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George M. Cook

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Article abstract

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“Spray, Spray, Spray!”: Insecticides and the Making of Applied Entomology in Canada, 1871–1914¹

GEORGE M. COOK

ABSTRACT

As insecticides were adopted by Canadian farmers and fruit-growers after 1871, the resources conferred on economic entomology by the Dominion and Ontario governments grew. In 1886, with the establishment of the Experimental Farms system, James Fletcher, the Dominion entomologist and botanist, and his colleagues inherited the task of promoting insecticides to orchardists and others. In 1898–1900, in response to the arrival in Ontario of the San José scale, Canada and Ontario adopted laws mandating the use of insecticides, as sprays and fumigants, in orchards and at plant quarantine stations. To meet the resulting demand for trained technicians and scientifically-minded farmers, the institutions of applied entomology federally and at the Ontario Agricultural College were further developed. In 1910, after a decade of rapid diffusion of insecticides, Parliament adopted the Destructive Insects and Pest Act, thus creating a national system of horticultural hygiene.

RÉSUMÉ

Après l'adoption des insecticides aux vergers canadiens dès 1871, les ressources consacrées par les gouvernements du Canada and de l'Ontario à l'appui des institutions de l'entomologie économique se sont accrues. En 1886, suite de l'établissement du système national des Fermes Expérimentales, James Fletcher, l'entomologiste et botaniste du Dominion, et ses collègues ont hérité la responsabilité de la promotion des insecticides aux horticulteurs et autres agriculteurs. L'arrivée dans l'Ontario du pou de San José en 1897 a provoqué l'adoption des projets de lois canadiens and ontariens pour rendre l'usage des insecticides mandataire pour le seringage des vergers et la fumigation des saugeons aux postes de quarantaine. Afin de satisfaire la demande pour les techniciens instruits et les agriculteurs d'esprit scientifique, les institutions de l'entomologie économique étaient encore élargies. En 1910, après une décennie d'accroissement rapide des insecticides, le Parlement a adopté la loi sur les insectes nuisible, créant ainsi un système nationale d'hygiène horticole.

In June 1886, seven months after the driving of the ceremonial last spike to mark the completion of the Canadian Pacific Railway, Parliament passed a bill to establish a national system of Experimental Farms. In conformity with the Dominion government's National Policy of immigration, colonization, economic expansion and development, the Experimental Farms system was to promote settlement of the west and agricultural improvement in the east. Entomology and the other departments of the new institution would contribute to the achievement of these objectives. Accordingly, the Dominion entomologist and botanist, James Fletcher, urged farmers – fruit-growers in particular – to adopt insecticides and fungicides and provided information and advice concerning the materials, tools and techniques required. By means of chemical “preventives and remedies” for injurious insects and plant diseases, farming and fruit-growing would, he claimed, become more stable and profitable.²

In the context of government economic policy, Fletcher and the other members of the staff of the Experimental Farms became agents of agricultural change. Beginning in the late 1880s, they adopted the technology of chemical spraying from the United States, promoted it aggressively in speeches, bulletins, reports and articles in the press, demonstrated the use of insecticides and fungicides, and carried out field trials designed both to test and propagate them. Despite their early efforts, however, adoption was slow, inhibited by the difficulty of achieving the desired results with the available tools. When gasoline-powered pumps began to replace horse- and hand-powered ones after 1904, the use of insecticides spread rapidly.³

The practice of applied entomology in Canada grew and changed with the growth of insecticide use. Professional economic entomologists in the federal and provincial governments continued to provide advice, as they had in the past, but added a regulatory dimension to their responsibilities. Fletcher, his colleagues, and their successors became supervisors, inspectors and officers who managed a national system of plant quarantine stations and enforced laws that made orchard spraying mandatory. Entomologists' often noted reputation as eccentric butterfly collectors faded as they became government officials. Thus, by their persistent advocacy of the benefits of spraying – and their sometimes exaggerated claims of success – they won new powers under the law and were afforded greater professional and public respect. The wide diffusion of spraying and the acquisition of legal authority that followed

provided the technical and legal basis for a rapid expansion of the institutions of applied entomology in the years after 1910.⁴

“THE SOVEREIGN REMEDY”

The dramatic increase in insect infestation in the North American between 1870 and 1887 has been called the “insect emergency”. The colonization of the west, the extension of monoculture, the mechanization of farming and the increasing ease of transportation by rail and steamship created conditions that favoured the spread and explosive population growth of indigenous and introduced insects. The currant worm, chinch bug, codling moth, cotton army worm, plum curculio (a weevil) and Rocky Mountain locust were the most feared. Farmers did what they could to resist insects, of course, but the available methods of control were mechanical or cultural – picking insects from plants by hand, for example, or burning stubble after harvest – and often of little help. The insecticides available were botanical, such as pyrethrum and hellebore, and could not be purchased in sufficient quantity and at low enough prices to be practical on large farms.⁵

The situation worsened with the appearance of the Colorado potato beetle in the 1860s. Originally confined to the Colorado mountains where it fed on a member of the Nightshade family, to which the potato also belongs, the beetle spread rapidly when potato farming reached the west. The damage to the crop, an important staple, provoked fear and a desperate search for ways to kill the insect. Such a means was discovered in the form of a toxic arsenical compound known as Paris green – copper acetoarsenite [$3\text{Cu}(\text{AsO}_2)_2 \cdot \text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2$] – widely used to colour paint, wallpaper and other products.⁶

The first use of Paris green as an insecticide was not recorded; one account suggested that a farmer observed its effects when the green paint he was applying to his window shutters dripped onto a nearby potato plant, killing the beetles feeding there. The earliest recorded use was attributed to one Byron Markham, a Michigan farmer, who claimed to have applied Paris green in powdered form in 1867. In 1868 it was adopted by another potato-grower, George Liddle of Illinois, and came to the attention of the *American Agriculturist*, a leading farm periodical. In 1871, William LeBaron, entomologist of Illinois, recommended it to the farmers of his state. Other American entomologists soon followed and its use grew.⁷

The Colorado potato beetle was discovered in southwestern Ontario in 1870, inciting calls for control. In June of that year, John Carling, Ontario's Commissioner of Agriculture, asked William Saunders, vice-president of the Entomological Society of Ontario, and Edmund Baynes Reed, its secretary treasurer, to study the outbreak. Saunders had founded the Entomological Society of Canada with C.J.S. Bethune, another Ontarian, in 1863. The government of province did not employ a professional entomologist, but in 1869 began to contribute funds to the renamed Entomological Society of Ontario in exchange for advice concerning the control of agricultural pests. In 1873 Carling created the Ontario Agricultural College and in 1886, as John A. Macdonald's minister of agriculture, the national Experimental Farms, with Saunders as the founding director.⁸ Thus, the presence of Saunders, Bethune and their entomological club, and their close association with Carling, himself a member of the Entomological Society, created the basis for an Ottawa-Ontario alliance in applied entomology that was to prove important in the years ahead.

In their report to Carling, Saunders and Reed added their own observations to those obtained from American entomologists. They described the insect and its life cycle, the damage it had done in the province and the likelihood of its continued presence, and discussed the use of "artificial remedies" such as Paris green, arsenious acid, powdered cobalt, sulphate of copper, bichromate of potash, hellebore and carbolate of lime (a mixture of carbolic acid and lime wash). They concluded that Paris green was the most practical and efficient way of ridding potatoes of the beetle, but noted that the commercially available brands varied considerably in composition. Some contained too much arsenic and would damage foliage, some too little to be effective. They therefore recommended that the province make "such arrangements with the wholesale dealers in Toronto as will enable farmers and others to obtain a reliable preparation at a stated uniform price". In a note appended to their report, Saunders and Reed recorded that the government had taken their advice. Henceforth farmers would be able to purchase Paris green at 30 cents a pound.⁹

Carling's response to the Saunders-Reed report marked the beginning of measures in Ontario to ensure the legal availability of arsenicals and other insecticides. In 1884, the provincial Pharmacy Act made special provision to exempt insecticides from regulations prohibiting the sale of poisons. The exemptions were maintained when the act was amended in 1905 and extended to several new

insecticides, including lead arsenate, when it was further amended in 1909.¹⁰

As Ontario sought a remedy for the Colorado potato beetle, the insect continued to spread. It soon came to the attention of the new Dominion government. In 1877, the deputy minister of agriculture, Dr. Joseph-Charles Taché, published a long pamphlet concerning the beetle and its control, for the farmers of Quebec. Taché described the benefits of Paris green in glowing terms. "Has it not ... been demonstrated that the application of Paris green has become a necessity for the cultivation of the potato wherever the devastating insect has spread?" he asked. "Paris green is the only means [of control] certain to be effective." He cited observations and recommendations of American entomologists and described the work of his assistant, John Lowe, secretary of the department. "I can confirm all this testimony by that of my own observation," Taché wrote, "having, during the previous and current season, studied the results of the use of Paris green in the fields surrounding the capital of our Canadian Confederation, and above all in the fields of my colleague Mr. Lowe, ... who has now become a master of the art of using Paris green."¹¹

Taché also noted that the federal ministers of agriculture and internal revenue had ordered the analysis of Paris green, already on sale across the country, by three chemists – Dr. Hubert LaRue of the Faculty of Medicine at Laval University, M.B. Edwards of Montreal and W.H. Ellis of Trinity College, Toronto.¹² Like their counterparts in Ontario, federal officials acted quickly to guarantee the availability of a "reliable preparation." By this means, both the Dominion and the province protected the reputation of the new technology and, by extension, the credibility and authority of their governments.

