A Profit in Our Own Country

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A Bountiful Harvest

R.A. Fischer

International Maize and Wheat Improvement Centre (CIMMYT), Mexico

The Consultative Group on International Agricultural Research (CGIAR or simply CG) upon which I will focus this talk consists of 18 international agricultural research centres whose mission is to contribute to sustainable increases in productivity in agriculture, forestry and fisheries in poor countries through international research in partnership with national agricultural research systems (NARS). The centres are publically funded, non-profit and usually located in developing countries. IRRI, the International Rice Research Institute, and CIMMYT, the International Maize and Wheat Improvement Centre, are the oldest and best known centres of this system.

As an agricultural scientist sandwiched between economists and urged to give an economic analysis of the benefits to Australia's grain industries of the money Australia invests in the CG system, I feel rather uneasy. Thus I am not going to attempt to prove that a dollar invested in grains research in the CG system yields even more for Australian farmers than one invested in Australia. However, I do hope to present arguments that suggest to us noneconomists that this could well be the case. For if you have, as I am sure you do, more than a passing interest in the ideas of Charles Darwin, Gregor Mendel and William Farrer, I believe we have sufficient common ground upon which to build a more interesting, if less quantitative, story.

Lessons from Evolution

Let's start in the Galapagos off the coast of Ecuador. Charles Darwin noticed small differences in finches and tortoises indigenous to each of the adjacent islands. He concluded that these differences were inherited and conferred adaptive advantage to the subtle environmental differences between apparently similar islands. The notion that in nature evolutionary processes based on heritable traits, or genetics, drive animals and plants to become adapted to small environmental differences—the concept of specific adaptation—has now of course become widely recognised. One need only contemplate the diversity of form and adaptation amongst the numerous species of Australian eucalypts. This is paralleled by the widely recognised efforts of farmers from the dawn of agriculture to select adapted and diverse land races from amongst the natural variants in their crops. And beginning some 100 years ago, plant breeders began to deliberately breed for adaptation to their environments. With the case of wheat in Australia, selection by farmers, for earliness and disease resistance and later by William Farrer and successive wheat breeders, was fundamental to improved performance and establishment of a strong wheat industry here. Throughout, specific adaptation seems to be the key to success. It might therefore be hard to see how crop varieties from the far-flung institutes of the CG system can be of any use in the distinctive agricultural environments of Australia.

Experience of Recent Plant Breeding

The overwhelming experience has reinforced the importance of global genetic exchange.

Whilst specific adaptation dominated thinking for a long time, even Farrer realised the importance of obtaining parental material from other countries. And the overwhelming experience of the last 40 years or so in plant breeding has both reinforced the importance of global genetic exchange, and introduced the concept of broad adaptation. This implies that certain crop varieties can show superior performance in many locations around the globe with seemingly distinctive environments. I am proud to say that Norman Borlaug at CIMMYT was one who pioneered this concept of broad adaptation in wheat breeding, and it was successfully taken up by my earlier colleagues at Wagga Wagga, wheat breeders Albert Pugsley and Jim Syme. Why is it therefore that foreign germplasm bringing not only specific desirable traits but also broad adaptation can be so valuable to Australia and what does the CG system have to do with its availability anyhow?

Agricultural environments Modern crops are grown in agronomically managed systems in which the management compensates for some of the vagaries of the natural environment. Thus cropping environments around the world are not as different as adjacent natural ones. For example, Australia's natural vegetation has generally evolved adaptation to low P levels in our native soils: in cropping it pays to get around this by adding P fertiliser.

Broadly desirable traits There are traits in crop plants which appear to be desirable in many environments and clearly contribute to broad adaptation. One example in wheat would be the famous Norin 10 dwarfing genes almost always associated with higher yields. These genes have been spread over the last 30 years via CIMMYT germplasm to spring wheat varieties grown on over 50 million hectares in the developing world and on more than 85% of the wheat area in Australia. Another such trait which helps confer adaptation to CIMMYT wheats, including immediate fitness to Australia, is daylength insensitivity. A further example in wheat would be broadly based durable resistance to rust in which CIMMYT germplasm has excelled.

