# CIMMYT CONTRIBUTIONS TO NEW ZEALAND WHEAT AND MAIZE IMPROVEMENT

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## ABSTRACT

CIMMYT, the International Maize and Wheat Improvement Centre, has conducted successful wheat and maize improvement programmes for many years. New Zealand wheat and maize breeders have collaborated with CIMMYT since the 1960s, and CIMMYT germplasm has been important in the New Zealand wheat industry since 1972. In this article CIMMYT is described, the role of CIMMYT germplasm in wheat and maize breeding in New Zealand is reviewed, and an estimate is made of the monetary benefit received by New Zealand from the increased yield of CIMMYT material. The value of international collaboration, even to countries not designated as target regions, is demonstrated.

Old Chinese proverb - "By taking food from others one can eat for only one day. By learning how to grow crops one can eat every day."

***Additional key words:** wheat,* Triticum aestivum, *maize,* Zea mays, *economic impact, CIMMYT, yield improvement*

## INTRODUCTION

The name CIMMYT is the Spanish acronym for *Centro Internacional de Mejoramiento de Maiz y Trigo*, which translates to the International Maize and Wheat Improvement Centre. The centre is an autonomous, internationally funded, non-profit making scientific and training organisation with its headquarters in Mexico (Figure 1).

CIMMYT is engaged in a worldwide improvement programme for maize, wheat, triticale and until recently, barley, with emphasis on developing countries.

CIMMYT maintains offices in 17 other locations around the developing world (Figure 2) and provides various forms of support to national maize and wheat research programmes in over 100 developing countries.

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## CIMMYT STRUCTURE AND FUNDING

CIMMYT is one of 13 non-profit international agricultural research and training centres supported by the Consultative Group on International Agricultural Research (CGIAR) which is sponsored by the Food and Agriculture Organisation (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank) and the United Nations Development Programme (UNDP).

Donors to the system are a combined group of 30 countries, international and regional organisations and private foundations that support international agricultural research on the food production problems of the developing world.

CIMMYT's donors now include (in addition to its original benefactors, the Ford and Rockefeller Foundations) the international aid agencies of 22 countries, the European Economic Commission, Inter-

American Development Bank, International Development Research Centre, OPEC Fund for International Development, UNDP and the World Bank. New Zealand does not contribute financially to CIMMYT.

## THE CIMMYT MAIZE AND WHEAT PROGRAMMES

Germplasm development is central to CIMMYT's operations.

The wheat programme utilises the high-altitude El Batán and Toluca stations near Mexico City during the summer (wet) season and the lowland CIANO station near Ciudad Obregon in northwestern Mexico in the winter season (Figure 2). This enables the programme to produce two crops per year and so halve the time it normally takes to develop usable germplasm. These three sites also expose wheat lines in the programme to two different environments, with different pests, diseases, and abiotic stresses.