Although Paris green was first used against the Colorado potato beetle, its second and more extensive application was against orchard insects, particularly the larva of the codling moth, responsible for wormy apples. Like the potato and other crops, apples had suffered increasingly from insect attacks in the 1870s. By the end of the decade, only 60 to 75 per cent of the Ontario harvest was undamaged. During the early 1880s, the problem continued to grow. By 1885, only 25 percent of apples were unblemished. Because the planting and cultivation of fruit trees required a relatively large capital investment over a long period, the incentive to spray was greater than for many field and garden crops, where a lost harvest could be replaced in a year. Encouraged by the success

of Paris green against the potato beetle, Ontario apple-growers began to apply the arsenical against the codling moth in 1878.¹³

A decade after Ontario had begun to support the Entomological Society with an annual stipend, the government appointed a commission to study the progress of agriculture. In its report, published in 1881, the commission noted the growing numbers of state entomologists in the U.S. and the availability of American entomological advice. "The interests of the Province and a large portion of the Union are so nearly identical in this particular that an exchange of good offices would at all times be both beneficial and natural," the commissioners noted. Although they refrained from recommending the immediate appointment of a provincial entomologist, they concluded that a qualified naturalist working full-time on insect problems could indeed put knowledge obtained from American sources to good use.¹⁴ Saunders underscored the point two years later in his *Insects Injurious to Fruit*, North America's first text book on the subject, by citing articles and reports by chief U.S. entomologist C.V. Riley, his assistant L.O. Howard, J.A. Lintner of New York, J.H. Comstock of Cornell University and virtually every other important American entomologist of the day.¹⁵

By 1883, when the federal government began to consider the establishment of a national institution for agricultural research, insecticides had already been adopted and endorsed federally and in Ontario by those who were soon to lead the development of agricultural policy and the creation of the Experimental Farms system – Carling, Taché, Lowe and Saunders. Their influence in government and commitment to insecticides formed the political and technological context in which arguments for applied entomology in federal agricultural institutions were made. Accordingly, in his testimony of 1884 to the House of Commons' Select Committee on the Agricultural Interests of Canada, chaired by MP George Gigault, James Fletcher was emphatic in his claims for a causal connection between the discovery of insecticides, the work of agricultural entomologists and the rapid diffusion of the new technology in the United States. "Paris green is now one of the principal remedies used," he told the MPs. "It was discovered as an insecticide by an entomologist in the United States, about 1869." Asked by Gigault to name the discoverer, Fletcher admitted that he could not, but deftly asserted that the work of an American entomologist was indeed responsible for its rapid adoption. "The first mention of it was in a newspaper as being used by some one in Illinois," he said. "Prof. Riley then took it up. But it was an ento-

mologist who found it out, after using a great many other substances."¹⁶

Born in Ashe, Kent, England, in 1852, Fletcher was educated at the cathedral grammar school in Rochester. He took a job with the Bank of British North America in 1871 and was posted to Montreal and then to Ottawa where, in pursuit of his interest in entomology and botany, he joined the Entomological Society of Ontario and helped to found the Ottawa Field Naturalists' Club. In 1876 he took a new job as an assistant in the Library of Parliament. Three years later he married Eleanor Gertrude Schreiber, the daughter of Collingwood Schreiber, Sandford Fleming's successor as chief engineering of the CPR. From his post in the library, Fletcher was an unofficial adviser on insects to members of Parliament seeking answers to the questions they received from their rural constituents. In 1879 he became a vice-president of the Entomological Society.¹⁷

From his vantage as unofficial adviser to politicians and a leading naturalist, Fletcher appeared before the Gigault committee to make the case for economic entomology. After claiming insecticides for the profession, he went on to describe their use, displaying a mastery of the subject that was, at this early stage, more apparent than real. He discussed the application of Paris green in liquid and powdered form and the addition of flour or plaster as adhesives to keep the poison on the leaves. He insisted on the importance of purity for toxicity, and proper dilution for the avoidance of damage to foliage. Applications, he warned, must be properly timed. He went on to discuss the oyster shell bark louse, a fruit pest, crediting Comstock with the discovery of the antidote, a simple soap wash. He referred to experiments by C.V. Riley with coal oil and the means of emulsifying it in water for use as a spray. And he described a new arsenical, London purple, a waste product of the aniline dye industry, formerly dumped at sea, that had come into use as an insecticide in much the same way as Paris green. He called it a useful poison but cautioned that the proportion of arsenic in the available products was irregular and unreliable.¹⁸

Insect damage cost Canadian farmers \$20 million a year or about one-tenth the value of the annual national agricultural output of \$200 million, Fletcher said. A government entomologist working closely with a network of rural correspondents could, he claimed, significantly reduce these losses by identifying injurious insects as they appeared and issuing immediate instructions for the most effective remedies. "Some farmers say that a State entomologist

would not be of advantage," he said, "yet you will find those very farmers reporting that the whole of their clover crop has been destroyed by the clover midge. There is an inconsistency there. The two statements are equivalent to saying that the man who would tell them how to prevent the loss of their crops is not necessary."¹⁹

Not for the last time, Fletcher reminded the MPs of the good example of the United States. "Let us look at it in this way," he said. "The United States Government is certainly not a Government to waste money upon a useless officer, but the United States has done more to support the service of entomology, and the study of economic entomology than any other country. If the expenditure thus entailed were useless, the United States would not be the country to enter upon it."²⁰ Canadian politicians, he suggested presciently, could not be fairly accused of wasting money when, by appointing a single official, they would make the benefits of the much larger American entomological enterprise available to Canadian farmers.

In its final report, the Gigault committee recommended the creation of an Experimental Farm to study the introduction and culture of new plant varieties, test the comparative value of various fertilizers and undertake "careful investigation into the origin, distribution and habits of insects injurious and beneficial". Through an information bureau the Experimental Farm would distribute reports and bulletins containing information on these and other agricultural questions.²¹

On June 17, 1884, some four months after delivery of the committee's report, the government appointed Fletcher "honorary entomologist" in the Department of Agriculture, a non-remunerative post he would occupy while continuing to carry out his official duties in the Parliamentary library. In this capacity Fletcher submitted annual reports for 1884 and 1885.²² In the latter, published as the government was preparing to introduce the bill to create the Experimental Farms, he reminded the minister of agriculture of the growing importance of economic entomology in the United States and the ease with which Canadian farmers communicated with American experts.

Year after year fresh States of the great Republic, whose boundaries touch our own for more than 3,000 miles, are added to those who acknowledge the necessity of having a Government official who shall devote all his time to studying the habits of insects injurious to agriculture, and the methods for controlling and preventing their depredations.... The results of their studies are published regularly, and are easily accessible to all.... Any applications from Canadians

for information have always received as prompt attention, as if they had come from residents within the Union.²³

He concluded by acknowledging the assistance of Riley, Lintner, J.B. Smith of the U.S. National Museum and J.J. Rivers of the University of California. The implication was clear: if the government of Canada failed to meet the growing national demand for information and expert advice on the control of injurious insects, Canadians would turn to the growing number of scientists appointed by the state and federal governments of "the great Republic".

In September 1885, John Carling became minister of agriculture. In November he asked William Saunders, to whom he had turned in 1870 during beetle outbreak, to visit agricultural research institutions in the United States and prepare a report to guide the implementation of the Gigault committee's recommendations.²⁴ Saunders obliged and, on February 20, 1886, submitted a report in which he identified ten areas for research, including study of "the ravages of destructive insects" and "the most useful preventives and remedies to be used."²⁵ Governments and insecticides were already closely associated; now insecticides and a legally constituted government institution were conjoined.

On April 30, Carling introduced legislation to create the Experimental Farms system and on June 2 it became law. He appointed Saunders the first director. The Experimental Farm Station Act established a Central Experimental Farm just outside Ottawa and four satellite farms, in Nova Scotia, Manitoba, the Northwest Territories (Saskatchewan) and British Columbia. Under the act, the Experimental Farms, centrally administered from Ottawa, were charged with the promotion of agriculture "by the dissemination of useful and practical information" derived from research concerning the relative value of breeds of livestock, varieties of wheat, fertilizers and "preventives and remedies" for injurious insects and plant diseases. Governments and insecticides were already closely associated; now insecticides and legislation were firmly conjoined.²⁶

On July 18, the government named Fletcher Dominion Entomologist and Botanist at a salary of \$1,500 a year. On March 8, 1887, he was officially transferred from the Library of Parliament to the Central Experimental Farm.²⁷ As he began his work, he was already a member of the Washington-based fraternity of North American economic entomologists and was therefore able to call

on his colleagues for advice and support. He acknowledged their assistance in 1885, prior to his permanent appointment. "The courtesy of Prof. Riley, and his able staff of Assistant Entomologists, at Washington, as well as of the gentlemen entrusted with this work in the several States which are advanced enough to employ Entomologists, cannot be exceeded," Fletcher wrote. "From the geographical position of Canada and the United States, many of our interests and theirs are naturally identical."²⁸

At this early stage Fletcher's efforts to encourage the use of insecticides consisted of letters to farmers, articles in the agricultural and popular press (particularly the *Farmer's Advocate* and the *Montreal Family Herald and Weekly Star*), his annual reports, circulars and bulletins, and addresses to entomological and agricultural associations and institutes.²⁹ In his first major excursion outside Ontario – to the annual meeting of the Fruit-Growers' Association of Nova Scotia at Kentville – he repeated the claim that insecticides had been invented by an entomologist and began the difficult task of fostering their adoption. Fletcher defined entomology as the knowledge required to correctly identify insects and insisted on the efficacy of spraying. He explained the mysterious appearance, often sudden and explosive, of injurious insects, and justified the use of chemical poisons, according to the popular theory of the balance of nature, the guiding ecological concept of the day in Canada.³⁰ He appears to have adopted the theory from Riley or B.D. Walsh, another entomologist.³¹