Climatic similarities The fact that the CG crop research programs target developing-country agroclimatic zones of low to intermediate latitude, some of which are the same, broadly speaking, as those of Australian agriculture, adds greatly to the general usefulness of their germplasm in Australia. And incidentally, few other developed countries have this good fortune. Let's look at the most relevant centres:

- ICARDA—winter rainfall dominant environments of intermediate latitude, which correspond with the cereal belt of western and southern Australia
- CIMMYT—All wheat and maize environments of intermediate and low latitude, which equate to all cropping environments of Australia but especially higher rainfall and irrigated ones
- ICRISAT—semi-arid tropics, the climatic zone of north eastern and northern Australia
- CIAT, IRRI, IITA—humid and sub-humid tropics, the climatic zone of coastal north eastern Australia.

I have outlined some general issues which make foreign germplasm, and in particular CG centre germplasm, well suited to Australia. Let's look at some more specific ones:

New crops The whole history of agricultural expansion is tied up with the introduction by man of plants to new cropping environments, often environments far removed from that in which the plants evolved in nature. This is not an easy process as Australia has learnt through its major role in the domestication and adaptation of narrow-leafed lupins (*Lupinus angustifolius*), which now after 30 years of effort occupies almost one million hectares of our crop lands. Hence the establishment of other new crops in Australia such as chickpea, lentil, faba bean, triticale, pigeon pea and millet has and will continue to benefit greatly from already adapted germplasm coming from well-established breeding programs in CG centres. To this list could

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be added CG centre germplasm adapted to ecological or market niches which are too small to warrant special attention in Australia, e.g. wheats adapted to acid soils or to cold tableland conditions, or durum wheats for dry winter rainfall environments, all available from CIMMYT, or hull-less barleys from ICARDA.

CG centre germplasm often carries genetic resistance which can be extremely valuable to Australia.

New diseases and pests Australia still lacks a number of important pests and diseases of its crops because of its isolation and strict quarantines. However, there will inevitably be new arrivals from time to time. CG centre germplasm, having being exposed to all pests and diseases, often carries genetic resistance which can be extremely valuable to Australia in such cases. A good example was provided by the chance arrival of stripe rust of wheat in 1979. Quite a bit of genetic resistance was already present in Australian varieties unwittingly introduced via the use of resistant CIMMYT parental material. Losses were thus mitigated substantially, while the quick introduction of more resistance varieties was facilitated. Australia does not yet have Russian wheat aphid or Karnal bunt but CIMMYT has resistance to both in adapted wheats. Australia similarly does not yet have stripe rust of barley or ascochyta of chick peas—ICARDA has resistant germplasm for both.

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Comparative advantages of scale Breeding programs in CG crop centres tend to have comparative advantages relative to programs in Australia, which means that even when programs have the same objectives, the CG ones can make more rapid progress. This is exemplified by the CIMMYT Wheat Program. The program makes three to four times more crosses and grows more area of segregating populations annually than all Australian programs put together. The program runs two generations in the field a year, taking advantage of Mexico's unique environments, potentially doubling the annual rate of progress. Besides, the program has access to several distinctive screening environments in Mexico and many through its collaborators in the developing world. While yield-testing opportunities in Mexico may not match those across Australia, international testing more than makes up the difference. Thus CIMMYT screening nurseries and yield trials go to more than 100 global sites each year. Finally, the breeding program has a strong backup of support disciplines in particular plant pathology. I do not wish to sound boastful but it is a wheat breeding machine without equal and it is no surprise that its germplasm products are to be found behind over 75% of the varieties currently being released each year, and occupy over 40 million ha in the developing world outside of China. Since breeding is a numbers game, in which creating and identifying the rare superior gene recombinations is crucial, size does count, along of course with skill. CIMMYT's Maize Program is about equal in size to its wheat one, as is the IRRI rice breeding program. Other crop programs in the centres are smaller but still very large by any standards.

