Lethbridge Research Station

1976-1986

The Eighth Decade

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The Lethbridge Research Station.

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Research Branch
Agriculture Canada

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Foreword

In 1986, the Lethbridge Research Station celebrates 80 years of agricultural research, as the Research Branch of Agriculture Canada commemorates its centennial. During the past century, the goals of the department have been to improve the efficiency of agricultural production, to develop new technology to solve agricultural problems, and to develop suitable food products for domestic use and export.

Research is essential to increase the productivity of agriculture, just as research is necessary to ensure that resources are used wisely and that conservation management is at the center of agricultural production. In the future, as competition for natural resources increases, only highly efficient agricultural production will be economical. Through research, crops and animals adapted to specific environments are made available to producers.

In this publication, we present a summary of agricultural research at the largest of Agriculture Canada's research stations. The first 70 years of research at Lethbridge were described in a previous publication (To Serve Agriculture, by Alex Johnston). To commemorate the 80th anniversary of the Lethbridge Research Station, this volume has been produced to bring the reader up to date on the last decade of research, and to indicate the direction that future agricultural research is likely to take.

D. G. Dorrell
Director

Chapter 1

Lethbridge Research Station

The early years

From the time that the Dominion Department of Agriculture established the first experimental farm at Ottawa in 1886, the department has expanded across the country, building research stations and experimental farms in locations where agriculture is a dominant industry. In 1906, the sixth Dominion Experimental Station was established at Lethbridge, Alberta, a small coal-mining community that was rapidly attracting settlers to irrigated land.

Initially, 160 hectares (400 acres) of Station land were cultivated, 120 on dry land and 40 under irrigation. On this land, W. H. Fairfield (the first superintendent) and a handful of staff began research on the problems of agricultural production in southern Alberta. The pioneer farmers of the region required technical advice on dealing with the problems of drought, wind, weeds, and insect pests.

In the early years, researchers were concerned with land-use studies. They established crop rotations (rotation U, a 10-year rotation on irrigated land, was established in 1911 and is the oldest continuous rotation in Canada) and conducted tests of forage, cereal, and horticultural crops. Date and rate of seeding studies were initiated on irrigated and dry land, and hay production was assessed on irrigated pastures. Crop varieties adapted to the local climatic conditions were tested and recommended to producers.

During the next few decades, researchers concentrated on improving farm productivity. They developed higher yielding crop varieties, more efficient land and pasture management practices, and effective insect and disease control.

Soil drifting has always been a serious problem in southern Alberta, because of the strong winds. During the dry years of the 1930s, when topsoil losses were extensive, researchers at Lethbridge experimented with many soil conservation methods. After establishing that strip farming and the use of a trash cover were excellent soil conservation practices for the region, they informed the producers. Half a century later, farmers still protect their land with these methods.

Studies with livestock began in 1911 with feeding trials for lambs and steers. In the next decade, facilities were established to study poultry and hog production, and sheep management practices were studied under range conditions. Dairy cattle were purchased in 1925 and nutritional and reproduction research began. Several years later, at the Manyberries Substation (now Onefour Substation), crossbreeding experiments with bison and studies on the carrying capacities of rangeland were implemented. With the establishment of the Stavely Substation in 1949, rangeland ecologists were able to begin grassland grazing studies.

The Dominion Entomological Laboratory was established at Lethbridge in 1913 to investigate crop insect problems in southern Alberta. For some pests, researchers were soon able to recommended effective control methods. In fact, the procedures established in 1913 for control of wheat streak mosaic, then known only as 'eelworm' on winter wheat, are still in use today. Grasshopper surveys began in 1932, and have been conducted annually to provide forecasts of outbreaks and potential problem areas.

By the 1940s, Station facilities had expanded to include research on livestock insect pests such as sheep keds and warble and horn flies. Weed research, breeding of better forages and cereals, and plant pathology programs were also in progress. The irrigation (water-use) studies begun at Lethbridge in 1922 were extended to different soils with the establishment of the Vauxhall Substation in 1953.

Through the years, land was purchased to allow expansion of both irrigated and dryland studies. By 1986, the total holdings were 500 ha at Lethbridge, 17 000 ha of rangeland near Manyberries, a 400-ha ranch near Stavely, and a 130-ha irrigation substation at Vauxhall.

The 1980s

In 1986, after 80 years of research on the agricultural problems unique to southern Alberta, the Lethbridge Research Station is the largest of the 26 regional research stations and 28 experimental farms located across Canada and administered by the Research Branch of Agriculture Canada. It has developed from a demonstration farm with one scientist into a modern research institution with 70 scientists, many of whom have achieved international reputations in their fields of expertise.

At the Station, 300 federal employees—research scientists, administrators, technicians, and other professional and support staff—are involved with research applicable to the agricultural needs of the prairies in general and southern Alberta in particular. The Agriculture Centre houses both federal (Agriculture Canada) and provincial (Alberta Department of Agriculture) personnel, who cooperate in disseminating research results to producers, consumers, and agricultural manufacturers.

Scientists at the present-day Research Station are involved in extensive agricultural research programs that include innovations in soil engineering and conservation, genetic manipulation of plants and animals, studies in livestock immunology, beef breeding and feeding, and insect pheromone research. The focus of research has expanded greatly since the early years, and innovations in research techniques have attracted many foreign scientists to Lethbridge. Through working liaisons with colleagues in developed and developing countries, the reputation of the Lethbridge Research Station has become international. Visiting scientists are always in residence at the Station, where they conduct research with local scientists in such diverse areas as rumen microbiology, nitrogen fixation, and leafcutter bee management.

The following chapters summarize research conducted at the Station in recent years. The effects of the many changes in technology in the past 80 years are evident in the types of research programs now underway.

Chapter 2

Land-Water Resource

The soils of southern Alberta support a variety of crops that yield well when the soils are properly managed and conserved. The continuing scarcity of water for both irrigated and dry land farming is the stimulus for the development of new approaches to increasing the productivity of the land. Decades of research and on-farm experience have determined which management practices are the most beneficial, and research continues to stress increasing crop yields and preventing soil deterioration.

Soil conservation

Since the 'Dirty Thirties', when farmers watched the winds carry away millions of tons of precious topsoil, soil conservation has been a major focus of research for soil scientists at the Lethbridge Research Station. The Chinook winds—strong westerlies that sweep across southern Alberta—remove moisture and erode unprotected topsoil. Soil management and cropping practices that counter these effects have been studied extensively by researchers. The Station is now the major federal center for the study of soil conservation, salinity, and irrigation management.

On dry land, scientists are studying alternatives to summerfallow, which has been shown to degrade the soil and reduce water retention. Minimum or zero tillage in a cereal recropping system offers the greatest potential for both resource and energy conservation.

Under no-till chemical fallow on Research Station land, spring wheat yields equal or exceed those of wheat grown on conventionally tilled fields. Similarly, winter wheat on no-till fallow and stubble plots has consistently yielded more than that on conventionally tilled fields. The higher wheat yields are attributed to shallower seeding and more efficient use of soil moisture, which is conserved when cultivation is replaced with suitable herbicides. Although no-till cereal production is possible on a wide range of soil types in southern Alberta, the benefits of increased yields often are not enough to offset the cost of herbicides. Nevertheless, no-till or minimum tillage cereal production has been shown to conserve soil moisture, permit more timely seeding, and minimize soil erosion by wind and water.

Survival of winter wheat is much higher when it is planted directly into standing stubble rather than on summerfallowed fields. Direct seeding into stubble is possible with high-clearance hoe drills, provided crop residues are not excessive and are uniformly distributed. Various conventional and prototype seed drills have been evaluated at Lethbridge for no-till production systems. Evaluation of seed drills is continuing in cooperation with local manufacturers to develop machines that provide more effective seed and fertilizer placement under minimum-till conditions.

Scientific management of rangelands in semiarid regions has as its objective the maintenance of organic residues, which act as binding agents in the soil to ensure a healthy, fertile soil-plant system. In grazing studies at the Manyberries Substation on revegetated range, scientists noted that the organic matter content of the soil decreased under heavy grazing. Monitoring of the study site will continue to assess the fate of soils under heavily grazed prairie.

top
Saline land near Taber, Alberta; reclaimed land in background has been seeded for pasture.

bottom
Many producers in southern Alberta practise no-till seeding of winter wheat into stubble.

Crop rotation studies have been maintained since 1911 on Rotation U, an irrigated 10-year rotation including oats, barley, sugar beets (formerly potatoes), alfalfa, and wheat. From it, scientists have compiled data on yields, organic matter, and nutrient contents. The use of manure, fertilizer, and better varieties has improved the productivity of the soil, and yields of all crops have increased with time. This continuous rotation, the oldest in Canada, will continue to provide valuable information on the long-term productivity of irrigated agriculture in the future.

Salinity control

Nearly 1 million hectares of agricultural land in southern Alberta are unusable or produce poor crop yields because of salinity. On dry land, a high salt content in the soil, shallow bedrock, marginal precipitation, and cultural practices such as summerfallowing contribute to salinity. When water from snowmelt, runoff, or precipitation is not fully utilized by crops, the excess drains through the soil, dissolving salts and discharging at lower elevations, where salts are deposited on the soil surface. The area affected by salinity is increasing on the Canadian prairies because of cultural activities and temporary excesses of surface and groundwater.

After 8 years of research at the Lethbridge Research Station, a technique was developed to map the extent of soil salinity using LANDSAT satellite imagery. Mapping of moderately and strongly saline soils in a 90 000-km^2 area of southern Alberta can be done with about 75% accuracy. The technique appears to be suitable for rapidly estimating the total area of saline soils in the Prairies and for monitoring changes. With improved computer technology and better sensors on satellites, the accuracy of mapping will increase.

Subsurface tube drain and filter are installed with an experimental drain plow on irrigated land.

At the Lethbridge Research Station, the emphasis of salinity control is on the use and dissipation of excess water to prevent development of saline seep areas. Research with intensive, nonfallow cropping systems and deep-root crops such as alfalfa has been successful in controlling the discharge of saline water in some areas. Installation of a subsurface drainage system in the discharge area improved waterlogged soil conditions on land severely affected by annual spring flooding and prevented the spread of a saline seep area.

In southern Alberta irrigation districts, 7-10% of the land is barren or low-yielding because of salinity. The major cause of salinity in these areas is canal seepage. Corrective measures include preventing seepage and maintaining unobstructed canals that allow water to flow freely.

Lethbridge scientists have experimented with canal linings, such as a flexible asphalt emulsion that is not damaged by thaw/freeze cycles, and with auxiliary drains. Waterlogged soils with a clay or clay-loam texture were successfully drained in field tests with 'mole' drains, unlined drains that have proven to be as effective as more costly subsurface tube drains.

A new method of reclaiming soils made saline and waterlogged by seepage from irrigation canals was developed at Lethbridge. A vertical plastic curtain inserted in soils bordering canals, in conjunction with a subsurface drain, intercepts seepage water and directs it into plastic drainage drains. The saline water is drained to dugouts where it is pumped out by standard methods. As part of this research, a prototype machine was developed to simultaneously dig a drainage ditch and install the drain and plastic material.

When canal seepage was controlled, soils actually improved under irrigation. Long-term records of irrigated Chernozemic soils indicate that 75 years of irrigation have not increased the salt content of glacial till soils. Salts were leached to below the crop root zone by normal irrigation practices, resulting in decreases of up to 69% in the salt content of the soil.

There are 3 million hectares of Solonetzic soils in southern Alberta, of which a substantial portion is presently irrigated or situated within Irrigation Districts. These soils contain high levels of sodium salts and a hard, compact layer that resists penetration by water and crop roots. Scientists are testing methods of breaking up the compact sodic layer in these soils to permit better penetration of water and increase crop yields. Reclamation of the impermeable Solonetzic soils becomes more desirable as the availability of prime agricultural land decreases.

Irrigation technology

More than half a million hectares of agricultural land in southern Alberta are irrigated, and expansion is anticipated in the future in response to the need for increased food production. Careful management and distribution of limited water supplies is necessary to maintain efficient and economically productive irrigation systems.

One impediment to efficient distribution of irrigation water is the growth of aquatic weeds, which can clog inlet valves and slow the rate of water flow.

An integrated aquatic plant management program uses a combination of chemical, mechanical, and biological techniques to reduce populations of undesirable aquatic plants. Herbicides have successfully controlled many such plants in canals and dugouts. Scientists monitor environmental factors that favor the establishment of water weeds such as Eurasian water milfoil, to prevent its invasion into the southern Alberta irrigation system, and conduct research on runoff control to prevent nutrient enrichment of the water system. Through extension programs, the results of this research are used to manage waterways.

As Irrigation Districts continue to make major improvements in their distribution facilities to provide more efficient delivery of water, agricultural research is assisting users of the irrigation system.

Computerized scheduling of irrigation is now possible for farmers with home computers. After many years of research on the seasonal water requirements of commonly grown crops (alfalfa, wheat, oats, sugar beets), scientists at Lethbridge developed a computer program that determines when and how much water to apply to a specific crop. Factors such as soil moisture, soil type, planting date, and weather data are analysed to produce an estimate of the optimum timing of irrigations. Producers can supplement the computer decisions with information on disease or pest problems, which influence crop growth, to obtain maximum crop yields and conserve water supplies.

Another computer program developed at Lethbridge assesses water losses from an irrigation distribution system in the Lethbridge Northern Irrigation District. Recorders situated at specific sites in the system provide information on stream flow and the amount of water lost through percolation, seepage, and evaporation. Analysis of the data on the computer provides accurate assessments of the actual distribution of irrigation water. With this information, managers of Irrigation Districts can modify or repair canals to improve the efficiency of water use. Furthermore, improved water use will increase the productivity of land in the long term, by preventing soil degradation.

top
Pondweed in irrigation canals is the major aquatic plant problem in the Prairies.

bottom
Climatic variables such as hours of sunshine, air and soil temperatures, wind speeds, precipitation, and seasonal evaporation are recorded automatically with electronic sensors in this underground bunker. The data are transferred to a computer for analysis and are made available to researchers who require accurate climatic data when interpreting the results of field experiments.

Soil fertility

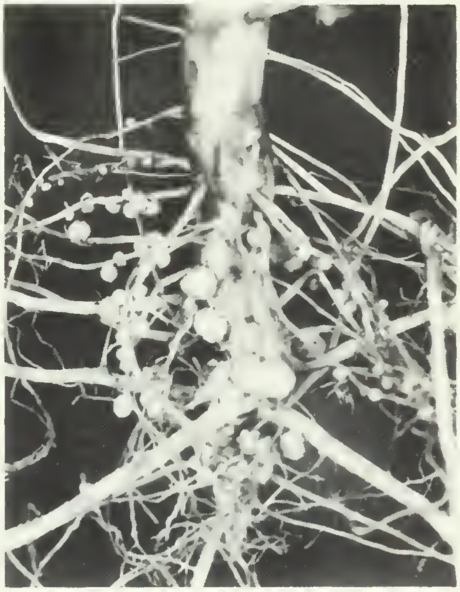
Intensive cropping depletes nutrient and mineral reserves in the soil and can lead to poor crop yields. When fertilizers are applied, producers must use the most economical form and method of application to obtain maximum returns.

Nitrogen loss through the actions of soil microorganisms can occur in southern Alberta soils. In tests at Lethbridge, scientists discovered that high levels of available carbon and excessive moisture encourage the process. In a 4-year field experiment with methods of application and various forms of nitrogen fertilizer, banded fertilizers proved to be the most effective on both dryland and irrigated plots. The concentration of fertilizers in a band reduced the conversion of nitrogen by soil microoganisms, resulting in more nitrogen for crop uptake.

