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The Accidental Plant Pathologist

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Abstract: This article presents the experiences of a woman in academic plant pathology from the 1950s to today. Topics include the social climate for women in science, personal and professional developments and research discoveries, public policy issues in agriculture and biotechnology affecting plant pathology, and projections for the future of plant pathology.

Keywords: phytobacteriology, bacteriophage, bacteriocins, women in plant pathology, biotechnology policy

INTRODUCTION

Being invited to write a prefatory chapter for the *Annual Review of Phytopathology* requires reflection and analyses of several decades of the profession. The charge to provide insights into my career as researcher, teacher, administrator, and career-long contributor to service and leadership in plant pathology leaves considerable latitude. I am especially honored to be the first woman invited to write a prefatory chapter, and I hope that the presentation herein of aspects of my life and career and the plant pathology field in general will be useful and informative.

THE REFUGEE

I was born in Vienna, Austria, into a middle-class, secular Jewish family just before Hitler's occupation of the country. Most of my relatives were killed by the Nazis and we were among the last to be allowed to leave. Although the United States knew of the atrocities being committed, refugees still had to abide by the quota system, despite having sponsors. A few of our relatives had migrated to New York state, where we eventually landed. Prior to our arrival in New York, we spent over a year in the Shanghai ghetto, thanks to the Japanese. My parents and I were fortunate to come to the States before Pearl Harbor.

My father was a shopkeeper in Austria who sold furniture and general household goods. When we arrived in the States, we were housed in a converted chicken coop on a farm in Rhinebeck, NY, owned by our sponsor. My first recollections of this situation were being chased by a rooster!

We eventually moved to North Perry Street in Poughkeepsie, the poorest section of town and the most ethnically and racially diverse. Our street was often in the news due to inhabitants' run-ins with the law. For example, I was unaware that the friendly people next door to us ran a house of ill-repute. With such a reputation of where I lived, the parents of my childhood friends wouldn't allow their children to come play with me. Zoning regulations were not practiced in that area of town, so a rendering factory and a live chicken market as well as three-and four-story cold-water flats coexisted on the street for many years.

THE EARLY YEARS

My parents encouraged my education and studies, including art and music. We were not nearly as well-off financially as we had been in Austria. In fact, I had rummage-sale clothes until I started to earn my own money. My father became a sewing machine repairman and worked until he contracted early Parkinson's disease. My mother was an accomplished seamstress who worked in a lingerie factory and conducted a side business of selling repaired secondhand clothing. Until I entered first grade I spoke only German, so I was originally considered backward. I don't recall any science education until high school, where the course of instruction was bifurcated into a business module or college-preparatory track. Although I had no particular passion for science, I disliked the business option intensely. Thus, with a scholarship to Russell Sage College in Troy, NY, I started my scientific career in 1956. When I entered, I intended to major in medical technology, a field considered acceptable for a woman to pursue at that time. However, during the first semester we visited a morgue of preserved deformed babies; I quickly switched my major to biology. I earned extra money by becoming the laboratory preparation technician for the parasitology and microbiology courses. Making media and solutions in a high-ceilinged, well-lit lab with huge ornamental windows was an enjoyable experience. As a senior, I was given the opportunity to design and carry out a project involving gibberellins and plant growth. Thus began my foray into the world of plant research.

In addition to medical technology, other accepted careers for a woman at that time included teaching. So, with an education minor, I did some compulsory student teaching at the Emma Willard school, a lovely private school that still operates in Troy, NY. The experience convinced me that I was unprepared to go out into the world and earn a living. I also had the good fortune to spend two summers as a research assistant at Brookhaven National Laboratory in Long Island, NY. I don't recall how I found out about the summer program, but I was probably the only applicant who expressed an interest in plant pathology, one of the solicited areas. I didn't know what that encompassed, but I thought I should explore new areas of science. The project involved trying to increase nitrogen fixation by rhizobia by inducing mutations with radiation. I remember thinking that rhizobia grew too slowly and that I wouldn't choose to continue in that line of inquiry. However, the work unwittingly prepared me for some research problems I encountered in later years.