In its pristine condition, undisturbed by human activity, the natural order was a more or less stable hierarchy in which the availability of food and the presence of predators, pathogens and parasites regulated the size of a given population of insects or other organisms. Imbalances were local and fleeting. "When from special circumstances any injurious insect is abnormally multiplied, it is sure to be attacked and kept in check by some other kind, which itself may be a prey to another species." However, human activity, such as agriculture, transcontinental transportation or trade, could disrupt the natural balance by increasing particular food sources and introducing new species. "When we cultivate large areas under any one crop we naturally attract those insects which feed upon it, and in this way insects which have previously been scarce, may suddenly increase in numbers so enormously as to become a serious hindrance to agriculture."³²

Fletcher cited the standard example of the Colorado potato beetle. The arrival and ubiquity of potato cultivation presented the

insect with an opportunity, he told the Nova Scotia fruit-growers. "A bridge was ... formed over which it has swept eastward like a whirlwind, carrying devastation in its wake." Balance would be restored, of course, but only as the insect's food was depleted – crops destroyed – or as predator populations grew. It was therefore necessary for the farmer to maintain the imbalance (or establish a new one) by substituting chemical control for the checks that would ordinarily be exercised by the depletion of food and the increase in predation. In the beetle's case, Paris green was "the sovereign remedy," he said. "The application of this substance to the Potato fields is now almost as much a part of the culture of this necessary tuber as manuring the soil."³³ A more homely and reassuring comparison could not have been found.

As his testimony to the Gigault committee, annual reports and address to the Nova Scotia fruit-growers demonstrate, Fletcher based his public claims for his own position, and for applied entomology in general, on insecticides and the expert knowledge of them. In private, however, he sought the assistance of Riley, Howard and others, to gain greater proficiency in their use. Throughout the period under consideration, Fletcher and other Canadian entomologists depended heavily on their colleagues in the U.S. for biological and technical knowledge and advice.

On May 22, 1889, Fletcher wrote to L.O. Howard, Riley's assistant in the U.S. Department of Agriculture, lamenting his lack of experience in spraying and seeking support for an intended application to Saunders, the director of the Experimental Farms, for permission and funds to visit Washington. "I could see in 2 minutes a great deal which now takes me hours to work out," he told Howard. "Particularly I could benefit by seeing some of Prof. Riley's experiments in spraying and the necessary apparatus. I now feel my ignorance and want of experience in this line a serious hindrance, and I am ... troubling you with the object of getting you to help me in this particular." He went on to request advice on spraying nozzles before returning to the matter at hand:

Mr. Saunders's idea of Economy will I anticipate make him refuse to recommend my taking a trip to Washington to see the methods in use there. I however imagine that I should so benefit that it will repay me to ... go at my own expense. Please let me know what you think before I apply formally and please tell me if I could hope to find you there and if you would have [leave to devote?] any time to me when there or if you could hand me over to any of your assistants

to be instructed. I suppose I could find a boarding house without having to go to the expense of living at an hotel in the Capital.³⁴

Early in July, in a memorandum to Saunders, Fletcher made his request. He reminded the director of the development in the U.S. of "apparatus and methods" for the suppression of injurious insects. "While I believe I have made good use of the published records concerning Economic Entomology, I feel convinced that my usefulness to the country at large would be materially increased if I could go to Washington and examine the newest instruments and see them used." He quoted Howard's response to his letter of May 22, affirming the value of a visit and his willingness to assist. The cost of the trip, Fletcher said, would be about \$65.³⁵ As it happened, Saunders's "idea of Economy" was less parsimonious than he had feared. Late in July he travelled to Washington at government expense, "for the purpose of examining the apparatus and collections" of the entomological division of the Department of Agriculture. He returned to Ottawa further instructed in insecticide use and armed with samples of the "Riley cyclone nozzle" and "Kutzner New Zealand triplet nozzle", small but important tools designed to distribute sprays for complete coverage of the foliage, branches and trunks of trees.³⁶

"UP-HILL WORK"

In 1890 Fletcher's colleagues at the Central Experimental Farm, John Craig, the horticulturist, and Frank Shutt, the chemist, began systematic tests of insecticides and fungicides. Craig was a graduate of the Iowa Agricultural College in horticulture and economic botany who had worked briefly at the Iowa Agricultural Experiment Station before joining the Experimental Farms in 1890. Shutt began his professional life as assistant to the Public Analyst of Ontario. After graduating in chemistry from the University of Toronto in 1885, he worked there briefly as a demonstrator before Saunders invited him to Ottawa in 1887.³⁷

The division of labour between Craig, Fletcher and Shutt appears to have been a function of their areas of expertise, official duties and personalities. Charged with aiding horticulture, including fruit-growing, Craig concentrated his efforts on the demonstration of the economic advantages of spraying in controlled field trials designed to determine costs and benefits expressible in dollar terms, while the more gregarious Fletcher, with his national net-

work of agriculture correspondents, continued to exhort farmers to spray and marshalled evidence to counter charges that insecticides were damaging to the health of humans, livestock and the plants themselves. Shutt supported the work of his colleagues with the necessary qualitative and quantitative chemical analyses and the careful preparation of precise mixtures of insecticides and fungicides.

Craig began by testing 14 combinations of fungicides and insecticides in various concentrations on three-year-old trees, one per combination, at the Central Experimental Farm. He then tried a second series of tests in which new trees were selected.³⁸ The trials continued until 1894. By then he was testing more than 30 spray mixtures on apple, pear, plum, cherry and peach trees and on most of the small fruits grown in Canada. On the basis of these results, he began supervised trials in Ontario and, at the request of the influential Ontario Fruit-Growers' Association, extended them to seven working orchards.³⁹

Craig expressed his results in terms of income earned less the cost of spraying, measured against income earned on unsprayed trees. "As a result of the experiments referred to, and looking at spraying as *affecting the yield*, we find that the sprayed trees gave 74 per cent. of the total yield," Craig reported. "This return, added to the improved quality, gives a difference in the net receipts of \$51.53 in favor of the sprayed acre."⁴⁰

In 1895, Ontario's minister of agriculture, John Dryden, inspired or provoked by the growth of the federal "experiment-demonstrations", inaugurated a provincial program involving 30 orchards, most associated with the "fruit experiment stations" established at the urging of the Fruit-Growers' Association, on Craig's advice, in 1894. The stations were under the joint direction of the association and the Ontario Agricultural College. A director of experimental spraying was appointed and demonstrations continued until 1899. Local growers were invited and sometimes up to 100 attended.⁴¹ The results were published annually.

In 1894, Craig published Canada's first "calendar guide to spraying" for fruit-growers, based on a model developed at Cornell University. Depending on the kind of tree cultivated, the calendar indicated the times of application – up to six per growing season – of standard fungicides and insecticides alone and in combination.⁴² Craig's calendar was adopted in Ontario by J. Hoyes Panton, professor of geology and natural history at the Ontario Agricultural College. He included several other insecticides not found in Craig's

calendar, including kerosene emulsion, hellebore, pyrethrum and "air-slaked lime".⁴³

As Craig and Shutt continued their work, Fletcher participated energetically in efforts to defend the use of chemical insecticides and fungicides against those who suggested that they might be dangerous. The defensive campaign was international, involving the United States and Great Britain. An unfavorable press in New York or London demanded a Canadian response. In this work Fletcher once again relied heavily on his colleagues in the United States for information and in return made a contribution to their domestic defensive efforts.

Arsenic had long been known as both a medicine and poison. In minute doses it appeared to have beneficial effects and was prescribed for ulcers, digestive disorders and many other ailments. In slightly higher doses and over longer periods of time, however, it was deadly. Because the symptoms of arsenic poisoning were easily confused with those of common diseases, it became the poison of choice for murderers and suicides. Its toxic effects were observed with alarm as it infiltrated the home. Paris green and Scheele's green were widely used to pattern wallpaper.⁴⁴ In 1886 the American physician Charles Dana described a man who, while drunk, swallowed a handful of Paris green. The man lived, but suffered chronic damage to his nervous system resulting in burning sensations and numbness in his extremities, dizziness, loss of muscle control and impaired vision. "He became slightly hysterical in anxiety over himself," Dana observed.⁴⁵

It is not surprising, then, that the introduction of Paris green in the early 1870s excited anxiety among some farmers. Although many embraced its use, others were wary, citing the dangers of damage to foliage, soil, trees and animals. The *American Agriculturist* gave voice to these reservations as early as 1868. Federal and state chemists and entomologists hastened to contradict the doubters.⁴⁶

In Canada, government officials and entomologists had taken up the cudgels for Paris green from its first introduction. In 1871, Saunders and Reed decried the "foolish prejudice against the use of this mixture" that had already arisen among some Ontario potato-growers.⁴⁷ In 1877, Taché dismissed the persistent rumours, aired in the American agricultural press, that new and incurable diseases had arisen in the west with the coming of Paris green. Citing the results of a study published by the U.S. Department of Agriculture

in 1875, he declared that the arsenical could be used continuously without threat to human health.⁴⁸

With the establishment of the Experimental Farms Fletcher and Shutt inherited the task of defending insecticides. In an address to the North Lanark Farmers' Institute (in Almonte, near Ottawa) in December, 1887, Fletcher assured farmers that they would not poison their potatoes or those who ate them by spraying with Paris green. Potatoes were tubers, not roots, he said, and tubers did not absorb nutrients from the soil, but stored starch manufactured in the leaves. Leaves did not absorb arsenic. Apples too were safe, for two reasons: first, the flower's stigma was extremely delicate and would be destroyed by the direct application of Paris green; and second, even if arsenic did reach the intact stigma, it was non-absorbent. Pollen grains sent out penetrating tubes; arsenic did not possess this power of penetration.⁴⁹