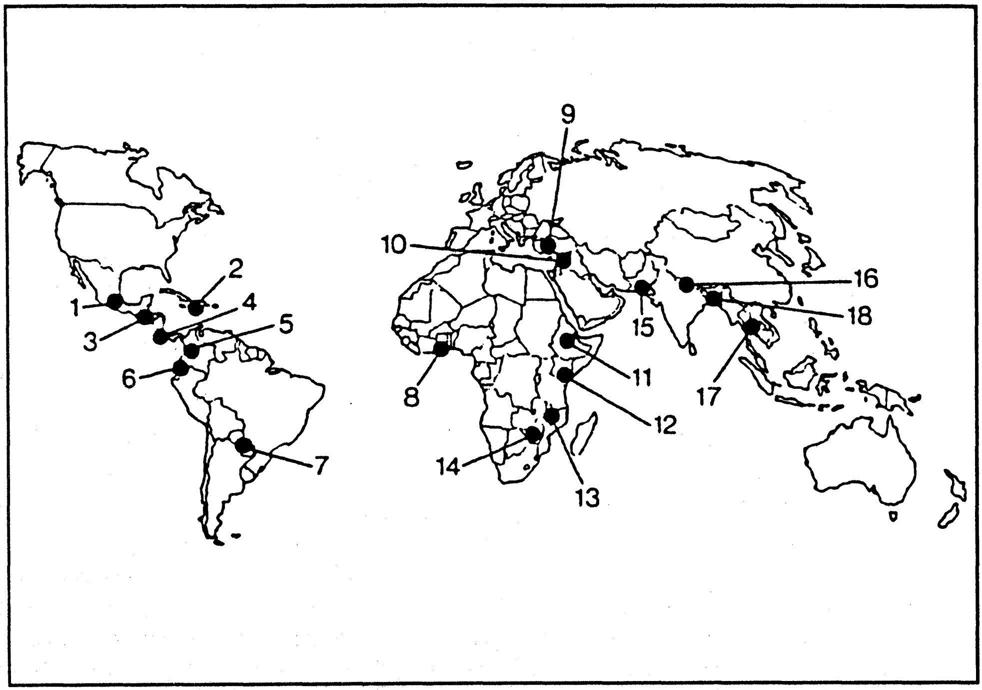


**Figure 1.** **International locations at which CIMMYT staff are based. (1, El Batán, Mexico; 2 Les Cayes, Hati; 3, Guatemala City, Guatemala; 4, San José, Costa Rica; 5, Cali, Colombia; 6, Quito, Ecuador; 7, Asunción, Paraguay; 8, Kumasi, Ghana; 9, Ankara, Turkey; 10, Aleppo, Syria; 11, Addis Ababa, Ethiopia; 12, Nairobi, Kenya; 13, Lilongwe, Malawi; 14, Harare, Zimbabwe; 15, Islamabad, Pakistan; 16, Kathmandu, Nepal; 17, Bangkok, Thailand; 18, Dhaka Bangladesh.)**

The major objective of the maize programme is to develop germplasm for developing countries in the tropics. The programme of greatest interest to New Zealand is the highland programme, which develops germplasm for cool, highland regions of the tropics. The highland programme utilised the El Batán and Toluca sites for selection. El Batán has a growing season with temperatures similar to those of Palmerston North.

Both the maize and wheat programmes make thousands of crosses in Mexico each season. Lines derived from these crosses are tested for their yield potential, resistance to a wide range of diseases and pests, tolerance to environmental stress and

