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# Spillover Effects of International Agricultural Research: CIMMYT-based Semi-Dwarf Wheats in Australia

**John P. Brennan**

*Department of Agriculture New South Wales, Agricultural Research Institute, Wagga Wagga, N.S.W. 2650 (Australia)*

## Abstract

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The spillover effects of agricultural research are of interest because research-induced supply shifts in non-target regions can reduce the benefits for producers in the target regions. The introduction of semi-dwarfing genes in wheat into Australia provides an example of spillover from the CIMMYT program. Australia's wheat-growing environments were not those for which the CIMMYT material was specifically targeted. However, some of these lines were introduced into Australia and used in breeding programs to produce important supply shifts in Australia. An examination is made of the effects that the spillover had in Australia.

Using an index of varietal improvement, with its attendant qualifications, an estimate of the extent of that shift resulting from the CIMMYT-based varieties was obtained. While the extent varied widely between states, the shift was found to be between 0.2 and 7.7%, with an overall average for Australia of 3.5% by 1983. On the basis of an assumption of perfectly elastic export demand for Australian wheat, the estimated total cost savings to Australian producers were US$747 million (in 1983-84 dollars) for the period 1974 to 1983, or an average of US$75 million per year. The annual contribution of Australia to CIMMYT has averaged approximately US$340,000 in recent years, while the average annual expenditure on wheat breeding in Australia has been US$4 to 5 million. On the basis of pedigrees, approximately two-thirds of the cost savings of CIMMYT-based varieties could be attributed to CIMMYT per se, with the remaining one-third attributable to the inputs of the Australian wheat breeders.

## Introduction

Mexican dwarf wheat varieties originally were developed by the Cooperative Wheat Improvement Program of the Mexican Ministry of Agriculture and the Rockefeller Foundation "to solve Mexico's wheat production problem" (CIMMYT, 1969, p. 55). Subsequent research has been carried out by CIMMYT in Mexico to develop "high-yielding, widely adapted, semidwarf spring-

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habit bread wheats that were suitable for immediate release in key developing countries" (CIMMYT, 1984, p. 11). The varieties developed have been grown in many areas apart from the 'target' regions in the developing countries.

The net benefits of agricultural research in a tradable commodity such as wheat for its 'target' region are influenced by the spillover of the effects of that research into the rest of the world, with which the target region competes for a share of the world market. Edwards and Freebairn (1984) showed that the greater the extent to which the research innovations are adopted in other regions, the lower the net benefits for the target region. Davis et al. (1987) have further developed the incorporation of spillover effects into the analytical framework for the evaluation of research.

In this paper, the effects of wheat research at CIMMYT on the production from the generally dryland areas in Australia are identified. An attempt is made to quantify the extent of those spillover effects from the CIMMYT program.

## Semi-dwarf wheats in Australia

Semi-dwarf wheats were first introduced into Australia from the United States of America in 1956 (Pugsley, 1974). From the late 1950s and early 1960s, material was also imported from the Mexican program conducted by the Rockefeller Foundation, precursor of the CIMMYT program. The imported lines