With my teaching and research experience in hand, I felt the professor's life beckoning. There seemed no better career than to keep learning while conducting research and teaching. So, with the strong encouragement and support of several professors, I applied to several graduate schools in microbiology. Most schools offering microbiology programs at that time were essentially restricted to bacteriology. However, Indiana University at Bloomington was in the process of initiating a truly comprehensive microbiology program, including phycology, protozoology, mycology, and virology. With simply a fascination for living things that could not be seen with the naked eye, and a full fellowship, I entered graduate school.

GETTING MY CREDENTIALS

At Indiana, though exposed to all facets of microbiology (except mycology, which was unavailable when I needed it owing to the untimely death of the instructor), I chose bacteriology as my major. I chose plant physiology for my minor, which was novel for a microbiologist. Plant pathogens were barely mentioned, except in virology. The most useful course, in retrospect, was systematic bacteriology because of the exposure to the different types and variety of microorganisms, with accompanying laboratory challenges.

I became the first PhD student of the noted microbiologist Tom Brock, conducting research on the properties of a bacteriophage receptor site of *Streptococcus* (now *Enterococcus*) *faecium*. However, with my marriage to George Vidaver, then a postdoctoral fellow in biochemistry, my advisor essentially abandoned me. He expected me to drop out of graduate school, since I had already completed my master's degree. At that time, most female graduate students dropped out before or after gaining a master's degree. But, in spite of my advisor's disinterest and a mentally unstable student sabotaging experiments of mine (and others), I completed my PhD, with my husband's help and support.

My husband was offered a position in the chemistry department at the University of Nebraska-Lincoln (UNL), and I arranged for a postdoctoral position in biochemistry with a prominent professor. However, a month before I was to begin, the professor left to take a position at another institution.

THE ACADEMIC FORTRESS

In 1965, there were few women PhDs at UNL, or for that matter anywhere else. The underrepresentation of women in academe in the sciences continues to this day, as documented, for example, in the statistics compiled by the National Science Foundation. I was unaware of the reluctance to hire women, and discrimination against them in salary equity and promotions. I had to work against the prevailing view that single women could be tolerated, but married women took jobs away from qualified men. If women who were married were employed, they obviously didn't need to be paid as well as their husbands, and if they had children, they were clearly not serious about their career choice. I didn't know if I could succeed, but I certainly wanted to try.

With a fresh PhD in hand, and a failed postdoctoral opportunity, I made a list of departments that might be interested in and potentially appreciative of a microbiologist. I thought it fair to offer to work for no salary to demonstrate my skills and ability before any support or commitment was made. The chair of the microbiology department wasn't interested in having a woman in his department. Second on my list was plant pathology. Despite the fact that I had no formal training or experience in plant pathology, the department head, Mike Boosalis, a mycologist, in consultation with Myron Brakke, a virologist, thought I was worth a modest risk. Then, with the mentorship of Max Schuster, the resident bacterial disease expert, and a cash input of about $600 from the department, I was on my way. Within six months, I had my own grant funds. My early work was on examining the potential for biocontrol of bacterial diseases, using bacteriophages and bacteriocins, both areas little examined in plant pathology. The lack of knowledge and application of bacterial areas well known in medical bacteriology to plant pathogens was an example of interdisciplinal insularity, described by Mortimer Starr (8). After several years, I concluded that these approaches were unsustainable from a practical perspective. Today, there are those who disagree, and in the human health and food safety areas, both bacteriophages and bacteriocins are in use. I supported myself and my program from 1965–1972, and during that time bore our two children, Gordon and Regina.

UNEXPECTED OPPORTUNITIES

The departure of plant virologist Joe Semancik for California in 1972 left an open position in the plant pathology department at UNL. The majority of the faculty wanted another virologist. I had indicated I would like to be considered for the position on the basis of departmental need and performance. John Fulkerson, who had worked with bacterial plant pathogens, and who was one of the most forward thinkers in plant pathology at the United States Department of Agriculture (USDA), was influential in persuading the administration that I was a very capable scientist and would make a good faculty addition. Thus, in 1972, I was on the first rung of academe. I progressed through the ranks of associate to full professor by 1979.