Fletcher's assurances might well have impressed those who thought of potatoes as roots and of plant fertilization as a kind of "absorption" of pollen, but he did not rely solely on this kind of common sense refutation. He went on to cite experimental evidence from A.J. Cook of Michigan. In response to a letter of inquiry from Fletcher, Cook had described tests with concentrated arsenites conducted in 1871 and 1881. On both occasions he had found that potatoes, potato plants and apples treated with Paris green were free of arsenic. Fletcher published Cook's letter in his report for 1887 with an introductory recommendation from entomologist Stephen Forbes of Illinois: "Of course," Forbes wrote, "you will have no trouble in proving by the highest authority that there is no possibility of the poisons being absorbed by the plants."⁵⁰

Concerns expressed regarding the potential danger of insecticides to public health were a source of anxiety for entomologists. In 1891, three events – in Ontario, New York City and England – prompted Fletcher, Shutt and their colleagues in the U.S. to take further action in defense of Paris green. As early as 1885 Fletcher had noted American reports of the death of honey bees near sprayed trees. "Instances have been brought under my notice where an apple-grower, by applying Paris Green when the flowers were in perfection and filled with honey, killed all his own and his neighbours' bees."⁵¹ Fruit-growers discounted the claim, but the Ontario Bee-Keepers' Association was undeterred. It petitioned the provincial government for legislation to prohibit the use of Paris green and other poisons while fruit trees were in blossom. The controversy became serious enough by 1891 that the Association of

Economic Entomologists struck an investigatory committee under F.M. Webster of Ohio.⁵²

At hearings on the matter in Ontario, Fletcher testified that there was no evidence to support the claim that Paris green killed honey bees, but that even if such evidence were to appear it should not be assumed that the comestible honey would contain arsenic. "The poison taken by the bee is in the nectar that comes from the flowers and before the bee can deposit it the bee is dead, so that the honey in question is never deposited." Besides, he continued, even if the bees lived, the honey they deposited would be fed to their larva, not collected for human consumption.⁵³ Despite his scepticism, however, Fletcher supported a provincial bill to prohibit spraying while fruit trees were in bloom. He did so, he told Cook, not because the law was necessary, but simply to placate the beekeepers, whose continued opposition to spraying might incite further unwanted legislation.⁵⁴ Like Fletcher, J.H. Panton of the Ontario Agricultural College supported the bill and it became law on April 8, 1892, the only time a legal limitation was imposed on insecticide use during this period.⁵⁵

As Ontario moved to protect bees, a more serious challenge arose in New York when, in September 1891, the municipal board of health detected a residue on grapes grown in the Hudson River valley. The board suspected Bordeaux mixture – copper sulphate and lime. "Poisoned Grapes on Sale," the *New York Times* declared. The health authorities confiscated and destroyed the fruit. Led by B.T. Galloway, Craig's counterpart in Washington, American agriculturalists struck back. They condemned the board for needlessly alarming the public and challenged it to justify its actions. Unable to demonstrate any danger of acute poisoning from the sprayed fruit, the public health officials were forced to recant.⁵⁶

Were it not for a similar case that soon threatened their largest export market, Canadian fruit-growers might have been heartened by the victory in New York. In 1891 the *Horticultural Times*, a popular English weekly, reported that apples imported from North America were often covered in a powdery residue containing arsenic. American and Canadian fruit-growers contended that the powder was merely flour used in packing the fruit for shipment, but other newspapers took up the allegation, circulating it widely and attracting the attention of the *British Medical Journal*. "Whatever may be said," the *BMJ* cautioned, "the use of poisons for the treatment of food is a matter which calls for the closest attention and the strictest control, where it is not absolutely prohibited

under severe penalties. As in the case of food adulteration, the public cannot be left to the tender mercies of the interested or the ignorant."⁵⁷

In a letter to Riley of July 4, 1892, Fletcher suggested that the offending articles in the *Horticultural Times* and the *British Medical Journal* were the result of efforts by "our conservative countrymen in England" to discredit the use of Paris green in Britain. (Like Fletcher, Riley was English by birth.) The arsenical had recently been introduced there, to the displeasure of some horticultural traditionalists. Fletcher requested information. "Do you know of any actual analyses having been made showing what trace of arsenic, if any, was found on sprayed fruit?" he asked Riley. "I am just going to prepare my report and should like to quote your opinion on the matter."⁵⁸

Fletcher rejected the British charges of arsenic residue on apples, but conceded that "it is possible that these [newspaper] articles, having been so widely copied, may have affected temporarily the sale of American apples in the English market".⁵⁹ To supply evidence for the defense in both Canada and the United States, and to reduce rising trade anxieties at home, he asked Shutt to analyze Canadian-grown fruit that had been sprayed with Paris green. Fletcher began by soliciting apples from Linus Woolverton, editor of the *Canadian Horticulturist*, who could be trusted to follow instructions exactly. The apple trees from which the sample was taken were sprayed twice with Paris green. Shipped as picked, they resembled fruit for market in every particular. Fletcher passed the sample to Shutt, who analyzed one peck weighing 9 lbs., 7 oz.⁶⁰

In his annual report for 1891, Shutt did not describe his method of analysis, but he did take pains to assure his readers that it was extremely sensitive, capable of detecting as little as one fifty-thousandth of a grain. (One grain is 15.4 grams.) "If 23,000 bushels of apples contained 2_ grains of arsenic (As_2O_3), the minimum fatal dose for an adult, the poison could have been detected by this method." Despite the delicacy of the test, however, Shutt discovered "not a trace" of arsenic and therefore concluded that "further experiments of this nature would only serve to corroborate the negative result and to prove that there are no grounds on which to base a suspicion that our sprayed apples are poisonous."⁶¹ Fletcher wrote the *Canadian Horticulturist* with Shutt's results. "Coming from so high an authority," he said of his colleague, "I feel sure it will be of interest to all fruit-growers."⁶² Later he cited Shutt's work

in his own annual report and republished the results in the U.S. *Experiment Station Record* for 1892–93.⁶³

In 1895, the success of Craig's spraying demonstrations prompted the Ontario Fruit-Growers' Association to declare its approval of insecticides and fungicides. "The profits to the fruit-grower of spraying his trees and plants as directed by professional experimenters appears [sic] to be of sufficient importance to induce every one of us to engage in it in real earnest during the year 1895," the *Canadian Horticulturist* said. "Indeed the benefits appear to be so decided, that no fruit-grower can any longer afford to neglect the work."⁶⁴

Encouraged, perhaps, by the orchardists' endorsement, Fletcher addressed the fellows of the Royal Society of Canada on May 15, 1895, as president of the geological and biological section. "In no branch of natural science," he said, "have such important results been obtained, when gauged by their effect upon the revenue of the country, as in that branch of zoology which treats of insects and their depredations on the crops of the orchard, the garden, and the farm." In evidence, he cited the growing use of insecticides. "There is more spraying being done throughout the country than has ever been previously the case over an equal area of territory and during the present spring there is certainly an enormous increase in the number of fruit-growers and farmers who are adopting this useful method of protecting their crops from injury."⁶⁵

Having secured the approval of Ontario fruit-growers and communicated the results of his work to the Royal Society, Fletcher made his case to the government. On May 21 he described a decade of effort to the Select Standing Committee on Agriculture and Colonization, the permanent successor to the Gigault committee, charged by the House of Commons with overseeing the Experimental Farms.

For the last ten years entomologists have been trying to get farmers and fruit-growers all over the country to adopt the methods of spraying insecticides and fungicides on plants to protect them against the attacks of injurious insects and fungous diseases. This work was, naturally, rather up-hill work at first, because it was then thought to be of a purely scientific nature, and it had to be first demonstrated that these methods were useful, and then that they could be practically applied by farmers all over the country without special information or special training in the matter. After ten years' study by good men, both in the United States and Canada, we have found there are certain standard remedies which we can definitely

recommend to obtain certain results. And with these we find that the chief and most serious diseases of many of our crops can now be kept within control by simple, easily applied and cheap remedies which are now available for all, as a result of careful study; and further than this, these remedies are actually being applied by farmers all over the country.⁶⁶

Less than 10 years after the establishment of the Experimental Farms, the claims of agricultural science had – so Fletcher contended – been vindicated. In fact, according to the contemporary evidence of a survey carried out for the Ontario Agricultural Union, a cooperative with close ties to the provincial agricultural college, spraying was practised only by a minority of fruit-growers.⁶⁷ The expense in time and labour was considerable and the results were not always as satisfactory as the agricultural scientists claimed. Given the inefficiency of hand- and horse- powered pumps, the difficulty of preparing spray mixtures on the farm, the inconvenience and time required for their regular application, the difficulty of correct timing (even with the aid of spraying calendars), and the vagaries of the weather, success was infrequent. As many as half of those who sprayed failed to achieve an observable reduction in insect damage. One knowledgeable observer later estimated that no more than a quarter of all Ontario orchardists sprayed before 1904.⁶⁸

“SPRAY, SPRAY, SPRAY!”