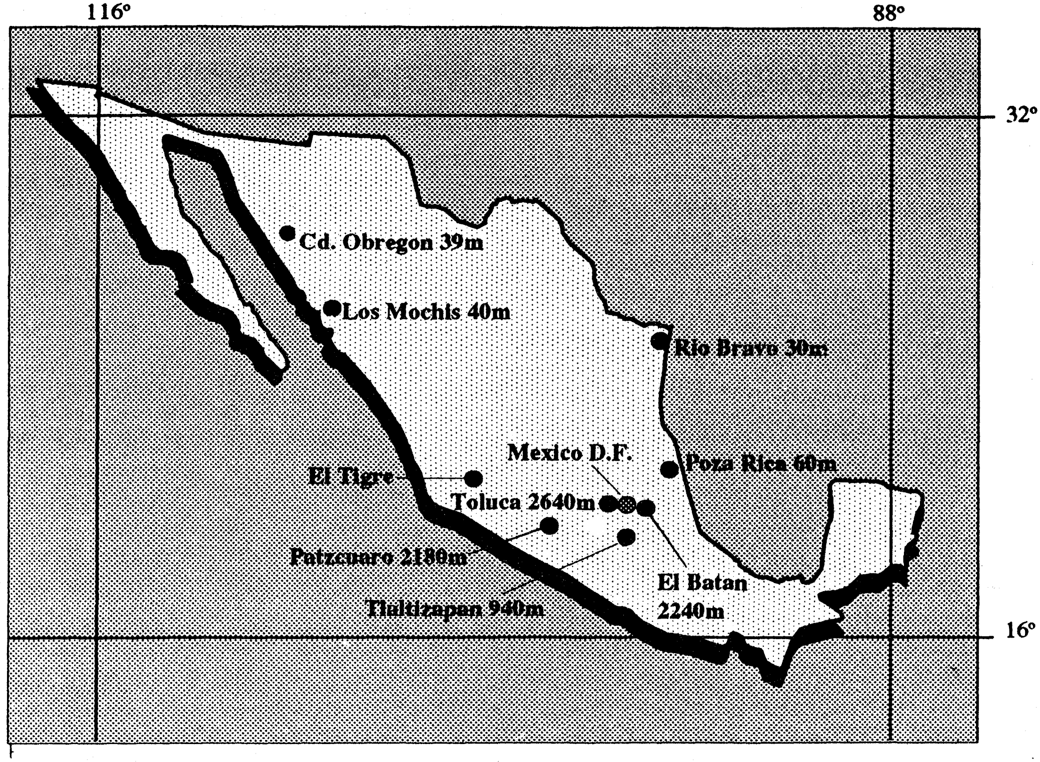


**Figure 2.** **The location and elevation of CIMMYT experimental stations in Mexico.**

nutritional quality. Through international collaborative networks, CIMMYT tests and distributes promising lines and varieties in many environments throughout the world. This provides a unique capability to identify cultivars with wide adaptation and resistance to many pests and diseases.

International collaboration also enables CIMMYT to identify new sources of germplasm, especially with new forms of disease resistance, and to rapidly utilise and distribute these new germplasm resources.

The continuing success of CIMMYT and its predecessor organisation in Mexico (the Office of Special Studies) dates from the 1950's. During the 1960's CIMMYT released wheat cultivars which spread rapidly throughout the world and were an important factor in the phenomenon later called the *Green Revolution.* For this activity a CIMMYT wheat breeder, Dr Norman Borlaug, received the Nobel Peace Prize in 1970.

Today, CIMMYT-derived semi-dwarf spring wheat cultivars are grown on 60 million ha, 45 million ha in developing countries and 15 million in developed countries. CIMMYT-derived maize cultivars are grown on 9 million ha in the developing world or 11% of the total area devoted to maize in those countries.

Because maize is out-crossing and the small-scale cultivation methods used in most developing countries, the contribution of CIMMYT germplasm for maize is probably underestimated.

## NEW ZEALAND AND THE CIMMYT PROGRAMMES

New Zealand as part of the CIMMYT international testing programme, has received wheat germplasm since the 1960s, and maize germplasm since the 1970s.

There are often spillover benefits from research in the CGIAR centres back to the donor countries. For example, even though the objective of the CIMMYT wheat programme in Mexico has been to develop lines suitable for developing countries (CIMMYT, 1984) average annual benefits to Australia of $US75 million per year have been identified (Brennan, 1989). CIMMYT's research and germplasm development has also had an impact on New Zealand.

In the remainder of this paper we review the role of CIMMYT wheat and maize germplasm in New Zealand and estimate the economic impact of CIMMYT on wheat production in that country. For convenience, a wheat cultivar with germplasm from CIMMYT is called a CIMMYT-based cultivar , whether the contribution of CIMMYT to its total genetic make-up has been large or small. In addition to estimating the total benefits from CIMMYT cultivars, a partition is made of the respective contributions of CIMMYT and local breeding programmes.

## USE OF CIMMYT WHEAT IN NEW ZEALAND

Semi-dwarf wheats from CIMMYT's predecessor organisation in Mexico were first tested in New Zealand in 1962. These were introduced by Dr A.T. Pugsley of Wagga Wagga Research Station, NSW, Australia while he was a visiting scientist at Crop Research Division (CRD), DSIR, Lincoln.

When a spring wheat breeding programme was initiated by CRD in the North Island in 1966, collaboration with CIMMYT became an integral part of the programme, and CIMMYT collaborative nurseries and trials have been regularly grown by the Palmerston North programme since that time.

In 1979, a second CRD spring wheat breeding programme was begun in the South Island at Lincoln and has similarly used the CIMMYT nurseries as an important source of germplasm. These collaborative nurseries and trials provided CIMMYT with further locations in its worldwide network and provided New Zealand wheat breeders with access to CIMMYT germplasm.

The first important New Zealand wheat cultivar derived from CIMMYT germplasm, Karamu (Table 1), was released in New Zealand in 1972 (McEwan et al., 1972), with an improved strain uniformly resistant to leaf rust released in 1976 (Wright, 1983).