Ready access to germplasm A feature of the CG crop centres, which is likely to be even more important in the future, has been their strict adherence to a policy of free availability of germplasm to all breeders, whether public or private, developing country or developed country. This policy arises largely because we believe it best serves our ultimate clients, namely the grain farmers and consumers. The policy also applies to the extensive collections of germplasm in our gene banks. Australia's access to germplasm of CG mandated crops is facilitated by this policy, as it will be by efficient computerised crop databases presently being developed in the Centres. Despite recent moves towards restricting use of certain germplasm in gene banks, the CG system will strive to maintain open access for greatest public benefit.

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Current and Future Impacts of CG Activities

Having introduced the general reasons why CG grain crop germplasm is so useful to Australian plant breeders and farmers, let us look briefly at the specific commodities involved.

Winter grain legume Eastern Australia's rapidly expanding production of chickpeas (200 000 tons in 1993) is in the words of one local specialist 'almost entirely based on germplasm from ICRISAT and ICARDA'. Material from these two centres is being used extensively in the breeding programs at Tamworth and Horsham. Chickpeas are now on the upsurge in West Australia and again CG material is being widely tested. Australia produced a record 140 000 tons of faba beans in 1993 based on a Waite Institute variety selected out of Greek material. However, the second faba bean release was a disease-resistant variety selected directly from material from ICARDA, which holds an extensive germplasm collection of faba beans. With respect to lentils, the Grains Research and Development Corporation has already adopted a policy that lentil breeding be left to ICARDA, and that Australia with its program based in Horsham concentrate upon evaluation of introductions. Currently production is small but the new red and green seeded varieties recently released from ICARDA materials and the taller types in the pipeline promise to change this. Both world market and Australian wheat cropping systems need more grain legumes and these new crops, along with other possible ones from ICARDA (*Lathyrus*, *Vicia*, *In the national navy bean breeding program based in Hermitage, Queensland, CIAT germplasm is used extensively to bring in yield, disease resistance and eating quality.*

Development of new techniques pioneered in Australia could speed up the breeding of drought-resistant peanuts.

Pisum spp.), will no doubt play an important future role in Australia.

Summer grain legumes There is an acute need for better summer grain legumes in Australia's warmer cropping regions, primarily in Queensland and northern NSW. Australia collaborates with ICRISAT on two such crops, namely peanut and pigeon pea, and with CIAT on navy bean. Soybean, the other significant summer grain legume in Australia, has only recently been taken up by a CG centre, namely IITA in Nigeria. The collaboration on pigeon pea led to the development of the first varieties ever suited to short-cycle cropping and mechanical harvesting for the Queensland environment—for lack of market, however, the crop is not yet grown widely in Queensland. In the national navy bean breeding program based in Hermitage, Qld, CIAT germplasm is used extensively to bring in yield, disease resistance and eating quality. A new rust-resistant variety released in 1993 is a direct introduction from CIAT. In the case of peanuts, undoubtedly the most important of this trio of tropical grain legumes, with annual production of around 30 000 tonnes, germplasm exchange has been less important than research collaboration between Queensland Department of Primary Industries, ICRISAT and (through ICRISAT) the Indian national program. Development of new techniques, pioneered in Australia but now being further developed and tested in ICRISAT, could speed up the breeding of drought-resistant peanuts. This ACIAR-funded project reaps several advantages by being based at ICRISAT, namely the availability of diverse germplasm, reliable selection environments and low field labour costs.

Summer cereals Here we are talking about maize, sorghum and millet. In the first two crops there has been germplasm exchange with CIMMYT and ICRISAT, respectively. However, the general use of hybrid material in Australia, commonly supplied by private companies, has meant less utilisation of CG germplasm which has in the past been non-hybrid. CIMMYT and ICRISAT are nowadays producing inbred lines of maize, and sorghum and millet, respectively, for hybrid performance in the tropics and subtropics. They are becoming a major source of inbreds for private and public seed companies in these regions. At both centres special emphasis is being placed on drought-resistant material. I anticipate spillover benefits to Australian farmers will increase, especially in the case of millet, which presently is almost unheard of in Australia.