The relative rarity of insecticide use became strikingly clear in 1897 with the arrival in Ontario of a destructive orchard pest with prodigious powers of reproduction – the San José scale, *Aspidiotus perniciosus*. The insect received its common name in 1873 after San José, California, where it first came to the attention of fruit shippers. It was thought to have arrived in California from China or Japan on imported plum tree nursery stock. By 1880, when Comstock described and named it, *A. perniciosus* had spread widely, doing great damage. An armoured scale, so-called for the shell-like covering under which the female lives, the insect could kill an orchard in three summers. It attached itself to trunks and branches, inserted a stylet through the bark and sucked the juices from the trees.⁶⁹

In the years after its first introduction, the scale was confined to the Pacific coast of the United States, but by 1896 was found in 14 states east of the Rocky Mountains. Meanwhile it had travelled

north. Fletcher received the first Canadian specimens in 1894 from Kelowna, on Lake Okanagan, in British Columbia. There, however, the provincial government, emulating California, had adopted the Horticultural Board Act of 1894 allowing it to respond quickly and decisively to injurious insects. The infested trees were burned, the scale eliminated.⁷⁰

In 1897, the San José scale was discovered in an orchard near Niagara-on-the-Lake, in Ontario's fruit-growing country. It was thought to have arrived on nursery stock from New Jersey. Alarmed, the provincial government directed J.H. Panton of the Ontario Agricultural College to issue a bulletin warning fruit-growers of the danger. "No insect," Panton wrote, "is more fitted to menace the fruit-growing interests of our Province than this San José Scale." A single female could give birth to four generations per season – up to 500 young. "Some have computed that her progeny may reach the incredible number of 3,000,000,000 [sic]," he reported.⁷¹

The Ontario Fruit-Growers' Association called immediately on both the federal and provincial governments for emergency measures to halt the influx and spread of the pest. Fletcher, a convinced continentalist in matters of flora and fauna and leery of meddling in matters of trade, opposed the introduction of legislation restricting or controlling the importation of nursery stock at the border. As early as November, 1894, he had warned John Lowe, Taché's successor as deputy minister of agriculture, of the cost of administering plant quarantine and treatment stations.⁷² He repeated his warning in 1895 and, shortly before the scale arrived in Ontario, expressed the same view in a letter to a leading member of the Fruit-Growers' Association: "I do not think it would be advisable to ask the Ontario Government to enact legislation against this insect, as in my opinion the danger does not justify such a step."⁷³

Fletcher based his conviction on Howard's assessment of the potential distribution of the San José scale, an appraisal founded on C. Hart Merriam's bioclimatological map of the life zones of North America.⁷⁴ Merriam, chief of the Division of Ornithology and Mammalogy of the U.S. Department of Agriculture, had divided the continent, north of Mexico, into tropical, lower austral, upper austral, transition and boreal zones. According to Merriam's divisions, most of southern Ontario was transitional, except for a narrow strip of upper austral territory in the orchard belt along the north shore of Lake Erie between Lake St. Clair and the Niagara peninsula.⁷⁵ Here, Howard suggested, the scale could survive.

Fletcher acknowledged this, but suggested – and did nothing to dissuade others from believing – that at the edge of its range the colder Canadian winters would prevent the insect from becoming an economically important pest.⁷⁶

Fletcher's counsel may have delayed the federal response to the scale, but in Ontario pressure mounted rapidly. On June 10 and 19, 1897, the Fruit-Growers' Association approved resolutions calling for laws banning the importation of nursery stock from the U.S., provincial inspection of fruit trees and the uprooting and burning of those found to be infested. Now, mindful of the need to protect the government and himself from charges that they had not done enough to prevent losses, Fletcher reluctantly changed his position. On June 14, 1897, he wrote to Saunders:

My own views with regard to this question of prohibitive legislation have changed to some extent since I had the honour of discussing the matter with the Hon. Minister, for the following reasons: In the first place, I think it is extremely likely that the San Jose scale will spread in a very short time from the States to the south of us and ~~will~~ [sic] may do much harm in Canadian orchards, and as the nursery-men and fruit-growers I have met seem willing to allow this legislation to be enacted it may be well for the Minister to meet their wishes in a certain measure. At any rate, so that he, as Minister, and I, as Government Entomologist, may not be held responsible for that which may be done by this insect.⁷⁷

Fletcher now endorsed the calls for drastic measures – banning nursery stock and burning infested trees. Spraying would certainly kill a large number of scale insects, he said, but insecticides as they were commonly used by fruit-growers, who were often less than absolutely thorough, were not yet sufficiently effective to extirpate the pest, and extirpation was the only acceptable outcome. “It must be borne in mind and should have very great emphasis laid upon it,” he told the growers, “that a tree once seriously infested can never be sound again – never be a profitable tree for you to save and keep in your orchards.” Fletcher now advised: “Total eradication – dig up the tree and burn it.”⁷⁸ Curiously, he did not cite the experience of British Columbia, where burning had successfully eliminated the threat.

On December 9, 1897, John Dryden, Ontario's minister of agriculture, introduced a bill to prevent the spread of the scale. His heightened rhetoric revealed something of the panic inspired by the insect. “Authorities of the State of Pennsylvania speak of it as

causing a greater damage than any other agency in the known world," Dryden told the legislature, "and they speak also of the difficulty of eradicating it. We are face to face with the very worst enemy that has attacked the fruit trees of this Province; it is an enemy that cannot be reached by ordinary spraying, and it is a case where single individuals cannot cope with the pest."⁷⁹ The bill became law on January 17. "An Act to prevent the spread of the San José Scale" prohibited the importation, exchange and sale of infested plants and gave inspectors the authority to enter any property – "nursery, orchard, store, storeroom, or other place where it is known, or suspected, that any plant is kept" – and to burn infested trees and other plants. Hindering an inspector would result in summary conviction and a fine of not less than \$20 and not more than \$100. Failure to pay could bring up to 30 days in jail. Orchardists would be compensated for trees destroyed, but only to one-quarter of their assessed value exclusive of the value of the fruit they bore.⁸⁰

On March 16, 1898, Sydney Fisher, the federal minister of agriculture, followed Ontario's lead and introduced legislation to give the Dominion government the authority to prohibit the importation of nursery stock from designated countries or places. "At present the existence of this pest in Canada is very limited," Fisher told the Commons, "... and those who have studied the question, and who are to-day engaged in the suppression of this pest in Canada assure me that if we can prevent its further introduction, we can in a short space of time absolutely free our country from the danger."⁸¹ The bill received first, second and third reading on March 16 and was immediately sent to the Senate, where it was read and approved the next day. It received royal assent March 18.⁸² On Fletcher's advice, the government immediately issued an order-in-council banning the importation of nursery stock from the United States, Australia, Japan and the Hawaiian Islands, all known as points of origin or transshipment of *A. perniciosus*.⁸³

While government inspectors in Ontario began to burn infested trees, Ottawa rigorously enforced the exclusion of nursery stock, effectively preventing the provincial growers from replacing many of the tens of thousands of trees lost. But as trees burned, opposition mounted. A letter in the Toronto *Globe*, signed by one "Pro Bono Publico", attacked Ontario's policy of orchard destruction. "The condemnation of the Act is well nigh unanimous throughout this section of the country," the anonymous correspondent declared, "and just as far as the scale travels this denunciation of

cutting down the orchards will travel with it. Just as soon as any fruit-raiser learns that his own orchards are condemned he at once joins in the chorus of denunciation, no matter how ardently he has supported the Act up to that time."⁸⁴ By one estimate 41,000 trees were destroyed in Ontario under the San José Scale Act of 1898.⁸⁵ Several fruit-growers attempted to exclude inspectors from their orchards by force; others formed a delegation and travelled to Toronto to express their opposition.⁸⁶

On June 16, 1899, the province conceded to the dissidents, declared a moratorium on the "mattock and matchbook" method of control and appointed a commission of inquiry. After touring the province and conducting hearings, the commissioners recommended a relaxation of the law. Trees should be destroyed only in the most extreme cases, they said, and inspectors should be given greater latitude in determining the extent and severity of infestations and the remedial action required. Most important, the commissioners recommended that all orchards be "thoroughly treated according to the most approved method". The work should be carried out by government officials, they added, "but the owner [should] be required to pay for the material and board the men and horses during the time of treatment".⁸⁷

As the province prepared to consider the commission's recommendations, Fletcher wrote to C.C. James, formerly the professor of chemistry at the Ontario Agricultural College and now the provincial deputy minister of agriculture, to alert him to the fact that the Dominion government was contemplating the replacement of its exclusionary legislation with a law to compel the fumigation of nursery stock at plant quarantine stations on the Canada-U.S. border. "Any weakening of the chain [of exclusion] will give a great deal of trouble and I have not yet made the recommendation to the Minister, but we have had some informal conversation," Fletcher told James. "Of course in addition to the amount of work which will be necessary it will be a considerable expense for I suppose 5 stations would be the least number to cover the work for all the Provinces."⁸⁸

In April 1900, both the Dominion and Ontario governments amended their insect control laws. Nationally, Ottawa lifted the prohibition on the importation of nursery stock. Henceforth, stock would be allowed to enter the country after fumigation with hydrocyanic acid gas (HCN) at designated points of entry – St. John, N.B., St. John's (St. Jean), Quebec, Niagara Falls, Windsor, Winnipeg and Vancouver.⁸⁹ In Ontario the government now had

the authority to “adopt regulations for the treatment of infested plants by spraying, washing or fumigation”.⁹⁰ Dryden promised restraint in enforcing the use of insecticides, but he did not relinquish the power to secure compliance. As the *Globe* reported: “The present amendment would not take away the power to destroy the trees.”⁹¹

The actions provoked by the arrival of *A. perniciosus* in Ontario demonstrated that of the alternatives available – inaction, exclusion, the destruction of infested trees and the mandatory use of insecticides – only fumigation and spraying were acceptable to fruit-growers. The amended statutes of 1900 were the legal ratification of this new political and economic consensus. Thus, as the century turned, insecticides became law.

