources at the University of Birmingham that trained 1400 scientists from over 100 countries, mostly from the developing world. Meyer Medal and Vavilov Medal.

Henzell, Edward Frederick (Ted) (1929 -).
After studies at the Universities of Queensland and Oxford he joined CSIRO's tropical pasture group in Brisbane in 1956 focusing on nitrogen use and uptake. Appointed the third chief of the Tropical Pastures Division in 1977-87. Chaired IBPGR's first Working Group on forage genetic resources. Engaged widely internationally, including with Australia's first pasture projects in Southeast Asia, as a member of TAC and in many CGIAR reviews. Noted historian of Australian agriculture including a detailed history of research on tropical pastures in his *Memoirs*. Many awards including the Farrer Medal and Officer of the Order of Australia.

Hutton, Edward Mark (1912-2005).
After studies in agriculture at the University of Adelaide, joined Roseworthy Agricultural College with a focus on Mediterranean pastures. Moved to CSIRO Canberra in 1941 and then to Brisbane in 1952 where he was the longtime leader and champion for breeding tropical

forage legumes. Became the second Chief of the Tropical Pastures Division of CSIRO, 1970-77. Advised the CIAT forage program, and after retirement, spent extended periods in residence in CIAT, Colombia and in Brazil working on tropical forage legumes. Farrer Medal.

McDougall, Frank Lidgett (1884-1958).
Born London and migrated to take up an irrigated fruit block near Renmark, SA. Moved to London as representative of the Australian dried fruit industry in 1922 and became highly influential in advising Australian prime minister, Stanley Bruce and British Empire economic policy more generally. Managed the research grants of the Empire Marketing Board that provided critical early financial support to pasture research in the CSIRO and the Waite, 1927-34. Regarded as the founder of FAO.

Miles, John Franklin (1908-1973).
Graduate of the University of Queensland and then joined the CSIRO as its plant introduction officer for the tropics. Evaluated around 1,000 introductions near Rockhampton and actively searched and promoted the need for a suitable forage legume. Pioneered collection expedition in MENA with Donald in 1951 and in sub-Saharan Africa in 1952 visiting about 30 countries over 18 months. Left CSIRO in 1957 to take up farming in Queensland.

Neal-Smith, Cedric Alfred (1909-2001).
Graduate of the University of Adelaide and close collaborator with Donald at the Waite. Moved to the Plant Introduction Section of CSIRO and led the 1954 FAO/CSIRO expedition on Mediterranean forages, and a subsequent expedition in 1968.

Oram, Peter (1920-2007).
After studies at Cambridge was appointed an FAO field officer in Libya where he participated in the 1954 FAO/CSIRO collection expedition. Active member of the FAO Working Party on Mediterranean Pastures and Fodder Crops and promotor of forage legumes both introduced and indigenous to replace fallow. As first Executive Secretary to TAC became a valued associate of Crawford, 1971-76 and played a leading role in creating IBPGR and ICARDA. Finished his career as Deputy Director General of IFPRI.

Pagot, Jean (1916-1982).
After training as a veterinarian in France, worked for most of the 1940s and 1950s in the French colonial territories of Niger and Mali, where he broadened his interest and expertise to livestock production systems and management. Director of IEMVT in 1962-1973. Founding member of TAC of CGIAR and first director general of ILCA, 1974-76.

Perkins, Arthur James (1871-1944).
British national raised in North Africa before graduating from L'École Nationale d'Agriculture in Montpellier, France. Professor at Roseworthy Agricultural College, SA, from 1892 and then Director SA Dept of Agriculture to 1936. Assembled the first shipment of seed from the Mediterranean region in 1891 and returned for a one-year tour of the region in 1910-11 seeking knowledge and seed relevant to SA agriculture. Presided over the first all Australian meetings on agricultural research and on agrostology.

Richardson, Arnold Edwin Victor (1883-1949).
After studies at the University of Adelaide moved to become founding dean of agriculture at the University of Melbourne. Founding director of the Waite Agricultural Research Institute in 1924 and member of the Executive Committee of CSIRO from 1927. A strong supporter of pasture research in both organizations he pushed for setting up CSIRO's Plant

Introduction Section. He also advocated forcefully for cooperation across the British Empire in agricultural research and for EMB grants to CSIRO to foster such cooperation. CMG.

Schultze-Kraft, Rainer (1941-2024).
After studying at Giessen University, moved to CIAT in 1973 to lead its work on forage genetic resources from 1976 onwards. Led 28 expeditions from 1976 to 1985 sometimes jointly with Australian scientists and built the world's largest tropical forage genebank, with a focus on legumes with potential for acid soils. Co-founded the journal, *Tropical Grasslands-Forrajes Tropicales*.

Stapledon, Reginald George (1882-1960).
After studies at Cambridge University, founded the Welsh Plant Breeding Station at Aberystwyth that became a global leader for research on temperate pastures. Employed a holistic approach to pasture improvement involving breeding, soil fertility, grazing management and rotation, always with legumes at the core. Exerted enormous influence on Australian pasture science through his many students, an extended visit to Australia in 1926, and EMB grants that linked Aberystwyth to scientists in CSIRO and the Waite. FRS and Knight Bachelor.