Winter cereals Wheat and triticale fall in the mandate of CIMMYT, while barley is handled by ICARDA. By any standards the impact of CIMMYT wheats in Australia has been huge: I have cited several examples already and will leave the quantification of this impact to the following speaker. I would like, however, to touch on the following advances which are in the pipeline and are of special interest to Australia:

(i) We are beginning projects with Grains Research and Development Corporation (GRDC) support to incorporate resistance to Russian wheat aphid (RWA) and improved preharvest sprouting resistance into Australia-adapted germplasm. We can do this efficiently because of suitable natural screening environments in Mexico. Since RWA has yet to reach Australia, the RWA work is precautionary and complements recent testing of Australian material in Colorado. The sprouting work is part of a longstanding effort at Narrabri to reduce expensive losses in grain quality due to rain at harvest.

(ii) In a project of clear mutual benefit we are taking unique barley yellow dwarf virus (BYDV) resistant germplasm developed at CSIRO in Canberra and incorporating it into improved high-yield materials. This step of incorporating resistance into a suitable plant type is not a trivial one and was therefore given relatively low priority by Australian breeders. Nevertheless, improved resistant material from CIMMYT will be beneficial to these breeders because BYDV does cause significant yield losses in Australia.

(iii) In an effort to expand the germplasm base of wheat and incorporate new sources of disease resistance, CIMMYT has been repeating the interspecific cross which in nature produced bread wheat as we know it some 7000 years ago. Interspecific crosses are not so easy to make but nevertheless, almost 500 new (so-called synthetic) bread wheats have been produced over the last five years. We are finding that not only do we have new sources of disease resistance but also it appears there could be sources for increased vigour and yield. This is very exciting and, taken along with the likely occurrence of unique grain protein and starch qualities, makes the material of considerable interest to Australia.

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This mention of interspecific crosses brings me to the Cinderella of CIMMYT's suite of crops, namely triticale. Triticale is the result of a man-made cross between rye and wheat, and has the potential to combine the best qualities of each. Some 2 million ha are grown globally with around 100 000 ha in Australia. Nowadays almost all the base germplasm for spring type triticale, the type grown in Australia and the developing world, comes from CIMMYT's triticale program, as do the varieties released by the Waite Institute and Sydney University. Triticale is a crop with considerable potential as a feed grain for poultry and pigs because of its nutritional advantages and adaptation to a whole range of marginal conditions (nutrient-deficient, acid, light-textured drought-prone soils, and disease-prone environments).

However, the area of triticale in the developing world is still minor (about 160 000 ha), largely because of the new crop syndrome and distortions in marketing. Indeed continued research on triticale at CIMMYT is now under threat because of budget cuts. This is something which ought to alarm those who have expressed so much concern about the lack of diversity in agricultural crops. For more pragmatic reasons it ought also to concern Australia, which has been a major beneficiary of the triticale program to date.

With respect to barley, germplasm from ICARDA has only recently started to have an impact in Australia with the release as varieties of three direct introductions from ICARDA's Mexico-based breeding program. Two of these incorporate the hull-less trait which gives the barley a special advantage in certain feed and food markets. No Australian barley breeding program works with this trait. In the future it is to be expected that special drought-resistant barley from ICARDA's Syria-based program will also be of value to Australia's breeders.

Balancing Investment in Australia and the CG

So there seem to be many reasons for Australia to be taking advantage of CG system germplasm. Nevertheless, there are likely to be some doubts and concerns regarding the implications of this proposition.

Why breed in Australia?

In our major crops we need the capacity to run crossing programs in which introduced germplasm might be used and from which varieties even better tailored to our needs are expected to arise.