In other experiments, on irrigated land, scientists applied nitrogen fertilizer with the irrigation water in a process called fertigation. This method is widely used by producers of corn, potatoes, and specialty crops. Researchers found that yields of soft white spring wheat did not always increase when part of the nitrogen fertilizer was applied by fertigation, and they concluded that the additional cost of fertigation may not result in economic gains.

Soil microorganisms also affect the efficiency of nitrogen fertilizer uptake by plants. Researchers are investigating the biological and environmental factors that affect availability of nitrogen to crops. Nitrogen fixation by wheat is a new area of research at the Lethbridge Research Station. Using nitrogen-15 isotope techniques, scientists have demonstrated conclusively that certain lines of wheat require less fertilizer nitrogen when associated with a specific strain of bacteria. These results provide an exciting basis for future research to replace part of the nitrogen fertilizer requirements of wheat.

Studies by scientists have shown that, in most southern Alberta soils, addition of sulfur fertilizers is unnecessary. On dry land, subsoil levels of sulfur are sufficient for crop growth. On irrigated soils, irrigation water supplies enough sulfur to meet crop requirements. Producers have been advised to obtain soil tests to avoid applying unnecessary sulfur to their land.



Field beans inoculated with *Rhizobia* bacteria produce nitrogen-fixing nodules on the roots, which increase nitrogen uptake by the plant thus reducing the amount of fertilizer nitrogen required for the crop.

Phosphorus is often lacking in heavily cropped soils. An adequate supply of phosphorus was shown to be necessary for overwinter survival of alfalfa in tests on Research Station plots, and producers were advised to add phosphorus to established stands every second or third year. In experiments with methods of applying phosphate fertilizers to wheat, scientists found that wheat yields on fertilized plots were 30-45% more than on unfertilized land. Work is currently in progress to determine the best treatments so that recommendations can be made to producers.

Soil microorganisms such as vesicular-arbuscular mycorrhizal (VAM) fungi assist in the uptake of phosphorus by plants. VAM fungi are present in Alberta agricultural soils, but their numbers are decreased by the use of phosphate fertilizers and the practice of summerfallowing. Research is now underway to select VAM fungi that will increase the growth of specific crops. In soils inoculated with these fungi, yields of alfalfa and wheat increased dramatically (up to 80% for alfalfa and 20% for wheat). Aside from increasing yields and decreasing the need for phosphorus fertilizer, application of VAM fungi could be used to stimulate plant growth in unusable land such as acidic soils, blowout areas, and other disturbed sites.

Some soil bacteria and fungi are capable of solubilizing rock phosphate to produce plant-available phosphorus. During 3 years of experimentation at Lethbridge, scientists obtained promising results with selected fungi and rock phosphates from 11 countries. Although these fungi have potential as rock phosphate inoculants, phosphorus yields from this process are less than the phosphorus content of commercial fertilizers.

Nutrients for crops have long been provided by spreading barnyard manure on the land. At Lethbridge, experiments were designed to determine whether heavy rates of feedlot manure could be safely applied to either dryland or irrigated soils. After 4 years of manure application, salt and nitrate levels had increased slightly, but did not result in lower barley yields. Researchers concluded that repeated annual applications of moderate amounts of manure (30-60 t/ha) to irrigated and dry land would maintain optimum grain yields without harmful effects on the soil.

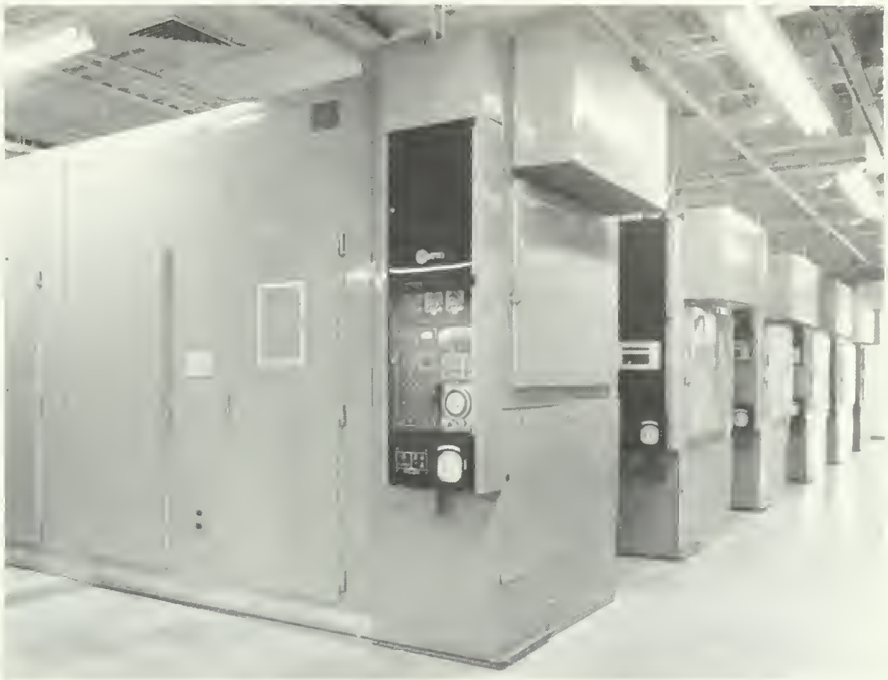
In other experiments, scientists have studied the use of wastewater for irrigation. Municipal sewage effluent applied to forage crops, and supplemented with nitrogen fertilizer, proved to be a satisfactory source of nutrients for reed canarygrass, smooth bromegrass, tall wheatgrass, and Altai wildrye. Alfalfa, because of its nitrogen-fixing ability, did not require fertilizer nitrogen. Potentially harmful bacteria in the wastewater were killed within 4 days of exposure to bright sunlight; within 2 weeks, no risk of contamination remained for livestock consuming forage or for humans working on the land. This practice for the utilization and disposal of wastewater has already been adopted by more than 25 municipalities and 30 agricultural industries in western Canada.

Chapter 3

Crop Adaptation

Full exploitation of the land resource requires crops adapted to the soil and climatic conditions of southern Alberta. Plant breeders at the Lethbridge Research Station, often in cooperation with breeders at other research stations and institutions, have tested many species of cereal, forage, and field crops, and have developed cultivars suited to the dry land, rangeland, and irrigated land of the region.

The development of suitable varieties is a long process involving numerous field trials and selection for desirable traits. In cooperation with plant pathologists, plant breeders have developed methods for selecting plants resistant to diseases common to the Prairies. Pathogens are inoculated onto the plants in growth rooms programmed to provide the ideal environment for the development of a specific disease. With this procedure, resistant plants can then be identified and selected.



The phytotron is one of the most valuable facilities at the Research Station because it overcomes the limitations of the climate. In it, plants can be grown under controlled conditions, permitting scientists to produce as many as six crops per year. Because many of the growth cabinets are unique, the phytotron has attracted visiting researchers from around the world. The facility consists of 10 greenhouses, 2 headerhouses, 23 controlled environment rooms, and 67 controlled environment growth cabinets. More than a third of a hectare of surface is available to researchers for studies on plant breeding and physiology, plant diseases, insect hosts, and soil nutrients. In the phytotron facilities, scientists have determined the minimum temperature for nitrogen fixation in legumes, screened corn for low-temperature tolerance, and bred, tested, and screened other crops for disease resistance and winter hardiness. Without these facilities, the research would have taken many years to complete.

Crop physiology

The crop physiology program at the Lethbridge Research Station has been involved with determining the physiological characters that control adaptation of crop plants, specifically canola, corn and sorghum. Studies of canola were conducted because all of the leaves on canola plants grown at Lethbridge began to senesce at the onset of flowering, which resulted in low seed yields. Through a series of experiments, scientists were able to show that nitrogen in the leaf tissue is mobilized for use by the seed, which results in death of the leaf. This conclusion also implies that heavy fertilization with nitrogen will prolong leaf survival and ultimately result in a higher seed yield.

Forage crops

Forage crops studied at the Lethbridge Research Station include legumes and grasses intended for consumption by livestock. Alfalfa is the major forage legume on irrigated land in southern Alberta, where it is grown for hay, seed, and the dehydration industry.

The Uniform Alfalfa Test and Alberta Alfalfa Seed Committee projects have provided data on the adaptation and forage and seed-yielding capabilities of alfalfa varieties and strains. The Lethbridge station has coordinated the Alberta Alfalfa Seed Committee trials since 1974, and the Uniform Alfalfa Tests since 1981. Data have been used to support applications for licensing of about 12 varieties in the past 10 years and to assist provincial authorities in the preparation of variety recommendations. The alfalfa variety Trek, the first Canadian variety developed with resistance to the alfalfa stem nematode, was released in 1975.

Verticillium wilt of alfalfa has, since 1977, been a threat to production in southern Alberta. Alfalfa populations with high levels of resistance to verticillium wilt and bacterial wilt have been developed in a breeding program initiated in 1979. Plant breeders at Lethbridge developed methods of screening alfalfa seedlings for resistance to verticillium wilt, which led to the licensing of Barrier in 1986. It is the first Canadian alfalfa variety that is resistant to both bacterial and verticillium wilt.

Other forage legumes suitable for production in the southern Alberta region are sainfoin, cicer milkvetch, and birdsfoot trefoil. None of these species appears to induce bloat in cattle, a feature that makes them attractive alternatives to alfalfa. The licensing of the sainfoin variety Nova in 1980 was the culmination of nearly 20 years of research on this legume. Prior to the release of Nova, about 250 sainfoin introductions from more than a dozen countries were evaluated for their suitability for hay, pasture, and seed production in western Canada.

Many principles for the establishment and management of sainfoin for hay, pasture, and seed production have been developed or modified at Lethbridge. For example, when herbicides were used in the year of establishment, approximately 5 t/ha more alfalfa and 3 t/ha more sainfoin was produced over a 4-year period and the treatment was found to be cost-effective. Research also included studies on depth of seeding, seeding rates of sainfoin alone and in sainfoin-grass mixtures, compatibility and planting patterns (alternate vs. mixed rows) in mixtures with grasses, harvest management, and grazing of sainfoin pastures by sheep and cattle.

Rangelands

In studies on rangelands in southern Alberta, research has focused on increasing beef production. Improving the productivity of rangelands and using pastures to complement native rangeland are two approaches to more profitable management of grazing lands. For example, when seeded with early maturing forages, pastures can support livestock until range species are mature. This allows the production of maximum forage from native plants and extends the grazing season, thereby increasing the carrying capacity of producers' lands.

Several variety trials that included wheatgrasses, orchardgrass, Russian wildrye, Altai wildrye, Italian ryegrass, and meadow foxtail were conducted and provided valuable information on the suitability of several cultivars for use as hay or pasture. Cabree, a new variety of Russian wildrye, was licensed for use in Canada in 1976. It was developed at the Research Station from selections having resistance to seed shattering, good seedling vigor, and good forage and seed yield. In addition, it has resistance to powdery mildew, spot blotch, and leaf rust.

The use of fast-growing, short-lived crops in the establishment of slow-growing Russian wildrye provided grazing during the first few years without affecting the production of the grass. Fall rye and sweet clover proved to be the most suitable species to seed with Russian wildrye because they died out in the third year. Less suitable were slender wheatgrass, which persisted until the fourth year, and pubescent wheatgrass and alfalfa, which persisted throughout the 9-year trial.

In other experiments, native range production was increased substantially after one application of nitrogen fertilizer at 300 kg/ha. The increased forage yield was accompanied by a change to more productive forage species and persisted over 7 years. The single application of nitrogen was more effective in increasing forage production than three annual applications of 100 kg/ha, and was cost-effective.

bottom
Harvesting alfalfa forage yield trials; samples are weighed in a portable weigh station.

right
In greenhouse studies, the top growth of alfalfa plants is clipped to measure forage yields.

Poor rangeland or abandoned cropland can be improved by renovation. Renovation trials in southern Alberta showed that complete tillage and seeding with a conventional drill resulted in excellent stands of the introduced forages. Partial tillage and sod-seeding techniques usually failed to provide an adequate seedbed and stands, if established, were generally poor. A strip-tillage technique, designed to renovate pasture in alternating strips of reseeded and native range, was successful on tilled strips 60 cm or more wide and is recommended for use in areas where soil erosion is a problem. Spraying glyphosate, a non-selective herbicide, over the entire area or in bands effectively reduced competition and thus allowed the introduced species to become established. Strip-spraying of glyphosate also rejuvenated old stands of Russian wildrye.

Disturbed areas, such as reclaimed strip-mined areas or sand and gravel pits, were successfully revegetated by seeding wheatgrasses, sweet clover, and wildryes. The introduced grasses were easier to establish than some of the native grasses on sandy sites. On saline sites, native grasses were more successful. Selection of northern and western wheatgrass lines suitable for regrassing of mechanically disturbed or overgrazed areas resulted in the licensing of Elbee in 1980 and Walsh in 1982. Both are the first Canadian varieties of these native grasses. They are drought-tolerant perennials suitable for hay and pasture production as well as revegetation.

Grazing studies on both foothills and plains rangeland are examining the effects of stocking rates and grazing systems. Results of a 35-year grazing study on rough fescue grassland were recently summarized and showed that light stocking did not affect range condition. However, increasing the stocking rate led to a marked decline in the performance of both vegetation and animals. Deteriorated rangelands may require more than 40 years of rest to fully recover their productivity.

A practical method of using LANDSAT data in the assessment of productivity and condition of foothill rangelands has been developed at the Research Station in cooperation with Alberta Energy and Natural Resources, the Canadian Centre for Remote Sensing, and the University of Calgary. Land inspectors or ranchers can use satellite photographs to detect problem areas or to monitor those areas where range improvements have been or could be initiated.

Field crops

The demand for field beans as a source of protein has increased in recent years as the cost of other sources of protein such as meat continues to rise and world food supplies become more critical.

In response to the expressed concern for energy conservation in agriculture, crosses of field beans were made in 1978 that resulted in the selection of 'High Profile' (HP) plants. These plants possess an extremely upright growth habit which permits direct combining, eliminates several field operations, and results in a considerable saving in fuel consumption. An unexpected bonus derived from the development of the HP plant type has

left
The long racemes on 'High Profile' field beans keep pods above the soil surface.

bottom
In lowland areas at the Stavely Substation, cattle graze on rangeland near a man-made dugout.

been the associated tolerance to white mold, a disease that has recently become a major problem in bean-growing areas. In addition, one HP line of field beans has the ability to fix a high level of nitrogen. The identification of suitable nitrogen-fixing bacteria by soil microbiologists parallels the work of plant breeders who are developing bean cultivars that produce high yields with low levels of soil nitrogen.

Soybean research at Lethbridge will help meet an increasing demand for information on new crops for the irrigated areas of southern Alberta. The soybean breeding program was initiated in 1978 to select and develop early maturing cultivars with acceptable protein and yield levels. Since 1979, funding assistance for soybean research has been provided by the government of Alberta through the Farming for the Future program.

Safflower is another new crop being studied at Lethbridge. It is drought-tolerant, which makes it suitable for the dryland areas in the southern Prairies. Because seeding and harvesting of the crop can be done with equipment designed for cereals, farmers could alternate safflower with traditional crops to expand their market base. A breeding program was initiated in 1978 to develop safflower cultivars that mature prior to a killing fall frost. As with the soybean program, safflower research is assisted by a provincial grant. Saffire, a cultivar that matures 1 week to 10 days earlier than standard U.S. safflower cultivars, was licensed in 1985. The shiny, white seed coat of Saffire makes it acceptable to the bird seed trade.

top
Saffire, a cultivar of safflower released in 1985, is adapted to southern Alberta growing conditions.

bottom
Grain sorghum yields well under dryland conditions in southern Alberta.