Fletcher, fearing the economic consequences of a ban or quarantine, opposed all legislation at first, but soon bowed to political pressure, embraced and vigorously defended the destructive measures of 1898, and finally conceded again when they were withdrawn in favour of the compulsory use of insecticides. His only consistent position throughout was the one he had long espoused – that whether the San José scale was extirpated or not, farmers should spray. It was a message he delivered with more than his usual passion to the annual meeting of the Ontario Fruit-Growers’ Association in 1897. “You may think what you like of me,” he said, “– that I scold you, or anything you like – but do spray your trees if you want to save your money. ... That is why I keep on line upon line, precept upon precept. That is why ... the Entomological Society keeps on year after year advising, Spray, spray, spray!”⁹²

Postscript

According to C.H. Merriam’s map of life zones, Nova Scotia lay entirely in the transition zone, outside the known range of the San José scale, but in the spring of 1912 federal entomologist G.E. Sanders discovered *A. perniciosus* near Aylesford, N.S. The provincial Fruit-Growers’ Association soon petitioned the government for the regular inspection of orchards. The province responded on June 4 by issuing regulations empowering officials to destroy “without indemnity” trees infested with San José scale and those adjacent to them. In 1912, 723 trees were destroyed, 57 in 1913 and three in 1914.⁹³ “Thus three years’ field work has brought this pest to the verge of extermination,” provincial entomologist W.H. Brittain reported.⁹⁴

The policy of extirpation by burning was pursued with initial success in British Columbia and unsuccessfully in Ontario, but in both places the measure had been taken in a genuine attempt to eliminate the scale. In Nova Scotia, however, it was deliberately deployed to enforce spraying and extract information. "Incidentally our campaign against the San José Scale was made to serve the purpose of an effective educational propaganda for the better treatment of injurious insects," Brittain wrote. "It enabled us, moreover, to obtain prompt reports of any unusual outbreaks, so that prompt action could be taken. Furthermore we were able by this means to secure a complete and accurate census of the fruit industry, with notes on the occurrence and distribution of injurious insects that will be invaluable for reference."⁹⁵

"WORK INDISPENSABLE TO NATIONAL DEVELOPMENT"

In addition to prompting governments to require spraying and establish a system of plant quarantine and fumigation, the San José scale crisis drew attention to the policy of minimum spending by the federal and Ontario governments on applied entomology. One man could perhaps keep superficially abreast of the latest American developments in the field, but could not hope to respond adequately to the increasing demands for assistance, advice, training and inspection. In the midst of the crisis it became clear to C.J.S. Bethune, the co-founder, with Saunders, of the Entomological Society, that the time had come to add staff and resources to the study and control of injurious insects. Two months after passage of the federal San José Scale Act of 1898, in an address to the geological and biological section of the Royal Society of Canada, Bethune made the case. Ironically, and pointedly, he quoted Howard, the chief U.S. entomologist: "Canada has the man and the knowledge, but has been hampered by want of funds," Howard had said. "The result is that while she has immediately and intelligently adopted the results of researches made in the United States, she has not been able to lead us in original investigation."⁹⁶

Bethune went on to compare the expenditures on agricultural entomology of the U.S. Department of Agriculture with those of its Canadian counterpart. He suggested that the government in Ottawa ought to spend no less than one-fifth the amount conferred on the Geological Survey of Canada for a national entomological survey. And he concluded: "It is earnestly to be hoped that this unsatisfactory condition may soon be rectified and that ento-

mology, especially in its economic aspect, may no longer be starved in this country, but with liberal aid may make more and more progress in its own field of work, and by its practical results justify all that may be done for it."⁹⁷

In the circumstances, his argument appears to have been persuasive. In 1899 entomologist Arthur Gibson joined Fletcher and his botanical assistant, J.A. Guignard, at the Central Experimental Farm. The following year, at the conclusion of the San José scale crisis, Bethune repeated his call for increased government support. In both 1898 and 1900 he cited the example of United States, with its greater commitment to economic entomology.⁹⁸

In Ontario, under the amended San José Scale Act, the work of nursery inspection and fumigation was given to entomologist William Lochhead, Panton's successor at the Ontario Agricultural College. Lochhead travelled first to Maryland "to inquire into the best modes of fumigation as practised in that State".⁹⁹ On the way he stopped at Washington to call on Howard. Later, he described his assignment to the Entomological Society of Ontario. "The Minister of Agriculture," he said, "placed the conduct of the whole affair in the hands of myself, and I at once proceeded to make an inspection of all the nurseries for the purpose of instructing the nurserymen how to build their fumigating houses and how to fumigate." He did not hesitate to connect success in fumigation with the status of his profession: "It must be conceded that this successful initiation of gas treatment of nursery stock to prevent the dissemination of the San Jose Scale is another victory for Economic Entomology."¹⁰⁰

Nationally, Fletcher was charged with establishing and administering six new plant quarantine stations. In 1902 he reported that the federal fumigation stations were operating with complete effectiveness. "The superintendents at all the stations have done their work carefully and intelligently, and no single instance has been brought to my notice of living species being detected on trees after passing through the fumigating houses, or of injury [to the trees] by the gas." Frank Shutt compared sodium cyanide and potassium cyanide for efficiency in producing hydrogen cyanide and found in favour of the former.¹⁰¹

As Lochhead and Fletcher implemented the quarantine and fumigation laws, the Ontario government intensified its efforts to encourage spraying. The most important of its initiatives involved the introduction from the United States of a new insecticide. In 1901 the first test of lime, sulphur and salt took place in Ontario.¹⁰² The California mixture, as it was called, was already the most

effective remedy for the San José scale and other sucking insects in the state for which it was named, but had only begun to be adopted in the east, where wetter weather during the growing season had discouraged its use.¹⁰³ In 1903, Fletcher endorsed the new insecticide and the method of preparation developed by Victor Lowe and P.H. Parin of the New York Agricultural Experiment Station. Their recipe eliminated the need for boiling by substituting lye, caustic soda or potash for salt, making preparation, they believed, much less laborious for the farmer.¹⁰⁴ On Fletcher's recommendation fruit-growers adopted lime-sulphur rapidly and it joined Paris green, lead arsenate, kerosene and hydrogen cyanide on the growing list of agricultural poisons.

The availability of commercially prepared lime-sulphur (eliminating the need for its manufacture on the farm) and, crucially, the introduction of gasoline-powered spraying pumps to replace the horse- and hand-powered models at last created conditions for wide popular acceptance of the new technology. Insecticide use burgeoned. In 1905 an unsigned article in the *Canadian Horticulturist* quoted Murray Pettit, a prominent Ontario grower, one of the early adopters of spraying. "It is astonishing how stirred up fruit-growers are this year over spraying," Pettit said. "For every power sprayer used in this vicinity last year there are three being operated this season." The author of the article confirmed Pettit's observation:

The *Horticulturist's* representative, who visited the section to ascertain what the growers are doing this year in the line of spraying, was astonished at the evidence on every hand of the amount of that work that was being done. Orchard after orchard was passed where the trees were almost perfectly white, they had been sprayed so thoroughly. The main topic being discussed by the fruit-growers who were seen was spraying, and it included such subjects as the spraying experiments being conducted by prof. Lochhead, of the Agricultural College at Guelph, the test that was recently made on the farm of Mr. E.D. Smith, of Winona, of different makes of spraying machinery, or some of the new spraying mixtures which are being introduced this year.¹⁰⁵

A report published by the provincial Department of Agriculture showed that "co-operative spraying" increased from 3,200 acres in 1907 to 4,328 in 1908 and 5,697 in 1909. These figures pointed to its spread among small orchardists, those least able to afford the cost of equipment, labour and material. A second table showed the

amount of spraying material used co-operatively in Ontario orchards in 1907, 1908 and 1909. (On the assumption, perhaps, that its readers did not need to be told, the report omitted units of measure.) Lime and sulphur were by far the most popular substances. Lime use rose from 156,980 units in 1907 to 301,400 in 1909, sulphur from 76,551 to 200,000. Copper sulphate use grew from 33,760 units to 51,484. However, Paris green fell dramatically, from 1,466 units to only 15, while lead arsenate (with greater adhesiveness to foliage and therefore great effectiveness) rose from 565 to 8,119. Arsenic oxide, often mixed with copper sulphate, doubled from 1,205 units in 1908 to 2,200 in 1909. "The above figures indicate a great development in spraying amongst the fruit-growers of the Province," the report concluded.¹⁰⁶

By 1914 government agricultural publications looked back to the years before spraying as to a distant past. An article in the *Agricultural Gazette*, a monthly magazine published by the national government, summarized the official history of spraying in Ontario and linked the development of more effective insecticides to knowledge of insects themselves. "Any person who compares the interest shown to-day through the province in the control of insects and the results obtained with the condition of affairs ten years ago, will see that very rapid progress has taken place. At the former date very few men were convinced that the spraying of orchards paid.... Spray mixtures to-day are cheaper and more effective and the number of applications reduced as a result of better knowledge of the life histories of insects and diseases."¹⁰⁷

The wide diffusion of insecticides, the increase in their effectiveness and the decrease in their cost fostered a rise in the reputation of entomology. At the annual meeting of 1912 of the Entomological Society of Ontario, Thomas W. Fyles of Ottawa, one of the aging group of amateur naturalists, ascribed entomology's higher status to farmers' growing reliance on the knowledge it produced.

