HISTORICAL PERSPECTIVE

Five Decades of Entomology Come to an end: Winnipeg Research Station – Cereal Research Centre, 1957-2013

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The Cereal Research Centre (CRC) of Agriculture & Agri-Food Canada (AAFC) will close in early 2014, after 90 years on the campus of the University of Manitoba in Winnipeg. The facility opened in 1924 as the Dominion Rust Research Laboratory, in response to devastating rust outbreaks. Research focused on plant pathology and cereal breeding from the beginning, and on entomology since 1957. The final year of operation is an opportune time to remember CRC entomologists and review their contributions. This summary is based on staff lists prepared by Brent McCallum, CRC, earlier accounts (Bird 1963; Loschiavo 1990), biographies in *Entomologists of Manitoba* (Riegert 1989), and publications and memories of those who worked at CRC.

The first Entomology Section, led by Ralph Bird, was formed in 1957 when the Stored Product Insect Laboratory, Winnipeg, and the Field Crop Insect Laboratory, Brandon, relocated to the Research Station. In recognition of the amalgamation of three units in a new building, the laboratory was renamed the Winnipeg Research Station (WRS) in 1959. The next big change came in 1972 with the closing of the Entomology Research Institute, Belleville, Ontario, and transfer of many of its staff to WRS. The newcomers formed the Integrated Pest Management Section led by Bill Turnock, existing in parallel with the already established Crop Protection Section led by Fred Watters. The sections were reorganized as Stored Products and Integrated Pest Control in 1983, only to be recombined as a Crop Protection Section 6 years later. In 1995, budget cuts resulted in a substantial reduction to the entomology program, achieved primarily by transferring all research on non-cereal crops to the Saskatoon Research Centre. A number of entomologists were forced to take early retirement, or did so voluntarily, to avoid moving late in their careers. Those remaining joined the Cereal Quality Protection Section or the Cereal Breeding Section in the renamed Cereal Research Centre.

In 1957, ten entomologists began research at WRS (Table 1) out of a total scientific staff of 36. These numbers include two AAFC employee categories: Research Scientists who direct a research program and Biologists who carry out independent research under the direction of a Research Scientist, but not technicians or other support staff. When the Integrated Pest Management Section was formed in 1972, WRS had 18 en-

tomologists. Scientific staff peaked four years later at 46, including 16 entomologists. A decade later, six stored-product entomologists and eight crop protection entomologists were still active. By 1996, after reductions to the field crop entomology program, six entomologists remained. The last Research Scientist working on entomology of field crops retired in 2003 and was not replaced, leaving two Biologists working with wheat breeders on resistance to wheat midge, and three stored-product entomologists. When CRC closes, three stored-product entomologists will continue to be employed by AAFC, in rental space at the University of Manitoba.

Over the years, many technicians, visiting scientists, graduate students and summer students contributed greatly to entomology at WRS-CRC. The highlights of the contributions of all the entomologists to agriculture and to the scientific literature are described below.

Stored-Product Entomology

In the first 30 years after 1957, stored-product entomologists at WRS focused on pest control using fumigants, detecting low densities of insects in grain bulks, and the basic biology needed to understand stored-product pests (Fig. 1) (Loschiavo 1990**)**. Sam Loschiavo made important contributions to sampling stored product insects and to understanding the feeding biology of the pests (Baker and Loschiavo 1987). His escape-proof, pit-fall, probe trap allowed effective sampling of bulk grain. Versions of his trap continue to be manufactured and used in many countries to detect living insects in stored grain. Lawrie Smith's research on the cold tolerance of the ten most important species of stored-product insects set the stage for the use of ambient air to cool and protect grain. After earlier work on DDT and fumigants, Phil Barker spent many years conducting developmental studies of mites in stored grain. Upon retirement he continued volunteering at CRC, turning his attention to pests of wheat in the field, particularly the wheat midge (see below). Ron Sinha pioneered a community ecology and whole system approach for stored products. He developed a long-term collaboration with Bill Muir in the Agricultural Engineering Department, University of Manitoba (Sinha and Muir 1973). This research led to an improved understanding of the role of insects, mites and fungi in the heating of stored grain, and ultimately the introduction of aeration technology to dry and cool grain stores (Sinha and Watters 1985). His work was recognized with a Gold Medal from the Entomological Society of Canada in 1985.