Potato research at Lethbridge is conducted as part of the Prairie Cooperative Breeding Project, which was established in 1978. The project involves researchers in the three prairie provinces and is partially funded by a Farming for the Future grant. Storage and irrigation facilities were established at the Vauxhall Substation to accommodate the new selection project. In the early 1980s, the Lethbridge Research Station assumed responsibility for the coordination of the regional trials. A centralized data collection and analysis system was developed, using computer facilities at Lethbridge.

One of the major objectives of the potato breeding program is to develop varieties for the french-fry and chipping industries. Varieties should have early maturity and good yields under prairie growing conditions, and possess the required processing traits. The Prairie Project is responsible for the introduction to the Prairies of suitable varieties developed by other breeding projects.

Cereal crops

Barley Barley is more tolerant of salty soils than other cereals or oilseeds, and seedlings can withstand temperatures of -8°C for a short period of time. These factors make it a suitable crop for the southern Alberta region. The emphasis of the barley breeding program at Lethbridge is on the production of 2-row dryland varieties, which usually outyield 6-row varieties in southern Alberta. Fairfield, a 2-row variety named in honor of the first superintendent of the Lethbridge Experimental Farm, was licensed in 1976. In trials, it outyielded previous varieties in all except the driest areas of western Canada and was more resistant to lodging and net blotch than Betzes or Hector, varieties also grown in southern Alberta.

During the 1960s and 1970s, barley from the Lethbridge breeding program was grown in the Imperial Valley of California during our winter. Since 1976, the indoor growth facilities at Lethbridge have made cropping in California unnecessary. In the phytotron, researchers have adopted a more efficient breeding procedure which allows the production of three generations per year. A new high-plant-density technique allows a tenfold increase in plant populations within the same area of plant growth rooms. These larger populations greatly increase the efficiency of selection, thus reducing the time required to identify superior plants for a new variety.

Corn The main objective of research in the corn-breeding program at Lethbridge is the development of short-season, high-yielding varieties for irrigated land. Inbreds and hybrids developed at the station, and those developed by the industry, are tested in field trials conducted annually at four locations in Alberta. The trials are under the direction of the Alberta Corn Committee, a group representing Agriculture Canada, Alberta Agriculture, the corn industry, agribusiness, and farmers. Trials provide data that are used for licensing and recommending hybrids for production in southern Alberta. One early maturing corn hybrid, developed from 10 years of plant research at Lethbridge, has been licensed for silage production on irrigated land. The hybrid yielded 24% more dry matter than standard early hybrids in silage trials.

Other aspects of corn research at Lethbridge include growth and development studies related to adaptation and production in a short, semiarid growing season. The area seeded on dry land is increasing as a result of the introduction of tested hybrids. In the future, the very early grain corn hybrid will likely have a strong stalk and a small cob and may also be a dwarf so that it can be seeded and harvested with conventional small-grains machinery.

Wheat In the irrigated regions of southern Alberta, soft white spring wheat is widely grown. Ten years of research at Lethbridge indicated that the best seeding date for spring wheat in southern Alberta was early April. The soil moisture reserves and cooler temperatures in the spring promoted greater tillering and earlier head development.

A sawfly-resistant hard red spring wheat variety, Chester, was licensed in 1976 and was briefly popular in the southern prairies. It was removed from production because of its high alpha-amylase levels. For most markets, low alpha-amylase wheat is essential. Spring wheat breeders are currently screening plant material for a number of characteristics, including resistance to sawflies and root rot, high yields, acceptable alpha-amylase levels, salinity tolerance, and high water absorption, which affects the volume of bread obtained from a given amount of flour.

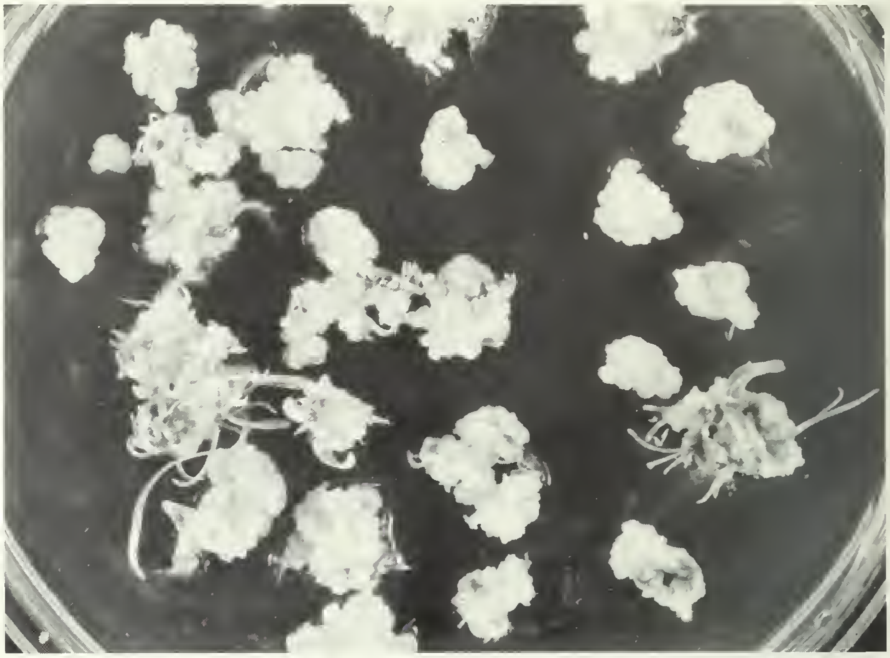
A focus on incorporation of bunt resistance into spring wheat resulted in the development of hard red spring and semidwarf lines carrying a gene for bunt resistance, and will provide important material for the development of future varieties.

Grazing seasons are extended into the fall when corn is used as forage for cattle.

In dryland areas, winter wheat is the traditional cereal crop. On dryland plots at the Research Station, winter wheat has outyielded spring wheat by an average of 20%. Production of winter wheat in southern Alberta has increased since the introduction of Norstar in the late 1970s. Norstar was developed at Lethbridge specifically for the dry southwestern prairies. It is winterhardy, high-yielding, and has good milling qualities.

Plant breeders are currently working to develop new varieties that combine the best qualities of Norstar with resistance to common diseases. Cooperative research between plant pathologists and wheat breeders led to the discovery of an excellent source for resistance to organisms that cause take-all and common root rot. Research also indicated that winter wheats could be vernalized by seeding in the field in February and March. This enables plant pathologists to use, under field conditions, bunt-resistant lines that lack winterhardiness.

The degree of coldhardiness in winter wheats determines their survival over the cold, dry winters on the Prairies. Cytogenetic work at Lethbridge has recently identified two wheat chromosomes that carry genes for coldhardiness and methods have been developed for transferring chromosomes and genes from some grasses to wheat. Analysis of the free amino acids in cold-hardened winter wheat crowns indicated that two acids, proline and glutamine, increased in the crowns of winter wheat when exposed to hardening temperatures. The increase was enhanced with the application of phosphorus but counteracted by nitrogen. The marked increase in proline during coldhardening could be useful in the detection of coldhardiness in winter wheats. When coldhardiness is better understood, the breeding of more coldhardy wheat varieties can be accelerated.



An embryonic callus from a single, immature embryo of bread wheat is produced by tissue culture techniques for the evaluation of somaclonal variation.

Chapter 4

Crop Protection

The performance of adapted crops is diminished by weeds and attacks by insects and diseases. The effects of these competitors on crop yields are assessed by weed scientists, crop entomologists, and plant pathologists at Lethbridge.

Weed control

Weeds compete with crops for nutrients and water reserves in the soil. Researchers at Lethbridge are studying the effects of using herbicides to control Canada thistle, quackgrass, and dandelions in small stands and on native rangeland. Control of weeds in forage crops increases crop yields, but weed control is not always necessary, as the nutritive value and digestibility of many common weeds is often equivalent to that of the forage crop. However, for production of seed crops, weed control is essential.

Testing the efficacy of new herbicides for control of weeds in cereal and special crops is an ongoing program at Lethbridge. A method was developed for using metribuzin to successfully control downy brome, a widespread weed in winter wheat stands. In other experiments, the rate, method, and timing of application of herbicides are studied to determine the most effective and economical management procedures.

A major part of research with herbicides is the study of their interaction with the soil environment. For example, although paraquat does not break down in Lethbridge soils, tests have established that it can be used for several hundred years before it will have deleterious effects on wheat crop yields. Scientists studying chlorsulfuron use determined that it persists in the soil for 5 years at levels unsuitable for some crops such as sugar beets.

Carefully managed herbicide applications can increase yields by as much as 35% in some cereal crops. Although herbicides can be potentially hazardous to humans and the environment, continual testing and monitoring of their effects keep food producers and the public informed. The future supply and cost of food will depend heavily on herbicides for weed control.

Insect control

As scientists continue to study the life cycles of insect pests and their effects on crops, they are placing more emphasis on natural, non-chemical means of control. Research results are combined into an integrated pest management program to provide control of crop competitors without total reliance on toxic chemicals. The release of biological agents such as predators and parasites, monitoring of pest populations, and development of techniques for predicting the occurrence and timing of insect damage will enable reduced and more effective use of insecticides.

Monitoring Several research programs at Lethbridge monitor population levels of pest insects, assess their potential for damage, and alert producers when infestations are at economically critical levels.

Lepidopterous pests such as the beet webworm, bertha armyworm, European corn borer, and various kinds of cutworms frequently cause crop losses. Localized infestations are common and widespread outbreaks, although relatively rare, can be devastating. Outbreaks often come as a surprise because the larvae are difficult to detect until the crop damage is extensive.

One way of predicting the number of larvae in an area is to monitor the abundance of moths in the preceding generation. A monitoring technique has been developed which is based on the natural communication system used by male and female moths for mating. In nature, the female attracts her mate by emitting minute quantities of a chemical blend (sex pheromones) into the air. Males 'smell' these with the olfactory receptors on their antennae and respond only to the pheromones of their own species. Once the pheromone components of a particular species have been identified and synthesized, synthetic blends can be used as trap baits to capture and monitor the abundance of only the target species.

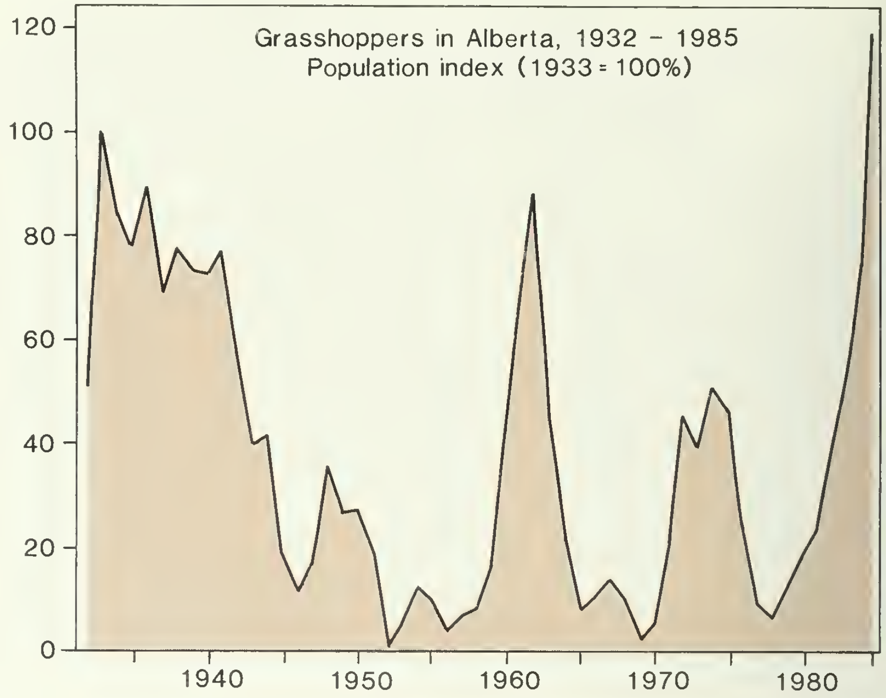
Based on chemical identification of the natural sex pheromone components and extensive field testing of possible blend combinations, we have developed synthetic sex pheromones for 17 pest species. Some of these are being produced commercially in Canada and are available for monitoring. In western Canada, pheromone-

Researchers monitor pest insects with pheromone traps, here placed next to wheat.

baited traps have been used since 1978 to monitor the population levels of eight pest species, including bertha armyworm and pale western, red-backed, and army cutworm.

If detected early enough, infestations can be effectively controlled with currently available insecticides before serious crop loss occurs. Sometimes it is possible to recommend agronomic practices that prevent larval infestations without the use of an insecticide. Monitoring of insect-pest populations with pheromone-baited traps leads to more efficient use of insecticides and lessened impact of toxic chemicals on the environment.

Grasshoppers Although approximately 40 species of grasshoppers exist in Alberta, only three are of economic concern. Yet, in years of high grasshopper population levels such as 1985, those few species attack cereal crops and rangeland grasses, causing extensive losses for the farmer and livestock producer alike.



Since 1932, when annual surveys of grasshopper populations began, there have been six major outbreaks of the most damaging species. The surveys, conducted by Agriculture Canada in cooperation with provincial and municipal departments of agriculture in Alberta, sample the number of adults in late summer on agricultural land throughout the province. Population densities of the adults provide an indication of the number of eggs laid. From this information, researchers can predict the areas most likely to have severe infestations of grasshoppers the following year. Summer drought conditions increase the grasshopper risk, but cool, wet springs usually decrease grasshopper populations.

Applications of insecticides are the most effective means of controlling grasshoppers. Research has recently been initiated on other forms of control for grasshoppers. Application of insecticide on bran bait achieves control in some cases with much smaller quantities of active ingredient. Biological control with a protozoan that causes debilitation, reduced feeding, and eventual death in grasshoppers has been accomplished in a limited area. Extensive testing of these and other forms of control will be required before they can be recommended for general use. For the present, monitoring of grasshopper populations and precise timing of insecticide applications remain the most effective treatments.

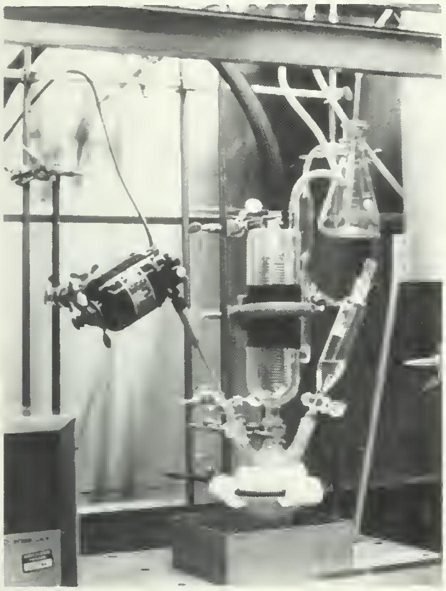
Aphids At the Lethbridge Research Station, research on the ecology of aphids has added information on the occurrence and importance of the more than 125 species in Alberta, several of which are major pests.