In 1984, the position of department head became vacant and another faculty member was rumored to be an applicant for the position. I thought that the department would become a very difficult place in which to work, should he be selected. Moreover, I was more highly qualified for the position. So, I applied with the hopes that an outside candidate would be chosen or, if not, that a difficult choice would be placed before the administration. An historic decision

was made when I was chosen as the first woman to head a department of plant pathology in the United States. My husband couldn't fathom why I would want the position and I wasn't sure I actually did. However, with significant mentoring from Arthur Kelman, it was the beginning of a long and fruitful journey in administration. The extant and new colleagues, students, postdoctoral fellows, and visiting scientists over the years have been a delight to work with.

Being a department head afforded me additional opportunities. I had become reasonably well-skilled at fair and equitable leadership, damage control, and sound business practices. I lead an aborted effort to establish a viable Center for Microbes in Managed Ecosystems to focus on research on microorganisms in agriculture and natural resources. I was asked to be the director for the Center for Biotechnology at UNL, from 1988–1989 and 1997–2000. I have been the only woman to direct the Center. A major program I started was on comparative infectious diseases or comparative pathobiology. Later, I was asked to accept another position for which I had not aspired: the first woman Chief Scientist of USDA's National Research Initiative Competitive Grants Program, from 2000–2002. While in this role, I initiated a program on microbial sequencing between USDA and the National Science Foundation. I was also appointed chair of an Interagency Working Group (IWG), called the Microbe Project, to coordinate the sequencing, functional genomics, and bioinformatics investigations of microorganisms among 12 agencies. The IWG compiled a list of microbes of 'sensitive interest' for the agencies to use in priority setting and cooperative ventures. Due to my persistence, the list includes viruses, but nematodes were omitted because of cost constraints. I also was involved in initiating the National Plant Diagnostic Network, supported by USDA, which has five regional centers. The Network will serve to identify natural and potentially bioterror-caused outbreaks using data systems that ideally will be interoperative with those involving animal pathogens.

UNANTICIPATED DISCOVERIES: ADVANCES IN PHYTOBACTERIOLOGY

Every scientist expects to make new discoveries. Some are more interesting than others, and I present some of my favorites. The discovery of previously unknown pathogens is always of interest to plant pathologists, yet I was surprised to find new pathogens, especially of established crops, in the twentieth century in Nebraska. I helped characterize a purple pigment-producing bean wilt bacterium, now known as *Curtobacterium flaccumfaciens* (7). This variant wilt bacterium is rarely seen, and even in its usual yellow form is uncommon: I have seen only two mild outbreaks in Nebraska, occurring over 30 years apart. I was also involved in the discovery of another gram-positive bacterium, a highly virulent maize pathogen, now *Clavibacter michiganesis* subsp. *nebraskensis* (16). The bacterium causes Goss' bacterial wilt and blight of corn (maize), which is now rarely seen in field corn, thanks to the success of plant breeders. However, this disease remains a challenge for producers of popcorn and sweet corn. A relative of this bacterium, *Cl.m.* subsp. *tessellarius*, was subsequently discovered on wheat. A mosaic appearance resembling viral yellowing was observed on plants displaying multiple symptoms. Although the disease never became severe in Nebraska, it showed up in breeding material in Alaska. After about three years, long enough for a student to obtain a degree researching this problem (1), the disease disappeared. Perhaps the most unusual pathogen I discovered was *Xanthomonas campestris* pv. *asclepiadis*, which causes a blight of milkweed, *Asclepias syriaca* (2), the subject of another student's thesis. Milkweed is a highly versatile plant. It was collected in the wild for multiple purposes in World War II and subsequently evaluated for oil fraction substitutes in the petroleum crisis of 1973. A state entrepreneur wanted to grow it as an agronomic crop for its floss, which was to be used as an alternative to goose down bedding. However, when milkweed was farmed as a row crop, it became infected with both a fungal and bacterial pathogen. Regrettably, milkweed's commercial potential has not been realized. Another student project was among the first to recognize the genomic and biological complexity of plant pathogenic and clinical strains in the taxon *Burkholderia* (*Pseudomonas*) *cepacia* (3).

Besides pathogens, colleagues and I also found beneficial bacteria associated with plants. A biotype of *Bradyrhizobium japonicum*, indigenous to alkaline soils and competitive with commercial inoculants, was originally discovered in determining the cause of chlorosis in soybeans. The biotype ultimately was found to be highly efficacious in nitrogen fixation, despite slower growth than other strains of *B. japonicum* (4). Efforts to interest industry in commercializing these strains were unsuccessful owing to the limited potential market and the slow growth rate of the bacterium. Finding *Microbacterium testaceum* as a maize endophyte was interesting for its potential in biocontrol (17). However, its inability to colonize seed limits its commercial use.

