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FARMING FOR THE FUTURE

Alberta AGRICULTURE

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Evaluation Of Alberta Agriculture's Farming For The Future Program

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Abstract

This evaluation of the Farming for the Future program sought to measure the benefits and costs of the program to Alberta. The costs have been straightforward: The Government of Alberta transferred $65 million from the Alberta Heritage Trust Fund to the program. Farming for the Future has awarded $55.6 million in research grants, $3.8 million for demonstration projects up to April 1991 and an additional $600,000 for 1991-92 awards. Most of the remainder financed conferences, publications, and other means of dispensing information. A small amount has been used to help administer the program, but most of the administrative costs have been borne by Alberta Agriculture.

The benefits of the program are many and diverse, some are direct and easy to specify and some are indirect and intangible. Grants have supported 684 research projects involving some 300 scientists. The funding has enabled researchers to carry on valuable work that could not have been done as well or as completely without the support. Research funds from Farming for the Future have supported at least 137 graduate students. Many of them have graduated and gone on to do scientific research on their own. The training provided to these young scientists is an invaluable part of the accomplishments of the Farming for the Future program.

A survey of previous studies of returns to investments in agricultural research suggested that on average an annual return of about 50% can be expected. These benefits begin after a lag of about five years between completion of the research and adoption by farmers (or processors as the case may be), and they continue for twenty-five years or more. My best estimate is that the full benefits from the $55.6 million granted for research are about $28 million per year in current dollars or $37.5 million per year in 1991 dollars. The aggregate returns assuming a 25-year life span will be $695 million in current dollars. They have a present value of $307 million using a 5% discount rate. The values would be 35% higher, $939 million and $415 million respectively, in 1991 dollar terms. They would be considerably greater based on the full cost input to the research. Few if any private business ventures earn such handsome returns. Few public investments, except education, are likely to yield such returns.

The Farming for the Future program has proven itself as one of the best possible ways to benefit the farmers and consumers of Alberta. Its continuation will enable farmers to continue increasing their productivity and to maintain and perhaps improve their competitive standing in world and domestic markets. The results of this study provide strong arguments for the continued support of the program. Inflation alone would require a doubling of the level of funding from $5 million to $10 million per year just to maintain 1979 purchasing power. Taking full advantage of the availability of research personnel and facilities in Alberta would require an additional 33% to 50% increase in funding.

Chapter I. Origins of Agricultural Science

People had practised agriculture some 10,000 years before scientists became concerned with farming problems. However, much progress was made during that time, although slowly and in very small steps. In a paper given in Lethbridge a few years ago, T. W. Schultz said "Whereas Neolithic women invented agriculture and invented many of the food crop species that we have today, our highly skilled plant breeders with all their fancy theories and large expenditures on research have produced only one new food species, triticale."[1] To be fair, however, Neolithic farmers took several thousand years to develop their crops, while modern scientists have been engaged in crop breeding only a few decades. Notably, Manitoba scientists invented triticale. Also notable is the fact that plant breeders in Canada and other countries have developed most of the crop varieties grown in Canada.

A. Agricultural Science in Europe

1. Before 1700

Discovery is essential to progress. Before the eighteenth century, discovery resulted almost entirely from the efforts of inventive artisans and observant planters as well as from sheer accident. Farmers knew that manuring usually increased yields and that seeds from better plants usually reproduced better plants, but no one understood why. While new discoveries could be seen to work, few understood why they worked. Consequently, further improvements often followed slowly if at all. The situation was confused by beliefs in magic, superstition, and erroneous "scientific" theories.

If science is defined as an organized and structured search for knowledge, one may justifiably say that agricultural science began with Sir Francis Bacon about 1620. Bacon studied the effects of various agents (such as dung, marl, lime, sand, ashes, etc.) on the germination and growth of wheat. He was aware of the value of saltpetre (nitre: potassium nitrate or sodium nitrate) as a fertilizer. The low state of scientific knowledge of his time clouded his understanding, despite his strong belief that scientists should put aside all theories and presumptions and deal strictly with the facts.

2. During The Eighteenth Century

Landowners were responsible for most of the agricultural progress in the eighteenth century. Farmers began to raise crucial questions. Why do some soils wear out? Why do some rotations improve subsequent yields more than others? What are the roles of humus, manures, and tillage in plant nutrition? Most of the questions raised for study concerned chemistry. Many of the leading British farmers experimented with soils, crops, rotations, and various soil amendments. They kept records that they analyzed and, in some cases, they published the results.

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[1] Theodore W. Schultz. 1985. "Agricultural research: Canada and beyond." In *Economics of Agricultural Research in Canada*. Edited by W. W. Klein and W. H. Furtan. The University of Calgary Press. p. 13.

Several people (including Jethro Tull, Joseph Black, Joseph Priestly, Antoine Lavoisier, and Erasmus Darwin) made significant contributions to scientific knowledge of agriculture. However, the state of science in the eighteenth century was so limited that it greatly inhibited progress. Scientists still believed in the ancient notions of four basic elements (earth, air, water, and fire), transmutation, phlogiston, and the ether. Such theories seriously retarded the search for an understanding of plant nutrition. Nevertheless, they did progress although slowly. Priestly discovered oxygen and several other gases. He studied the carbon/oxygen cycle in plants and animals. Lavoisier overthrew some of the older theories and thus facilitated further progress in science. Erasmus Darwin seems to have been the first British scientist to realize that nitrogen and phosphorus are essential to plant growth. Perhaps the greatest contribution of these scientists was the laying of the groundwork for those who followed.

3. During The Nineteenth Century

The nineteenth century brought much enlightenment in science. Chemistry in particular advanced remarkably, and scientists applied much of it to agriculture. A number of scientists (notably Humphrey Davy, Charles Daubney, John Lawes, Justus Liebig, and Joseph Gilbert) contributed to the advancement of agricultural science. They discovered the roles of various elements and compounds in plant nutrition, and they rejected many of the older false notions about plant growth.

John Bennet Lawes was born at Rothamsted in 1814; the Rothamsted manor goes back to 1212, and farmers occupied the area as early as the first century A.D. Lawes spent two years at Oxford, then returned to manage the home farm. He established a chemistry laboratory and began to analyze medicinal plants. Then, he became interested in plant nutrition, particularly in the plants' source of nitrogen in the soil. In studying the effects of bone meal on various soils, he discovered that acid made the phosphate soluble. He obtained a patent for making superphosphate and built a factory to produce it in 1842.

Justus Liebig (1803-73) was a professor of chemistry at Giessen University from 1824 to 1853 and at the University of Munich from 1853 to 1873. Some scientists acclaimed his book, *Organic Chemistry in its Application to Agriculture and Physiology,* as the most important book ever published on the subject. Liebig was an outstanding chemist, and his work had a strong influence on agriculture. He had the most complete understanding of plant nutrition of his time, particularly of the mineral needs of plants. However, he disputed the value of organic matter, claiming that it contributed nothing to soil fertility. He believed that manure was beneficial only for its mineral constituents.