A perception of the importance of entomological pursuits was gradually brought about in the public mind through the occurrence of a series of insect plagues – the ravages of the Hessian Fly, of the Midge, the Locust, the Potato-beetle, the Cabbage-worm, the Phylloxera, the Larch Sawfly, etc. The trouble over these induced men to read and spread the information published by Entomologists, as to the nature of the pests, and the ways of combating them. And the impression was made and deepened that an Entomologist was not one who merely engaged in the childish sport of chasing butterflies, or indulged his miserly propensities by storing away his captures.¹⁰⁸

The triumph of spraying marked the beginning of a decade of rapid expansion of the institutions of agricultural science, including applied entomology. "With 1905," William Lochhead wrote, "a new era dawned upon the Biological Department" of the Ontario Agricultural College. About to leave Ontario for the newly founded Macdonald College in Ste. Anne de Bellevue, near Montreal, Lochhead used his final report to describe a reorganization of the OAC that would divide the responsibilities of the professor of geology and biology, creating two new professorships, one in chemistry and geology, the other in entomology and zoology "to prepare trained investigators who will be able to work out the life-histories of, and the best remedies for, the diseases induced by insects and fungi."¹⁰⁹

In 1906, Bethune, Saunders' close associate, was appointed professor of entomology and zoology at the Ontario Agricultural College, joining T.D. Jarvis, the lecturer in entomology. In 1908 the staff was again enlarged. J.E. Howitt and Lawson Caesar joined Bethune and Jarvis, as lecturer and demonstrator respectively. Jarvis was promoted the following year, becoming associate professor.¹¹⁰

By 1909 some 30 posts at American agricultural colleges and experiment stations had been filled by graduates of the Ontario Agriculture College, including several entomologists.¹¹¹ In 1910, for example, all five graduating entomologists found work in the profession, two in Ontario and one each in Quebec, Massachusetts and New Jersey, inspecting nurseries, breeding dipterous parasites and tending insectaries, among other tasks. Of the four entomological graduates of 1912, two joined the Bureau of Entomology at the U.S. Department of Agriculture, one as a draughtsman and "systematic worker", the other as an investigator of insects affecting cereals. The third found employment with the Canadian Ministry of Agriculture as an inspector at a border quarantine station and the fourth as an instructor at the agricultural college itself.¹¹²

In 1912 Lawson Caesar, a graduate of the University of Toronto and the OAC, was appointed provincial entomologist in charge of administering the inspection of nurseries and orchards and reporting on insect infestations and plant diseases. By 1914 he managed a staff of up to 53 people during the summer months – inspectors, orchard demonstrators and lecturers – and monitored the activities of 43 district representatives, mostly farmers, some probably graduates of the college, who were charged with teaching their neigh-

bours to spray effectively.¹¹³ In the course of his career he would train approximately 80 fruit and insect inspectors.¹¹⁴

As knowledge of insecticides spread, the bulletins written by agricultural scientists for the growing group of field trainers, officers and scientifically educated farmers became increasingly sophisticated. Between 1907 and 1912 the Ontario Department of Agriculture issued several such bulletins by Robert Harcourt, the professor of chemistry at the Ontario Agricultural College, and H.L. Fulmer, his demonstrator, including two on insecticides and fungicides. These documents signalled the rise of scientific agriculture and the fulfillment of the claims made for agricultural science in the 1880s. They replaced simple exhortations to spray with discussions of the interactions of acids and bases in the preparation of various combinations of insecticides and fungicides and detailed descriptions of insects' life cycles and behaviour.

The Ontario Department of Agriculture issued "Insecticides and Fungicides" in February, 1907, and reissued it, with revisions, in January, 1912.¹¹⁵ In the earlier edition Harcourt and Fulmer described 16 insecticides – arsenicals, sulphur- and petroleum-based poisons, carbolic acid, soap washes, fumigants (hydrogen cyanide and carbon bisulphide), the botanicals (tobacco, hellebore and pyrethrum) – and nine fungicides, six copper-based and three based on formaldehyde, mercury chloride and potassium sulphide respectively. The later edition included these compounds and mixtures and added four more, two variants of Bordeaux, an insecticidal mixture of lead arsenate and lime-sulphur and an insecticide-fungicide combination known as Pyrox that contained oxides of lead, copper, arsenic, sulphur and calcium.

The 1912 version also provided more information concerning lead arsenate and calcium arsenate, the compounds that had replaced Paris green. The former was described in two forms, acid lead arsenate, $PbHAsO_4$, and neutral lead arsenate, $Pb_3(AsO_4)_2$. The discussion of the relative merits and appropriate uses of the PbH and Pb_3 variants, absent from the 1907 edition, indicated the growing sophistication of both the applied chemistry of insecticides and fungicides and of the officials and farmers for whom such bulletins were intended.¹¹⁶

Harcourt and Fulmer linked the growing number, kind and combination of insecticides available with the need for a more specific and detailed understanding of insects, their life cycles, behaviour and physiology. "To spray with any degree of success requires, besides a knowledge of the acting principle of the remedy

which is being employed, a rather intimate acquaintance with the enemy which is being combatted."¹¹⁷ Entomologists were charged with supplying this knowledge.

In "The Codling Moth", a 40-page bulletin published in 1911, Lawson Caesar described the distribution of the insect and its larva, the injury it caused, and its life history and behaviour in Ontario, based on rearing experiments carried out in the Niagara district.¹¹⁸ He tabulated the difference between the date of pupation and the date of emergence of the moth in spring and summer from one month to the next and found that the warmer the weather the shorter the period of pupation. Date of emergence determined the timing of the egg and larval stages of the insect, the probable size of the first brood and the likelihood of a second in a particular season. Late larva overwintered in cocoons under the bark of trees. The duration of incubation of the egg, also dependent on temperature, tended to be about 10 days in the spring. The total time for all stages, from egg to egg, was about 65 days, from egg to the death of the moth, about 70. Those larva that hatched before or just after the blossoms fell entered the base of the apple through the calyx, boring their way to the core in search of the seeds. The crucial time for spraying therefore arrived just after the blossoms fell and just before the larva entered the apples. A thorough application of lead arsenate at this time would kill the insect before it could damage the fruit, thereby reducing the population of the second brood. A successful first spraying would usually diminish the need for a second, but if a large enough number of first brood larva survived to maturity the prevention of further damage later in the season required a second spraying about three weeks after the first.¹¹⁹

The trend toward more widespread spraying in Canada was consolidated and confirmed in 1910 when the Ontario and Dominion governments replaced their San José Scale Acts with new laws for agricultural inspection, compulsory spraying and fumigation of nursery stock.¹²⁰ Ottawa and Ontario again acted together, as they had in 1898 and 1900, this time in response to the discovery, at points of entry in New York, Nova Scotia and New Brunswick, of the brown-tail moth on seedlings from France.¹²¹

The provincial law took effect on March 19, 1910, followed by the federal statute on May 4. In Ontario, the Fruit Pests Act extended the government's powers of inspection and treatment to virtually all insects and plant diseases. The law also gave municipal and county councils the authority to appoint inspectors and order the spraying of infested or infected plants.¹²² Nationally, the

Destructive Insects and Pest Act authorized the Dominion entomologist to inspect for a larger number of insects and plant diseases at quarantine stations on the Canada-U.S. border and to issue regulations permitting the treatment or destruction "of any crop, tree, bush or other vegetation or containers thereof".¹²³

By order-in-council of February 27, 1911, the federal government confirmed the operation of the six existing quarantine stations and created three new ports of entry for European nursery stock, at Halifax, Sherbrooke and Montreal. European stock was exempt from compulsory fumigation but subject to inspection upon entry or prior to unpacking at its destination. Stock from Japan and the states of Vermont, New Hampshire, Maine, Massachusetts, Connecticut and Rhode Island was to be inspected after fumigation. The federal government also reserved the right to ban importation outright, as it had done in 1898, and applied this provision in 1911 to potatoes from Newfoundland and the French islands of St. Pierre and Miquelon.¹²⁴

In 1909 the federal government selected Charles Gordon Hewitt to replace James Fletcher, who had died suddenly in 1908. Fletcher had combined both economic entomology and botany – weed control, for the most part. Following his death these duties were divided, in keeping with the trend towards specialization and professionalization in the civil service. Hewitt became the Dominion entomologist; Hans T. Güssow, educated in Germany and previously employed at the British Museum, became the Dominion botanist.¹²⁵

Born in Macclesfield, England, in 1885, Hewitt graduated D.Sc. from the University of Manchester in 1909 where he had worked as a lecturer in invertebrate and economic zoology. His expertise lay in the areas of plant quarantine administration, public health entomology and forest entomology.¹²⁶ Given the increasing provincial participation in and control of agricultural entomology and spraying programs, his selection may have indicated a determination on the part of the Dominion government to redirect its efforts to public health, horticultural hygiene and forestry. It may also reveal a determination to bolster the Imperial connection. Although Fletcher and Hewitt moved with ease in the both the American and British communities of economic entomology, Fletcher was much closer to the former.

The entomological department now occupied four rooms at the Central Experimental Farm, one for the entomologist, two laboratories and a museum to house the growing collection of insects. "In

equipping the Division," Hewitt said, "the primary object has been to provide facilities and the means for the prosecution of investigatory work."¹²⁷ At the outset Hewitt spent much of his time drafting and then implementing the Destructive Insects and Pest Act and its regulations. Because it required many more inspectors and much greater vigilance, enforcement of the new law was more costly and time-consuming than the San José Scale Act had been. "With the opening up of the country, the extension of orcharding and horticulture and the growth of our cities there is naturally a concomitant annual increase in the numbers of trees and plants, classed as nursery stock, imported into Canada from foreign countries," Hewitt noted in his report for 1911–12.¹²⁸

In 1911 six federal entomological field laboratories were established, two in Ontario and one each in British Columbia, New Brunswick, Nova Scotia and Quebec, augmenting the regional staff of the Experimental Farms system. Two more were subsequently established, in Manitoba and Alberta. All reported to Ottawa. "The extension of our work into the field by the establishment of field laboratories," Hewitt said, "has not only rendered possible the inception of really valuable investigations on certain of the more serious insect pests and their control, but in many other ways has enabled the Entomological Division to reach a larger number of people to whom its work can be of service."¹²⁹ In 1913 an additional federal fumigation station was established at North Portal, Saskatchewan, and space was added to the quarantine buildings at St. John, N.B., and Niagara Falls.¹³⁰

The federal enterprise had grown rapidly, with annual inspections of more than four million plants a year between 1910 and 1914.¹³¹ Dominion agricultural appropriations rose to approximately \$3.36 million a year from \$377,000. Appropriations for the administration of plant quarantine and fumigation stations increased to \$30,000 from \$1,600.¹³² In 1900, appropriations for the purposes of quarantine and fumigation accounted for less than half of one percent of total agricultural appropriations. In 1914 they accounted for a little less than one percent, or double the proportion at the turn of the century.

