Plant Pathology in General Education

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Only 35 years ago, 18% of Americans participated directly in farm production; today, only 2% of the population produces our food. Yet food production remains critical to our survival, and agricultural activities affect us all. Urban citizens are bombarded by media reports of farm surpluses, groundwater contamination by pesticides, and the specter of uncontrolled release of genetically engineered microbes. Is it any wonder that we are now faced with a populace that, in its ignorance, is unresponsive or even hostile to the problems and concerns of farmers and agricultural scientists?

A recent reevaluation of the general education curriculum for all undergraduate students at the University of Massachusetts at Amherst stimulated me to consider the role of plant pathology in general education. To obtain general education designation, science courses must meet requirements that include 1) historical material about the evolution of the science and how its fundamental theories were formulated, 2) a consideration of the scientific method and how it is used to build general principles from fundamental facts and observations, and 3) relevance of the science and its impact on society.

Plant Pathology 100 is specially designed to fulfill the general education requirements, using plant pathology as a vehicle for instruction. Students study the traditional topics of introductory biology such as cell structure and physiology, genetics, ecology, microbiology, and so on, with appropriate areas from the science of plant pathology illustrating the major principles of biology. Students maintain a high level of interest when they see some "application" to topics that are commonly discussed in a more abstract way. For example, I discuss plant systematics repeatedly in the topics of breeding for resistance, crop rotation, host-parasite specificity, and genetic diversity. Rather than just memorizing the features of basic leaf anatomy, students consider the barriers and access points for pathogens attempting leaf penetration.

The second major goal of the course is to educate students about modern agricultural practices and the general principles of plant pathology. To accomplish this, I first prepared a list of topics that should be included for introductory biology and a comparable list of topics for introductory plant pathology. I then created a format that combines both lists in a reasonable sequence so that the students know enough biology to understand the plant pathology, while the plant pathology illustrates and reinforces the biology.

Perhaps students completing the course will never again look at a plant without thinking of the various organisms and environmental factors that affect it. After studying a century of evolving beliefs about the causes of plant diseases, they should understand that our body of knowledge is always changing and that our ideas are subject to challenge. They may also begin to appreciate the immense diversity of nature and the fascination it holds for those of us who spend our time trying to understand the rules that govern it.

Many agricultural colleges are facing declining enrollments as large numbers of students pursue popular programs such as business and computer science. This new course, in addition to educating a broader cross section of students, might also attract students to plant pathology and the agricultural plant sciences early in their academic careers.

Major topics of study

Plant Pathology 100 is offered for three credit hours and meets for three 50-minute lecture periods a week. The following discussion is a brief overview of the major topics studied in the course (Table 1). I use many of the famous historical stories of plant pathology to lead into a study of the biology of the particular pathogen group, with an update of current issues and problems. The classic diseases, history, and introductory biology will probably be repeated from year to year, but modern problems and disease situations can easily be chosen to take advantage of biological and/or political current events, materials available, geographic locale, or the personal interests of the instructor.

Basic principles. The first week is dedicated to making students aware of the complexity of interactions among organisms, beginning with the disease triangle. Many students attracted to the course have amateur experience with plants, so it is important to broaden their view to include the various parasites and symbionts that are part of any plant's environment. I then discuss some of the factors that change a relatively undamaging host-parasite relationship to one of

Table 1. Outline of Plant Pathology 100, a course for general education in a core curriculum[a]

Week	Topic
1	Introductory definitions and some general principles: Irish potato famine, a case history to introduce important concepts
2	Role of plant disease in world agriculture: coffee rust, South American leaf blight of rubber, Panama disease of banana
3	Plant-pathogenic bacteria: citrus canker, fire blight, crown gall, genetic engineering
4	Epidemiology, disease management, and pesticides: southern corn leaf blight epidemic, integrated pest management, reduction of pesticide use
5	Fate of pesticides in the environment, groundwater contamination, and plant-pathogenic nematodes
6	Healthy home gardens: practical information on planning, cultural practices, common diseases
7	Grain pathogens, part 1: ergot, smuts, storage fungi
8	Grain pathogens, part 2: grain rusts, other rusts
9	Tree pathogens: chestnut blight, Dutch elm disease, oak wilt, compartmentalization of decay
10	Plant-pathogenic viruses: replication, transmission, detection by serological methods, tissue culture
11	Abiotic diseases: nutrients, air pollution, acid rain
12	Parasitic higher plants and beneficial parasites: mistletoes, *Striga*, *Rhizobium*, mycorrhizae
13, 14	Plant disease in a hungry world: genetic diversity, biological control, sustainable agriculture