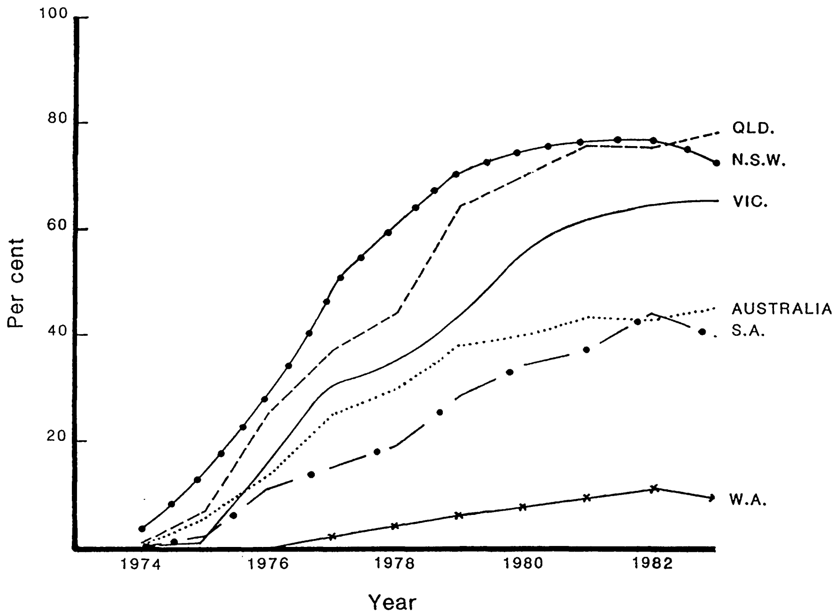


Fig. 1. Percent of total wheat area sown to CIMMYT-based varieties.

were not released directly for commercial growing by Australian farmers (generally because of inadequate milling or baking quality). All were subject to further crossing before commercial varieties were released. This delayed the initial adoption of semi-dwarf wheats in Australia compared to most other countries (Brennan, 1986a). The first semi-dwarf bread wheat cultivars were released for commercial production in Australia in 1973.

In this paper Australian varieties which had a CIMMYT line in their parentage are classified as CIMMYT-based varieties. Between 1973 and 1984, 58 new wheat varieties were released for commercial production in Australia; of these, 45 (or 78%) were CIMMYT-based varieties, seven (12%) were semi-dwarfs of other origin, and six (10%) were non-semi-dwarf. The spread of CIMMYT-based varieties in Australia from the first release was rapid–see Brennan (1986a) for more detail. By 1976, over 14% of the total Australian wheat area was sown to CIMMYT-based varieties. By 1983 the percentage had reached 45%, or 5.8 million ha, and a further 8% was sown to semi-dwarfs of other origin. There were wide differences in the rate of adoption in different states (Fig. 1).

## Yield advantage of CIMMYT-based varieties

Although virtually all semi-dwarfs released commercially in Australia have involved selection from, or further crossing with, CIMMYT material, other facets of progress in breeding have been incorporated at the same time. Thus, ideally, the study should make a comparison between the progress (in yield and quality) which has actually occurred in the presence of CIMMYT material and that which would have occurred without it.

Several simplifying assumptions were made in estimating the yield advantage of CIMMYT-based varieties over other varieties, including (a) that the

TABLE 1

Yield comparisons from interstate wheat variety trials[a]

| | Yield advantage of CIMMYT-based lines (%) |
|---|---|
| New South Wales | 9.0 |
| Victoria | 8.1 |
| Queensland | 9.2 |
| South Australia | 6.1 |
| Western Australia | 2.7 |
| Australia | 7.1 |

[a]Results from Interstate Wheat Variety Trials, series A and B, from 1975 to 1982. Figures shown are weighted averages of A and B series results, weighted by the number of entries (Brennan, 1986a).

CIMMYT-based varieties led to a permanent upward shift in yield potential: (b) that the yield advantage from trials can be used to indicate the yield advantages on farms; (c) that the yield advantage of CIMMYT-based breeding lines over other leading lines in the Interstate Wheat Variety Trials over the period 1975–1982 provided a measure of the inherent yield advantage of CIMMYT-based varieties; and (d) that the varieties chosen by breeders as standard check varieties in the trials do indeed represent the standard in each state, and that the lines being compared are representative of the new wheats in the process of being released.

The procedure for estimating the yield advantage for CIMMYT-based varieties, as detailed by Brennan (1986a), was as follows. The pedigree of each line in the Interstate Wheat Variety Trials was examined and was classified as 'CIMMYT-based' if either of its parents was from the CIMMYT program or had CIMMYT material in its parentage. The mean yields for the 'CIMMYT-based' and the 'other' groups were then calculated for all trial sites in each state for each year between 1975 and 1982. The overall average yield of each group was then estimated for each state for the full period from a weighted average of the annual mean yields. In total, data covered 176 site-years, with an average of 25 lines at each site and an average of four sites per state per year.