Lest I am misunderstood, let me deal at the onset with the idea I expect some are now harbouring that if germplasm from the CG centres performs so well in Australia, why should we invest in local breeding at all? This is not a difficult question to answer: without a national breeding capacity in a given crop, a capacity which will always include the ability to select, screen and test introduced germplasm, little progress would be made with the crop. Besides, there is no doubt that in our major crops we also need the capacity to run crossing programs in which introduced germplasm might be used and from which varieties even better tailored to our needs are expected to arise.

Why not freeload?

If Australia also freeloads on the system, benefits may still flow passively as in the past, but bigger opportunities will be missed. If instead Australia's grain industry invests in CG commodity research, it can ensure rapid access to products more likely to be of use to Australia. CG centres do not have as their mission assistance to developed countries like Australia, but quite often projects can be devised which permit the Centres to get on with meeting their goals while Australia specifically benefits as a spin-off.

Interchange of breeders between Australia and the Centres is one very obvious mutual benefit and is often supported by such projects. Indeed, without these person-to-person contacts on a frequent basis, many other benefits are missed by Australia. Plant breeding is still very much an art and seeing is an important way for it to be appreciated and the way advances are transmitted. Beyond enhanced linkages between scientists lie the possibilities of executing projects of mutual benefit which can clearly be done more efficiently at or with the Centres. Screening germplasm adapted to Australia for pests and diseases not yet present is an obvious example. Besides, it is often cheaper to do a piece of research at a CG centre than to do the same research in Australia.

In all cases direct project investment in CG centres and rapid access to results have the potential to give Australian grain growers the jump on their competitors. Getting there first is the name of the game in the export business, and to the extent that Australian researchers can also quickly adapt CG advances to their country's conditions and transfer them to its farmers, Australia will come out ahead. To miss out on links with what are probably the strongest and most successful breeding programs in the world in each particular CG commodity would seem very shortsighted.

Relative levels of investment A related question is the appropriate level of investment in breeding in Australia compared to that which Australia might fund in a CG centre. Here the ground is much shakier—the arena of uncertain biology, assumption-ridden economics, and ever-present local politics. But let's try by looking at the present balance of Australia's investment in wheat improvement (Table 1). For every $19 dollars the Australia taxpayer invests in wheat improvement in Australia, only $1 is invested in CIMMYT wheat improvement (and of course this investment in CIMMYT has several objectives besides producing better germplasm for Australia, objectives about which we will learn from other speakers today).

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Table 1. Investment by Australia in wheat improvement in Australia and at CIMMYT ($A'000 p.a.).[d]

Source	Australia[a] 1991–92	CIMMYT 1994
Public sector	7723[a]	415[b]
GRDC	5777	45[c]
Non-Australian sources	–	10,341[d]
Total	13500	10,800[d]

a. Total wheat improvement cost (breeding plus breeding support) as reported in Clements, Roseille and Hilton (1992).
b. Australia's grant to CIMMYT's core multiplied by Wheat Program costs as a percentage of CIMMYT's core (40%) plus Special Purpose Grant from ACIAR for Genetic Resource Information Project (wheat) of $A55 000.
c. GRDC-approved funding of wheat breeding activities at CIMMYT (Probe genotypes, Russian Wheat Aphid and grain sprouting resistance, Brennan study on impact of CIMMYT wheats).
d. Wheat improvement in core plus special project estimated at 70% of total.

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The GRDC, however, has a narrower set of objectives. It has just started to invest in CIMMYT, and currently only invests about $1 in CIMMYT for every $128 in Australia (Table 1). Given this wide disparity and the serious shrinkage in CIMMYT's wheat budget, amounting to a 40% real cut in the last five years, it seems that the marginal return on an extra dollar invested at CIMMYT could well exceed that on an extra dollar invested in Australia. But the question of returns on dollars invested in CIMMYT will be dealt with in detail by the next speaker.