The importance of grain aphids on cereals was determined by researchers at Lethbridge and control methods were developed. Grain aphids can carry the barley yellow dwarf virus to barley and oats, reducing protein contents in the cereals and seriously reducing crop yields. The ecology of the pea aphid, a serious pest on forage alfalfa in the irrigated areas of the province, has been the focus of recent research. Scientists have determined that the pea aphid is a vector of verticillium wilt of alfalfa. Effective control of this pest is therefore necessary to prevent spread of the disease, and several insecticides have been assessed for their effectiveness in controlling pea aphids. At the same time, scientists have monitored the effect of insecticides on predators and other insects in alfalfa fields. Predators such as the ladybird beetle are important in control of pea aphids, as is the parasite *Aphidus smithii*. Populations of this parasite have become established in southern Alberta after rearing and release by Agriculture Canada scientists.

The spotted alfalfa aphid, a potentially serious pest, has been discovered in Alberta, and researchers are currently monitoring its distribution.

Forage crop insects A thorough understanding of the complex association of pest insects, predators, and parasites on forage crops is necessary to maintain high crop yields and compatible population levels of each insect species.

The major forage legume in Alberta is alfalfa, grown extensively in the irrigated areas of the south and on dry land in the central and northern areas of the province. The seed alfalfa industry supplies the domestic market with disease-free seed of hardy and adapted Canadian-bred varieties of alfalfa. In 1984, 40% of the alfalfa seed produced in Canada came from Alberta.



top
Liquid ammonia reduction is the final step in the process of pheromone synthesis.

bottom
Pea aphids carry verticillium wilt of alfalfa, a disease that threatens alfalfa production in Alberta. Pea aphids were recently shown to be a vector of the disease.

One factor that determines the seed yield of alfalfa is the extent of pollination of the crop. The major pollinator of seed alfalfa in Canada is the alfalfa leafcutter bee, a species maintained by beekeepers throughout the alfalfa-growing regions of the country. Researchers at Lethbridge developed the loose-cell system of bee management to facilitate handling the large populations of bees required to pollinate alfalfa. The quality of bees produced from this system has made Canada the world's leading exporter of this valuable pollinator.

Currently, research at Lethbridge on the alfalfa leafcutter bee is concerned with improving management techniques and controlling the two main pests of the bee, the driedfruit moth and *Pteromalus venustus*, a parasitic wasp. Research results are provided to growers and beekeepers at meetings and through extension bulletins, to continually improve the effectiveness and quality of the bees. The development of management techniques for the alfalfa leafcutter bee has also resulted in a steady expansion of the bee and seed alfalfa industries. Annual increases of 40-50% in the seed alfalfa-growing area in Canada in the past decade reflect the rapid growth of the industry.

More than 200 species of insects occur in stands of seed and hay alfalfa in Alberta, but few cause serious damage to the crop. Natural predators, parasites, and diseases keep populations below critical levels in most years. The major pest insects requiring control are alfalfa weevil, lygus, plant bug, and pea aphid. Heavy infestations of the pea aphid have been shown to increase winterkill of alfalfa. Recent discoveries also indicate that the pea aphid and other insects can spread verticillium wilt of alfalfa.

In 1978, an integrated pest management program was established in southern Alberta to assist producers of seed alfalfa. The program is a cooperative effort between Agriculture Canada, provincial agricultural departments, and seed growers.

Researchers monitor insect population levels in seed alfalfa fields to alert growers to potential problems. Damage by pest insects can be costly, but control measures such as spraying of insecticides often destroy predators and pollinators along with the target insect. Therefore, accurate timing of insecticide spraying is essential to control pest insects and protect beneficial insects. Determination of the optimal time for spraying is now possible with the use of a computer model that incorporates weather data and biological data on the insect to predict the relative abundance and time of appearance in the field of pests such as the alfalfa weevil. Researchers hope to eliminate ill-timed spray applications in the future, thereby reducing costs to the growers and increasing the yields of seed alfalfa.

The nutritional value and growth habit of cicer milkvetch make it an excellent substitute for alfalfa for livestock on pasture, but it is not widely grown because of low seed set. Pollination research on this and other forage legumes is attempting to overcome such restrictions. Plots containing 30 species of forage legumes have been established at the Lethbridge Research Station for pollination research with several bee species. A pollination model, which predicts the number of pollinators required to obtain maximum pollination of the crop, was developed for use on cicer milkvetch and sainfoin.

Field crop insects Investigations on insect control by researchers at Lethbridge have provided information and management techniques on a variety of insect problems associated with sugar beets. For example, the use of a 4-year crop rotation for control of the sugar beet cyst nematode and use of cultural methods for control of the sugar beet root aphid and beet leafminer have greatly reduced the use of insecticides for these pests.

Recent tests at the Lethbridge Research Station have shown that use of insecticides can be improved in terms of application method, rate, and timing of application. Research was conducted to investigate the application of insecticides after seedling emergence, rather than applying insecticides to the soil during planting. This method allows growers to monitor their fields before treatment to determine if control measures are really needed. The success of postemergent programs will depend on proper timing, to ensure that an insecticide is applied if and when pests are present in the field.

Pesticide use is an integral part of pest management, but the impact of insecticides on the environment must be assessed before they can be licensed for use. At Lethbridge, scientists examine residue levels in soil and plants, methods of application, and the effect of insecticides on both the target and beneficial insect species.

Synthetic pyrethroids are a new group of insecticides that are highly active against insect pests but are relatively safe for human applicators. The persistence of two synthetic pyrethroids, fenvalerate and deltamethrin, was measured in Lethbridge soils. Both remained in the soil for moderate durations and were deemed environmentally acceptable for use. From that research, a model was developed to improve the prediction of residue levels of deltamethrin. The persistence of deltamethrin on rangeland is currently being studied. This insecticide has potential for controlling grasshoppers, but residue studies are required first to determine when cattle may safely graze treated fields.

Fenvalerate has been licensed for use as an insecticide, but research at Lethbridge indicated that its use could threaten some beneficial insect populations. Research is in progress to determine whether fenvalerate and deltamethrin can become biologically available to beneficial insect species such as alfalfa leafcutter bees after they are applied to crops.

Aerial application of insecticides is a special area of research which offers several advantages: it enables timely treatment of outbreaks of pest insects, large areas can be treated in a short time, it is more effective than ground application on rough terrain, and mature crops are not physically disturbed by aerial spraying. Applicators and researchers are currently concerned with ensuring that adequate amounts of insecticides reach the target insects.

left
Pale western cutworms damage spring cereals before emergence of leaf.

bottom
In aerial application trials, an AgCat 164 sprays permethrin to control pale western cutworm in wheat.

Disease control

Research on the control or elimination of diseases in crops is focused on studies of the epidemiology of disease pathogens to determine which environmental conditions favor disease establishment. The effects of drought, rainfall, irrigation, and both soil and air temperatures on survival of disease pathogens are assessed in experiments with the major crops of southern Alberta.

Many of the diseases common on crops are most severe in irrigated areas where cool, damp soils provide conditions conducive to development and survival of pathogens. Other diseases reach peak infection levels on dry land, particularly when the crop is stressed during drought periods. Pathologists monitor the incidence of plant diseases by means of field surveys and reports from growers.

Research on ring rot bacteria in potatoes has led to effective decontamination procedures for control of the disease.

Forage crops Bacterial wilt, stem nematode disease, and crown bud rot were the most important diseases of alfalfa in southern Alberta in the past two to three decades. Research was carried out at the Lethbridge Research Station to develop alfalfa cultivars resistant to these diseases and to determine how long pathogens will survive in soil. Through the efforts of breeding and pathological studies, new winterhardy alfalfa varieties with resistance to bacterial wilt and stem nematode were developed and released for commercial production. These potentially dangerous diseases are now controlled in western Canada by the use of resistant varieties.

Verticillium wilt of alfalfa, an important disease in Europe, became established in North America in 1976. It now threatens alfalfa production in the northern United States, British Columbia, Alberta, and Ontario. A new research project on this disease was initiated in 1982 to support the Station's ongoing efforts in developing disease-resistant cultivars and to investigate the pathology, survival, epidemiology, and control of the disease. Major achievements to date are the discovery of insect pests that serve as vectors for verticillium wilt of alfalfa and the elucidation of mechanisms involved in the seed-borne verticillium pathogen in alfalfa. Scientists have also proved that the pathogen survives in alfalfa tissue after passage through the digestive tract of ruminant animals. Current research is assessing the survival of the pathogen in the soil, during ensilage, and in dehydrated alfalfa. The possibility of controlling the disease by biocontrol agents and chemical seed treatment is also under investigation.

Field crops White mold caused by *Sclerotinia sclerotiorum* is a devastating disease of bean, canola, and sunflower in southern Alberta, particularly when these crops are grown under irrigation. A research project was initiated in 1982 to develop methods for controlling this disease. Researchers have developed an effective technique for screening bean cultivars for resistance to white mold. This has accelerated the breeding program for release of high-yielding bean varieties with white mold resistance. Current studies involve the biological control of white mold by fungi that attack *S. sclerotiorum*, with special emphasis on using these fungi in soils to suppress the pathogen.

Bacterial ring rot is a persistent disease of potatoes, which, if uncontrolled, causes serious losses to potato producers. For almost half a century the industry has battled to eradicate this tuber-borne disease from seed and commercial stocks. Research at Lethbridge on survival of the ring rot bacterium demonstrated that it can survive for up to 5 years in dried infected potato stems, for at least 2 years on jute bags and other surfaces, but for only a few days in warm, moist soil. This has led to more effective decontamination procedures in potato operations where outbreaks of ring rot have occurred.

Uncontrolled Fusarium root rot can result in yield losses of 15% or more in irrigated fields of processing peas in southern Alberta. Experiments on Research Station plots demonstrated that a rotation of pea crops and fallow reduced root rot severity and increased pea yields. Rapeseed as a rotation crop also decreased the disease severity but depressed pea yields. Other crop sequences are being tested to identify those that will reduce root rot of peas without decreasing yields.

Cereals The cereal crops successfully grown in southern Alberta are resistant to several diseases and insects, and possess sufficient hardiness to withstand dry summers and saline soils. Wheat, barley, oats, rye, and corn are the main cereal crops in the province. Soft white spring wheat is grown under irrigation in southern Alberta, where it is susceptible to infection by diseases such as black point, rusts, powdery mildew, root rot, and ergot. Although black point seldom reduces crop yields, it lowers grades, which creates losses for the producers. Because timing of irrigation appears to be a key factor in disease severity, an irrigation management system is being developed at Lethbridge, with the support of the Alberta government's Farming for the Future program, to reduce black point and maximize returns.

Diseases such as stripe rust, leaf rust, and powdery mildew are more important on soft white wheat than on the non-irrigated hard red wheats. Control of these and other diseases can best be achieved by growing resistant cultivars. Plant pathologists and plant breeders are studying the genetics of resistance to common root rot and black point, and they continue to screen lines and crosses for improved resistance to leaf rust and stripe rust. When new sources of disease resistance are identified, they are used to improve the level of resistance in soft white spring wheat cultivars adapted to prairie conditions.

The virus disease wheat streak mosaic caused serious losses to winter wheat in southern Alberta until the epidemiology of the disease was understood. The virus that causes the disease is carried by a mite, which also transmits the wheat spot mosaic virus. Wheat streak mosaic has now been virtually eliminated by changes in agronomic practices, such as destroying mite-harboring immature crops prior to seeding winter wheat. Cytogenetic work has led to the transfer into winter wheat of mite resistance from a grass, *Agropyron elongatum*. Lines that carry resistance to the mite are expected to provide improved control of wheat streak mosaic, particularly in the more northerly parts of the Prairies where cultural control is more difficult to use because of the short growing season.

top
Scientists are testing fungicides for control of the disease take-all, which has damaged the roots of the wheat plant on the right.

bottom
Ergot on rye. Wheat, barley, and most grasses are susceptible to this highly epidemic disease that renders grain unsuitable for human or animal consumption.

Bunt is a disease in which the kernels of both spring and winter wheats are replaced with spore masses of the fungus. Even low levels of infection—one bunt ball in 10 000 kernels—can result in a grade loss. Control of bunt is complicated by the existence of several races of the pathogen. Wheat resistant to one race can be infected by other races of the bunt fungus. Plant pathologists are establishing which races occur in western Canada and they are collaborating with plant breeders to develop wheats resistant to one or more races of bunt.

The pathogen *Coprinus psychromorbidus*, which causes snow mold in cereals and grasses and winter crown rot in legumes, was identified at Lethbridge in 1980. Researchers have studied its occurrence and spread in the central and northern regions of the Canadian prairies where prolonged snow cover throughout the winter and early spring provides an ideal environment for development of the snow mold fungi. The susceptibility of winter wheat to snow mold pathogens is one restriction to expansion of wheat production into central and northern regions of the Prairies. Current research at Lethbridge emphasizes the identification of winter wheat lines resistant to the snow mold pathogen under controlled conditions. Scientists are also studying the different environmental conditions that promote the development of resistance in winter wheat and conditions that predispose winter wheat plants to attack by snow mold fungi.

Diseases such as stem smut, ergot, and snow mold affect rye crops in Alberta. The incidence of stem smut is highest in areas where the preferred but susceptible cultivar, Cougar, is grown. In tests with fall rye, scientists determined that treating seed with a fungicide controlled stem smut originating from both seed- and soil-borne spores of the pathogen. Other means of control include growing rye once in a 4-year rotation, and using a smut-resistant cultivar such as Kodiak. Plant pathologists at Lethbridge are working with plant breeders at the Swift Current Research Station to develop highly smut-resistant lines of rye that retain the desirable characteristics of Cougar.

Very coldhardy winter wheats have a prostrate growth habit in the field. Scientists at the Research Station have recently succeeded in producing this type of growth by exposing wheat plants to high light levels at near-freezing temperatures in growth chambers. As a result, they can now investigate whether the prostrate growth habit is directly related to winterhardiness.

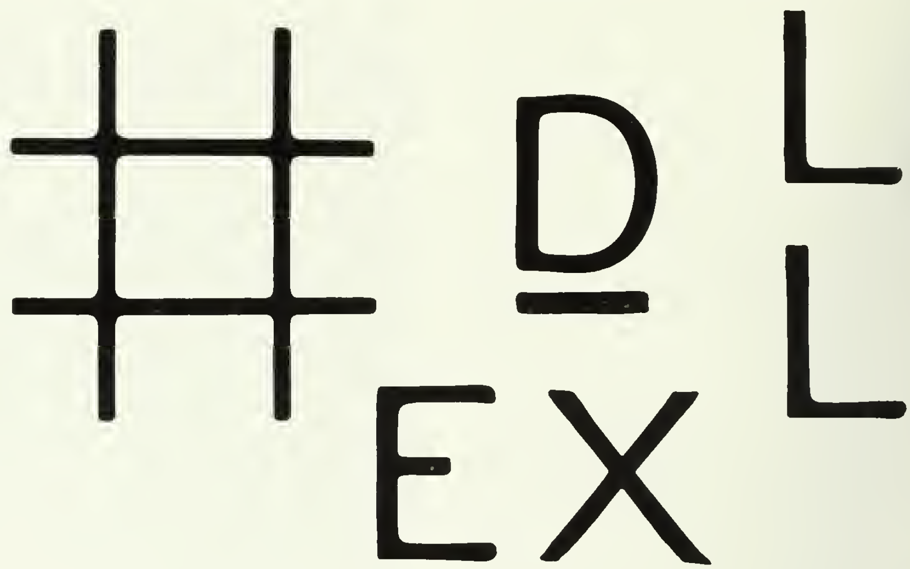
Studies on the coldhardiness of winter wheats have also determined several factors influencing the degree and duration of hardiness. The coldhardiness of winter wheat changes with duration of exposure to hardening (near 0°C) temperatures both in growth cabinets and in the field. It is also influenced by the duration of growth at warmer temperatures before hardening commences. Our best winter wheat varieties when adequately hardened can withstand 2 days at -15°C but not 2 days at -20°C. Hardiness in plants eventually declines under hardening conditions in growth chambers and also in late winter in the field. When plants are exposed for long periods (10-20 weeks) to temperatures below -5°C, damage increases with time and with decreases in temperature. This research explains why differential winter killing, apparently caused by low temperatures, occurs late in winter in the field even though temperatures of the wheat plant crowns do not drop to -15°C. We are now using a screening method that takes into account both temperature and duration of exposure to identify lines with improved coldhardiness.