[a] Three 50-minute lecture periods a week for three credits; fulfills the general education requirement for a course in biological science.

disease, stressing particularly the agricultural practices that lead to epiphytotics.

Historical examples. Because people of Irish heritage are a significant component of the Massachusetts population, our first disease study is late blight and the Irish potato famine. The subject includes most of the lessons that will be repeated throughout the semester: the role of environmental factors in disease, introduction of foreign pathogens, dangers of a genetically uniform crop, dependence of a population on few food plant species, and economic and sociological aspects of food production. The science of plant pathology blossomed in the mid-1800s when scientists finally accepted the role of microorganisms as agents of disease—nearly 200 years after the invention of the microscope. Introductory students need to appreciate that science is not a list of facts to be memorized, but a fluid body of knowledge that is continually challenged by new techniques and ideas. Koch's postulates are a good introduction to the idea of the scientific method and how new theories are developed. The students are introduced to the fungi and learn the life cycle of *Phytophthora infestans*. They are expected to master the associated vocabulary: mycelium, oospores, sporangia, and zoospores. Once they have learned a general Oomycete life cycle, I can use the same brief vocabulary to discuss closely related pathogens, such as *Pythium* spp., other *Phytophthora* spp., and the downy mildews, later in the semester. The *P. infestans* story also allows us to begin to consider the problem of breeding for resistance, centers of origin, the heterogeneity of both pathogen and host populations in natural communities, and the incredible ability of many pathogens to adapt to our resistant plants.

The theme of monoculture problems and the movement of pathogens around the world continues with a discussion of some important tropical cash crops: rubber, coffee, and bananas. The books *Famine on the Wind* by Carefoot and Sprott and *The Advance of the Fungi* by E. C. Large are a good starting source of material on these subjects. Many of the famous stories of plant pathology are new to undergraduates and are only briefly mentioned, if at all, in books about these crops. A particularly good example is coffee and its rust with the movement of major production from Southeast Asia to South America. I discuss South American leaf blight of rubber and coffee rust as leaf pathogens that cause repeated infections without detailed life cycles. The disease for which students are responsible is Fusarium wilt, with special attention to Panama disease of banana. This introduces the Ascomycetes and the concept of a soilborne pathogen.

Plant-pathogenic bacteria. The cash-crop discussion ends with the story of *Pseudomonas solanacearum* and bananas to lead into a study of phytopathogenic bacteria, again stressing problems associated with vegetative propagation and genetic uniformity. Fire blight presents an interesting history as well as an opportunity to discuss the basis of the controversy over the use of antibiotics in agriculture. Citrus canker is still being covered in the popular press. Of those students who have heard of citrus canker, few know that the recent outbreak is really a reintroduction of the pathogen. Again, the dangers of genetic uniformity can be balanced against the market demands for specific varieties in a high-value crop. I emphasize the biological basis of quarantine regulations and the dangers of "botanical souvenirs." *Agrobacterium tumefaciens* is the organism studied in detail, first as a pathogen for which a commercial biological control agent is available. I find it effective to present the structure of DNA and the mechanism of the genetic code, then describe prokaryotes and eukaryotes. I discuss meiosis, haploid/diploid states, and various means of genetic recombination. This leads nicely to the use of the Ti plasmid as a vector in genetic engineering and some of the biological, legal, and political issues surrounding this activity.

Epidemiology and pesticides. An area of controversy is the use of pesticides in agriculture. Many students have very emotional opinions about this subject that have little basis in fact. The interesting story of grape downy mildew and Bordeaux mixture is followed by information to replace inaccurate, preconceived notions of pesticide use. For example, most students believe that all crops receive repeated applications of pesticides, that all pesticides are equally toxic and dangerous, and that "natural" pesticides are innately safer than "artificial" ones. They also have essentially no knowledge about the degradation of pesticides in the soil. Students learn about pesticide registration, risk assessment, applicator licensing, the fate of pesticides in the environment, disease forecasting, and attempts to reduce pesticide application through integrated pest management.