Joseph Henry Gilbert (1817-1901) studied chemistry at Glasgow University, University College in London, and the University of Giessen under Liebig. He joined Lawes at Rothamsted in 1843 and continued chemical research and directing field studies for 58 years. He and his staff pioneered in field experiments. Gilbert and Lawes challenged Liebig's "mineral theory". They found that plants obtained nitrogen from the soil or fertilizer, not from the air as Liebig thought. However, they were unable to account for the increase of nitrogen from legumes, a knowledge gap later filled by two German scientists. James Finlay Weir Johnston (1796-1855) studied at the University of Glasgow, where he received his M.A. degree. He opened a school in Durham in 1825 and, when Durham University was established in 1833, he became a reader in chemistry and mineralogy. He took an abiding interest in agriculture and worked with the Highland and Agricultural Society to encourage farmers to do experiments on their own farms. He wrote a number of books dealing with agricultural science, one of which, *Catechism of Agricultural Chemistry and Geology,* went through 33 editions and was published in several languages. His research work stressed soil analyses and the study of various manurial systems.

The many contributions to agricultural science from the Rothamsted Experiment Station are far too numerous to list much less describe. Ronald Aylmer Fisher developed the design of experiments and the concept of randomization at Rothamsted. The experiment station had a profound effect on the development of agricultural science in Britain and in North America. Great advances were made in soil science and plant nutrition, and some advances were made in animal nutrition. It led to the creation of the Agricultural Research Council, and it helped make Great Britain a world leader in agricultural research.

European contributions to agricultural science include the discovery of bacteria by Louis Pasteur in 1859-60 during his work on fermentation. This discovery enabled agricultural scientists to advance the understanding of the role of humus in plant nutrition. In 1890, Serge Winogradsky, working at the Pasteur Institute, isolated nitrifying bacteria that created nitrates in the soil. Hermann Hellriefel and Hermann Wilfarth discovered the role of nitrogen-fixing bacteria in legumes in 1886-88. The work of Charles Darwin and Gregor Mendel made possible later developments in animal and plant breeding.

B. Agricultural Science in North America

Interest in agricultural science in North America was stimulated by the problem of "worn-out" soils. Land was so freely available that many farmers simply "mined" the soil and moved on to new territory. Not only was this practice wasteful of land, but it left behind towns, markets, and people who were indirectly dependent on agriculture. As the problem grew increasingly serious, scientists devoted more effort to solving it. The work of Liebig in Germany and of various agricultural scientists in Britain became known, and several people attempted to initiate agricultural science at some American universities.

1. The United States experience

Eben Horsford of New York trained under Liebig at Giessen. Harvard University appointed him to a newly created chair in agricultural chemistry 1847. Meanwhile John Norton, a relative of Horsford, had gone to Edinburgh to work with James Johnston. He held an unpaid professorship in agricultural chemistry at Yale from 1847 until his early death in 1852. Although Horsford stressed research and Norton stressed extension, both men were tireless promoters of agricultural science.

The Morrill Act of 1862 provided for grants of federal lands to the states to create colleges to teach agriculture and the mechanic arts. Samuel Johnson of New York was a student of both Norton and Liebig, and later a professor at Yale. He led a long fight to establish agricultural science in the United States. In particular, he worked hard for twenty years to convince farmers and legislators of the need for agricultural experiment stations. He was a major force in the creation of the Connecticut Agricultural Experiment Station in 1875, the first in the United States. He later became director of the station, and he was very influential in shaping agricultural science into the twentieth century. Other states established experiment stations during the next few years, until almost every state had at least one. Several federal acts, such as the Hatch Act of 1887, provided funding to the state agricultural stations.

American agricultural researchers have made many useful contributions to the agriculture and food industries. Wilbur Atwater at Yale and later at Connecticut contributed to the beginning of the science of nutrition. Edward East and Donald Jones, working at the Connecticut Agricultural Experiment Station, developed a practical breeding method for hybrid corn.

2. The Canadian experience

The importance of agricultural science was recognized early on in Canada. The Dominion Department of Agriculture (now Agriculture Canada) was established in 1868, and the Ontario Agricultural College started operations in 1874. Nova Scotia, Quebec, and each of the four western provinces established agricultural colleges. Prince Edward Island, Quebec, Ontario, and Saskatchewan established veterinary colleges.

The Parliament of Canada passed the Experimental Farm Stations Act in 1886. The government chose William Saunders (a chemist, pharmacist, and horticulturist) to head the new Dominion Experimental Farms Service (now the Research Branch of Agriculture Canada). It began with five research stations located in Ottawa; Nappan, Nova Scotia; Indian Head, NWT (Saskatchewan); Brandon, Manitoba; and Agassiz, British Columbia. Saunders started a wheat breeding program in 1892 and his sons continued the work. Charles Saunders, building on the work of his brother, Percy Saunders, developed the Marquis variety released in 1909. Many scientists subsequently performed plant breeding work of great importance to agriculture. Barrie Campbell and his colleagues at the Winnipeg Research Station developed Neepawa and several other wheat varieties. Keith Downey of the Saskatoon Research Station helped lead the work that culminated in low-erucic acid rapeseed or canola.[2] Scientists of Agriculture Canada's Research Branch develop some 30 to 35 new varieties of agricultural crops annually.

The Rust Research Laboratory in Winnipeg helped keep the rust problem within bounds. Many research contributions have helped make dryland farming in Alberta and the other prairie provinces economically feasible. Imported science and technology can solve the unique problems of northern prairie agriculture only to a limited extent by imported science and technology. Research oriented toward Alberta conditions has been essential in making and keeping Alberta agriculture competitive with other regions. Agricultural scientists at the University of Alberta have made many important contributions to Alberta, some of which are highlighted in Chapter III.

[2] Baldur Stefansson of the University of Manitoba also contributed in a major way to the development of canola. See Chapter V.

Chapter II. Farming for the Future

Farming for the Future is a commitment by the Alberta Government of funds from the Heritage Savings Trust Fund to agricultural research to improve net farm income and the long-term viability of agriculture in Alberta.[3]

A. Origin and Early Development

In October 1977, the Honourable Marvin E. Moore, then Minister of Agriculture, announced to the Legislative Assembly "A new program called 'FARMING FOR THE FUTURE' will be introduced. It is proposed that Ten Million Dollars, over a five year period, will be provided from the Alberta Heritage Savings Trust Fund to the 'FARMING FOR THE FUTURE' program. These funds will be used for agricultural research to augment, and complement, existing programs carried out by the Government of Alberta, our universities, our Federal and private agencies." He went on to describe the administration of the program and ended by saying that "this announcement is another visible example of how funds from the Alberta Heritage Savings Trust Fund can be invested today for long term benefits tomorrow." In April 1978, the Minister announced the formation of the Agricultural Research Council of Alberta (later designated the *Farming for the Future Council)* to administer Farming for the Future. Two years later, in 1980, an additional $15,000,000 was allocated from the Heritage Trust Fund to the initial five-year term.

The mandate of Farming for the Future was focussed on two objectives:

a. improvement of the long-term viability of agriculture in Alberta, and

b. improvement of net farm income in Alberta.

The program's guidelines state that it provides financial assistance for carrying out research and demonstration projects showing promise to increase agricultural productivity and to improve the health and well-being of the agricultural industry in Alberta. Each grant proposal is judged on its significance to the agricultural industry, the soundness of the research design, the past record of the principal investigator, the competence of the researchers as demonstrated by scientific output in the previous three years, the size and cost of the project, and the institutional commitment of the applicant to complete the project.