Winter wheat on plots kept clear of snow (background) is killed by low temperatures during the winter.

Chapter 5

Livestock Adaptation

At Lethbridge, animal scientists conduct research to improve the efficient production of cattle and sheep through breeding, reproduction, nutrition, physiology, rumen microbiology, and management. By crossbreeding, selection and management of livestock, scientists have increased the productivity of ewes, the milk production of dairy cows, and the gains of beef cattle, and have reduced physiological disorders of livestock. Grazing studies are complemented by the work of rangeland ecologists on the carrying capacities of various ranges and the nutritional value of range forages.



Registered brands of the Lethbridge Research Station. Top: window frame, for cattle at Onefour Substation; D, for horses at Lethbridge, was discontinued in the 1960s; L over L, for cattle at Lethbridge. Bottom: EX, for sheep at Lethbridge, was discontinued in the 1980s and replaced with painted brands.

Breeding

Beef cattle A long-term selection study with beef cattle was initiated in 1963. During a 168-day feedlot trial, male and female Angus and Hereford calves were fed one of two diets, either a traditional high-concentrate diet intended to promote a rapid growth rate, or an all-hay diet. They were then selected as replacements on the basis of feedlot gain. After one year of age, cattle were treated as a single grazing herd. Females selected on the hay diet produced more milk and weaned heavier calves than those selected on the high-concentrate diet. Digestive disturbances, rumen wall damage, and deaths (primarily due to bloat) were greater among the calves fed the high-concentrate diet than among those on the hay diet. The results demonstrate that it is unnecessary and unwise to subject replacement male or female stock to high-concentrate diets during the test periods to select the fastest-gaining animals. The effect of a high-energy diet on heifers can be reduced fertility and longevity, as well as reduced milk production, which lowers the weight gain of their calves. The results of this project are having an impact on the way cattlemen manage their herds.

In studies on a short-grass range, Hereford x Highland cows produced more milk and weaned heavier calves than straight-bred Highland or Hereford cows. Although the Highland cows are not recommended as a pure breed under range conditions, the Hereford-Highland has proven to be an excellent range cow.

The establishment of quarantine stations in Canada in 1965 to permit importations of cattle from Europe led to the introduction of many new breeds. Importers extolled the virtues of each breed imported, but the performance potential of these breeds in the Canadian environments was unknown. In 1969, the Research Branch of Agriculture Canada, utilizing resources at the Research Stations at Lethbridge, Brandon, and Lacombe, undertook a program to evaluate three of the newly imported breeds (Simmental, Charolais, and Limousin each in combination with Hereford, Angus, and Shorthorn) as well as the Hereford x Angus cross in a crossbreeding program. The Lethbridge Research Station centered its work at the Onefour Research Substation and contributed information on cattle raised under extensive management conditions on the short-grass prairie, while a similar group was evaluated under semi-intensive management at the Brandon Research Station. The birth and weaning weights of calves were greater for the large imported breeds than for British breed crosses. However, under the short-grass range conditions, some of the larger and more productive crosses were unable to meet their energy requirements which resulted in low conception rates. Many of the exotic crossbred animals had little or no measureable backfat after weaning their calves in the fall. With larger body weights and little backfat to act as insulation and a store of energy, their winter feed requirements were higher than for the fatter British breeds. The need for changes in management systems with different breed crosses was evident. Also evident was the difference in response of the various breed crosses in the two environments. Interest in this project is extensive and producers across North America have adopted the research findings to improve their management decisions and production systems.

Dairy cattle Since 1955, dairy research at Lethbridge has been part of a national dairy cattle breeding project involving four other research stations. Since 1971, the selection criterion has been milk protein yield. A significant observation is the variation in milk production among the different cooperating stations. Since semen from the same bulls has been used at all stations for the past 30 years, the herds are genetically similar. However, the Lethbridge herd annually produces about 30% more milk per cow than herds at the other Agriculture Canada stations. This difference in production is attributed to management, feeding, and environment of the cows.

Breeding trials with Holstein x Ayrshires and Holsteins will conclude in 1987. Researchers have documented greater reproductive efficiency and improved health, but slightly lower milk production, in crossbred cows than in the purebreds.

top
Crossbred cows and calves are maintained on the open range in the Foreign Cattle Breed Evaluation project at the Onefour Substation.

center
Good management is responsible for the high production (8500 kg/year) of the Lethbridge dairy herd.

bottom
Under intensive management, these Finnish Landrace crossbred ewes each produced four lambs.

Reproduction

Beef cattle Research on the reproductive physiology of beef bulls began in 1974. By studying the effects of diet on the reproductive capacity of Hereford and Angus bulls, scientists established that feeding high-energy diets to young bulls reduced their reproductive potential. Bulls fed high-energy diets to appetite had substantially fewer spermatozoa and more scrotal fat than bulls fed medium-energy diets. This increase in fat is thought to impair regulation of temperature in the testes and consequently reduce sperm production and semen quality. Producers can protect the reproductive potential of young beef bulls, which is more important economically than growth potential, by maintaining them on medium-energy diets.

Paired testes weight, which is highly correlated with sperm-production capacity of young beef bulls, was estimated by measuring scrotal circumference. Breed averages for scrotal circumference were determined for several breeds of beef bulls at 1 and 2 years of age. Sufficient variability within breeds was demonstrated to permit the use of scrotal circumference as a criterion to select bulls with high sperm-production potential. Adjustment factors have been developed to correct scrotal circumference for age and body weight of bulls. Because testicular size and body growth rate of young bulls are not related, it is necessary to use both of these factors in beef bull selection.

A comprehensive field trial is being conducted to determine the efficacy of methods for testing the fertility of beef bulls used for multiple-sire breeding under range conditions. An extensive technology transfer program, related to selection and management of young beef bulls to improve reproductive capacity, has been developed. Recommendations resulting from the research program on beef bulls have been adopted widely by the Canadian beef cattle industry.

Sheep With the introduction of the Finnish Landrace sheep in the early 1970s and the Romanov breed in the early 1980s, scientists at Lethbridge began cross-breeding experiments to increase the reproductive capacities of ewes. Sheep research currently stresses the development of intensive systems to produce more lambs per ewe and more lamb crops per year than in a traditional farm flock with one lamb crop per year. Through the use of controlled lighting, a system has been developed to permit breeding at any time of the year with conception rates of 85% and higher, and a threefold increase in the annual lamb crop, from ewes sired by Finnish Landrace and Romanov rams. With the support of good management, several ewes in the Lethbridge flock have weaned four lambs each.

An experiment with Rambouillet and Romnelet sheep demonstrated that, through selection, an increase of 0.01 kg in daily growth rate from birth to marketing could be attained each year.

Nutrition

Most of the beef cattle marketed in Alberta start on pasture and finish in feedlots. For economical production, producers require information on efficient diets that promote high growth rates and result in high quality carcasses. Controlled studies are conducted on rangeland in southern Alberta and in facilities at the Research Station to determine the most productive management procedures.

Studies of the utilization of forage by ruminants have led to the formulation of diets to improve feed efficiency and increase productivity. Ruminants require diets balanced in energy and protein to attain full growth rates. In experiments at Lethbridge, steers fed a diet having a protein level considered to be adequate by National Research Council standards gained faster when the diet was supplemented with formaldehyde-treated canola meal than with plain canola meal. Protein in the treated canola meal was protected from degradation by rumen bacteria. It thus bypassed the rumen intact and was digested in the intestines. There, the amino acids released were absorbed and contributed to muscle growth.

The advantages of feeding protein supplements with low-protein forages are well documented, and it is also recognized that urea may serve as a source of nitrogen for ruminant animals. Rumen microflora convert urea nitrogen to protein nitrogen, which can be used by the animal. Urea in large quantities is toxic; however, when fed as part of a mash diet, urea inhibits consumption by the animal. Using this information, researchers formulated a high-urea diet that was self-fed and self-limiting, and provided the nitrogen required as a protein supplement for low-protein forages.

The results of studies at Lethbridge suggest that the digestion and metabolism of feeds are not influenced by breed type. The total energy required to produce 1 kilogram of beef was the same for offspring of dams of four breed types differing in size at maturity (Simmental x Angus, Charolais x Angus, Hereford x Angus, and Jersey x Angus). Among the four breed types, heifer calves grew at the same rate despite large differences in milk production of their dams. Bull calves consumed about the same amount of milk as heifer calves but consumed more creep feed and gained faster.

Frothy bloat occurs in ruminant animals fed legumes on pasture and in feedlots. Rumen bacteria easily rupture the leaves of alfalfa, releasing plant sugars that result in rapid proliferation of bacteria. The resulting rapid digestion of the alfalfa leaves produces large quantities of gas and foam mixed with plant particles; thus the term frothy bloat. Work on a bloat-safe alfalfa variety at the Saskatoon, Kamloops, and Lethbridge Research Stations was enhanced by the development of techniques to determine the initial digestion rate of forages. Testing of the first generation of alfalfa selections demonstrated that the initial rate of digestion was reduced by about 6%, which is about one-third that considered necessary to prevent legume bloat.

above
In digestibility trials, carefully weighed samples of rations are fed to sheep.

Scientists at the Research Station found that the incidence of feedlot bloat was nearly eliminated by maintaining coarse particle size in all-concentrate diets, and concluded that feedlot bloat was not caused by the concentrate diet itself, but by fine particle size. Maintaining coarse particle size of all-concentrate diets of barley or triticale was also found to increase rate of gain by about 15% and feed efficiency by about 10%, compared with fine particle size diets.

Physiology

In addition to breeding and nutrition programs, scientists are looking for other ways to improve growth potential in cattle. Work is under way to study the relationship between the growth rate of beef calves and the hormonal mechanisms that control it. The goal is to find hormonal indicators, measureable at an early age, that will predict growth rate. With a better understanding of the hormonal mechanisms involved in growth, it may be possible to manipulate the natural hormone systems of calves to increase their growth rate. Such an increase would further improve the efficiency of meat production.

Research on the treatment of digestion-related disorders improves the productivity of cattle and sheep. When calves on rangeland are weaned, water consumption is low relative to forage intake, with the result that minerals, particularly silica, are deposited in the form of urinary calculi. Blockage of the urinary tract can cause death. From studies with calves at Lethbridge, the cause of calculi formation was determined and preventative procedures were developed. Since calculi form when the water intake of calves is too low, a high-salt creep feed added to their diet before weaning induced calves to consume more water and reduced the risk of urinary calculi.

Microbiology

The rumen and its complement of microorganisms set the ruminant animal apart from single-stomach animals. The presence of cellulose-digesting bacteria in the rumen enables these animals to utilize roughages that monogastric animals cannot use in large quantities.

left
The feed mill, which began operations in 1986, contains equipment equivalent to that of a commercial mill and has several additional features designed to enable preparation of feed mixes with specific additives. Researchers can prepare special rations for feeding trials on a hand-batch basis or use computerized processing to ensure highly accurate ration formulation.

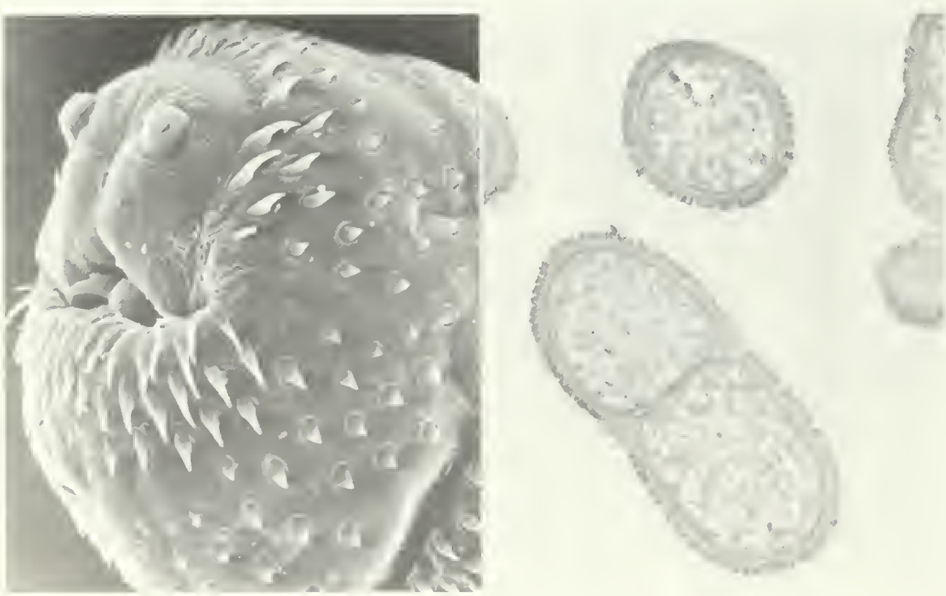
In the last decade, significant progress has been made in the understanding of different functions performed by the three distinct rumen microfloral populations: those attached to feed, those that are free-floating in the rumen fluid, and those attached to the rumen wall. Each plays a different role in the overall digestion of feed, in the recycling of ammonia and dead epithelial tissues of the digestive tract, and in the production of volatile fatty acids, enzymes, and vitamins required by the animals.

The work at Lethbridge followed two lines: a basic study of digestive tract microbiology, and a series of chemical and biological treatments to improve digestive tract functions. The important role that the adherent rumen microflora play in the digestion of cellulose, in the production of digestive enzymes, and in the recycling of dead epithelial cells that account for about 5% of the protein needs of the animal has been identified. Bacteria adhering to the rumen wall convert the urea that diffuses into the rumen from the blood into ammonia. The ammonia, in turn, is converted into microbial protein that is available to the animal.

The introduction of desirable bacteria into the digestive tract of newborn ruminants has been accomplished and may be a possible means of preventing the establishment of disease-causing organisms. Scours is an intestinal infection caused by bacteria, which results in severe dehydration and often death of young livestock. When lambs were treated with an antibiotic (monensin), it did not alter the pattern of rumen microbial fermentation, but did increase the feed efficiency of animals. This was attributed to its suppression of coccidia, the scours-causing bacteria present in the rumen. These findings suggest that monensin will be most effective in improving feed efficiency in coccidia-infested animals.

Cooperative research with the Kamloops Research Station showed that rumen microflora adapt to toxic levels of nitrite and nitrotoxins in feeds by developing higher levels of enzymes that degrade these compounds. Feeding trace amounts of nitrate and nitroethane stimulates the adaptation of rumen microorganisms that degrade nitrites and nitrotoxins rapidly. These results provide the basis for the development of chemical additives to prevent animal deaths from nitrite poisoning.

In 1982, a bacterial culture center was established at Lethbridge to facilitate the work of researchers in the fields of rumen and soil microbiology and provide a readily available source of reference cultures as well as facilities for the isolation, identification, and preservation of bacterial strains collected during current research.