Plant-pathogenic nematodes. In western Massachusetts, people in "Tobacco Valley" are receiving reports of groundwater contaminated by Vorlex, ethylene dibromide (EDB), and aldicarb. I again discuss risk assessment, the chemicals involved, and possible solutions. Contamination by nematicides and soil fumigants introduces nematology, beginning with *Anguina* and *Meloidogyne* spp. Cyst nematodes are studied in detail because of their specific host-parasite interactions and available resistant cultivars. In addition, quarantines of soilborne pathogens, economic damage levels, and the difficulties of successful biological control by organisms introduced into soils are discussed.

Healthy home gardens. Most of the students have gardens and want some practical information. I provide this in an applied discussion in which I emphasize the principles of sanitation, rotation, and pathogen-free planting materials, describe some common diseases, and supply various sources of information and advice.

Grain crops and their pathogens. We study some important diseases of grain crops. Besides the fascinating history associated with ergot, particularly during the Middle Ages, I discuss the phenomenon of plant pathogens that directly threaten human health, with special attention to storage problems. These are contrasted with the smuts, which cause tremendous yield losses and may be disgusting but are not nearly as toxic to humans and animals.

I continue with the rusts and the biological phenomena of alternate hosts and multiple spore stages. For ancient history, the grain rusts have little competition. In addition, the observation by farmers that barberry-increased wheat stem rust led to the first plant pathology legislation on two continents, antedating de Bary's scientific explanation by 200 years. The continuing battle for genetic resistance and the vulnerability of our important grain crops bring the discussion to modern times. In the northeastern United States, cedar apple rust and white pine blister rust are of particular interest, and these introduce us to the next topic.

Tree pathogens. Major forest and shade tree species have been decimated by introduced pathogens. Many American towns have streets named Chestnut or Elm that are now lined with uniform rows of maples or oaks. I encourage future members of community park and conservation boards to speak up for genetic diversity in tree and shrub plantings. This is also an opportunity to consider the economic aspects of disease management by comparing acceptable costs of protecting individual trees in a yard to the costs of protecting forests. The students become familiar with the anatomical differences between woody and herbaceous plants and the means by which long-lived trees withstand the continual threat of pathogens.

Plant-pathogenic viruses. Beginning with tulip breaking, we examine viruses and the diseases they cause. Here is an opportunity to again observe the universality of the genetic code and to discuss the discovery of viruses, with attention to Stanley's Nobel prize-winning work with tobacco mosaic virus. Tissue culture and pathogen-free propagation have revolutionized the flower and ornamental industry and greatly reduced disease in only a few years. I also discuss immunological detection techniques, including monoclonal antibodies, a frequent topic in newspaper medical articles and an important new tool for rapid disease diagnosis in both plants and animals.

Abiotic diseases. The media in the Northeast provide many acid rain stories, which I use to begin a discussion of abiotic pathogens, air pollution, and stress in urban environments. I present the interactions of biotic and abiotic pathogens and the political and economic aspects of environmental quality standards.

Parasitic higher plants. The role of parasitic higher plants in many mythologies speaks to the detailed observations of ancient people. The phanerogamic parasite *Striga* has current significance because dormant seeds germinate to attack newly planted crops in famine-stricken parts of Africa. Also, *Striga* has invaded North and South Carolina, resulting in the first quarantine against a "weed." Beneficial parasites, such as *Rhizobium* and the mycorrhizal fungi, are also discussed.

Plant disease in a hungry world. This final, extended section of the course is built on the concepts learned in the specific topics preceding it. It is an opporunity to reconsider, in a broader context, the major topics of preserving genetic diversity, biological control, agricultural practices that increase disease, and threatening diseases of world importance. I present information about agricultural economics, loss of agricultural lands, growing populations, water supplies, and world food production. Students are given the opportunity to apply their new knowledge of plant pathology as one important piece in an exceedingly complex puzzle that requires the attention of all people.