Since Ron Sinha's retirement, this work has been expanded by Noel White in collaboration with Digvir Jayas at the now Biosystems Engineering Department, University of Manitoba. Over the years they have co-supervised 75 MSc and PhD students on aspects of stored grain management, usually including an entomological component. Recent studies used CAT scans to measure intergranular space in grain bulks, MRI to measure and then model moisture changes in single grains, and X-rays to detect insects in grain kernels. This collaboration was recognized by the 2008 NSERC Brockhouse Award for outstanding interdisciplinary research. Their work improved monitoring and control of insect pests infesting bulk stores of food (White 1995).

Paul Fields was hired in 1988 to work on the eco-physiology of stored-product insects. With colleagues, he has developed pest control strategies based on diatomaceous earths and a patented legume extract, and continues to test botanicals as control agents. He has worked extensively on heat and cold treatments to disinfest food products at various points in the food production system (Fields 1992), and is active in developing and promoting alternatives to methyl bromide in flour mills as this ozone-depleting substance is phased out as a fumigant (Fields and White 2002). Recently, he developed an application for mobile phones to identify stored-product insects, in collaboration with colleagues at the Canadian Grain Commission. The stored-product entomologists working at CRC recently are shown in Fig. 2.

Field Crop Entomology

At WRS-CRC, research on field crop entomology went through three phases: testing chemical pesticides and pest monitoring systems; developing economic thresholds and more precise monitoring tools for farmers, studying pest biology to identify novel control strategies, and biocontrol; and developing crops resistant to key pests of field crops.

When Harold Westdal arrived at the Research Station in 1957, he continued his groundwork research on sunflower pests. Wally Romanow continued the Manitoba grasshopper survey first established by Norman Criddle at the beginning of entomology in western Canada (Bird 1963). When the new oilseed rape crop (canola) became important in the early 1970's, Harold Westdal developed an insecticidal control program for the key pest, flea beetles. This control program became a standard for the new industry and set the stage for research that came with the influx of entomologists in 1972.

When Bill Turnock arrived as Section Head of Integrated Pest Management with the group of entomologists from Belleville, he brought with him an ecological perspective from his time in forest entomology, and an enthusiasm for multi-disciplinary research and a systems approach. Many of the entomologists who arrived with him were physiologists or biochemists and few had backgrounds studying insect pests of field crops. As a group, they decided to focus on the diverse pests of oilseed rape (canola), especially as the area sown to this new crop was growing rapidly, and new pests seemed to be attacking the crop each year. Garth Bracken, a physiologist and biochemist, and Gord Bucher, an insect virologist, began a series of studies on bertha armyworm. This careful field and laboratory research culminated in a reliable economic threshold for the pest, remarkable in part because the research departed so dramatically from their previous experience, and because it so effectively integrated an understanding of the armyworm's feeding biology with the estimation of a threshold (Bracken and Bucher 1984). A publication from this research described a rearing method for bertha and is still one of the most cited papers in The Canadian Entomologist.

Damage assessment and economic thresholds became an important focus for the field crops group. Research was completed on many of the crops and pests important in western Canada: bertha armyworm, flea beetle larvae (Garth Bracken), lygus bugs (Bob Lamb and Ian Wise), and root maggots (Bill Turnock) on canola; aphids on field

peas (Bob Lamb), flax (Ian Wise and Bob Lamb), and wheat (Bob Lamb); Hessian fly (Ian Wise) and wheat midge (Bob Lamb, Ian Wise and Marj Smith) on wheat. Once thresholds were established, monitoring systems were often developed to help farmers use them effectively. Graduate students from the Department of Entomology, University of Manitoba, conducted some of this research at WRS-CRC as part of their degree programs.

The damage assessment work was underpinned by research on the life histories and ecology of pests, many of which had been little studied in western Canada. Noteworthy was the long term research on red turnip beetle (George Gerber), a native canola pest, and on the seasonality of cutworms (Gord Ayre). Initially, cold hardiness was the focus of many studies, with the thought that pest outbreaks might be better predicted and managed if the effects of winter weather were understood. Studies on cold hardiness were completed for red turnip beetles (George Gerber), flea beetles (Bill Turnock and Bob Lamb), and root maggots (Bill Turnock, Bob Bodnaryk and Bob Lamb). Studies on the seasonal timing of pest life histories and the effects of temperature on development were completed to time control of pests better, including bertha armyworm (Gord Bucher and Garth Bracken), red turnip beetle (Bob Lamb and George Gerber), cutworms (Gord Ayre and Bob Lamb), and pea aphids (Bob Lamb and George Gerber). Bob Lamb's contribution to this work was recognized by a Gold Medal from the Entomological Society of Canada in 2002.