Economic analysis

Animal scientists working in cooperation with agricultural economists have generated computer models to determine the economic outcome of various management practices. For example, a computer simulation model was developed in the 1970s to study the economics of various systems of sheep production. Comparisons of conventional production systems with systems that use new breeding and management techniques indicate the economically important factors and those requiring further investigation.

A computer model was developed using data from grazing and feedlot trials to calculate net returns on beef cattle. The factors considered include type of forage, steer requirements and performance, and cost of non-feed inputs including fertilizers. Researchers concluded that legume pastures gave higher net returns than grass under most price conditions even though grass pastures produced faster gains. However, the cost of nitrogen fertilizer required for grass pastures was more than offset by the advantages of the faster gains.

A linear program model was developed to determine the amount of feed required for a specific rate of gain in feedlot cattle. Development of the model required a definition of nutrient requirements to take full advantage of available information. This led to the definition of digestible energy as a function of the weight of the animal and the rate of gain. Redefinition of protein requirements, generally the second most expensive nutrient of beef cattle diets, followed the development of the linear program model. The definition of protein requirement is important to minimize feed costs while maintaining optimal performance of the cattle.

Photomicrographs such as these prove invaluable to researchers in interpreting their work. Left: SEM of the head of a newly hatched cattle grub (X1000). Right: TEM of cellulolytic bacteria in a bovine rumen (X23,000).

Chapter 6

Livestock Protection

To realize the full potential of their livestock, producers must protect them from parasites and attacking insects. Through studies in chemistry, immunology, and biology, our knowledge of the host-parasite relationship increases and new approaches to protection are developed. Research on the use of chemical insecticides includes assessments not only of their effectiveness, but also of their safety to humans, livestock, and the environment.

The effectiveness of insect repellents is assessed in experimental applications to cattle.

Toxicology

Chemicals used as insecticides must be more than effective against insect attacks; they must also be safe to use and easily degraded by animal enzyme systems so that residues do not accumulate in the tissue of food animals. Tests on the host animals' reactions to chemicals are an essential part of insecticide research. These studies in toxicology are done to ensure that insecticides have no adverse effects on livestock. Small laboratory animals are treated with systemic insecticides and monitored for changes in physiology and reproduction before the chemicals are recommended for use on livestock. In addition, assays have been developed to measure the key enzymes involved in the metabolism of chemicals by animals.

New mosquito repellents with desirable properties for human protection are being tested in cooperation with the U.S. Department of Agriculture. Results to date are encouraging. Pure samples of synthetic pyrethroid insecticides, which offer considerable potential for protection of livestock from biting flies, have been prepared for research purposes.

Treatment

Insecticides are applied to animals in several ways. Pour-on and spot-on methods involve dousing part or all of the backs of livestock with solutions of systemic insecticides. Provided the chemical remains on the animals and does not run off onto the ground, the treatment is effective.

Solutions of insecticides are also applied as sprays to livestock. A dual-cloud electrostatic sprayer, developed by the University of Western Ontario under contract to Agriculture Canada, emits two clouds, a water aerosol above and a permethrin aerosol below. Because the aerosol clouds are charged with the same polarity, there is an electrostratic repulsion between them. Thus, the water aerosol cloud forces the permethrin aerosol cloud toward the ground surface, depositing the permethrin onto the cattle. The droplets of permethrin are attracted to the hairs on all parts of the animal's body and protection from black flies is provided for 3 to 5 days after each treatment. The sprayer is easily transported to herds on open pasture. Another advantage is that only small amounts of spray emulsion are needed to completely cover an animal's body; thus, there is minimum waste of expensive chemicals and minimum impact on the environment.

Plastic ear tags impregnated with insecticides have become an important device for control of certain livestock pests on grazing cattle. The synthetic pyrethroid or organophosphorus insecticides in the ear tags are gradually released onto the hair coat of cattle, where they come in contact with insects. If used properly, the ear tags provide season-long protection.

Biting and blood-feeding flies

Attacks by many species of biting and blood-feeding flies cause stress and discomfort to both farm and range cattle and result in economic losses.

Blood-feeding flies disperse rapidly from untreated areas to infest animals on farms and ranches and to cause unpredictable problems in livestock management. Basic biometeorological relations between fly behavior and physical conditions of the atmospheric environment have been defined, which facilitates forecasting of pest infestations and insect-borne diseases. Modern computerized monitoring of important species will greatly improve the efficiency and effectiveness of control methods in managing outbreaks of pests and vectors of disease.

Because biting flies can be contaminated with disease organisms during a blood meal and subsequently transmit them to other animals, the feeding habits and hosts of biting flies are being studied. Blood extracted from various species of animals is stored in a blood bank at Lethbridge for preparation of antigens to be used to determine which animals a particular biting fly species has been feeding upon. Identification of the hosts of biting flies will aid researchers in developing disease-control programs.

Mosquitoes Mosquitoes are one of the many blood-feeding pests of livestock in Alberta. In the irrigated areas of the province, stagnant bodies of water provide excellent breeding grounds for the pest. Complete eradication is not practical, so the alternative is to protect the livestock from attack. Chemical control with repellents is the usual method of protection.

Another method—biological control of pests—offers the promise of a self-perpetuating system that uses natural organisms and reduces the use of chemicals. A fungus that is a parasite of the larval stage of one of the 18 species of mosquito in Alberta occurs naturally in the irrigated regions. In cooperation with scientists from other institutions, mosquito researchers at Lethbridge have determined the geographic distribution of the fungus and studied its life cycle. Field trials in 1979, in which mosquito-breeding ponds were artificially infested with the pathogen, yielded 60% control of mosquitoes. Further trials are underway to extend the geographical distribution of the pathogen, with the objective of establishing a natural population balance between it and the mosquito. As more information on the pathogen-parasite relationship becomes available, the potential to apply the biological control concept in other areas of the world will increase.

Horn flies Adult horn flies feed on the blood of cattle, as often as several dozen times a day, and rarely leave their host. Untreated animals subjected to stress from horn flies spend less time grazing than do treated animals. Moderate infestations of horn flies consistently reduce weight gains in untreated, immature cattle by 20%; losses can reach 45% when fly populations are high (more than 200 flies per animal). Thus, protecting grazing cattle from horn flies improves productivity. In field trials in southern Alberta, ear tags impregnated with a pesticide (fenvalerate) protected steers for the full grazing season. Gains of protected animals were 18% greater than those of unprotected steers.

In other trials, permethrin sprayed onto cattle prevented horn flies from taking a blood meal for up to 10 days. Retreatment was necessary throughout the grazing season.

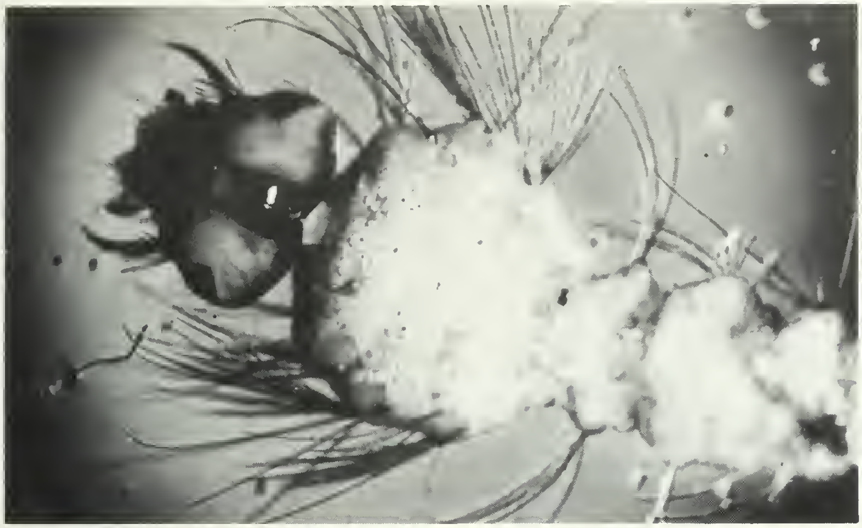
Because horn flies have developed resistance to some pesticides now in use, researchers are investigating nonchemical methods of pest control.

Black flies Black flies (*Simulium* spp.) are a major livestock pest in the beef and dairy production areas of north-central Alberta and limit expansion of the industry. Attacks by black flies reduce weight gains in beef cattle, reduce milk production in dairy cattle, disrupt the breeding activities of bulls, and can cause animal fatalities.

Water velocity is measured in black-fly studies to assess the influence of environmental factors on fly populations.

Agriculture Canada organized and led a multidisciplinary interagency program on black-fly control in the Athabasca River. For 5 years, researchers examined the effect of pesticide use on black-fly populations and the environment. On the basis of the results of the program, recommendations for abatement of black flies in large rivers have been developed. An annual spring treatment of the water with the pesticide methoxychlor provided effective control of black-fly populations without detrimental accumulations of pesticide residues in river water or delta deposits.

Subsequent research has concentrated on methods of assessing the population levels of black flies. A device constructed at Lethbridge collects black-fly eggs floating on the surface of small rivers and creeks as part of a study on the embryonic development



top
Coelomomyces psorophae, a water mould that exists naturally in the Lethbridge area, kills mosquito larvae.

bottom
Black fly attacks on cattle in the Athabasca region of Alberta limit livestock production.

and hatching of black flies. Information derived from the study will be used to improve the scheduling of larvicides for better control of black flies.

By studying and recording the effect of weather on the flight activity of black flies, scientists may soon be able to predict the optimal conditions for flight activity and thus improve the timing of on-farm chemical treatments. Insecticides currently in use can provide protection from black flies for up to 10 days, but timing of application is important because of the short protection period.

Recently, all major rivers and creeks in southern Alberta were surveyed to determine the geographic distribution of black-fly species. Studies on the seasonal abundance of black flies in this area have also been completed. From these baseline data will come a better understanding of the impact of human activities, such as dam construction, on the composition and distribution of species.

Warble flies Two species of the warble fly, *Hypoderma lineatum* and *H. bovis*, are widespread on cattle in Alberta and Saskatchewan. The larvae, which hatch from eggs laid by the fly on cattle hair, enter the animal's body by way of the hair follicle and migrate to the back where they cut a breathing hole and form a cyst (warble). When mature, they drop onto the ground and flies emerge from the pupae to continue the cycle. Larvae inside the animals reduce weight gains, the encysted grubs damage carcasses and hides, and the egg-laying activities of the flies cause gadding in cattle herds. Thus, control of the warble fly is essential to reduce economic losses to the producer and packer.

Treatment of the warble larvae with systemic insecticides can be more than 90% effective when properly timed and conducted. However, populations of warble flies can recover rapidly after near-extinction and, for this reason, inspection and control must be constantly maintained. Results from research on the control of warble flies with systemics served as a basis for establishing legislation in Alberta for mandatory control of warble flies.

Studies on the environmental, reproductive, and host factors that regulate population fluctuations of warble flies have been developed into a successful integrated pest managment (IPM) program. One aspect of IPM is biological control. Releases of sterile male flies, which mated with wild warble-fly females, were first tested in the late 1970s. Populations of *H. lineatum* were eradicated by this method in a pilot-scale test on a cattle ranch in Alberta. In 1982, the 5-year U.S.A.-Canada Project on Integrated Control of Cattle Grubs was initiated to determine the feasibility of eliminating warble grubs, within a limited area, by releasing sterile male flies and treating cattle with insecticides.

Scientists are now studying the acquired resistance of cattle to warble grubs, which appears in older animals. The cellular responses of bovines to infestation by warble grubs, and the major antigenic compounds are now known. This research has the objective of providing immunization to cattle for protection against warble grubs. Preliminary trials using crude larval extracts have provided significant control of both species of cattle grub.

Sheep keds The sheep ked is a wingless, blood-sucking fly that spends its entire life cycle on the sheep. At times of peak infestations, a susceptible animal may harbour as many as 1600 sheep keds. Sheep eventually acquire resistance to sheep keds, after exposure to reproducing populations of the parasite. After this resistance develops, however, weight gains in ked-infested sheep are lower than in ked-free sheep, and wool production can be as much as 11% less than in ked-free sheep. Registered insecticides, sprayed or sprinkled on infested sheep, provide some control of sheep keds.

In recent years, immunological studies revealed the mechanism of acquired resistance to keds. Vasoconstriction, the cutting off of blood supplies to ked-infested areas of the skin, was shown to be the means by which sheep limit the feeding of the insect pest. Unable to obtain a blood meal, keds gradually die. The same phenomenon occurs in livestock in reaction to lice infestations.

Scientists have established that this acquired resistance is not caused by antibodies. Research on the biochemical and immunochemical aspects of acquired resistance continues to expand our knowledge of the host-parasite relationship. It is hoped that a vaccine will be developed in the future to protect livestock from sheep keds and other insect pests.

House flies

Several nuisance flies, including house flies, breed in manure. Sanitation is the most effective control, followed by treatment with insecticides of buildings, pens, and other areas housing livestock.

Confined livestock operations offer favorable conditions for year-round generations of house flies. Flies in the heated buildings soon become resistant to insecticides and the confined environment prevents susceptible flies outdoors from joining the breeding population. Control of resistant flies has been achieved in pig and dairy barns by the use of parasitic wasps. *Muscidifurax raptor*, a natural enemy of several manure-breeding fly species, uses house-fly pupae to nurture its own eggs and larvae. When proper sanitation was maintained in the livestock facilities, up to 98% control of house-fly populations was achieved with releases of the *M. raptor* wasp. Biological control methods such as this reduce our reliance on toxic chemicals.

Cattle lice

Of the two types of lice affecting cattle, the blood-sucking, short-nosed cattle louse is the most common parasite of cattle in western Canada. When heavily infested with lice, cattle lose weight and become anemic, cows may abort, and bulls may become sterile.

Louse control is often a side benefit of warble-fly control, because the same systemic insecticides are effective on both species. Heavily infested, anemic cattle were freed of up to 74% of lice by pour-on and spot-on treatments of phosmet and chlorpyrifos, and they subsequently recovered from anemia. Ear tags impregnated with fenvalerate gave gradual but 100% control of lice on pregnant range cows without adverse effects. Animals habitually infested with lice must be culled, but insecticidal treatments continue to be the most effective means of control for most beef and dairy cattle.

Ticks

Rocky Mountain wood ticks frequently cause paralysis in humans and livestock. During the last decade, extensive testing of insecticides (acaricides) for season-long protection of cattle against ticks in British Columbia was one objective of research in animal parasitology. Phosmet and pyrethroid acaricides were the most promising substitutes for the former recommendation of lindane.

Much work was done on control by other methods, such as the use of resistant cattle, immunization of cattle, and development of range management systems to avoid types of vegetation associated with tick abundance, but these methods did not reach the stage of practical application.

It was demonstrated that ticks from a Nicola Valley (B.C.) area induced paralysis in sheep, whereas ticks from two localities in Alberta did not. The B.C. ticks attach to the upper sides of cattle while those from southeast Alberta attach on the undersides, where they are less accessible for treatment with insecticides. If the tendency to induce paralysis is inherited and dominant. precautions will be required to prevent the B.C. and Alberta ticks from interbreeding.

Chapter 7

Future Research

Scheduled for completion in 1986, the new Controlled Environment Building will provide facilities for research on chemical and biological control of animal pests. Scientists will also evaluate methods of pesticide application, determine the fate of pesticides in animals, and conduct assays for residues in insects. The building, which has an area of 1500 square meters, has been designed specifically for this research and is unique in Canada.