Karamu was selected from the CIMMYT cross II8739, which also produced cultivars released in the USA, Algeria, Sudan, Iran, Chile and South Africa. The line from which Karamu was derived was tested in Australia as WW15, a sample of which was furnished to CRD in 1968. In Australia it was high yielding and showed good resistance to diseases, but because of red grain was unacceptable to the Australian wheat industry. However, WW15 was used extensively in Australian wheat breeding and many important Australian cultivars where derived from crosses with it (Syme 1983; Brennan 1986).

**Table 1. Wheat and Triticale cultivar with CIMMYT germplasm released in New Zealand**

| Cultivar | Year of release | % CIMMYT Germplasm | Type |
|---|---|---|---|
| Karamu | 1972 | 100 | Spring bread wheat |
| Rongotea | 1979 | 50 | Spring bread wheat |
| Oroua | 1979 | 50 | Spring bread wheat |
| Tiritea | 1981 | 50 | Spring bread wheat |
| Tara | 1983 | 100 | Durum wheat |
| Aranui | 1984 | 100 | Triticale |
| Karere | 1984 | 100 | Triticale |
| Otane | 1985 | 100 | Spring bread wheat |

Karamu is an early maturing, high yielding, spring wheat with short straw characteristic of CIMMYT semi-dwarf lines. It has red grain, and like most red-grained wheat lines, it has some seed dormancy and shows good resistance to pre-harvest sprouting. At the time of its release, Karamu was resistant to stem rust, had a mixed reaction to leaf rust and was moderately susceptible to powdery mildew. However, races of stem and leaf rust capable of infecting Karamu were present in New Zealand by 1981 (Burnett & McEwan 1983; Griffin & Worsnop 1986). Barley yellow dwarf is an important disease of cereals in New Zealand (Smith 1963). Karamu has shown significant levels of tolerance to barley yellow dwarf virus (Qualset et al. 1973; McEwan 1984), which probably contributed to its success in New Zealand.

Karamu rapidly became an important cultivar in New Zealand and accounted for nearly 30% of wheat production for several years. The decline in area grown is attributed to variable bread-baking quality of the grain (Douglas 1987, Douglas et al. 1988). It is still grown on a small area for making biscuits.

Two new cultivars containing CIMMYT germplasm, Oroua and Rongotea, were released in 1979 (Table 1). These were produced by the breeding programme in Palmerston North from crosses between semi-dwarf wheat lines from CIMMYT and conventional tall wheat lines with good baking quality (McEwan & Vizer 1979). Tiritea, a cultivar with the same pedigree as Rongotea (McEwan 1983), was released in 1981 (Table 1) but was only well suited to the southern area of the South Island. Cultivars with CIMMYT germplasm accounted for between 44% and 79% of New Zealand's wheat production between 1981 and 1986 (Table 2).

The most recent release from CIMMYT germplasm is the cultivar Otane (Table 1). New Zealand wheat breeders selected this cultivar from CIMMYT cross CM8327, which also produced a cultivar released in Chile. At the time of its release, it was resistant to most diseases, including stripe rust, which had reached New Zealand by 1980 and had rapidly become an important factor in wheat production (Wright & Wright 1983; Griffin & Worsnop 1986). Since then, Otane has become an important wheat in New Zealand, presently accounting for around 75% of the total production. It is notable for good bread-baking quality.

The continuing importance of CIMMYT germplasm to the CRD spring wheat programmes is emphasised by the entries in CRD's 1989/90 regional spring wheat trials. Of the 17 lines in the trials, 12 have 50% or greater CIMMYT germplasm in their pedigrees, three have 25% and only two have no CIMMYT germplasm.

**Table 2: Percentage of New Zealand wheat area sown to CIMMYT-based cultivars, 1973-1986**

| Year | Karamu % | Rongotea % | Oroua % | Tiritea % | Total % |
|---|---|---|---|---|---|
| 1973 | - | - | - | - | 0.0 |
| 1974 | 3.0 | - | - | - | 3.0 |
| 1975 | 11.0 | - | - | - | 11.0 |
| 1976 | 24.6 | - | - | - | 24.6 |
| 1977 | 24.1 | - | - | - | 24.1 |
| 1978 | 21.4 | - | - | - | 21.4 |
| 1979 | 25.8 | - | - | - | 25.8 |
| 1980 | 16.0 | - | - | - | 16.0 |
| 1981 | 9.5 | 25.3 | 9.1 | - | 43.9 |
| 1982 | 10.6 | 29.3 | 7.8 | - | 47.7 |
| 1983 | 14.1 | 24.1 | 17.7 | - | 55.9 |
| 1984 | 14.9 | 40.4 | 13.4 | - | 68.7 |
| 1985 | 14.1 | 42.7 | 17.7 | - | 74.5 |
| 1986 | 1.0 | 43.0 | 34.0 | 1.0 | 79.0 |