The overall average advantage of CIMMYT-based lines over other lines was 7.1% (Table 1), although there was wide variability between states. The ranking of these mean yield advantages by state is broadly in line with the rate of adoption of CIMMYT-based varieties in each state.

## Index of varietal improvement

Given the average yield advantages for each state, and the data on adoption of the varieties, it is possible to calculate a simplified relative yield index or 'index of varietal improvement' (Silvey, 1981; Brennan, 1984). This index combines the yields obtained in trials with data on the varieties being grown by farmers, to provide a measure of the contribution that new varieties make to increasing wheat yields.

A modified index of varietal improvement is calculated as follows:

$$I_{it} = 100 + (V_i p_{it})/100$$

where $I_{it}$ is the index in state $i$ in year $t$; $V_i$ is the percentage yield advantage of CIMMYT-based varieties in state $i$; and $p_{it}$ is the proportion of the area sown to CIMMYT-based varieties in state $i$ in year $t$. Thus in New South Wales, with a yield advantage of 9.0% ($V_i = 9.0$), and 71.0% of the area sown to CIMMYT-based varieties in 1979 ($p_{it} = 0.710$), the index for 1979 is 106.39. The index has a base value of 100 for all years in which these varieties were not grown in the state.

These indexes have been calculated for each state for each year from 1974 to 1983. The index increases steadily for each state with the increasing adoption of these varieties. The index increased between 1973 and 1983 by 6.6% for New South Wales, 5.3% for Victoria, 7.2% for Queensland, 2.4% for South Australia and 0.3% for Western Australia. The overall increase over this period for Australia was 3.6%.

Godden (1985, 1987) pointed out that relative yield indexes are a biased estimator of genetic improvement unless there is no interaction between the varieties and the level of inputs used. A brief examination of input levels in Australia (Brennan, 1986a) showed that, except in Western Australia (where CIMMYT-based varieties were only of minor importance), there was scant evidence of any major changes in input levels for wheat production in Australian over the period since the early 1970s. Thus the extent of the possible bias in this study, while unknown, is argued to be likely to be relatively small.

On the other hand, if the CIMMYT-based varieties were adopted mainly in the areas where their superiority over other varieties was greatest, then the index of varietal improvement would understate the true contribution of these CIMMYT-based varieties. Given the other limitations on the precision of this index, it is not appropriate to attempt to estimate the size of this bias. Nevertheless, it is a possible further source of inaccuracy in the results of this study.

## Estimate of shift in Australia's wheat supply curve

Edwards and Freebairn (1984) define the increase in supply as a vertical downwards shift in the supply curve through a lowering of costs per unit. An approximation of the equivalent percentage reduction in costs for a given percentage yield increase can be obtained from the change in the index of varietal improvement. If the cost of growing the marginal hectare is $C$ and the yields are $Y$(t/ha), the marginal tonne of production will cost $C/Y$ per t. If the yield increases by the proportion $A$ with no increase in costs per ha, then the cost per t falls to $C/[Y(1+A)]$, and the proportional fall in costs per t is $A/(1+A)$.

Thus, a costless (in terms perceived directly by farmers) increase in yields of 3.6% for Australia is equivalent to a fall in costs of 3.5%. This is the extent to which the overall Australian supply curve is estimated to have shifted downwards as a spillover from the Mexican wheat breeding programs. The shift thus calculated for each state was: Queensland 6.7%, New South Wales 6.2%, Victoria 5.0%, South Australia 2.4% and Western Australia 0.2%.

## Effect on prices for Australian wheat

It is possible that the increased supply resulting from the semi-dwarfs in Australia has affected the prices received for Australia's wheat exports. If the

t, metric tonne = 1000 kg.

export market is perfectly elastic (that is, Australia is a price-taker on the world wheat market), the increased supply would not have influenced world prices. However, there is some debate as to whether Australia faces a perfectly elastic demand for its export wheat; for example, see Alaouze et al. (1978a,b, 1979), Grennes and Johnson (1979) and Longworth and Knopke (1982). The analysis in the present study is based on the assumption that the export demand is perfectly elastic, as argued by Alaouze et al. (1978a,b) and Longworth and Knopke (1982). To the extent that the market is less than perfectly elastic, the increased supply would have reduced the price, and the gains indicated by this analysis would be overstated.