In the future, advances in techniques, methods, and equipment will be reflected in the focus of agricultural research, but the objective will remain the same—to increase the efficiency of agricultural production. Research in future decades promises to be as creative and rewarding as research in the past.

The focus of future research in the Soil Science section will be the prevention of soil degradation. Scientists will assess innovations in agronomic practices intended to increase crop yields and maintain soil quality.

The results of 7 years of research on minimum tillage will be subjected to economic analysis to determine the best tillage practices and crop rotation for the production of winter wheat. Scientists will assess the effects of tillage (including zero till), with either recropping or summerfallow systems, on crop yields and the physical properties of soil. Also, the effects of timing and intensity of tillage practices on soil moisture conservation and soil temperature will be clarified by future experiments. Evaluations of equipment for seeding into untilled cereal stubble will continue until researchers determine which machinery is most effective.

Soil productivity studies will include an economic assessment of the costs of restoring soils from which surface soil has been lost, and the identification of nutrient deficiencies induced by ion imbalances in crops. Scientists will also analyse the effects of root exudates and high manure rates on organic matter and other soil properties. The results of more than a decade of fertilizer experiments will be assessed to determine if fertilizer use in long-term rotations has improved soil quality. Decomposition rates of plant residue will be determined to identify crop rotations that will improve soil quality and be effective soil restorative treatments.

Data from fertilizer experiments will be analysed to determine the effectiveness of fall-applied urea-nitrogen as influenced by soil moisture status, and to modify fertilizer recommendations in accordance with nutrient source and time and method of application. In other work with fertilizers, researchers will analyse the results of fertigation experiments to determine their cost-effectiveness, determine the relationship of nitrate-nitrogen and soil depth to improve soil-test fertilizer recommendations, and continue studies on fertilizer placement.

Research in agrometeorology will assess the effects of chinook episodes on overwinter soil moisture balances, and quantify daily and seasonal variations in radiation and energy balances at soil surfaces, as a basis for predicting soil moisture and temperature under different environments.

In the area of soil microbiology, research will focus on improving crop yields and reducing fertilizer costs through the use of soil microbes, particularly those that fix nitrogen from the atmosphere and make it available to crops. As well, organisms that solubilize soil phosphorus will be investigated as a possible means of facilitating the use of unprocessed rock phosphate as a less expensive fertilizer source.

Scientists will determine the amount of nitrogen fixed by recommended cultivars of chickpea, lentil, pea, and fababean to establish a baseline for the assessment of future improvements. Optimal combinations of bacterial strains and lentil species and cultivars for different prairie locations and various agronomic conditions will be established. A method will be established for sampling and analyzing field beans to determine the relationships among nitrogenase activity, nitrogen fixation and energy cycling within the plant.

Nitrogen fixation for wheat cultivars will be quantified using nitrogen-15 isotope techniques and new research on genetic manipulation to improve the efficiency of nitrogen fixation will be initiated.

As part of an international project with researchers in Thailand, funded by the International Development and Research Centre, scientists will compare the performance of indigenous and superior multi-strain rhizobium inoculants in tests with soybean cultivars. The combinations of bacterial strains and soybean cultivars that provide maximum nitrogen fixation and yields will be determined and on-farm demonstrations will be established with Thai scientists to ensure application of results.

Scientists will advance the technology required to establish weed-free irrigation canals by continuing to control undesirable aquatic plants with herbicides and initiating new work on control of aquatic macrophytes through a fish-stocking program in selected water bodies. The life stages most vulnerable to control measures will be identified in selected species of aquatic plants. The nutrient status of the upper Oldman River watershed and its role on downstream aquatic development will be determined. Effective control measures for Eurasian water milfoil will be defined and publicized.

Through research on irrigated land, scientists will define optimum soil management and fertilizer practices (including the use of micronutrients) on irrigated land. An assessment of drainage experiments currently in progress will provide guidelines for optimum depth and spacing of perforated plastic tube drains on fine-textured soils.

A genetic engineering program is underway at the station to improve crop yields with strains of nitrogen-fixing bacteria. Here, a scientist detects plasmids in strains of bacteria by gel electrophoresis.

In work on irrigation scheduling, scientists at Lethbridge will identify causes of inefficiency in irrigation systems and continue the development of a computer model for predicting optimum water delivery in canals. A simulation model will be made available to growers to assist them in effectively scheduling irrigation applications on farms.

Dryland salinity research will remain a high priority. Researchers will cooperate extensively with personnel of provincial and federal agencies in the prairie region to ensure optimum efficiency in the use of resources. They will initiate research to quantify rates by which salts in solution can be removed from soils under a variety of conditions, and undertake new studies to establish whether abnormal salt balances have induced nutrient deficiencies and whether correction will permit crop growth under relatively high salt concentrations.

The development of a hydrologic zonation map will assist in identifying conditions that favor salinity development, categorizing salinity occurrence by causes, and determining the most effective corrective measures. New experiments to define the hydrology of selected dryland saline areas and to assess the effectiveness of vegetative control will be initiated, in cooperation with the University of Alberta.

In the Plant Science section, future research will emphasize increasing crop productivity. Scientists will concentrate on adding to our basic knowledge of and technological expertise in plant genetics and agronomic practices to provide greater efficiency and stability of crop production.

The emphasis in cereal breeding work will be on the production and release of: a sawfly-resistant hard red spring wheat having improved quality and better root rot resistance than Leader; a soft white spring wheat with acceptable quality and kernel type, resistance to powdery mildew and stripe rust, and improved yield under irrigation in Alberta and Saskatchewan, and a two-row barley variety with superior yield and quality acceptable for malting or for animal feed. Winter wheat strains with resistance to snow mold will be identified for developing varieties for production in the eastern and northern prairies.

The development of new varieties of legumes and grasses will allow increases in forage yields on irrigated and dry land in western Canada. As research in grazing management continues, new techniques will be identified that will enable more efficient use of native grasslands and extend the grazing season on pasture. Scientists will continue to search for more effective and economical methods of managing insects that pollinate forage legumes.

Research on other crops will be aimed at developing cultivars that are adapted to local growing conditions and give high yields. Early, strong-stalked corn hybrids will be released for growers' use. New varieties of field beans, soybeans, and safflower suitable for commercial production in western Canada will be released and the cultural practices required to optimize commercial production of these crops will be identified. High-yielding, disease-resistant and early maturing potato varieties that meet the needs of the prairie processing industry will be developed.

The process of embryo rescue will be used to incorporate useful genes from grass species into wheat plants. This and other tissue culture techniques such as somaclone production from immature embryos and anther culture will lessen the time required to develop new varieties.

Future research in the Crop Entomology section will emphasize the development of pest management programs to control pest insects on forage crops. Control methods will be more effective and economical than current controls, and will have fewer detrimental effects on the environment.

Grasshopper control will remain a major focus of research in the future. A granular insecticide applied with winter wheat seed will be evaluated for protecting the autumn seedlings from adult grasshoppers. Two potential biocontrol agents for grasshoppers, the microsporidian *Nosema locustae* and the fungus *Verticillium lecanii*, will be evaluated.

The two-striped grasshopper is one of the four major grasshopper species that cause extensive crop damage in southern Alberta.

Scientists expect to improve grasshopper monitoring and control through the use of a computer model of weather conditions that influence the emergence and survival of grasshoppers, and subsequent crop damage. A study will be initiated on the economics of grasshopper control to assist in management decisions with various crops and conditions.

The identification of sex pheromones of five crop pest species and refinements in monitoring procedures will expand and improve the existing monitoring of moth populations. Data from an extensive cutworm monitoring project will be analyzed to assist in correlating moth catches and subsequent larval infestations for forecasting purposes. The rate of pale western cutworm development under various temperature conditions will be determined to develop predictive models for accurately timing crop damage by larvae under various weather conditions. A more efficient sex pheromone monitoring system will be developed for the European corn borer. All of these studies will improve forecasting and timing of infestations of these pests, which will lead to reduced and more efficient use of insecticides for their control.

A mathematical model will be completed for determining the dissipation of an insecticide (deltamethrin) in soil under various weather conditions, and under aerial and ground applications. These data will provide an understanding of the persistence of deltamethrin in soil applications for control of grasshoppers, cutworms, and other insects.

The penetration patterns of aerially applied sprays through the canopy of a seed alfalfa crop and the daily vertical movement of alfalfa weevils within the crop will be determined to establish the most effective timing of insecticide applications.

In research with beneficial insects, the biological availability of insecticide residues will be determined on seed alfalfa to establish when alfalfa leafcutter bees can be safely released in fields treated for pest control.

Research in Plant Pathology is dedicated to minimizing losses from plant diseases. Future research will focus on developing resistant varieties, more effective biological and chemical controls, improved forecasting of disease outbreaks, and changes to agronomic practices to reduce losses in yield and quality of our major crops.

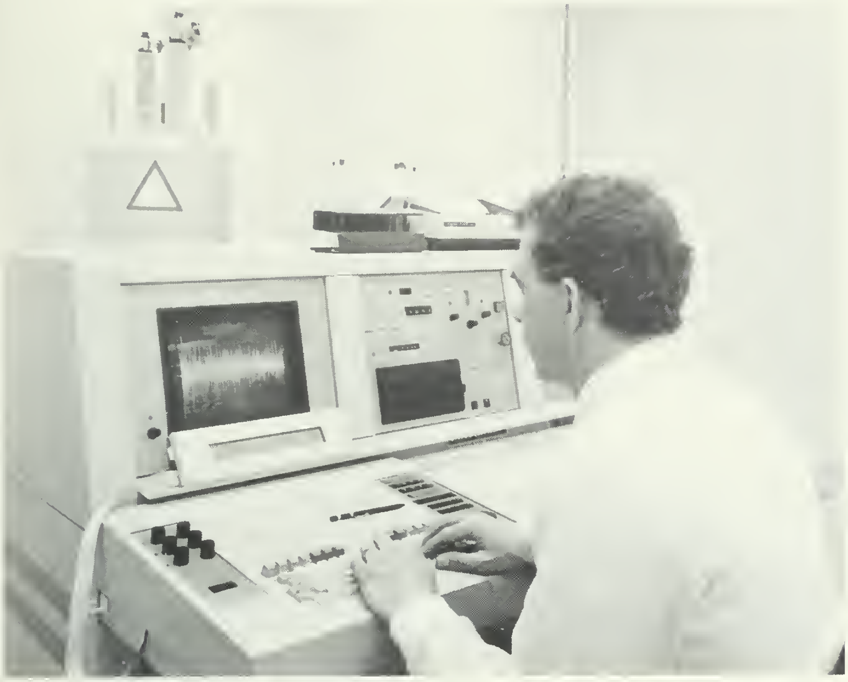
New winter wheats with a superior level of cold resistance and improved resistance to bunt, loose smut, stem rust, wheat streak mosaic, and snow mold are expected to permit production of winter wheat in parts of the Prairies where the risk of failure is currently too great. Biotechnology will become increasingly important in transferring genes for cold resistance from grasses to the winter wheat plant.

Even though the currently grown varieties of spring wheat are moderately resistant to common root rot, further improvements are expected from the addition of resistance from new sources. The effects of diseases such as kernel black point, powdery mildew, stripe rust, and leaf rust, which can be particularly devastating to irrigated soft white spring wheat, will be reduced as a result of cooperation between breeders and plant pathologists to find new sources of resistance and incorporate them into higher yielding, better-adapted varieties.

Barley varieties less debilitated by common root rot, leaf diseases, and smuts will increase the profitability of barley production under irrigation and on the moister parts of the Prairies.

Improved control of ergot on cereals and grasses may be possible. An increased understanding of the weather and biological factors that lead to epidemic outbreaks should improve the accuracy of predicting serious outbreaks in time to permit producers to protect these crops from the disease.

The release in 1986 of an alfalfa variety with resistance to verticillium wilt will decrease future losses from both diseases. Research into the means by which the pathogen is spread will enable us to improve our defences against other dangerous plant pathogens in the future.



left
A high-resolution nuclear magnetic resonance (NMR) spectrometer was installed at the Lethbridge station in 1986. This ultra-modern instrument will facilitate research on organic chemical compounds, toxic plant compounds, soil chemistry, and biochemistry.

above
A library was established at the station in 1936 to hold scientific journals and reference materials for the use of researchers. As part of a departmental network of branch libraries, the Lethbridge library has on-line access to collections in research institutions throughout North America.

Bacterial ring rot is a major threat to potato production in Canada. The nature of the disease indicates that eradication is practical even though almost a half century of effort has failed to achieve it. Current research to improve methods for detecting and controlling the disease should provide the means for eliminating the ring rot pathogen from both seed and table potatoes in the near future.

The fungus *Sclerotinia sclerotiorum* causes serious losses in a wide range of oilseed, vegetable, and ornamental crops. Recent research has provided a means for identifying sources of resistance that will be used to develop resistant cultivars of crops such as safflower and field bean. Practical biocontrol of *Sclerotinia* using soil-borne fungi is likely to be available to producers within the next decade.

Reduction of disease losses through the use of resistant crops, biological controls, and more effective timing of chemical controls will increase the stability of crop yields. This should increase the profitability of agricultural production without increasing the cost of food to the consumer.

Future research in Animal Science will emphasize improvement in efficiency of production rather than increased productivity alone. This will be accomplished by the integrated approach of a ruminant team and will include economic analyses to assure that innovative ideas will fit into an economically sound production system.

The hub of the program is the breeding projects where several scientists work together toward a common goal or from which animals are drawn for basic work in a single discipline. The immediate goals of the breeding work will be to complete the evaluation of the Foreign Cattle Breed projects at the Lacombe and Brandon Research Stations and at Onefour, a substation of Lethbridge. Of primary importance is the study of energy requirements of the various crossbred groups during the winter maintenance period between weaning and calving, and during the lactation period.

Twenty years of selection for post-weaning gain in four lines of cattle have just been completed. A final series of tests, to be completed by 1989, will determine the effect of long-term selection for feedlot gain, the effect of that selection on other traits, and the influence of all-roughage and concentrate-roughage (80%:20%) diets on that selection. Line differences in performance are being identified and the reasons for the differences are being elucidated.

A new project, for which foundation animals are just being accumulated, will make use of the progeny of cows that had a high level of performance in their first eight calf crops in either the semi-intensive management conditions at the Brandon Research Station or the extensive management range conditions at the Onefour Substation. Although the cow herds were genetically similar to begin with, nature selected different kinds of cows to be productive in the two environments. The objective will be to identify the factors contributing to efficient reproduction and productivity of both male and female cattle. Once these are identified, researchers will attempt to improve testing and selection techniques through the identification and manipulation of traits that are good predictors of future performance.

Sheep research to date has been successful in increasing the number and size of lamb crops each year. In future research, scientists will be studying means of increasing the ability of ewes to handle large and frequent litters independently of special management procedures. The identification of breeds and management systems that will permit efficient production of heavy weight lambs with good carcass quality, and economic analyses of such systems, will also be major components of future research.

Work in the microbiology area will contribute to the interpretation of research in both the breeding and nutrition fields and will include the development of techniques to neutralize the effects of certain plants that are toxic to animals, the elucidation of procedures that can be used to make straw or other fibrous materials into more digestible and useful animal feeds, the development of bacterial cocktails that will help to prevent scour problems in calves and lambs, and the genetic manipulation of rumen bacteria to improve their function in relation to their benefit to animals.