CIMMYT has also been an important germplasm source for the development of durum wheat and triticale cultivars (Table 1). Currently, the cultivar Tara occupies almost all the durum wheat area in New Zealand and Aranui occupies approximately 35% of the area sown to triticale. A new durum cultivar, Waitohi, derived from CIMMYT cross CD31119, is due for commercial release in 1989 and is expected to largely replace Tara.

Through collaborative nurseries, New Zealand has provided information of benefit to CIMMYT. Of particular importance has been the information on barley yellow dwarf virus resistance in wheat and triticale, which has assisted CIMMYT to identify germplasm sources with resistance to this disease (CIMMYT 1977; 1979; Burnett & Klatt 1986).

## THE VALUE OF YIELD INCREASES FROM CIMMYT WHEATS IN NEW ZEALAND

In 1987 the New Zealand wheat industry was deregulated and the New Zealand Wheat Board which previously had statutory control over the buying and selling of wheat and flour, was abolished. Since 1987 the processing industries have been free to buy wheat from whatever source they choose, within New Zealand or from outside, at whatever quality specification they decide upon and at whatever price they can negotiate. Quality has become the predominant factor in new cultivar releases, with increased disease resistance allowing reduced chemical inputs also an important consideration. Yield is now very much a secondary factor, although very important in determining the overall economics of wheat production.

The following economic analysis is based solely upon a consideration of yield and on cultivars released prior to deregulation. The latest cultivar considered, Otane, was released in 1985 when deregulation and thus quality factors looked likely to become more important. Otane has gone on to become the best quality New Zealand wheat ever grown (Wheat Research Institute, pers. comm.). It would still be valid to use yield to measure the impact of new wheats in New Zealand now, but this would have to be within quality or end-use categories. An economic analysis of the significant quality improvements and other factors such as disease resistance has not been attempted. Thus the authors do not claim a comprehensive assessment of economic impact.

The measurement of the impact of new cultivars on farm yields ideally would be determined in conjunction with the impact of other input changes using production functions (Godden 1987). In practice, the lack of available data often prevents the use of detailed production functions. As a simplification, an index of varietal improvement, or relative yield index (Silvey 1981, Brennan 1984), can be calculated. The index combines data on cultivar yields with data on the area sown to each cultivar to provide a measure of their relative contribution to increasing yields. Godden (1987) has pointed out that indices of varietal improvement are a biased estimate of genetic improvement unless there is no interaction between cultivars and other inputs. Because of lack of data on this interaction, the extent of this bias in the analysis presented here is unknown. If, however, it is reasonable to assume that the impact of improved agronomic practices is uniform across all new cultivars, the bias will not be a major problem.

The index of varietal improvement used here is:

$$(1) \quad I_t = 100 + (V_{Ct} P_{Ct})/100$$

where $I_t$ is the index in year t; $V_{Ct}$ is the percentage yield advantage of CIMMYT-based cultivars over non-CIMMYT cultivars in year t; and $P_{Ct}$ is the proportion of the area sown to CIMMYT- based cultivars in year t.

Data are available in New Zealand on the yield of individual cultivars from the New Zealand Department of Statistics annual survey of wheat-growing districts up to 1986. The weighted average yields of CIMMYT-based cultivars (weighted by the proportion of the area sown to each cultivar) are then compared to the average of the non-CIMMYT cultivars (Table 3). The yield advantage varied from year to year, ranging from 10.15% in 1986 to a yield disadvantage for CIMMYT-based cultivars of 7.55% in 1982; the mean over the whole period was 1.28%.