In addition, the large shifts in world wheat supply (measured as increases in world production) attributed to varieties emanating from CIMMYT (Anderson et al., 1987) can have had a substantial impact on the world price for wheat (Edwards and Freebairn, 1984). These effects could have substantial disbenefits for Australian producers, offset to some extent by benefits for Australian consumers. These effects are not estimated in this paper.

## Estimate of cost savings for Australia

If the assumption is made that Australia is a price-taker on the world wheat market, facing perfectly elastic demand, then the figures derived in this study allow some broad estimates to be made of the cost savings to Australian producers from CIMMYT-based varieties. This involves continuing the earlier

TABLE 2

Cost savings from CIMMYT-based wheats, Australia (US$ million) (1983-84 values[a])

| Year | N.S.W. | Victoria | Queensland | S.A. | W.A. | Australia |
|---|---|---|---|---|---|---|
| 1974 | 3 | – | [c] | – | – | 3 |
| 1975 | 11 | [c] | 1 | [c] | – | 13 |
| 1976 | 19 | 3 | 3 | 1 | – | 26 |
| 1977 | 25 | 6 | 3 | 1 | [c] | 35 |
| 1978 | 63 | 16 | 14 | 4 | 1 | 98 |
| 1979 | 72 | 22 | 10 | 8 | 1 | 113 |
| 1980 | 33 | 21 | 6 | 6 | 2 | 68 |
| 1981 | 65 | 20 | 17 | 6 | 2 | 111 |
| 1982 | 16 | 3 | 8 | 3 | 3 | 34 |
| 1983 | 83 | 29 | 19 | 10 | 2 | 142 |
| Total[b] | 458 | 139 | 92 | 45 | 12 | 747 |

[a]Converted to US$ at the annual average rate for 1983-84 of A$1 = US$0.9056 (Bureau of Agricultural Economics, 1987, table 27).
[b]Compounded at real interest rate of 5% per annum.
[c]Less than US$0.5 million.
Source: Derived from calculations in Brennan (1986a).

assumptions that the yield advantage of CIMMYT-based varieties in trials is the same as that on farms for each state, and that there are no major interactions of these varieties with changes in inputs during the period of analysis.

On the basis of these several assumptions, the annual savings to Australian wheatgrowers are estimated (in 1983–84 US dollars) as shown in Table 2. Details of the calculations underlying these assumptions are given in Brennan (1986a). These figures show substantial savings for Australian producers. After the initial small savings during the early adoption phase, the annual savings reached US$113 million in 1979, fell to US$34 million in the drought-affected season of 1982, and increased to US$142 million in 1983. In the period 1974 to 1983, total savings in 1983–84 dollars, compounded at a real interest rate of 5% per annum, were US$747 million, or an average of US$75 million per year.

## Partitioning contributions

The savings of the CIMMYT-based varieties cannot all be attributed to CIMMYT, since many of these varieties have large inputs of germplasm and breeding, evaluation and testing resources from Australian wheat researchers. It is of interest to examine the relative contribution of the CIMMYT and Australian research programs to these cost savings.

A simplified partitioning of CIMMYT and non-CIMMYT savings uses the pedigree of each variety to allocate the savings for each according to the origins

TABLE 3

Contribution of CIMMYT to cost savings from CIMMYT-based varieties (US$ million) (1983-84 values[a])

| Year | N.S.W. | Victoria | Queensland | S.A. | W.A. | Australia |
|---|---|---|---|---|---|---|
| 1974 | 2 | – | [c] | – | – | 2 |
| 1975 | 11 | [c] | 1 | [c] | – | 12 |
| 1976 | 18 | 3 | 3 | 1 | – | 25 |
| 1977 | 21 | 5 | 3 | 1 | [c] | 30 |
| 1978 | 47 | 14 | 10 | 4 | 1 | 76 |
| 1979 | 49 | 19 | 4 | 7 | 1 | 80 |
| 1980 | 21 | 18 | 1 | 6 | 1 | 48 |
| 1981 | 42 | 18 | 3 | 5 | 1 | 69 |
| 1982 | 7 | 3 | 1 | 2 | 2 | 15 |
| 1983 | 28 | 26 | 3 | 7 | 1 | 66 |
| Total[b] | 295 | 124 | 36 | 38 | 7 | 502 |