Nutrition work will include studies on: the solution of problems associated with the feeding of all-concentrate diets to cows during their gestation period; water quality problems as they affect livestock production; methane production in the rumen to aid in the partitioning of energy components during the digestion of feeds that vary in

V. Vorotnikov, chairman of the Council of Ministers of the USSR, met administrative staff during his tour of the station facilities in 1985.

type, composition and method of processing; optimum particle size of concentrate feeds as they affect utilization by beef cattle and the cost of production. A research feedmill on the Station will greatly facilitate accurate diet formulations for special nutrition studies as well as the development of new processing techniques.

In studies to improve the efficiency with which feeds are converted into muscle in beef cattle, researchers will assess the biochemical factors involved in the utilization of protein. The cause of the greater efficiency of cattle on concentrate diets, compared with those fed roughage, will be examined through studies on blood metabolites, and the role of amino acids in protein synthesis.

Research in the Animal Parasitology section at Lethbridge will continue to expand the information base of host-parasite relationships. The increasing concern with the environmental impact of various chemicals used for pest control necessitates studies on alternative methods such as biological control. The effects on livestock of chemicals used as insecticides will receive more intensive study, and the economic impact of all pest-control programs will also be examined in more detail.

To facilitate research, a new Controlled Environment barn is currently under construction, with completion anticipated during 1986. It will permit scientists to test new chemicals and biological agents on animals and insects in carefully controlled environments. Traditional methods of application of pesticides and new technology in control methods will be assessed and improved. Research will continue on the determination of the fate of pesticides in animals through assays of residues in meat products.

The objectives of research in animal parasitology will continue to be increased protection of animals and the environment, and greater productivity of livestock.

Appendix I

Professional Staff, 1976-1986

Administration and Scientific Support

Dr. J. E. Andrews, *Director*	1969-1981
Mr. S. B. Arnason, *Head, Administration*	1964-
Dr. J. C. M. L'Arrivee, *Information Officer*	1984-
Dr. T. G. Atkinson, *Asst. Director*	1980-1983
Mr. P. E. Blakeley, *Information Officer*	1946-1977
Ms. P. Bolton, *Librarian*	1986
Mr. H. Chung, *Programmer*	1980-
Mr. B. D. Clark, *Finance & Material Management*	1984-
Mr. G. C. R. Croome, *Scientific Editor*	1973-1981
Ms. C. M. Cutler, *Library, Area Coordinator*	1983-
Dr. D. G. Dorrell, *Director*	1983-
Mr. T. Entz, *Statistician*	1986-
Mr. B. S. Freeze, *Economist*	1983-
Mr. G. K. Honey, *Information Officer*	1978-1984
Miss S. M. Howard, *Librarian*	1984
Dr. K. K. Klein, *Economist*	1972-1981
Mr. G. C. Kozub, *Statistician*	1967-
Mr. W. H. Mains, *Facilities Management Engineer*	1983-
Mr. M. G. McCormick, *Personnel Officer*	1980-1985
Mr. J. P. Miska, *Library, Area Coordinator*	1972-1983
Mr. D. W. Pang, *Computer System Manager*	1985-
Dr. W. L. Pelton, *Asst. Director*	1975-1978
Mr. R. B. Peveril, *Computer System Manager*	1982-1984
Mr. M. G. Roach, *Personnel Officer*	1974-1979
Mrs. C. M. Ronning Mains, *Librarian*	1974-
Dr. K. D. Russell, *Economist*	1971-1981
Mr. G. B. Schaalje, *Statistician*	1980-
Mr. C. G. Schoening, *Finance Officer*	1969-1984
Ms. L. J. L. Sears, *Scientific Editor*	1982-
Dr. B. H. Sonntag, *Economist*	1968-1979
Dr. E. E. Swierstra, *Asst. Director*	1984-
Mrs. M. M. Tarnava, *Personnel Officer*	1986-
Mr. R. P. J. Zentner, *Economist*	1972-1981

Animal Parasitology

Dr. R. W. Baron, *Immunology*	1978-
Dr. K. R. Depner, *Black fly ecology*	1950-1979
Dr. W. O. Haufe, *Section Head, Bioclimatology*	1953-1986
Dr. M. A. Khan, *Toxicology*	1957-1984
Dr. W. A. Nelson, *Parasitology*	1943-1982
Mr. R. H. Robertson, *Serology*	1953-
Mr. J. A. Shemanchuk, *Biting-fly ecology*	1955-
Dr. J. L. Shipp, *Black-fly ecology*	1980-
Dr. W. G. Taylor, *Pharmacology*	1976-
Mr. J. Weintraub, *Cattle-grub ecology*	1953-
Dr. P. R. Wilkinson, *Tick ecology*	1962-1984
Dr. J. M. B. Yeung, *Pesticide metabolism*	1985-

Animal Science

Dr. C. B. M. Bailey, *Animal physiology*	1959-
Dr. D. R. C. Bailey, *Beef cattle breeding*	1984-
Dr. D. M. Bowden, *Animal nutrition*	1969-1980
Dr. T. D. Carruthers, *Reproductive physiology*	1979-1981
Dr. K.-J. Cheng, *Rumen microbiology*	1971-
Dr. G. H. Coulter, *Reproductive physiology*	1974-
Dr. E. E. Gardiner, *Poultry nutrition*	1965-1980
Dr. G. A. Grigat, *Animal nutrition*	1981-1985
Dr. R. Hironaka, *Animal nutrition*	1959-
Dr. D. G. Keller, *Beef cattle breeding*	1975-1979
Mr. J. E. Lawson, *Section Head, Beef cattle breeding*	1964-
Ms. L. A. McClelland, *Sheep breeding & management*	1983-
Dr. G. J. Mears, *Animal physiology*	1978-
Mr. R. C. Phillippe, *Bacterial culture centre*	1982-
Dr. L. M. Rode, *Animal nutrition*	1985-
Dr. E. E. Swierstra, *Former Section Head, Reproductive physiology*	1976-1984
Dr. J. A. Vesely, *Sheep and dairy cattle breeding*	1964-

Crop Entomology

Dr. J. R. Byers, *Cutworms*	1981-
Dr. W. A. Charnetski, *Insecticide applications*	1965-
Dr. J. M. Hardman, *Grasshoppers*	1977-1982
Dr. A. M. Harper, *Aphids*	1948-
Dr. B. D. Hill, *Insecticide chemistry*	1978-
Dr. N. D. Holmes, *Former Section Head, Wheat stem sawfly*	1947-1978
Dr. D. L. Johnson, *Grasshoppers*	1983-
Mr. C. E. Lilly, *Potato and sugar beet pests*	1949-1981
Mr. S. McDonald, *Former Section Head, Toxicology*	1953-1983
Dr. K. W. Richards, *Insect Pollinators*	1976-
Dr. B. D. Schaber, *Forage crop pests*	1978-
Dr. D. L. Struble, *Section Head, Insect attractants*	1968-
Dr. G. E. Swailes, *Cutworms*	1948-1980
Dr. G. H. Whitfield, *Potato and sugar beet pests*	1982-

Plant Pathology

Dr. T. G. Atkinson, *Former Section Head, Cereal root rots, viruses*	1958-1980
Dr. R. L. Conner, *Cereal diseases*	1982-
Dr. K. J. Degenhardt, *Smuts & oilseed diseases*	1978-1983
Dr. D. A. Gaudet, *Snow molds*	1982-
Dr. F. R. Harper, *Section Head, Cereal leaf diseases*	1952-
Dr. E. J. Hawn, *Forage and nematode diseases*	1950-1980
Dr. H. C. Huang, *Forage and special crops diseases*	1981-
Dr. J. B. Lebeau, *Former Section Head, Diseases of grasses*	1953-1978
Dr. G. A. Nelson, *Potato and bacterial diseases*	1966-
Dr. D. W. A. Roberts, *Cold-hardiness physiology*	1949-
Dr. J. A. Traquair, *Forage and low-temperature diseases*	1978-1981

Plant Science

Dr. J. R. Allan, *Aquatic plant physiology*	1965-
Dr. P. Bergen, *Weed control*	1985-
Mr. R. E. Blackshaw, *Weed control*	1983-
Dr. M. N. Grant, *Winter wheat breeding*	1949-1981
Dr. W. H. Hamman, *Weed control*	1976-
Dr. M. R. Hanna, *Forage legume breeding*	1958-
Dr. A. Johnston, *Range ecology*	1946-1980
Dr. M. S. Kaldy, *Food science*	1965-
Dr. G. A. Kemp, *Vegetable breeding*	1951-
Dr. R. I. Larson, *Wheat cytogenetics*	1948-1979
Dr. D. R. Lynch, *Potato breeding*	1978-
Dr. M. D. MacDonald, *Corn breeding*	1949-
Mr. W. H. Mains, *Forage systems engineering*	1978-1983
Dr. D. J. Major, *Crop physiology*	1974-
Dr. K. W. May, *Barley breeding*	1980-
Mr. H. McKenzie, *Spring wheat breeding*	1951-1979
Dr. R. J. Morrison, *Spring wheat breeding*	1980-1985
Dr. J. R. Moyer, *Weed control*	1977-
Dr. H.-H. Muendel, *New crops, hard red spring wheat*	1978-
Dr. R. S. Sadasivaiah, *Soft white spring wheat breeding*	1985-
Dr. M. P. Sharma, *Weed control*	1981
Mr. S. Smoliak, *Acting Section Head, Dryland pasture*	1964-
Dr. J. B. Thomas, *Winter wheat breeding*	1980-
Dr. S. A. Wells, *Barley breeding*	1948-1980
Dr. E. D. P. Whelan, *Wheat cytogenetics*	1978-
Dr. W. D. Willms, *Rangeland ecology*	1982-
Dr. D. B. Wilson, *Former Section Head, Irrigated pastures*	1950-1985

Soil Science

Dr. R. W. Barendregt, *Irrigation engineering*	1981-1982
Dr. G. J. Beke, *Hydrology*	1981-
Dr. R. G. Bell, *Environmental microbiology*	1974-1977
Dr. J. B. Bole, *Plant nutrition*	1969-1985
Mr. J. M. Carefoot, *Chemical analyses*	1971-
Dr. C. Chang, *Soil physics*	1978-
Dr. J. F. Dormaar, *Organic chemistry*	1962-
Mr. S. Dubetz, *Irrigation agronomy*	1949-1984
Dr. N. Foroud, *Irrigation engineering*	1982-
Dr. S. Freyman, *Dryland agronomy*	1966-1982
Dr. W. D. Gould, *Soil denitrification*	1979-1982
Dr. B. W. Grace, *Agrometeorology*	1983-
Mr. E. H. Hobbs, *Irrigation engineering*	1951-1982
Dr. M. F. Hynes, *Microbial genetics*	1986-
Dr. H. H. Janzen, *Dryland agronomy*	1984-
Mr. K. K. Krogman, *Irrigation efficiency*	1949-1979
Dr. R. M. N. Kucey, *Soil fertility*	1980-
Dr. C. W. Lindwall, *Section Head, Agricultural engineering*	1976-
Dr. L. E. Lutwick, *Grassland soils*	1956-1979
Dr. D. C. MacKay, *Former Section Head, Plant nutrition*	1967-
Dr. R. G. L. McCready, *Biophysical chemistry*	1978-1982
Dr. J. L. Neal, *Soil microbiology*	1967-1977
Dr. M. Oosterveld, *Hydrology*	1973-1980
Dr. C. J. Palmer, *Physical chemistry*	1980-1981
Mr. U. J. Pittman, *Dryland agronomy*	1949-1979
Dr. R. J. Rennie, *Soil microbiology*	1978-1985
Mr. R. B. Rogers, *Engineering*	1977-1979
Dr. T. G. Sommerfeldt, *Drainage engineering*	1965-
Dr. J. C. van Schaik, *Soil physics*	1953-1978

Appendix II

Releases from Lethbridge Research Station

Name	Date of release	Originators
Horticulture		
Apple: 4 cultivars	1950s	J. Coyle & I. Nonnecke
Bean: Limelight	1968	G. A. Kemp
Green Limelight	1977	G. A. Kemp
Chrysanthemum: 11 cultivars	1960	I. Nonnecke, G. A. Kemp
9 cultivars	1963	I. Nonnecke, G. A. Kemp
6 cultivars	1968	I. Nonnecke, G. A. Kemp
Corn: White Alberta	1920	W. H. Fairfield
Sugar Prince	1946	C. Walkof
Gladiolus: Puck	1952	M. W. Cormack, H. H. Downs
Baby Butterfly	1953	M. W. Cormack, H. H. Downs
Muskmelon: Early Gold	1968	G. A. Kemp
Potato: Chinook	1964	W. E. Torfason
Tomato: Earlinorth	1952	G. A. Kemp
Early Lethbridge	1953	G. A. Kemp
Earlicrop	1963	G. A. Kemp
Forage Crops		
Alfalfa: Beaver	1961	R. W. Peake, R. K. Downey, J. L. Bolton, M. W. Cormack
Kane	1970	M. R. Hanna
Trek	1974	M. R. Hanna, E. J. Hawn
Barrier	1986	M. R. Hanna
Grasses: Chinook	1959	R. W. Peake
Greenleaf	1966	R. W. Peake
Banff	1974	J. B. Lebeau, M. R. Hanna
Cabree	1978	S. Smoliak
Elbee	1980	S. Smoliak, A. Johnston
Walsh	1982	S. Smoliak, A. Johnston
Milkvetch: Oxley	1970	A. Johnston, S. Smoliak
Sainfoin: Melrose	1969	M. R. Hanna (Lethbridge) B. P. Goplen (Saskatoon) D. A. Cooke (Melfort)
Nova	1980	M. R. Hanna

Cereals

Barley: Betzes	1960	S. A. Wells
Palliser	1960	S. A. Wells
Galt	1966	S. A. Wells
Hector	1973	S. A. Wells
Fairfield	1976	S. A. Wells
Hard Red Spring Wheat: Chinook	1952	A. W. Platt, M. N. Grant
Cypress	1962	H. McKenzie, M. N. Grant
Chester	1976	H. McKenzie
Soft White Spring Wheat: Lemhi 53	1956	A. Wall, M. N. Grant
Lemhi 62	1968	M. N. Grant
Springfield	1972	M. N. Grant
Fielder	1976	M. N. Grant
Winter Wheat: Westmont	1959	J. E. Andrews
Winalta	1961	J. E. Andrews, M. N. Grant
Gaines	1965	M. N. Grant
Nugaines	1969	M. N. Grant
Sundance	1971	M. N. Grant
Norstar	1977	M. N. Grant

Special Crops

Safflower: Saffire	1985	H.-H. Muendel

Livestock

Romnelet sheep	1961	H. J. Hargrave, H. T. Peters, J. A. B. MacArthur, J. A. Vesely

Patents

Radiant Energy Integrating Meter	1976 U.S.	J. R. Allan
Attractant for Darksided Cutworm Moth	1978 U.S. 1980 CAN.	G. E. Swailes, D. L. Struble
Attractant for Army Cutworm Moths	1979 U.S. 1980 CAN.	D. L. Struble, G. E. Swailes
Attractant for Beet Webworm Moths	1977 U.S. 1978 CAN.	D. L. Struble, C. E. Lilly
Composite Attractant for Bertha Armyworm Moth	1975 U.S. 1979 CAN.	E. W. Underhill, M.D. Chisholm, W. F. Steck, B. K. Bailey, P. M. Lamb, D. L. Struble, G. E. Swailes
Bioadsorption Alteration of Iron Sulfide Surfaces	1981 U.S.	R. G. L. McCready, R. D. Coleman, G. E. Capes, A. G. Kempton, N. A. M. Moneib

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