**Table 3: Yield advantage of CIMMYT-based cultivars.**

| Year | CIMMYT yield[a] (t/ha) | Other yield[a] (t/ha) | CIMMYT advantage (%) |
|---|---|---|---|
| 1974 | - | 3.18 | - |
| 1975 | - | 3.12 | - |
| 1976 | 3.80 | 3.73 | 1.88 |
| 1977 | 3.74 | 3.66 | 2.19 |
| 1978 | 3.62 | 3.61 | 0.28 |
| 1979 | 3.58 | 3.32 | 7.83 |
| 1980 | 3.50 | 3.57 | -1.96 |
| 1981 | 4.01 | 3.94 | 1.78 |
| 1982 | 3.92 | 4.24 | -7.55 |
| 1983 | 4.25 | 4.23 | 0.47 |
| 1984 | 4.63 | 4.47 | 3.58 |
| 1985 | 4.26 | 4.46 | -4.48 |
| 1986 | 4.34 | 3.94 | 10.15 |
| Mean | 3.97 | 3.92 | 1.28 |

a: Weighed average yield of varieties using data on area and yield of individual varieties.

The index of varietal improvement can be calculated using the data from Tables 2 and 3 in equation (1). The form of the index in equation (1) implies that yield advantage over non- CIMMYT cultivars in 1976, and were grown on 24.6% of the area in that year. Thus, the increase in the index in that year was 1.88% of 24.6% or 0.46%. For the period 1974 to 1986, the index showed a mean increase of 0.62%, while in the four most recent years the mean increase was 1.85%.

**Table 4: Calculation of Index of Varietal Improvement**

| Year | CIMMYT % yield advantage | Percentage CIMMYT area | Index | Total production (%)(000 t) | Increased production (t) |
|---|---|---|---|---|---|
| 1974 | 1.28[a] | 3.0 | 100.04 | 214.6 | 86 |
| 1975 | 1.28[a] | 11.0 | 100.14 | 179.9 | 251 |
| 1976 | 1.88 | 24.6 | 100.46 | 388.2 | 1777 |
| 1977 | 2.19 | 24.1 | 100.53 | 354.0 | 1866 |
| 1978 | 0.28 | 21.4 | 100.06 | 328.7 | 197 |
| 1979 | 7.83 | 25.8 | 102.02 | 295.0 | 5841 |
| 1980 | -1.96 | 16.0 | 99.69 | 305.7 | -951 |
| 1981 | 1.78 | 43.9 | 100.78 | 325.7 | 2521 |
| 1982 | -7.55 | 47.7 | 96.40 | 292.0 | -10905 |
| 1983 | 0.47 | 55.9 | 100.26 | 300.8 | 780 |
| 1984 | 3.58 | 68.7 | 102.46 | 314.6 | 7553 |
| 1985 | -4.48 | 74.5 | 96.66 | 309.6 | -10698 |
| 1986 | 10.15 | 79.0 | 108.02 | 379.7 | 28191 |
| Total | | | | | 26509 |

a: mean overall CIMMYT yield advantage, used because no yield information for Karamu in 1974 or 1975 (see Table 3).

The yield contribution of CIMMYT-based cultivars to increases in production can be estimated from these indexes, if it is assumed that the new cultivars do not interact with other inputs. On this basis, the percentage increase in the index of varietal improvement can be taken as the percentage increase in production attributable to CIMMYT-based cultivars. Thus an increase of 10% in the index means that production was 10% higher than it would have been without CIMMYT-based cultivars, so that 9.1% of the production (10/110) in that year can be attributed to them. The estimated total extra production attributable to CIMMYT cultivars was 26,509 t, or an average of 2,039 t per year between 1974 and 1986 (Table 4).

In estimating total yield benefits, the extra production is valued at the 1988 price in New Zealand of $NZ260/t. The results show that the total benefits of the CIMMYT-based cultivars in New Zealand (at 1988 prices) are $6.9 million (Table 5), or an average of $530,000 per year between 1974 and 1986.

The benefits of CIMMYT-based cultivars cannot all be attributed to CIMMYT, since some of the cultivars have large inputs of germplasm and breeding, evaluation and testing resources from the New Zealand programme. A simplified partitioning uses the pedigree of each cultivar and allocates the benefits from each according to the origins of its parents (Brennan 1989). Where a cultivar such as Karamu has 100% of its parentage in CIMMYT, all the benefits of that cultivar are attributed to CIMMYT. However, where the cultivar is the result of a cross between a CIMMYT line and another line (Rongotea, Oroua and Tiritea), then 50% of its benefits are attributable to CIMMYT and 50% to the local programme.