Similar calculations could be made for winter pulse breeding at ICARDA, an activity of measurable benefit to Australia and one in which Australian grain growers have begun to invest. I suspect there is a closer balance than is the case with wheat between what they invest for this purpose in ICARDA and what they invest at home—there ought to be, since the winter pulses involved are new and still minor crops in Australia. Indeed, considerations of critical mass and of likely returns to local crossing and selecting versus reliance upon spillover benefits of exotic germplasm may mean we should never invest in a fully-fledged local breeding program for these minor crops, since such a program is generally not profitable unless the target crop is worth at least $200 million (Brennan 1991).

Won't others freeload?

Since CG germplasm is freely available to all it is obvious not only does Australia benefit but so also can grain growers in other countries. To a large extent this includes poor food-importing nations. I believe other speakers will present the overwhelming case that their freeloading is to our advantage. That leaves rich countries and/or exporters. Other than Australia most rich countries are in the North and will not benefit so immediately or to such a large extent because their environments are different from those targeted by CG centres. Indeed, some don't even grow CG mandated grain crops.

Saudi Arabia is an interesting exception as a freeloading beneficiary but this situation is not likely to last. Poor grain-exporting nations on the other hand—Argentina and Turkey come to mind—do freeload on the CG system and do receive immediate benefits. However, for a number of reasons—largely related to weak infrastructure, variable grain quality and poor marketing skills—they are not yet significant competitors with Australia. But the real answer to their freeloading is not to freeload ourselves but rather, as explained earlier, to invest wisely in CG centres.

Dependency and genetic vulnerability

It has often been argued that CG centres, by the very success of their germplasm, engender a dangerous dependency in their client countries, besides increasing the genetic vulnerability of their crops. Emotional stuff for which there are sound answers, in the case both of developing countries and of Australia. Suffice to say here that Australia is clearly in control of its destiny in this respect, and has chosen to restrict the use of CG germplasm where it has deemed it desirable. For example, the strict quarantine laws have never been questioned as a result of the increase of opportunities for germplasm import, and otherwise desirable CG-derived varieties have been quickly rejected if they don't meet all of the industry's requirement (e.g. the repeated rejection of CIMMYT-derived high-yielding 1B/1R wheat varieties because of a grain quality risk).

Otherwise desirable CG-derived varieties have been quickly rejected if they don't meet all of the industry's requirement.

Conflict with plant variety rights

Australia has moved towards protection of plant breeders' rights along the lines of the UPOV convention. It should be pointed out that in no way does the CG policy of free access to its germplasm conflict with the operation of plant variety rights (PVR) in client nations. Centres are prepared to grant permission for germplasm in which they have an equity to be registered under PVR in a country. They may, however, restrict registration (provisional or otherwise) in other countries so that the material is freely available outside Australia. Where a variety is derived under a joint project between, for example, a CG centre and the GRDC, it seems both reasonable and feasible that rights to the variety in at least Australia belong to the GRDC.

Conclusions

CG centres deal with all the major grain crops grown in Australia, with the exception of lupins, canola, and until recently, soybeans.

1. CG centres deal with all the major grain crops grown in Australia, with the exception of lupins, canola, and until recently, soybeans.
2. Despite the centres' geographic distances and apparent environmental differences from Australia, germplasm carrying either special traits or broad adaptation has been and continues to be of value to Australian breeders and farmers. Australia amongst developed countries has a unique advantage in this respect because of the latitudinal and climatic correspondence between our cropping areas and those which CG centres target.
3. Australia should not simply freeload on the CG system but must work closely with the centres' crop programs in order to reap the greatest advantages for itself and relative to its export competitors. This requires investment in specific projects of mutual benefit. Many opportunities exist.
4. The nature of Australian collaboration will differ depending on the strength of local breeding. Thus an obvious case exists for collaboration with new and currently minor crops like chickpea, lentils and triticale. But our multimillion-tonne crops with strong local breeding programs, namely wheat and barley, should not be overlooked in the push for more collaboration, as the huge gains from the past use of CIMMYT germplasm attest.
5. Breeding and breeding research is an ongoing activity and I see no reason why the benefits from collaboration will not continue and even grow, as long as the CG centres run world-class breeding programs and germplasm exchange remains relatively free.

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