B. Evolution of the Research Program

The Farming for the Future program received almost 500 research grant applications in its first year, full testimony to the unmet needs for research funding. The Agricultural Research Council, administered the program and awarded $2,133,680 for 54 research projects for 1979-80. They funded an additional 31 projects in the following year, and the total award for 1980-81 was $3,191,107. The Government fully recognized the need for additional funding

[3] *Farming for the Future, Terms of Reference, 1989.* Alberta Agriculture

by the time the second year awards were made, and they met that need with the additional $15,000,000 allocation. During the five years of the first term, 1979 to 1984, Farming for the Future supported 343 research and demonstration projects. In the fall of 1983, The Alberta Legislature approved a new three-year term for the program and allotted $5,000,000 for 1984-85. Each of the following two years received the same level of funding. The third term began in 1987 and will expire on March 31, 1992. The program has supported nearly 700 projects, and more than 300 scientists and 500 farmers have participated in the program. By the end of the third term, the Heritage Trust Fund will have provided $65,000,000 to the program.

The Agricultural Research Council of Alberta decided to allocate funding largely on a commodity basis, and it created eight program divisions to represent the makeup of the agricultural industry. These divisions were (1) apiculture/entomology [later crop protection and entomology], (2) forages, (3) grains and oilseeds [later cereals and oilseeds], (4) land use and soils [later land resources and engineering], (5) non-ruminants, (6) processing, transportation, and marketing [later processing and marketing], (7) ruminants, and (8) special crops. A review committee was established for each program area. A ninth division, irrigation, was added in 1982. Funding was allocated according to these divisions up to 1991 as shown in Table 2.1. For 1991-92, the last year of the current term, the structure has been overhauled and the number of divisions reduced to six.

Table 2.1. Farming for the Future Funding by Program Area

Program Area	1979-80	1980-81	1981-82	1982-83	1983-84
Cereals and Oilseeds	$576,800	$870,120	$894,880	$1,040,281	$1,951,519
Crop Protection and Entomology	180,500	304,365	343,060	359,900	409,200
Forages	413,200	672,500	703,300	974,630	935,993
Irrigation				270,000	190,735
Land Resources and Engineering	226,200	311,050	563,465	627,610	767,880
Non-Ruminant Livestock	120,460	118,750	192,000	449,900	619,500
Processing and Marketing	73,060	132,250	136,250	188,400	325,000
Ruminant Livestock	390,160	556,600	985,718	1,478,350	1,445,764
Special Crops	153,300	225,472	259,644	322,340	396,869
Total	$2,133,680	$3,191,107	$4,078,317	$5,711,411	7,042,460
Program Area	**1984-85**	**1985-86**	**1986-87**	**1987-88**	**1988-89**
Cereals and Oilseeds	$598,356	$654,392	$691,500	$507,100	$626,000
Crop Protection and Entomology	332,534	427,090	236,645	298,335	409,000
Forages	262,800	369,965	286,002	316,000	266,000
Irrigation	209,320	215,800	259,055	160,645	193,000
Land Resources and Engineering	671,166	789,281	722,593	529,000	596,000

Table 2.1. (Continued)

Program Area	1984-85	1985-86	1986-87	1987-88	1988-89
Non-Ruminant Livestock	284,421	424,178	348,415	233,381	331,000
Processing and Marketing	541,492	576,705	651,900	534,500	418,000
Ruminant Livestock	1,213,200	1,132,100	1,062,800	903,000	796,000
Special Crops	230,480	233,556	313,447	329,222	281,000
Total	$4,343,769	$4,823,067	$4,572,357	$3,811,183	3,916,000

Program Area	1989-90	1990-91	1991-92	Total
Cereals and Oilseeds	$690,000	$619,000	$887,854	$10,607,802
Crop Protection and Entomology	691,000	667,000		$4,658,629
Forages	212,000	214,000	807,642	$6,434,032
Irrigation	109,000	98,000		$1,705,555
Land Resources and Engineering	504,000	509,000	361,305	$7,178,550
Non-Ruminant Livestock	271,000	333,000	740,734	$4,466,739
Processing and Marketing	478,000	576,000	174,690	$4,806,247
Ruminant Livestock	635,000	776,500	998,046	$12,373,238
Special Crops	349,000	209,500		$3,303,830
Total	$3,939,000	$4,002,000	$3,970,271	$55,534,622

Total research funding rose from about two million dollars in 1979-80 to seven million in 1983-84, then leveled off to about four million dollars in each of the succeeding years. Cereals and oilseeds led in funding at the beginning but was soon surpassed by ruminant livestock. Over the 13-year spread of the program, ruminant livestock led with total funding of $12.3 million, followed by cereals and oilseeds with $10.6 million. Land resources and engineering ranked third with $7.2 million and forages ranked fourth with $6.4 million. Some of the totals for all years shown in the last column of Table 2.1 may be slightly misleading because of the changed distribution in the final year.

The distribution of funding by institution is shown in Table 2.2. The breakdown of funding was not available for 1979-80, but it is shown combined with 1980-81, except for the yearly totals. The largest recipients of Farming for the Future funding have been the University of Alberta with a total of $19.9 million and Agriculture Canada with $18.8 million for the 13-year period. Alberta Agriculture ranked third with $6.9 million, and private industry as a whole ranked fourth with $3.2 million. The University of Saskatchewan ranked fifth with $2.8 million, almost all of which went to the Western College of Veterinary Medicine that serves as the regional veterinary college. Funding also has gone to various other institutions in and out of Alberta. The funding of institutions outside Alberta was for projects of direct interest to Alberta agriculture.

Table 2.2. Farming for the Future Funding by Institution

Institution	1979-80	1980-81	1981-82	1982-83	1983-84
Agriculture Canada		$1,680,337	$1,077,394	$1,552,860	$2,695,617
Alberta Agriculture		927,450	769,850	1,192,380	897,315
Alberta Environment		0	0	0	0
Alberta Research Council		135,000	28,900	35,300	145,000
Olds College		0	0	0	33,100
Private Industry		181,150	199,900	139,650	198,500
Queen's University		0	50,000	47,000	41,000
University of Alberta		1,963,930	1,428,793	1,952,471	2,331,528
University of British Columbia		18,000	19,500	0	0
University of Calgary		0	0	0	0
University of Guelph		0	0	20,000	0
University of Lethbridge		0	0	0	0
University of Manitoba		70,360	67,850	68,300	29,500
University of Saskatchewan		225,260	335,130	434,450	342,700
University of Toronto		33,000	35,000	74,000	83,900
Veterinary Infect. Disease Org.		90,300	66,000	195,000	244,300
Total	$2,133,680	$3,191,107	$4,078,317	$5,711,411	7,042,460

Institution	1984-85	1985-86	1986-87	1987-88	1988-89
Agriculture Canada	$1,320,384	$1,687,538	$1,429,578	$1,495,048	$1,290,000
Alberta Agriculture	452,750	412,978	325,824	281,504	325,000
Alberta Environment	0	0	0	0	79,000
Alberta Research Council	124,350	136,468	104,500	97,000	101,000
Olds College	9,900	11,750	9,000	0	0
Private Industry	208,510	310,890	813,234	198,050	375,000
Queen's University	0	0	0	0	0
University of Alberta	1,587,634	1,857,743	1,503,931	1,345,941	1,516,000
University of British Columbia	12,984	0	0	31,440	20,000
University of Calgary	0	2,750	0	36,200	24,000
University of Guelph	0	0	0	0	0
University of Lethbridge	0	0	0	29,000	10,000
University of Manitoba	42,170	7,000	35,000	33,000	0
University of Saskatchewan	293,850	283,874	185,000	214,000	176,000
University of Toronto	58,930	0	0	0	0
Veterinary Infect. Disease Org	232,307	112,076	166,290	50,000	0
Total	$4,343,769	$4,823,067	$4,572,357	$3,811,183	3,916,000

Table 2.2. (Continued)