[a]Converted to US$ at the annual average rate for 1983-84 of A$1 = US$0.9056 (Bureau of Agricultural Economics, 1987, table 27).
[b]Compounded at a real interest rate of 5% per annum.
[c]Less than US$0.5 million.
Source: Derived from calculations in Brennan (1986a).

of its parents (see Brennan, 1986a, for more details). Thus a variety which is a direct cross between a CIMMYT line and an Australian line has 50% of its saving attributed to CIMMYT. A variety which is the product of a cross between two CIMMYT lines is allocated 100% to CIMMYT, even though the crossing, selection, evaluation and testing were all carried out in Australia.

Such an allocation is arbitrary, and understates the value added by the Australian researchers in testing and release of the varieties. Nevertheless, calculations have been carried out on this basis to provide an indication of the contribution of CIMMYT to the impact of CIMMYT-based varieties in Australia (Brennan, 1986a). The weighted average of the contribution of CIMMYT peaked at US$80 million in 1980 (Table 3) and declined to US$66 million (or 46% of the contribution of CIMMYT-based varieties) by 1983 as the varieties grown in Australia moved further away from the original material imported from CIMMYT. The CIMMYT contribution averaged approximately US$50 million per year, or 67% of the total cost savings from CIMMYT-based varieties over the period 1974 to 1983 (Table 3). Although this analysis is no more than indicative, the CIMMYT program appears to have made a substantial direct and indirect contribution to Australian wheat production, mainly through the use of CIMMYT lines as parents. Subsequently, the new varieties have been used as parents in further Australian-developed varieties.

Therefore, overall, approximately two-thirds of the supply shift due to CIMMYT-based varieties could be attributed to CIMMYT and one-third to Australian breeders. This reduces the direct cost savings to 2.3%, rather than 3.5% estimated above for the CIMMYT-based varieties as a whole.

## Conclusions

While the aims of the Rockefeller/CIMMYT programs may not have always appeared to be to the direct benefit of Australian producers, there is evidence that Australian producers have received important cost savings from the programs in terms of increased yields. These savings appear to far outweigh the contribution of the Australian Government to CIMMYT. Since 1977, Australia has contributed an average of some US$2.8 million per year to core programs of the Consulative Group in International Agricultural Research Center. Of this, some 12% has gone to CIMMYT and no more than one-half of that support went to its wheat program (J.R. Anderson, personal communication, 1986). Thus on an annual outlay of some US$340,000, Australia has received overall cost reductions averaging some US$75 million per year resulting from improved wheat varieties derived from CIMMYT. This compares with an average annual expenditure on wheat breeding in Australia of US$4 to 5 million (Brennan, 1986b).

These programs appear to have led to substantial supply shifts in other producing countries, which have had a negative impact on the world wheat price. Whether the net effect of these programs on Australian wheat producers is positive cannot be judged until the impact of these shifts in supply in other producing countries on the world wheat price has been identified. However, any such impacts will have been detrimental for Australian producers (countered by smaller benefits for Australian consumers), and will run counter to the effects identified in this paper.

These estimates are only an approximation, but they do reveal that there can be substantial spillover effects from international agricultural research programs in which there is free exchange of breeding material and wide access to breeding nurseries. If Australian production has not significantly affected world prices, then these spillover effects will not have reduced the benefits for producers in the regions targeted by the international programs. On the other hand, if the export elasticity for Australian wheat was finite, the spillover of these varieties into Australia will have resulted in a fall in world price, thus transferring some of the benefits from the producers to world wheat consumers.

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