Stebbins, George Ledyard (1906-2000).
After studies in botany at Harvard University became a renown botanist and evolutionist at the University of California, Berkeley and Davis with a focus on forage grasses. A close friend and colleague of Frankel, he participated in the 1954 FAO/CSIRO collection expedition in Algeria. As Executive Secretary of IUBS supported Frankel in opening CSIRO's first phytotron and as a leader of the IBP engaged Frankel to set up the IBP Gene Pools sub-committee.

Swaminathan, Mankombu S. (MS) (1925-2023).
Renown Indian geneticist and "father of the green revolution" in India. After his doctorate in genetics at Cambridge in 1952, established his reputation in potato breeding incorporating wild relatives in the 1950s and in bringing semi-dwarf Mexican wheats to India in the 1960s. Quickly rose to become Director, Indian Agricultural Research Institute, and Director General, Indian Council for Agricultural Research. Founding member of TAC and served on the FAO Panel of Experts and IBP committees. FRS and first recipient of the World Food Prize.

Trumble, Hugh Christian (1903-1960).
Son of legendary Australian cricketer Hugh Trumble, graduated in agricultural science at the University of Melbourne, appointed agronomist at the Waite in 1925. Studied at the Welsh Plant Breeding Station under Stapledon and made the first exploratory trip for plant collection in the Mediterranean region in 1928/1929. Led pasture research at the Waite and Professor of Agronomy from 1941. Moved to FAO in 1950 and except for a brief return to the Waite, served his remaining career in FAO, mainly in Indonesia.

Vallega, Jose (1909-1978).
Argentinian geneticist and wheat scientist with a focus on wheat rusts. Collection of indigenous food plants in Latin America and graduate work at the University of Minnesota laid the foundations for his appointment as Chief of the Plant Production and Protection in FAO in 1960. Collaborated closely with Frankel during the 1960s in planning global efforts to conserve genetic resources.

Vavilov, Nikolai Ivanovich (1887-1943).
Widely regarded as the "father of genetic resources conservation." After studies in Russia, he spent 1913/14 in the UK mostly at Cambridge University. Established the All-Union Institute of Plant Industry, now commonly known as the Vavilov Institute that conducted over 100 collection expeditions prior to WWII with Vavilov himself visiting some 50 countries. Established the world's largest genebank through periodic replanting of his collection that reached 250,000 samples by 1940. Also built a global scientific reputation by analysing diversity within crop species and with their wild relatives. Best known for identifying geographic centers of diversity that he associated with centers of origin. Arrested by orders from Stalin in 1941 he died in prison.

Williams, Ronald F. (1930-2017).
Joined the Plant Introduction Section of CSIRO in Canberra around 1953 working closely with Hartley. Moved to Brisbane in the early 1960s where he founded the Australian Tropical Pastures Genetic Resources Centre that grew to be the world's largest for tropical forages. Led plant introduction efforts for tropical Australia for the next two decades. He also pioneered an extended collection expedition to Brazil that resulted in release and adoption of a successful legume for the tropics. With broad interests in taxonomy and ecology, he contributed significantly to the science of plant introduction and evaluation.

Whyte, Robert Orr (1903-1986).
Born in UK and raised in NZ. After graduating from the University of Victoria in Wellington, completed his PhD at Cambridge University. Founding director of the CBP at Aberystwyth under Stapledon from 1929-1950. From 1951 to 1961 led FAO work on pastures and genetic resources collaborating closely with CSIRO. Author of many books on grasslands and of the first book on introduction, exploration and conservation of genetic resources in 1958 laying the foundations for the international genetic resources' movement. Left FAO in 1966 to the University of Hong Kong where he continued research on monsoon Asia.

Endnotes

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70 Dickson to Secretary CSIRO 16 March 1950. NAA, A9778, B1/5/35, Barcode 3146104.

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72 This expedition is often mistakenly associated with FAO, for example in Donald's biographies and in the source of accessions in the Register of Australian Herbage Plant Cultivars. However, during the first part of 1951 FAO headquarters were closed while it moved from Washington to Rome and FAO played no role in either the survey or the collection expedition.

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74 Donald to Dickson, 7 March 1951. NAA, A9778, B1/5/35, Barcode 3146104

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76 R. O. Whyte, *Land resources of Tripolitania*, Bulletin 38 (Aberystwyth: Imperial Bureau of Pastures and Field Crops, 1947), pp. 82-3.

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78 Sustained negotiation of CSIRO and the Prime Minister's Office in Canberra and the UK Dept of

Agriculture, the Australian Scientific Liaison Office, and the Commonwealth Liaison Office in London occupy over 100 pages in the official files.

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80 Photo courtesy of John E. Miles

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83 *Farmer and Settler (Sydney)* 9 Sept 1955, pp. 3.

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104 Photo courtesy of John E. Miles

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209 The six were Demuth (World Bank) (chair), G. de Bakker (Netherlands) (vice chair), A. H. Bunting (UK), L. Kahre (Sweden), L. M. Roberts (Rockefeller Foundation), and F. Albani (FAO). See minutes of the Second Meeting of the Subcommittee on Genetic Resources, 6-7 Feb 1974, Rome. World Bank Group Archives Folder 1768303, Washington DC.

210 In addition, TAC and FAO appointed one member each.

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The Crawford Fund

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