Institution	1989-90	1990-91	1991-92	Total
Agriculture Canada	$1,563,000	$1,498,000	$1,509,465	$18,799,221
Alberta Agriculture	416,000	512,500	376,630	$6,890,181
Alberta Environment	76,000	42,000	49,900	$246,900
Alberta Research Council	9,000	0	0	$916,518
Olds College	0	0	0	$63,750
Private Industry	221,000	241,000	120,900	$3,207,784
Queen's University	0	0	0	$138,000
University of Alberta	1,413,000	1,529,500	1,482,367	$19,912,838
University of British Columbia	0	0	0	$101,924
University of Calgary	0	0	0	$62,950
University of Guelph	0	0	0	$20,000
University of Lethbridge	0	0	0	$39,000
University of Manitoba	0	0	0	$353,180
University of Saskatchewan	164,000	25,000	135,361	$2,814,625
University of Toronto	0	0	0	$284,830
Veterinary Infect. Disease Org	$38,000	$129,000	$245,150	$1,568,423
Other universities	39,000	25,000	50,498	$114,498
Total	$3,939,000	$4,002,000	$3,970,271	$55,534,622

C. Development of the Demonstration Program

The On-Farm Demonstration Program has been an important aspect of Farming for the Future. The philosophy behind the program is that research results must be conveyed to the farmers if they are to be useful. The publication of research papers in scientific journals helps to spread knowledge among scientists and students, and it serves the very essential function of exposing all findings to scientific scrutiny and criticism by peer scientists. But it does little to convey information to the farmers. Furthermore, scientific findings often need to be tried under a variety of field conditions. Variations in local conditions may occur over relatively short distances, making cultivars and practices that succeed in one area inappropriate for another.

The Agricultural Research Council of Alberta established the demonstration program in 1982, and allocated $300,000 to it for 1982-83. From April 1982 to April 1991, 741 on-farm demonstration projects were supported for a total funding of $3.8 million as shown in Table 2.3. Another $600,000 has been set aside for 1991-92. These projects have been spread widely across the six agricultural regions of the province. The program participants include individual farmers, producer groups, and applied research associations. Applicants work with Alberta Agriculture personnel to develop proposals that are reviewed by committees in the six regional offices. Field days and project tours help to spread the transfer of new technology more widely and more quickly. They allow producers to view new varieties of crops, new management techniques for crops and livestock, and other new practices.

Table 2.3. Farming for the Future On-Farm Demonstration Program

Fiscal Year	New Projects	Total Funding
1982-83	47	$163,194
1983-84	60	303,182
1984-85	80	320,884
1985-86	92	358,170
1986-87	108	467,146
1987-88	96	541,336
1988-89	114	593,175
1989-90	86	580,831
1990-91	58	517,151
Total	741	$3,845,069

The range of subjects covered by the demonstration projects include such things as soil and water conservation, adaptability of crop varieties, farm management techniques, managerial decision making, irrigation, insect control, livestock management, fertilization, grain drying, animal housing, and many more. The versatility and strength of the On-Farm Demonstration Program were well developed during the first term, 1982 to 1984, and they have been further extended since that time. Some of the results of the demonstration program will be reviewed in the following chapter.

Chapter III. Contributions to Farm and Food Industries

This chapter explains how Farming for the Future accomplishes its objectives in promoting research to improve agricultural efficiency and promote the well-being of the farm and food industries. Firstly, it gives consideration to the kinds of research needs that exist in Alberta. Secondly, it gives consideration to how research projects are chosen to serve these needs. Thirdly and finally, it gives consideration to the use of on-farm demonstration projects to extend the results of research to the ultimate user, the Alberta farmer.

A. Research Needs of Agriculture and Food Industry

Farming in Alberta occurs at the margin in a great many respects. The growing season limits production even in the southernmost reaches of the province, and it grows more limiting to the northward, until a region is reached in which few crops will grow to maturity in most years. Likewise, degree-days of heat are limited, especially to the northward. Precipitation is limiting, more especially in the southeastern portion of the province that is included in the Palliser Triangle. On the positive side, much of the province is blessed with highly productive soil as well as adequate moisture in most years. The long sunny days of summer promote the rapid maturing of many crops so they are less limited by the short growing season.

The combination of climatic and geographic circumstances in Alberta are unusual among the agricultural regions of the world. Consequently, technologies developed for other climatic, geographic, and soil conditions are less likely to be useful in Alberta, particularly when the differences are marked. For example, irrigation in Alberta is unique in that it is the only irrigated region of the world where the subsoil is frozen several months each year. Few livestock growing regions of the world face such high windchills as Alberta. Only a few other crop producing regions must contend with late spring and early fall frost, often combined with inadequate soil moisture. The pioneer farmers in western Canada faced challenges that are hard to imagine today. Many years of experimentation, trial-and-error, and dedicated research efforts have been required to bring northern prairie agriculture to its present highly productive state. And the job is by no means completed.

Among the many needs of Alberta producers are new crop and livestock strains that are more tolerant of harsh climatic conditions, more resistant to disease and pests, less demanding of nutrition, and having less need of close management. A high priority must be given to soil conservation and management, plant breeding, livestock breeding, disease control, and plant and animal nutrition. In addition to the emphasis on production, priority needs to be given to processing, marketing, farm management to improve farm profits, and the development of new markets at home and abroad. Not only do old problems need solving but new problems arise continuously from new crops and livestock, new diseases and pests, soil degradation, and changing climatic conditions. Producers cannot consider climate a constant but must continually adjust to small and large swings in climatic conditions. Consequently, a continuing need for agricultural research exists.

B. Examples of Research Projects Serving Alberta

Although 684 research projects have been approved for funding, a considerably smaller number have been finished long enough to make a discernible mark on agriculture. A few of these completed projects have been selected as examples of the potential for improvement of Alberta agriculture. They do not constitute a random sample, but they are by no means unique in their potential benefits to Alberta farmers.

1. Grain production and productivity growth

The project leaders studied the effects of fertilizer and weather on prairie grain production. Terry Veeman of the Economics and Rural Economy Departments of the University of Alberta supervised the project with the assistance of Alberto Fantino of Rural Economy. The study revealed that crop output in Alberta increased 3.1% per year from 1948 to 1984 and crop inputs increased 0.75% per annum, while overall (total factor) productivity increased at an annual rate of 2.3%. However, looking at the latter part of the period, 1962 to 1984, crop output increased at a 3.6% rate, inputs at a 2.15% rate, while productivity increased only at a 1.4% rate. The changes seem to have been due in part to a greater input of fertilizer in the latter part of the period. Weather (rainfall and temperature) were found to explain much of the short-run variation in productivity while technology (using fertilizer use as a proxy) explained more of the longer-term variation.

2. Plant breeding research

The Plant Science Department at the University of Alberta received Farming for the Future support for a number of research projects in plant breeding and variety production. Important variety releases in canola include Altex, Andor, Alto, Eclipse, and the new *B. campestris* variety Eldorado. Farming for the Future also funded the development of the new Canada prairie spring wheat cultivar, Cutler. It is the earliest maturing registered wheat in Canada. Farming for the Future funds were used for plant growth facilities for this development and for establishing a wheat quality laboratory for breeding. The growth facilities are still actively used in the canola, forage, and cereal programs for selecting cold and frost tolerance, and for physiological studies of germination and seed ripening processes.