Laboratory component and term paper

So far, all classes have been small enough to be held in a combination laboratory-classroom. This situation allows us to use demonstration microscopes and various materials during the lectures. The desire to reach more students has precluded the addition of a laboratory at this time. I try to include one campus field trip even though the course is offered in the spring term. Students desiring more intensive study are encouraged to take our introductory course, Plant Pathology 500, which, of course, includes a laboratory.

University general education requirements emphasize critical thinking by students. All students must complete a short term paper, generally on a specific disease not discussed in class. They are expected to produce a life cycle of the pathogen, decide the appropriate points at which the pathogen might be vulnerable, describe standard practices of control including economic and environmental factors, and suggest alternative practices and their limitations.

Special class materials

The University of Massachusetts Plant Pathology Department has compiled an extensive teaching slide collection that is used in nearly every lecture. In addition, many new slides have been prepared from historical materials such as Ireland during the potato famine, famous plant pathologists, old extension posters, pesticide applications in the past, tropical agriculture, and current events such as the citrus canker outbreak. I plan to continue to produce slides appropriate to this collection and welcome suggestions of other sources. A "Nature" television show, available as a videotape, contains excellent time-lapse photography of mycelium growth, spore discharge, zoospores, and some historical material. The students watch this several weeks into the semester after they are somewhat familiar with the fungi.

Reading material has presented something of a problem because most plant pathology texts are too advanced for these general education students. Many of the figures and pathogen life cycles from *Plant Pathology* by G. N. Agrios are very useful. Most of the required readings, however, are reserve library readings of reprints from diverse sources, including *BioScience, Natural History, The New Yorker, Science, Scientific American, Smithsonian*, various state-sponsored agriculture and conservation publications, and some feature articles from Plant Disease. I am happy to offer these citations to anyone interested and would welcome suggestions of other potential readings. The collection can easily be modified each year. At least one commercial photocopier copies and binds all of the readings and handouts for purchase by students at a nominal cost. As part of this service, the copy company obtains copyright permission from all sources.

What kind of students?

In the past 2 years, quite an assortment of students has been attracted to the course, including some majoring in business, human nutrition, sociology, agricultural economics, fine arts, environmental design, geology, or political science and some without declared majors. A poster campaign around the campus brought numerous inquiries to the department. The interest level was high, and the primary limiting factor was whether students could receive science credit for taking the course. General education science credit began as of spring 1987, so I expect enrollments to increase. Most undergraduates have relatively inflexible course schedules, so science credit is probably necessary to attract many students. The course is certainly not a substitute for a standard plant pathology course. In fact, I strongly discourage enrollment by plant science majors.

Some practical suggestions

I would like to offer some practical comments that might be useful to someone considering the development of a general education course in plant pathology. It is particularly important for most plant pathologists to reacquaint themselves with the level of introductory material taught in biology courses. A traditional plant pathology student has already taken a number of college-level science courses. It is a demanding learning process to study biology for the first time at the college level. This is especially true for liberal arts students who often enter the class feeling a bit intimidated. I have also found that "nonscience" majors need some guidance in studying science. Very short Friday quizzes seem to help students keep up and understand the important ideas without involving enough points to be academically threatening.

I have tried to minimize the vocabulary associated with plant pathology because the students are trying to master a considerable biology vocabulary as well. New words are introduced when they make learning more efficient and clear and are used repeatedly during the semester. Some of the most effective readings are those written on plant pathology subjects for other scientists, because the specialized vocabulary is minimized but the science is accurately presented.

It is often necessary to discuss certain topics in detail in order to fully explain a phenomenon. For example, heteroecious rusts present an important and fascinating biological situation that is best understood by discussing each step and the relevant nuclear state of the fungus. Students in Plant Pathology 500 are expected to learn the entire life cycle and associated vocabulary. In Plant Pathology 100, I explain the life cycle, but the students are responsible only for the concept of the "repeating stage" and its potential role in disease management. I try to present complex situations as a taste of the fascinating detail of plant-parasite interactions rather than the predominant task of the course.