As part of my early research, many bacterial viruses were obtained and characterized, none more interesting than the then-novel dsRNA bacteriophage, $\phi6$ (15). The initial paper was rejected at first because the reviewers didn't believe the results. No one had yet found a dsRNA bacterial virus, whereas dsDNA, ssDNA, and ssRNA phages had been discovered quite readily. The paper is now part of scientific obliteration and is not cited. Not only does the phage have a chloroform-sensitive lipid membrane, but it also contains three dsRNA segments. Among $\phi6$'s potentially useful properties is the ability to induce interferon in mammals (at least in mice), a then-emerging area of pharmaceutical interest for viral infection prophylaxis. Other dsRNA phages have subsequently been found. Another phage, for *Erwinia amylovora*, the fireblight bacterium, was investigated for its role in the production of an unusual enzyme, a polysaccharide depolymerase (12). We anticipated that the polymerase would have commercial potential; however, this was not realized.

Other areas of interest were bacteriocins and plasmids. Bacteriocins were explored for potential as specific control agents. The complexity of interactions between and among the bacteriocins and the challenge of commercialization led to the reluctant abandonment of their study. Also, plasmid presence among several bacterial taxa and their properties were examined, including host transfer potential of pathogenic or virulence determinants. Although many plasmids were found, only one was of particular interest due to its conferring multiple metal resistance to *Curtobacterium flaccumfaciens* pv. *oortii* (5), a tulip pathogen.

GETTING INVOLVED: PUBLIC POLICY

Participation in significant national decision making was always of interest to me. It is fair to say, however, that I drifted into some areas, rather than being compelled by passion. With the indulgence of my administration and faculty, I was able to spend considerable time on other interests, as illustrated below. I had been a member or chair of several committees and secretary of the American Phytopathological Society (APS) before being nominated to be president. The presidency was particularly trying because my husband died of pancreatic cancer as I entered into that role. I considered resigning, but Arthur Kelman encouraged me to continue and provided me with substantial practical and emotional support. During my APS presidency, I spearheaded changing the nomination process for officers from an insider role to a member-driven process. I also addressed the issue of the role of women in APS, particularly in my presidential address. Helen Hart served as the first woman president of APS in 1956; thus, it was 30 years later (1986–1987) that I became the second woman—although the first married woman president. It has been gratifying to have several women tell me that I was an important role model for them, and several men, whose wives or daughters had also encountered discrimination, were pleased that I dealt with this sensitive issue. Several women have since followed me as APS presidents and all were wonderful. Along with the presidency of APS came the duty to chair the now defunct Intersociety Consortium for Plant Protection. It's a pity that the professional societies with strong interests in pesticides and biological control were unable to continue to work together in areas of mutual interest.

When Sue Tolin became President of APS in 1995, she asked me to organize and set up the Office of Public Affairs and Education and be its first director. This office provides internal communications and education services for members and the public, and the APS Public Policy Board (see below). Also, I had long been interested in creating a nationally oriented public and scientific affairs board, along the lines used by the American Society for Microbiology (ASM). With impetus from Cliff Gabriel (then at USDA, now at the Office of Science and Technology Policy), the APS Council, with President George Agrios' support, created the National Plant Pathology Board (now the Public Policy Board), which I chaired for a decade. Efforts to obtain a Washington presence, which I considered essential for plant pathology, finally materialized a couple of years ago. The issues the Public Policy Board considers include dealing with federal policies and regulatory affairs, and garnering support for plant pathology and related fields. Long before September 2001, I felt APS needed to make clear to the world our position that working with plant pathogens was a grave responsibility and that our ethical standards would prohibit work with pathogens as biological weapons. There is now such a position statement. With my involvement as a member, and then chair, of the ASM's Committee on Food and Agriculture, some issues were complementary to or supportive of those addressed by APS.