Using this partitioning, the analysis of monetary benefits was re-worked in order to identify the CIMMYT contribution to those benefits. The benefits in 1988 prices attributable to CIMMYT averaged $NZ338,000 per year, or approximately 64% of the total benefits of the cultivars.

**Table 5.** **Value of benefits of CIMMYT-based cultivars**

| Year | Increased production (t) | Total extra value[a] (1988 values) ($NZ000) | Extra value Aattributed to CIMMYT ($NZ000) |
|---|---|---|---|
| 1974 | 86 | 22 | 22 |
| 1975 | 251 | 65 | 65 |
| 1976 | 1777 | 462 | 462 |
| 1977 | 1866 | 485 | 485 |
| 1978 | 197 | 51 | 51 |
| 1979 | 5841 | 1519 | 1519 |
| 1980 | -951 | -247 | -247 |
| 1981 | 2521 | 655 | 400 |
| 1982 | -10905 | -2835 | -1729 |
| 1983 | 780 | 203 | 127 |
| 1984 | 7553 | 1964 | 1198 |
| 1985 | -10698 | -2781 | -1655 |
| 1986 | 28191 | 7330 | 3702 |
| Total | 26509 | 6893 | 4400 |
| Mean | 2039 | 530 | 338 |

a: Based on 1988 price of $NZ260/t.

## THE USE OF CIMMYT MAIZE IN NEW ZEALAND

Until recent years, the CIMMYT maize programme developed only open-pollinated cultivars of the type required by many developing countries in the tropics. Cultivars of maize recently used in New Zealand are all hybrids, produced from inbred lines. Nevertheless, CIMMYT germplasm has been important in the DSIR maize breeding programme at Palmerston North.

The most important CIMMYT germplasm resource for the DSIR programme has been the Highland Early Yellow Dent population (old Pool 5). This population, introduced into New Zealand in 1976, was developed for highland regions of the tropics, especially regions with mean growing season temperatures of less than 17øC. In New Zealand, old Pool 5 silked at the same time as adapted hybrid cultivars and showed outstanding resistance to low temperatures and foliar diseases. An inbred line, NZ1A, developed from this population, has been used extensively in planned crosses to develop lines adapted to the cool New Zealand environment (Eagles & Hardacre 1985). Advanced lines developed using NZ1A are currently being tested for commercial release.

Some inbred lines selected in New Zealand from old Pool 5 have been of value to CIMMYT's highland programme (Lothrop pers. comm.). Especially, some of these lines have contributed to experimental, open-pollinate varieties, which are currently being tested for release in cool areas of developing countries.

Since 1985, CIMMYT has been developing inbred lines in addition to open-pollinated varieties. Already, partially inbred lines have been developed from highland tropical germplasm of the type required for New Zealand conditions. We anticipate that inbred lines developed from this germplasm will be an important resource for maize breeding in New Zealand.

## CONCLUSIONS

CIMMYT has been successful in assisting the Third World to develop high yielding wheat and maize lines. It has also provided useful germplasm for developed countries. In New Zealand, this germplasm has been useful because of the existence of strong plant breeding programmes capable of evaluating CIMMYT germplasm and selecting lines and populations adapted to local conditions.

The CIMMYT wheat breeding programme in Mexico has led to large increases in wheat yields in many countries throughout the world (CIMMYT 1989). New Zealand has been importing germplasm from this programme since the 1960s. Some selected lines have been released directly for commercial cultivation, and several other important New Zealand cultivars have been based on the material imported from CIMMYT.

From this analysis of the impact of the yield increase CIMMYT wheats on New Zealand wheat production, CIMMYT's wheat programme has made a significant contribution to the value of the New Zealand wheat crop, both directly through its own lines and indirectly through the use of CIMMYT lines as parents. A substantial increase in agronomic merit and quality is also apparent but not measured here. Future decisions on whether New Zealand should support the CGIAR system should take into account the benefits that New

Zealand has received, and will continue to receive, from the system of international agricultural research.

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