An instructor in general education plant pathology should prepare a list of goals to be accomplished in the study of both biology and plant pathology and then create an outline that accomplishes these goals in a reasonable fashion within the limits of a one-semester course. I think it is very effective for the instructor to choose some topics that are of personal interest, so students see the individual excitement that leads one into scientific study. Topics that have application or analogy in medicine, such as monoclonal antibodies and genetic engineering, are always effective vehicles to maintain interest in diverse audiences. I bring clippings from newspapers and magazines to class to show students the connections between their studies and current events. I have yet to find a subject that was not interesting to the students, as long as I took the time to give them the background information necessary to understand it. In such diverse groups, students always vary in their favorite topics, but they should leave with some sense of the significance of all areas. For many students, this course is their only formal education in biology and agriculture. This responsibility demands serious consideration and commitment.

Appropriateness in general education

At the University of Massachusetts, all undergraduate students must take three approved science courses consisting of at least one biological science, one physical science, and one laboratory course. Many students take a general biology laboratory course, in some instances before taking Plant Pathology 100. However, Plant Pathology 100 can be considered an introductory biology course in which examples are chosen from plant pathology rather than from the entire biological world. The General Education Council of the University of Massachusetts believes that a student who completes Plant Pathology 100 has fulfilled the goals of the general education curriculum. I have been pleased so far with the ability of students to apply their new knowledge to examination problems, and student satisfaction is evident in their evaluations of the course.

Future prospects

Is there a plant pathologist who has not had to define plant pathology at nearly every social occasion? We remain essentially unknown to otherwise highly educated people, even those in other colleges of our own universities. University committees debate endlessly about the core curriculum of a college education but rarely is some knowledge of agriculture deemed necessary. Because our activities impinge on people's lives every day, I view Plant Pathology 100 as a vehicle to enlighten a broader cross section of students. We need to reach future lawyers and liberal arts majors who will be writing the legislation and deliberating over court cases that govern our science. Plant Pathology 100 is a continually evolving course built on the amazing century of history of our science, the consideration of our modern practices and how they are influenced by social and economic factors, and the role of plant disease in the future quality of life on earth. This is our chance to alter the stereotype of the socially irresponsible scientist and present ourselves as concerned citizens who struggle with the age-old problem of food production and its reduction by plant diseases. I have found this course exciting and satisfying to teach and welcome communication with others who have similar experiences or plans.

Salute to APS Sustaining Associates

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O. M. Scott & Sons, D. G. Scott Research Center, Marysville, OH 43041. The O. M. Scott & Sons Co., with its title, "First in Lawns," has been the recognized leader of the lawn products industry since 1870. Fertilizers, grass seed, and control products are sold to homeowners and professional users such as golf courses, parks, industrial lawn, and commercial growers. The most recent and rapidly growing category of Scott's specialty retail products are for flowers, shrubs, trees, and vegetable gardens. Scotts is an expanding company with Scotts' products currently being sold in Europe (both for home lawns and professional users).

Uniroyal, Contact: Judy A. Blasco, Technical Manager, Fungicides, 74 Amity Rd., Bethany, CT 06525. Uniroyal established an agricultural chemical company over 45 years ago as a developer and supplier of fungicides, herbicides, miticides, and plant growth regulants. Emphasis was directed toward providing unique products in each of these areas. With the introduction of systemic fungicides for cereal/cotton disease control, the company began a solid committment to seed treatment technology worldwide. Gustafson, Inc., an associate, has strengthened its efforts in this technology. Uniroyal also markets several soil fungicides for row crops, turf, and ornamentals. Its current spectrum of fungicide products consists of carboxin (Vitavax), etridiazole (Terrazole), oxycarboxin (Plantvax), PCNB (Terraclor), and Thiram. Current efforts are directed at foliar fungicides for fruit and field crops, including both systemic and nonsystemic active ingredients. The company has active programs with various universities, USDA pathologists, and extension people in the United States to evaluate these candidates in disease management programs

USDA Forest Service, Forest Pest Management, 324 25th St., Ogden, UT 84401; 801/625-5459. The USDA Forest Service, Forest Pest Management, is a part of state and private forestry. It is a link between forest pest research and forest managers.

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