In the interests of promoting harmony among those advocating alternative agriculture and conventional or input-intensive agriculture, I agreed to be a member of the Board of Directors for the now defunct H.A. Wallace Institute for Alternative Agriculture (now part of the Winrock foundation). I tried, largely unsuccessfully, to promote judicious use of biotechnology, but was nevertheless surprised to be elected President of the Board (1995–1997).

I am the only plant pathologist on the Scientific Advisory Board of The Alliance for the Prudent Use of Antibiotics, a group largely devoted to issues dealing with antibiotic resistance of bacteria of medical significance. In addition, I am currently the only plant microbiologist to have chaired the U.S. National Committee for the International Union of Microbiological Societies, an organization which could benefit from greater involvement of plant pathologists.

The use of plant pathogens, their products, or select genes for use in plant protection are viewed as part of the repertoire of plant pathologists as weapons against the onslaught of deleterious microorganisms. Biotechnology is still a contentious issue when applied to the use of microbial or plant products in the environment. In 1983, Sue Tolin, then on assignment with the USDA, was USDA's representative to the National Institutes of Health Recombinant DNA Advisory Committee (RAC), and party to the first decisions to release genetically modified organisms into the environment. Tolin invited me to a RAC meeting, as a credentialed bacteriologist and outside consultant, to address the risks and benefits of a proposed experiment to use ice-minus *Pseudomonas syringae*, a deletion mutant, for competitive exclusion of saprophytic ice-plus *P. syringae* in field tests on potatoes. The proposal was being reconsidered after having been originally approved on a close vote by RAC, but denied by the Director of NIH, who had asked for a revision and reexamination by experts. My testimony contributed to a unanimous recommendation by RAC to approve the experiment. The frank discussions involving the outspoken Nina Federoff and Tolin helped in obtaining consensus. The experiment itself, however, was delayed because of a lawsuit brought by Jeremy Rifkin challenging the authority of NIH in this matter. While Rifkin was very skilled with the news media, and brought his own entourage to protest, the scientists looked at the data and facts, weighed the benefits versus risks, and voted to approve the experiment. The experiment ultimately ended up as the first planned environmental release of a bioengineered microorganism under the jurisdiction of the Environmental Protection Agency (EPA). It was successful experimentally, but was not considered cost-effective in frost protection under on-farm conditions. After my testimony, I was asked to become a bona-fide member of the RAC. As members of RAC working groups, Tolin and I were instrumental in writing and obtaining full RAC approval for Appendix P, "Physical and Biological Containment for Recombinant DNA Research Involving Plants," in the NIH Guidelines for Research Involving Recombinant DNA Molecules (NIH Guidelines). We also developed "points to consider" for the planned release of modified organisms into the environment and documented many of our experiences in the 1989 *Annual Review of Phytopathology* (9). These very sensible, cost-effective, science-based guidelines are now being superceded in the United States by a security policy that imposes requirements for unnecessary costly physical containment systems. The RAC now deals principally with gene therapy issues. Plants and associated microorganisms are now considered the purview of regulatory agencies.

Recognizing the need for outside advice, the USDA did establish a comparable committee to the RAC, the USDA Agricultural Biotechnology Research Advisory Committee (ABRAC), on which both Tolin and I served. Its focus was on identifying safety concerns related to biotechnology applications in agriculture, whereas the RAC continued its focus on laboratory-contained research. However, ABRAC did not receive governmental support for very long. For example, a major report on conducting field experiments with recombinant organisms and plants (11) was never published in the Federal Register. The risks and benefits of field tests of genetically modified organisms were presented, including simulated case studies. The concepts from the report, however, provided a basis for decision-making by regulatory agencies in the United States and abroad. Tolin and I continue to collaborate on biotechnology assessments applicable to agriculture (10).

Field testing of genetically modified organisms is contentious enough that the U.S. National Academy of Sciences examined the issue. I was pleased to be part of a committee convened to address this subject. The resulting report (6) found that such tests could be done safely, provided certain conditions were met. The United States used the report and other findings to promulgate points to consider, and in rule-making by federal agencies for the legal framework to allow the commercialization of a number of crops.