Farming for the Future funds have been used extensively for evaluating new line adaptation to the varied field conditions in Alberta. Keith Briggs and Zenon Kondra in Plant Science started the current Alberta Regional Variety testing program, and they ran it for several years supported by Farming for the Future funds before it was transferred to Alberta Agriculture. The value of this work is inestimable at the present. However, the new varieties hold great promise for cereal and oilseed producers in Alberta, and their worth will become obvious within a few more years. Significant results have been obtained in many other plant science projects supported by Farming for the Future funds, notably in plant pathology work on disease resistance in alfalfa, virus diseases in forage crops, and potato spindle tuber viroid disease.

3. Potato physiology and production

Farming for the Future funded a three-year study of the efficacy of utilizing controlled seed-tuber aging as a technique to increase yield and improve tuber quality in areas with relatively short growing seasons. Different ages of seed-tubers were produced by varying the heat-unit accumulation during the storage season. A 20% to 90% increase in total yield and substantial improvements in tuber grade (size) were achieved by planting aged (700 to 800 degree-day) seed tubers. Based upon the results, storage temperature recommendations for seed potatoes should be modified to consider potential age-induced increases in yield for various potato producing regions.

4. Analysis of terramycin (Oxytetracycline) in honey

Peter Sporns of the Food Science Department of the University of Alberta undertook a Farming for the Future project to develop an analytical methodology for the antibiotic Oxytetracycline (OTC) used by beekeepers to protect against the bacterial disease called "American foulbrood." The concern was that the honey could be contaminated by the antibiotic and be rejected by honey importers. With the collaboration of the Food Laboratory Services Branch of Alberta Agriculture, several methods of analysis were developed and tested. As well as the analytical methodology, the routes of OTC breakdown were examined and recommendations for the control of OTC were developed. This methodology is being used routinely to certify that exported Alberta honey is free of OTC.

5. Control of microbial spoilage of bakery products

The project leaders studied microbial spoilage in gas-packaged bakery products. The research resulted in the development of a technology that can increase the shelf life of baked goods to more than six weeks in modified atmosphere storage without freezing. Buncha Ooraikul of the Food Science Department and Ron Forrest of Forcrest Foods Ltd. shared a CIFST award, the 1987 Gordon Royal Maybee Industrial Achievement Award for innovative technology. This technology permits Alberta baked products to reach distant markets in the Pacific Northwest, southern California, and as far east as Florida and as far west as Hawaii. It has enabled Forcrest Foods to become a world leader in gas-packaged bakery products, a significant result made possible by Farming for the Future funding.

6. Biological preservation of ground beef

Mike Stiles of the Food Science Department, ably assisted by several graduate students, conducted this research on the potential of lactic acid bacteria to preserve ground beef. A large number of lactic acid bacteria were isolated from vacuum packaged fresh and processed meats. These isolates were tested to determine which ones were most effective in preventing the growth of other competing microorganisms. Several pure isolates of lactic acid bacteria had high inhibiting powers to prevent the growth of competitive spoilage and pathogenic (disease-causing) bacteria. This "library" of lactic acid bacteria is now being used in genetic engineering studies for the further development of lactic acid bacteria to preserve meat products. This Farming for the Future project has provided the basis that contributes to the overall knowledge of the inhibition of competitive spoilage microflora by lactic acid bacteria, and spin-off studies with application to innovative preservation systems for meats are in progress.

7. Cattle adaptability

This research dealt with the effects of cold weather on cattle. It was directed by Bruce Young of the Animal Science department at the University of Alberta. The research involved the effects of ingesting snow, frozen feed, and shelter on pregnant cows, calves, steers, and pregnant ewes. The study concluded that eating snow or ice in the absence of liquid water was not detrimental for cows or steers and the effect on weaned calves was minor and not significant. The injection of frozen turnips did involve some cost in efficiency of digestion and energy. Cold adapted animals were able to withstand considerable cold without adverse effects. The research suggested that such animals might not benefit enough from cold weather shelter to cover the cost. Perhaps the most significant result of the study was the conclusion that the provision of liquid water to cattle is not necessary as long as they have access to snow to meet their moisture requirements.

8. Air quality in turkey housing

This research was conducted in successive projects under the direction of John Feddes of the Department of Agricultural Engineering at the University of Alberta. The first project determined that turkeys were exposed to high levels of airborne dust, and many high performing turkeys seemed to suffer from respiratory disorder or a decrease in lung function. In the second project, Feddes identified and characterized dust sources. He collected and analyzed airborne dust with the use of a scanning electron microscope (SEM) to determine the contribution of various sources (including feed, fecal material, feathers, bedding). The results indicated that most of the particles were of fecal origin. Chemical analyses of the dust particles confirmed the findings. The dust samples were drawn through various types of face masks to illustrate that masks should be worn in turkey confinement buildings. A study of the effect of oiled litter and ventilation rates suggests that ventilation rates are related to health and well being of turkeys and that oiled litter removes 75% of the airborne respirable dust. These results indicate that airborne dust should be reduced to more acceptable levels because they are biologically active, contain high levels of protein, and carry ammonia and endotoxins into lung tissues.

9. Production optimization on Gray Wooded soils

James A. Robertson of the Soil Science Department at the University of Alberta supervised this research on the Breton Plots. The results showed that the long-term application of even small amounts of ammonium fertilizer increased soil acidity while the application of fairly large amounts of animal manure had very little effect on soil acidity. Soil on the five-year rotation as compared with the two-year rotation had better tilth and higher levels of organic carbon and nitrogen. Two genera of free-living nitrogen-fixing bacteria (*Clostridium* sp. and *Azospirillum* sp.) were found to be present and may fix significant amounts of nitrogen. Preliminary estimates suggested that fababeans may fix up to 200 kilograms of nitrogen per hectare under favourable conditions. The yield results showed that most crops responded to applied phosphorus. Nitrogen response was noted on some crops. Response to potassium and sulphur was not very apparent.

10. Other studies

Numerous other worthwhile research projects have been conducted with Farming for the Future funding, and many of them were as worthy as those described above. They were omitted because of lack of detailed information on the results and space limitations. Mention should be made of the canola breeding research being conducted by Don Woods at the Beaverlodge Research Station of Agriculture Canada. This work has great promise for improving returns from canola in the Peace River region. Studies of the European corn borer in southern Alberta by Dennis Lee and John Spence offers corn producers a method of predicting when insecticides will be the most effective in controlling these pests. Ross McKenzie of Alberta Agriculture working with a Farming for the Future grant has devised a more accurate method of making fertilizer recommendations for irrigated crops in southern Alberta.

C. Demonstration Projects to Extend Knowledge

The On-Farm Demonstration Program is a very important aspect of the overall Farming for the Future program. Research results that are not communicated to their potential users have little if any effect on productivity or the improvement of farm income. In addition, research results often are too general, and further work needs to be done to test their applicability to particular circumstances. The groups selected for illustration were restricted to projects completed between September 1985 and November 1986.

1. Cereals and oilseeds

The cereals and oilseeds projects consisted mainly of wheat and barley varietal testing in various parts of the province. The results were applicable mainly to the areas in which the projects were conducted. Two of the projects dealt with winter wheat. A major conclusion, not unexpectedly, was that winter wheat is not adapted to areas that do not provide snow cover during the colder periods of the winter.

2. Forages

A large number of forage demonstration projects were instituted in different parts of the province. Many dealt with fertilization and the merits of different types and varieties of forages. In particular, several projects looked at different aspects of using Norstar winter wheat as a forage crop, usually in combination with barley or another crop. Several projects tested different grazing rotations and pasture improvement programs.