Largely as a result of Bill Turnock's enthusiasm for ecological entomology and integrated pest management, this approach remained central to the work as long as a critical mass of entomologists was present in the group. So, the economic thresholds were thought of as a first step, to be integrated with other approaches that might improve pest control and reduce pesticide use. Biological control was actively pursued for flea beetles and pea aphids (Glen Wylie) and root maggots (Bill Turnock). Ozzie Morris transferred to the group in 1982 to investigate the use of *Bacillus thuringiensis* as a bacterial insecticide, focussing on the identification of new strains of *Bt* for use in Prairie agriculture. Bill Turnock's perspective of the insects of the large area field crops of western Canada as an ecological system was well defined for canola early in the development of the group (Turnock 1977). The multidisciplinary and broad ecological approach was a success, rapidly leading to a body of knowledge on insect pests of canola, and their interactions with the new crop (Lamb 1989). Field crop entomologists involved in this work are shown in Fig. 3.

The interest in damage assessment of pests on crops initially focussed on the development of economic thresholds for insecticide applications, but gradually led to a more basic understanding of insect-plant interactions (Bob Lamb and Bob Bodnaryk) and by the mid-1980's to an attempt to develop crop resistance. The first target for crop resistance was flea beetles on canola because control of this pest seemed intractable except by prophylactic applications of systemic insecticides that were gradually being withdrawn from the market. Progress was made (Bob Lamb, Bob Bodnaryk and Swamy Pachagounder), but no breakthrough, and the work on crop resistance to flea beetles stopped at WRS with the cuts to the program in 1995. The remaining entomological expertise on field crops (Bob Lamb, Marj Smith and Ian Wise) was transferred to the wheat program.

At about the same time, the wheat midge appeared to come out of nowhere as a major pest of wheat in Manitoba and Saskatchewan. Phil Barker, a stored-product entomologist who retired in 1991, continued to volunteer at the WRS-CRC and took an interest in the seed damage that was detected in wheat seeds harvested during the early years of the outbreak. He began looking at samples of wheat seeds from the WRS breeding program, comparing old samples with seeds from the current lines. His focussed interest on seed damage by stored-product pests and his familiarity with the morphology of the seed surface enabled him to recognize a novel type of damage in seeds from winter wheat being tested by the wheat breeder, Ron MacKenzie, for Hessian fly resistance. Phil referred to the seeds with subtle changes in their shape as "tubbies". The lack of wheat midge larvae on these seeds led Phil and Ron to propose that some winter wheat lines might be resistant to wheat midge. A number of explanations other than crop resistance might have accounted for this phenomenon, but when the potential resistance was investigated further, the original hypothesis proved correct (Harris et al. 2003).

The closure of the canola program just when research on crop resistance was beginning to mature, the narrowing of the emphasis of entomology to cereals, the outbreak of wheat midge, and the sudden availability of a Research Scientist (Bob Lamb), two Biologists (Marj Smith and Ian Wise) (Fig. 4), and a number of entomological technicians provided a fortuitous environment for a strong collaboration between entomologists (including Phil Barker) and an enthusiastic, albeit retired, wheat breeder (Ron MacKenzie). The result was the rapid characterization of the *Sm1* gene, which provides a high level of resistance against wheat midge, and the simultaneous incorporation of the gene in well adapted wheat cultivars by the wheat breeder Stephen Fox. The tradition of ecologically-based entomology research at WRS-CRC influenced the development of crop resistance leading to the adoption of an interspersed refuge based on the mating system and dispersal characteristics of the wheat midge (Berzonsky *et al*. 2003). This refuge system has been adopted by the industry in Canada and should prevent the resistance provided by the *Sm1* gene from breaking down due to evolved virulence by the wheat midge.

The Future of Entomology in Manitoba

When CRC closes officially in early 2014, entomological research by Agriculture and Agri-Food Canada in Manitoba will be continued by three stored-product entomologists, Research Scientists, Noel White and Paul Fields, and Biologist Colin Demianyk. They expect to move to the Department of Biosystems Engineering at the University of Manitoba, to continue their collaboration with this agricultural engineering group. The remaining two field crop entomologists, Marj Smith and Ian Wise, were required to take early retirement at the end of March 2013. They will continue as volunteers until the end of 2013, as will Emeritus Research Scientist, Bob Lamb. At that point, no further field crop entomology research will be conducted by Agriculture and Agri-Food Canada in Manitoba. The Province of Manitoba has entomological extension personnel, but no research staff. When CRC closes in early 2014, research in field crop entomology in Manitoba will be in the hands of the Department of Entomology, University of Manitoba, which has one faculty position designated for this research area.

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