A PROPHETIC ROLE

Part of my charge for this chapter was to forecast the future of plant pathology and related sciences, which I do with trepidation. Some of the following challenges and prospects may fail to materialize, but it is essential to consider the future. Briefly, the current and projected scientific possibilities and capabilities will enable the generation of an overwhelming amount of information on pathogens, microbial interactions with plants, and major plants themselves. Being able to use that information in applied form will be a challenge. Plant pathology must continue to show its relevance to the world of today and tomorrow in agriculture, forestry, and urban settings. The challenge also applies to assisting in science-based decision making in plant phytosanitary regulations, biosecurity, and coping with the loss in plant genomic diversity of some crops grown on large acreages. I present here an adaptation on Challenges and Prospects in Plant Microbiology (13), along with some additional observations. These predictions and observations are not prioritized.

CHALLENGES AND PROSPECTS IN PLANT PATHOLOGY: PROJECTIONS TO 2025

- The role of endophytes will be better understood and some of them will be used to obtain healthier plants.
- Disease resistance in plants will be accelerated due to knowledge of both pathogens and plants, with genetic engineering playing a major role.
- New and reemerging disease problems will continue to be with us, including in transgenic plants. Novel pathogens may be selected in these cases. Climate changes will play a role in disease problem emergence.
- Insect vector management will be better understood and managed to decrease transmission of plant microbial disease agents, particularly viruses and phytoplasmas.
- Diagnostic capability for plant pathogens, via increased accuracy and speed, will approach that for human pathogens.
- The use of handheld devices/sensors for field detection and identification of pathogens will be common.
- Telemedicine for the detection of plant pathogens and virtual reenactment of disease progression will become routine.
- Some currently noncultivable pathogens will be cultured, enabling quicker progress in disease management.
- Phyllosphere and rhizosphere microbial biota will be better known and manipulated for plant health.
- Although fewer synthetic chemicals will be available for preventative or curative disease problems in plants, additional fungicides are likely to be developed.
- Acquired resistance—or systemic acquired resistance—inducers will become economically attractive for investment and use for some crops, especially as more becomes known about innate resistance or immunity of plants.
- Disruption of signal transduction pathways for preventing initial infection and spread of pathogens may be exploited with new chemistry.
- Unique products, such as polysaccharides and enzymes, will be obtained from knowledge of the chemistry of plant-associated microorganisms.

- Some rare and endangered plant species will be saved with beneficial microorganisms or by management of deleterious microorganisms.
- Underinvestment in plant agriculture will be a deterrent to new and established investigators, even as plant and microbial genomic–enabled science opportunities soar.
- Human resource development in plant pathology and related sciences will be difficult owing to the consolidation of industrial groups and funding concerns of traditional supporters, including states, commodity groups, international bodies, and the federal government.
- Microbial germplasm collections will be lost because of retirements and lack of support or mechanisms to retain such collections. The lack of professional curators will jeopardize, trivialize, or make evolutionary and epidemiological analyses difficult or impossible. No international body has agreed to tackle these issues that are of worldwide concern.
- Silent changes in emphasis in plant agriculture at U.S. universities will decrease the perceived need for plant pathologists. Hiring and retention practices are being based on obtaining extramural funding with full indirect cost recovery. These practices are not necessarily based on strategic needs for a safe and sustainable food and fiber supply in a state or region, and should be challenged or reexamined.
- Plant pathology specialists abound, but generalists are disappearing rapidly. Both are needed to ensure a healthy future for the field, as are academics who can balance teaching and research (14).
- New rules and regulations on working with microorganisms of high consequence will slow research and public sector education and service. Centralized and secret work on pathogens inhibits the peer review process and sets a dangerous precedent for a democracy.

PASSING THE BATON

The fields of plant pathology and related sciences are filled with enthusiastic, bright, and caring people. Professional societies, in my opinion, will need to carry the banner for support of the profession. We cannot rely solely on higher administrators to advocate for plant pathology funding, legislation, and policy issues.

As the world prepares for changes in international trade, climate, and new technologies, investments in human capital and infrastructure are needed to decrease the effects of plant diseases. Plant pathologists must also recognize that they all have a common goal to understand plant-microbial interactions, and to support other groups who work in these research and applied areas.

Those who study plants and their associated microorganisms will be intellectually rewarded in the years ahead as genomes become known, and complex ecosystems are better understood and managed. And women in academe, industry, and government will more closely represent the numbers of plant pathologists being credentialed with the appropriate degrees.

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