3. Land use

The land use demonstration projects concerned mainly fertilizer trials and different tillage regimes. Comparisons were made of zero tillage, minimum tillage, and conventional tillage. A few tests were conducted on the effects of liming for treating acid soils. The results from the various projects seem to have been mixed, no doubt because of differences in local conditions.

4. Ruminants

All but two of the ruminant projects dealt with cattle, the two dealing with sheep. Most of the projects tested different feeds and feeding systems. The effects of trace minerals were studied in several trials. Several different kinds of implants, particularly growth stimulants, were studied. Most of them indicated positive results.

5. Special crops

Most of the special crops projects dealt with pulse crops. Two of them tested methods of inoculating seed with rhizobia. Positive results on nitrogen fixation at low cost were obtained from the use of a slurry system. A study of the feasibility of wild rice production in northeastern Alberta had some positive results. A number of factors were identified that affect the feasibility of wild rice production.

Chapter IV. Contributions to Agricultural Knowledge

Research contributes to the accumulation of knowledge in two main ways. First, by expanding the knowledge base, and second, by providing training to young scientists who will go on to make contributions on their own in the future.

A. Role of Research in Expanding the Knowledge Base

Our knowledge base is the total of all of the reliable information that has been accumulated over time. People acquire knowledge primarily by practical experience. Practical experience is mainly, but not entirely, a matter of trial and error. Scientific research is in some respects a sophisticated system of trial and error. It is characterized by careful observation, usually under strictly controlled conditions. Whenever strict controls are not possible or practical, statistical methods are used to reduce the effects of errors and unobserved phenomena.

Competent scientists never claim to have found the **truth**, only to have moved closer to it. In this respect, scientists are no different than other observers and seekers after knowledge. All knowledge accumulation involves taking "two steps forward and one step back" so to speak. Scientists are capable of error as well as anyone else. But the beauty of the scientific system is that it demands checks and balances. Every scientific finding is checked and rechecked by other scientists. Usually, the discovery of a scientific error simply means that a correction must be made. However, when a fundamental theory is overthrown, the entire edifice built on it must be reconstructed.

A number of scientific discoveries were briefly described in Chapter I. In the early times of agricultural science, new discoveries often threw established "theories" into disrepute. Most such "theories" were not scientific at all. They were notions based on reasoning from false assumptions and imperfect observation of fact. Modern science is largely free of such rationalization, and it is firmly grounded in factual experience. Consequently, the acquisition of knowledge has more steps forward and fewer steps back. The advancement of knowledge has two aspects: One is the accumulation of scientific information, while the other is the education and training of young scientists. This passing on of knowledge of how to do science is fundamentally important. We cannot continue to advance without developing the young minds that will do future scientific research. Farming for the Future has contributed significantly to scientific knowledge about agriculture in Alberta.

B. Role of Farming for the Future in Education

A large number of graduate students have been funded by Farming for the Future research grants. A summary survey revealed that at least 124 students had been supported at the University of Alberta, at least one at the University of Calgary, and 12 at the Western College of Veterinary Medicine at the University of Saskatchewan. University records did not always distinguish students by type of funding, and some additional students probably were supported on Farming for the Future funds as well.

Detailed information was obtained on the 124 University of Alberta students (Table 4.1). Sixty-seven students have completed or are in process of completing master's degrees, 51 have completed or are in process of completing doctoral degrees, and six have discontinued their graduate programs. Some of the students who obtained master's degrees with Farming for the Future support are proceeding on for their doctoral degrees, but they were counted only once. By far the largest number of graduate students on Farming for the Future funding were in Animal Science with 41 supported. They were followed by Food Science with 22, Plant Science with 21, and Rural Economy with 20.

Table 4.1. Students Supported on Farming for the Future Funds, by Degree, University of Alberta

Department	MSc	PhD	Discontinued	Total
Agricultural Engineering	3	1	1	5
Animal Science	17	22	2	41
Entomology	1	0	0	0
Food Science	13	8	1	22
Foods & Nutrition	3	1	1	5
Genetics	0	1	0	0
Plant Science	8	12	1	21
Rural Economy	17	3	0	20
Soil Science	5	3	0	8
Total	67	51	6	124

Seventy-eight of the people who had been supported on Farming for the Future funds were known to be employed, 26 were continuing as students, and the employment status of the remaining 20 were unknown (Table 4.2). Among the 78 employed students, three were employed by colleges, 28 by universities, 28 by government, and 19 by private firms. All of the college and university employees were teachers, almost all were engaged in scientific research as well. Most of the government people were employed by either Alberta Agriculture or Agriculture Canada. The people employed by Alberta Agriculture performed research, extension, administration, or a combination of such tasks. Most of the Agriculture Canada people were engaged primarily in research. Those who were privately employed engaged in a number of different kinds of work, including research, extension, consulting, administration, and farming.

Most of the students who were still engaged in completing their degree requirements at the University of Alberta were still supported on Farming for the Future funds. Of those who had completed their degrees, most were engaged in scientific research, although they may have teaching and other duties as well. Farming for the Future has made a substantial contribution to the scientific capability of Alberta and Canada as a whole.

Table 4.2. Students Supported on Farming for the Future Funds, by Employment, University of Alberta

Department	College, University	Govern- ment	Private	Student	Not Known	Total
Agricultural Engineering	1	0	2	2	0	5
Animal Science	13	6	10	10	2	41
Entomology	0	0	0	0	1	1
Food Science	1	1	1	5	14	22
Foods & Nutrition	1	1	0	2	1	5
Genetics	1	0	0	0	0	0
Plant Science	8	6	0	5	2	21
Rural Economy	4	10	5	1	0	20
Soil Science	2	4	1	1	0	8
Total	31	28	19	26	20	124

In addition to the support provided to students, Farming for the Future also has provided support for a large number of research technicians. It has enabled the University of Alberta and other participating institutions to train these technicians and to provide them with continuing opportunities to engage in important agricultural research. Knowledge transfer is accomplished through trained people.

C. Subsequent Effects of New Knowledge

The new knowledge developed through scientific research has many implications. Much of it is immediately applicable to the solving of current problems. Several such projects were described in Chapter III. Even more importantly than immediate problem solving, every scientific finding represents another building block in the edifice of science. It provides one more essential stepping stone for future scientific progress. Just as we saw in the first chapter, every finding that stands the test of time becomes a part of the foundation on which future discoveries of science are based.

The newly trained researchers from the University of Alberta, the Western College of Veterinary Medicine, and other educational institutions supported by Farming for the Future funding have taken or will take their places alongside the previous generation of research scientists. In time, they too will become the leaders of scientific research in agriculture. The importance of this contribution to *future* scientific work in agriculture can hardly be overstressed. Although we cannot yet point to specific contributions of these new scientists, we can state unequivocally that they are the best trained scientists ever and they can be expected to make far reaching contributions to the future of agriculture in Alberta, in Canada, and in the rest of the world.

Chapter V. Benefits and Costs of Research

Farming for the Future has made important contributions to the producers and consumers of Alberta, but the question of how much is difficult to answer with precision. Many people agree that research brings about more benefits than it costs, but most are unsure just how beneficial research really is. Some people condemn science for contributing to mass destruction and the despoliation of the environment. However, most informed people recognize that science is neutral, and it is the users of scientific findings who are responsible for both the good and the bad effects of modern technology. Many people recognize that agricultural science and technology are beneficial to both producers and consumers, although an increasing number are critical of the development and use of agricultural chemicals. Nevertheless, as the problems of feeding a rapidly growing world population have become so obvious, agricultural research has received increasing emphasis and support.