The growth in appropriations reflected the addition of employees. Between 1908 and 1914 the entomological division had increased from a professional staff of three – Fletcher and his two hard-won assistants (only one of whom was devoted exclusively to entomology) – to 12 men, three in Ottawa and eight in the provinces. There were, in addition, three inspectors, an artist's assistant,

seven superintendents of fumigation, an inspector of Indian orchards, a laboratory assistant and four secretaries, 28 people in total. The complement would double again in the next decade.¹³³

In addition to the administration of the quarantine law, field work and consultation with farmers, the scope of the activities of the Dominion entomologist soon included forestry, animal and human health and the protection of urban gardens and greenhouses. As a result of the growing differentiation of his role and the increasing demands of administering the quarantine stations and field laboratories, the division was removed from the Experimental Farms in 1914 and made a separate branch of the federal Department of Agriculture. The Dominion entomologist now reported directly to the deputy minister.¹³⁴

In his presidential address to the Entomological Society in 1914, Hewitt reviewed the history of economic entomology in Canada. He dated the birth of the profession to 1869, the year Ontario granted the society \$400 on condition that it collect and report on insects injurious to agriculture, and he traced the history of government involvement to the passage of the Destructive Insect and Pest Act of 1910. He quoted Bethune's address to the Royal Society of Canada in 1898, in which, as we have seen, the older man had compared the substantial American commitment to agricultural entomology to the meagre Canadian one, and he argued that the demonstrated effectiveness of entomology accounted for its subsequent growth.

The sanction of Parliament to increased appropriations, which are now more in accord with the needs of the country, is encouraging evidence of a desire to afford the means whereby the entomological service of the Dominion shall be in a better position to meet the requirements of the situation. Our greater ability to assist the agriculturists, foresters and others demanding our help in preventing the introduction of insect pests, and in controlling by natural and artificial means the spread of those already within our borders, has been the stimulating factor in our development, and I venture to think that the grounds for Dr. Bethune's earlier reproach which I have quoted have already been removed.¹³⁵

In his address, Hewitt also noted the change in the structure of the discipline itself, and the debt owed to economic entomology by systematists.

We need not concern ourselves with the opinions of those who collect insects as they would stamps or china, but I would remind those systematists who are inclined to hold aloof from the practical application of their science that to the work of economic entomologists they owe almost entirely that large measure of respect with which entomologists and entomological work is now regarded by the general public. The prevention and eradication of diseases carried by insects and the control of insects which have devastated our forests and crops and depopulated whole districts is regarded as work indispensable to national development.¹³⁶

The perception of entomology's higher status and the specific recognition of the role played in the achievement of that status by the contribution to national development was accompanied by the emergence of the explicit recognition of the role of the government scientist as an agent of agricultural change through the dissemination of new technology. The most thoughtful analysis of this previously acknowledged but largely unexamined aspect of agricultural science was provided by Frank Shutt, the longtime Dominion chemist, in his presidential address to the mathematical, chemical and physical sciences section of the Royal Society of Canada in 1916. Shutt forcefully described the role of the Experimental Farms system in its first 30 years: diffusion of technology demanding a change in agricultural practice that was also, profoundly, a cultural change – the overcoming of “haphazard, rule-of-thumb methods and the adoption of methods based on the results of carefully, skillfully conducted investigation by chemists, botanists, physiologists, physicists, entomologists and other scientists. Rational, profitable farming to-day,” Shutt declared, “has scientific truth for its foundation.”¹³⁷

CONCLUSION

Before 1905 the diffusion of insecticides in Canada was limited primarily by the absence of spraying pumps strong and reliable enough to achieve complete coverage at a reasonable cost in time, money and labour. With the introduction of gasoline-powered pumps, the rate of adoption increased rapidly – a pattern consistent with historical models of rates of technological diffusion in agriculture and other industries. Slow growth to start leads to a threshold point at which all the necessary elements of the technological bundle – tools, techniques and a sufficient number of knowledgeable users – are in place.¹³⁸

Although Fletcher contributed to the growing body of knowledge of insect taxonomy and classification (he was a recognized specialist in the diurnal Lepidoptera), as an “economic” entomologist he was not primarily a researcher. Given the Canadian policy of low spending in this field, he and his colleagues became adopters and diffusers of imported technology and techniques and, in that capacity, agents of agricultural change. As they acquired greater authority they continued to foster the “industrialization” of agriculture in a supervisory and directing role by disseminating knowledge of and confidence in insecticides and fungicides among orchardists and other farmers.

Patterns of the diffusion of insecticides and the growth of entomological institutions varied across the country. Following California’s lead, British Columbia often anticipated developments in Canada both technically and legally, a circumstance expertly described by Paul Riegert in *From Arsenic to DDT: A History of Entomology in Western Canada*. However, because of its geographical isolation and unique environment, and the regional biases of central Canadians, B.C. rarely influenced national policy. Instead, developments in Ontario tended to set the agenda for the national government. Legislatively and institutionally, Ottawa and Ontario acted in tandem, even when indigenous developments – the B.C. response to the San José scale, for example – might have provided a model for legislated action nationally and in Ontario. The implications of the Ottawa-Ontario alliance for fruit-growers and other farmers outside Ontario have yet to be explored.

Were the claims that insecticides would generate greater profits for fruit-growers born out? The economic impact of spraying on fruit-growing is difficult to assess, but the answer appears to be no. Between 1900 and 1910 the acreage for orchards, vineyards and small fruits in Canada increased substantially, but the number of bearing trees decreased, as did the amount of fruit produced – from 20.7 million bushels in 1900 to 12.6 million in 1910. Over the same period, productivity also declined. The number of bushels of fruit per bearing tree dropped from 1.38 in 1900 to 0.89 in 1910. And total revenue from the sale of fruit also appears to have fallen dramatically.¹³⁹

Conversely, insecticides may have contributed to the maintenance of a declining industry that would otherwise have vanished or dwindled into insignificance as European markets shrank and American competition intensified. The question of agricultural diversification also arises. The ratio of orchard acreages to vegetable

crop acreages was roughly 3:1 in 1900, but by 1910 had declined to about 2:1. On this evidence farmers appear to have abandoned fruit-growing for vegetables at this time. Did the availability of insecticides help to drive this trend by making it possible to increase earnings from market gardens?¹⁴⁰

The growth in the institutions of economic entomology in Canada approximately tracked the adoption of insecticides, expanding slowly until the San José scale crisis, moderately until 1905 and then with increasing rapidity. Institutional growth was motivated by the expansion of agriculture in Canada, public demands for relief from insect infestations, the laws of the land, the presence of a growing number of professionally trained entomologists seeking work and the availability of specialized knowledge from federal and state agencies in the United States. Free access to the results of American research was the primary determinant of the Canadian policy in economic entomology. Both Conservative and Liberal governments chose, wisely perhaps, to take the greatest possible advantage of U.S. research at the lowest possible cost. Only when Ottawa was forced by the San José scale crisis to increase border inspections did it begin to add staff, but it was not until the passage of the Destructive Insects and Pest Act of 1910 and the election of 1911, in which the Conservatives under Robert Borden regained power, that resources were significantly expanded.

Did other areas of Canadian agricultural science stand in the same relation to U.S. research and scientific authority? The development of hybrid wheat and other grains during and after William Saunders's tenure as director of the Experimental Farms appears to indicate a more independent and innovative role for Canadian plant hybridization than for economic entomology. If so, one might conclude that the role of the latter was to satisfy eastern farmers' demands for assistance without incurring large costs *as part of a deliberate strategy* to free resources for the development of hardy, early ripening wheat and other grains to help sustain agriculture in the west. If further research were to bear out this hypothesis, the Experimental Farms might reasonably be interpreted as a foundational case of the formation of a distinctively Canadian policy of science and technology – the selective investment in specific programs of research and development according to an evaluation of the availability of research from the U.S. and elsewhere, the government's financial resources and the national interest.

In 1884, James Fletcher inherited the tasks first undertaken by John Carling, J.-C. Taché, John Lowe and William Saunders and began to build a system to collect and accurately identify injurious insects, for which he recommended “preventives and remedies” to be voluntarily adopted by farmers. By 1914 applied entomology included the regulation under federal law of many aspects of the nation’s horticultural life – the importation of plants, their quarantine, fumigation and spraying, and their exclusion, interdiction and destruction when infestation and disease warranted. The creation of a national system of horticultural hygiene was driven by changing environmental conditions, insect outbreaks, competitive markets for inexpensive produce of high quality, the demands of Ontario farmers for government assistance and – fundamentally – the existence and effectiveness of insecticides, the *sine qua non* of the enterprise.

NOTES

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BIOGRAPHICAL NOTE

George Cook is a part-time graduate student in the Institute for the History and Philosophy of Science and Technology at the University of Toronto, where he works as a writer in the Department of Development.