A. Review of Economic Returns to Agricultural Research

Economists have developed increasingly sophisticated methods for measuring the returns to various kinds of investments. Benefit-cost analysis, input-output analysis, and internal rate of return estimation are three of the leading methods used for measuring the effects of public investments in large scale investments. The internal rate of return (IRR) measure is simple in concept but complex in application.[4] Essentially, the IRR is similar to the interest rate on a long-term annuity. However, the IRR calculation is more complex for public investments, such as agricultural research, where varying amounts are invested each year and varying returns to the research are received each year.

At least several dozen studies of the returns to agricultural research have been done in various countries. A number of those done in Canada and a few from the United States were selected for comparison and are presented in Table 5.1. For the ten studies of returns to research for all crops and livestock, the range of annual returns was from 34% to 110%, and the simple average was 50%. This average means that for every dollar invested in agricultural research, the net benefits above all costs was 50 cents per year. To repeat the annuity comparison, it would be equivalent to buying an annuity for $100 dollars that would pay the owner $50 dollars per year over a long period of time.

The returns to research on individual commodities varied more widely, from 14% for alfalfa to 124% for eggs (both from Canadian studies), and the simple average was 54%. Returns of these magnitudes are almost unheard of in business investments. One might question why private industry does not invest more in agricultural research. The partial answer is that the benefits usually are very widespread and private business firms often cannot capture enough of the benefits to make the research investment worthwhile. There have been exceptions, in hybrid corn breeding for example.

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[4] The internal rate of return is that compound interest rate that equates the total benefits to the total costs.

Table 5.1. Estimated Returns to Agricultural Research

Author	Year of Study	Location	Commodity	Time Period	Rate of Return
Aggregate studies:					
Tang	1963	Japan	Aggregate	1880-1938	35%
Evenson & Jha	1973	U.S.A.	Aggregate	1953-1971	40%
Peterson & Fitzharris	1977	U.S.A.	Aggregate	1937-1942	50%
"	1977	U.S.A.	Aggregate	1947-1952	51%
"	1977	U.S.A.	Aggregate	1957-1962	49%
"	1977	U.S.A.	Aggregate	1957-1972	34%
Davis	1979	U.S.A.	Aggregate	1949-1959	66-110%
"	1979	U.S.A.	Aggregate	1964-1974	37%
Brinkman & Prentice	1981	Canada	Aggregate	1950-1972	65-68%
"	1982	Canada	Aggregate	1956-1978	66%
Simple Average			Aggregate		50%
Individual studies:					
Griliches	1958	U.S.A.	Hybrid Corn	1940-1955	35-40%
"	1958	U.S.A.	Hyb. Sorghum	1940-1957	20%
Nagy & Furtan	1978	Canada	Rapeseed	1960-1975	95-110%
Sim & Araji	1980	U.S.A.	Wheat	1945-1974	27-42%
Zentner	1982	Canada	Wheat	1946-1979	39%
Ulrich	1983	Canada	Malt. Barley	1951-1981	50-74%
Ulrich & Furtan	1985	Canada	Wheat	1950-1983	29%
"	1985	Canada	Rapeseed	1950-1983	51%
"	1985	Canada	Barley	1950-1983	22%
"	1985	Canada	Alfalfa	1950-1983	14%
Fox, Brinkman, *et al*	1987	Canada	Beef	1968-1984	66%
"	1988	Canada	Broilers	1968-1984	61%
"	1989	Canada	Dairy	1968-1984	115%
"	1987	Canada	Eggs	1968-1984	124%
"	1987	Canada	Sheep	1968-1984	25%
"	1988	Canada	Swine	1968-1984	50%
Simple Average			Various		54%

Sources:
K. K. Klein, R. P. Zentner, and C. A. Webber, 1990. *A primer on the economic evaluation of agricultural research in Canada.* Research Branch, Agriculture Canada. (Unpublished).
Vernon W. Ruttan, 1982. Agricultural Research Policy. Minneapolis: University of Minnesota Press.

The study of returns to rapeseed research by Nagy and Furtan at the University of Saskatchewan is especially relevant to Alberta. The high returns, 95 to 110%, were divided 53% to consumers and 47% to producers. The rapeseed research involved the development of varieties low in erucic acid and glucosinolates. The pioneering work was carried out under the direction of Baldur Stefansson at the University of Manitoba and Keith Downey at the Saskatoon Research Station of Agriculture Canada. The amazing success story of canola, the Cinderella crop, is a tribute to a great many researchers, including Don Clandinin of the University of Alberta who conducted feeding studies to determine the nutritional value and safety of canola meal. Canola oil is now recognized as one of the best dietary oils, being low in saturated fats and high in monounsaturated fats. Canola oil is now recommended for people with high cholesterol problems. It is not surprising that canola research has shown such a high (95 to 110%) return on the research investments. The work being carried out by Don Woods in the Peace River region, mentioned in Chapter III is a continuation of this productive research.

B. Returns from Research and Demonstration

The Farming for the Future program expended $55.6 million for research over the first 13 years of its existence, or about $4.25 million per year. Inasmuch as Farming for the Future usually does not cover the full cost of the research, the actual amounts expended are much higher. For example, the salaries of the principal investigators for university and government research projects are paid by their respective agencies. Likewise much of the fixed and overhead costs are borne by those agencies. Thus, the costs for agricultural research in Alberta involves much more than the costs of the Farming for the Future program. Consequently, if the returns to research are estimated from the Farming for the Future data alone, the returns will be underestimated.

Assuming that returns to Farming for the Future sponsored research are comparable to the research returns illustrated in Table 5.1, the dollar return will be one-half of the amount expended on research.[5] Table 5.2 shows the amounts awarded for (invested in) research each year in actual (current) dollars, deflated to 1979 dollars, and inflated to 1991 dollars. It also shows the returns to (net benefit from) research in 1991 dollars, in terms of the amount added each year and the total return for each year. The last column of the table shows the estimated total return each year in a cumulative fashion. For example, the returns to research in 1991-92 will include a return from the amounts expended (invested) for each previous year as well as the current year.

[5] Some economists believe the rate of return estimates for agricultural research may be too low because data availability restricts the analysis to comparisons of benefits that are both direct and tangible. The indirect and intangible benefits, which may be quite substantial, unfortunately are too difficult to measure. See C. Carter, B. Prentice, and A. Schmitz. 1984. "The Economics of Agricultural Research." Supplement to *Agronews*, published by the Agricultural Institute of Canada.

Table 5.2. Estimated Returns to Farming for the Future Research

Year	Price Index 1991=100	Price Index 1979=100	Research Grants Actual dollars	Research Grants 1991 dollars	Research Grants 1979 dollars	Estimated Returns Addition (in 1991 dollars)	Estimated Returns Total (in 1991 dollars)
1979	48.8	100.0	2,133,680	4,372,295	2,133,680	2,186,148	2,186,148
1980	53.8	110.2	3,191,107	5,931,426	2,895,741	2,965,713	5,151,861
1981	60.4	123.8	4,078,317	6,752,180	3,294,279	3,376,090	8,527,951
1982	67.0	137.2	6,134,411	9,155,837	4,471,145	4,577,919	13,105,870
1983	70.8	145.1	6,542,460	9,240,763	4,508,932	4,620,382	17,726,252
1984	73.9	151.5	4,343,769	5,877,901	2,867,174	2,938,951	20,665,203
1985	76.8	157.4	4,823,067	6,280,035	3,064,210	3,140,018	23,805,221
1986	80.0	163.9	4,823,067	6,028,834	2,942,689	3,014,417	26,819,638
1987	83.5	171.1	3,811,183	4,564,291	2,227,459	2,282,146	29,101,784
1988	86.9	178.0	3,858,000	4,439,586	2,167,416	2,219,793	31,321,577
1989	91.2	186.9	3,939,000	4,319,079	2,107,544	2,159,540	33,481,117
1990	95.6	195.9	4,002,000	4,186,192	2,042,879	2,093,096	35,574,213
1991	100.0	204.9	3,970,271	3,970,271	1,937,663	1,985,136	37,559,349
Total			55,650,332	75,118,690	36,660,811		

Actually, a lag occurs in the returns because the results of new research are not applied immediately. The usual lag has been estimated to be about five years. The total benefit for 1991-92 may be only $26.8 million but it will reach $37.6 million in 1996-97 even if no further investments were to be made. If the Province continues to invest in agricultural research at the rate of $4 million or more per year, the net return will continue to grow $2 million or more per year. However, we must allow for the probability that research results have a finite lifetime of usefulness, perhaps 25 years in most cases. Some 30 years after the start of the Farming for the Future program, the returns to the first year's research will be tapering off. It may never reach zero, however, because of the building block effect of new research being based on and an extension of previous research.

Table 5.2 also shows that the purchasing power of the research grant awards has declined significantly as a result of inflation. In terms of 1979 dollars, the 1991 award total of $3,970,271 will purchase only $1,937,663 of goods and services. The more than doubled general price level has had serious effects on the ability of research scientists to accomplish their tasks. It means that fewer technicians can be employed, fewer graduate students can be supported, and fewer essential supplies can be purchased. Had the purchasing power of the research grants been maintained, the beneficial results of the research would have been some 35% greater.

The existence and persistence of inflation complicates any calculation of costs and benefits. To simplify the analysis, suppose that the entire $55.6 million was spent on research in one year, that the returns of $27.8 million per year would begin after five years and continue for 25 years thereafter. The total returns from the research investment would be $695 million in terms of actual or current dollars (Table 5.3).[6] However, future returns are worth less today because people prefer present income to future income. The present value of the total current dollar future return would be $307 million using a 5% discount rate. In terms of 1979 dollars, the present value would be $202 million (34% lower); in terms of 1991 dollars, it would be $415 million (35% higher). In any case, the results are highly supportive of further investment in research.

Table 5.3. Present and Future Values of Farming for the Future Research Investment

Base	Total Investment	Annual Return	Future Value[1]	Present Value[2]
Current dollars	55,650,332	27,825,166	695,629,150	307,272,595
1979 dollars	36,660,811	18,330,406	458,260,150	202,422,203
1991 dollars	75,118,690	37,559,345	938,983,625	414,766,884

[1] The future value in each case is simply 25 times the annual return. It is the total return for 25 years in terms of dollars of a given purchasing power.
[2] The present values are the future values discounted back to the present at a 5% discount rate. Because of the five-year lag, it was necessary to discount the first year's returns for six years, the second year's returns for seven years, and so forth.

The returns to investment in the On-Farm Demonstration program are more difficult to estimate, but they are no less real. Perhaps the best way to consider the contribution of the demonstration program is as an extension of the research effort. This extension has the effect of speeding up the adoption of the research results. Thus, the benefits from the research may start being realized in three to five years rather than in eight to ten years. In addition, it may make the research results more effective by earlier discovery of how and where they may be best adapted.

[6] The average purchasing power of the actual or current dollar is roughly equal to that of the 1984 dollar.

Chapter VI. Conclusions and Recommendations

A. Conclusions

The research program of Farming for the Future is a continuation of a long tradition that can be traced back to Sir Francis Bacon in the 17th century. The early pioneers who contributed to the foundations of agricultural science included such noteworthy people as Jethro Tull, Joseph Priestly, Erasmus Darwin, Humphrey Davy, John Lawes, and Justus Liebig, to mention only a few. The tradition was continued in Canada, first under the leadership of William Saunders, and then by a wide succession of scientists who have helped make Canadian agriculture productive and competitive on world markets.

The Farming for the Future program, which began in 1978, has contributed immensely to the magnitude and value of agricultural research in Alberta. The On-Farm Demonstration program has been a companion to the research grant program, and it has helped make the research results speedily available to farmers. In addition it has helped carry out extensive testing of new agricultural technology on Alberta farms. Over the 13 years of its existence, Farming for the Future has awarded $55.6 million for research. An additional $3.8 million was awarded for demonstration projects.

One of the major contributions of the research funding, perhaps the most important in the long run, is the training of young scientists. These young women and men will do the important research of the future. Data were available for 124 graduate students supported by Farming for the Future grants at the University of Alberta. Sixty-seven students had completed or were continuing work on master's degrees and 51 had completed or were continuing work on doctoral degrees. Among the completed students for which data were available, 31 were employed by colleges and universities, 28 by government agencies, and 19 privately. Almost all of the university employees and most of the government employees were engaged in agricultural research. Not only did these students contribute to agricultural research during their graduate work but many of them are continuing to contribute to agricultural research.

Many of the research projects funded by Farming for the Future are making worthwhile contributions to the agriculture and food industries of Alberta. They also benefit consumers through higher quality of products, improved supplies, and lower prices. The future promise is very great because the full beneficial effects of much of the research extend over a long period of time. Estimates of the net benefits of this research, based on previous studies of net returns to agricultural research, suggest that the research already funded may contribute $37.5 million annually to the farmers and consumers of Alberta. The return, although it has not yet reached its full potential, is a handsome reward indeed. The total eventual value of the research already funded may reach $695 million in current dollars, and the present value of that amount discounted at 5% is $307 million. These values would be 35% greater in terms of 1991 dollars.

B. Recommendations

The first and foremost recommendation must be that the very successful Farming for the Future program be continued. Very few alternative public investments could hope to earn nearly the high rate of return that this program enjoys. The Government is dedicated to helping Alberta farmers, and it could hardly do better than to ensure that they will remain highly productive and competitive. The rest of the world does not stand still. American farmers have always led in the adoption of new technology. Now European farmers also are improving their technology and productivity rapidly. Many other nations, some of which were our customers in years past, have been making great strides in agriculture. Alberta farmers will face increasing competition in world markets and in domestic markets as well. They can meet and beat this competition only by increasing their productivity even faster. This productivity must rest on the output of agricultural scientists.

The level of funding needed by Farming for the Future is more difficult to foresee. Certainly, at the present level, the funds are being very well used. Interviews conducted with a number of research directors suggest that more funds could be used efficiently. These observations are reinforced by tighter base budgets at the universities and government research agencies, decreasing purchasing power due to continuing inflation and the effects of the Goods and Services Tax. It would be regrettable if the research scientists at these institutions were to become unable to achieve their full potentials because of inadequate funding.

No information obtained in this study casts any light on exactly how much funding should be provided by the Farming for the Future program. However, the information available strongly supports a continuation at a somewhat greater level than at present. By all means, an allowance must be made for inflation. Inflation has reduced purchasing power by 51% since 1979. A doubling of the level of funding would almost restore the purchasing power of the first year of the program. Examination of the statistics on numbers of research proposals received and number of awards made show that only about 25% of the applications result in awards. Although a 100% goal is not reasonable, a goal of 33% to 50% does seem reasonable. Achieving such a goal would require something more than a doubling of the present level of funding.