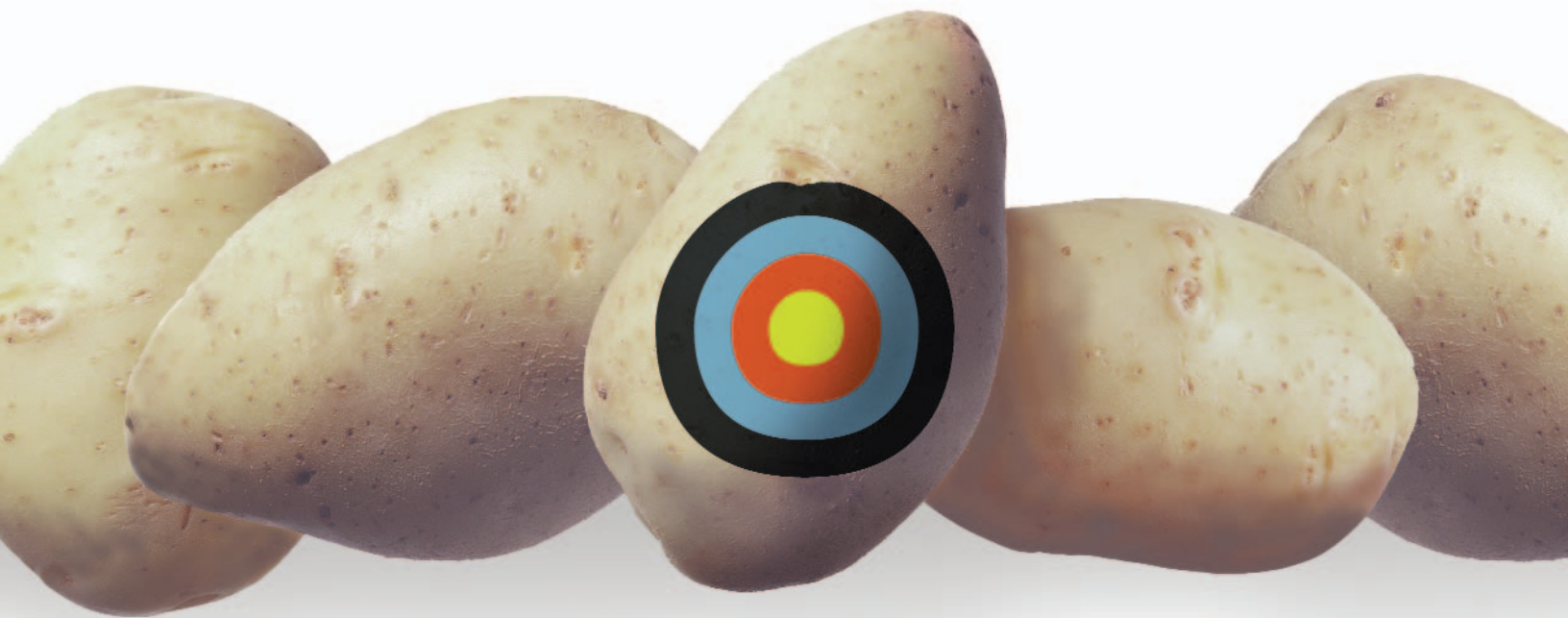


The Next Target of Bioterrorism:



The possibility of war increases in direct proportion to the effectiveness of the instruments of war.

Norman Cousins

Peter's Quotations: Ideas for Our Time, 1977

When someone cultivates pathogenic bacteria, fungi, viruses, or certain chemical compounds specifically to kill people or transmit disease, that's biological warfare. A lesser-known form of biological warfare targets major food crops instead of people, and carries the potential to wreak environmental health havoc. After health care, agriculture has been the largest market to benefit from genomic research and biotechnology. But while the ability to diagnose plant diseases and develop targeted treatments has improved agricultural products and yields, the same technologies can be used to build better biological warfare bugs, turning bac-

teria, viruses, and toxins into potential weapons of mass destruction.

In poor countries where millions depend on staple crops such as rice, an act of anticrop bioterrorism that destroys the harvest would create famine. According to authors Paul Rogers, Simon Whitby, and Malcolm Dando in their article "Biological Warfare against Crops," published in the June 1999 issue of *Scientific American*, such an attack "would be at least as costly in human terms as an anthrax attack on a city." The resulting malnutrition and starvation would take the greatest toll among the poorest populations, and would generally reduce immune resistance to a range of common illnesses. Even in more developed North American or western European countries, anticrop bioterrorism would take a toll, the authors say; the tendency of such nations to grow one or two major food crops would give disease-agent organisms a much bigger

bang for their pathogenic buck. And an enemy could release organisms when weather or a crop's own growth stage guarantees at least a regional epidemic. Even a reasonably developed country that managed to halt an outbreak short of total devastation could suffer massive economic losses.

Despite the futuristic sound of the word, bioterrorism is nothing new. People and pathogens have evolved together over centuries against a backdrop of agriculture. Soldiers have used disease as a weapon at least since the days of the Roman Empire, when enemies routinely threw dead animals into each other's water supplies to poison them. Another thing hasn't changed: people are as vulnerable to new and reemerging pathogens as they've always been. But the release—malicious or otherwise—of hazardous infectious agents is still only a theoretical threat to national and global security because, at least as far as anyone knows,

Your Food



such bioterrorism hasn't happened yet. Some think it won't ever happen, but others believe it easily could, and that's gotten the attention of those who would be in the front lines—mainly crop growers, plant scientists, and soldiers.

The Weapons No One Wants to Use

In his 1993 book *How to Make War*, James F. Dunnigan writes that, in terms of inflicting new plant diseases on enemy cropland or decimating herds of domestic animals with species-specific microbes, “no one seems too eager to unleash biological warfare. There appear to be too many risks with this potentially uncontrollable form of combat.”

In fact, while anticrop bioterrorism isn't much more than a theory, its potential is real enough. For example, according to Rogers, Whitby, and Dando, Iraq had an active bioweapons program before the Gulf War, part of which dealt with wheat smut.

The likely target of this anticrop effort was Iran, where wheat is the most important cereal crop. However, these operations were effectively shut down by the United Nations during the war.

With everything from natural plant disease outbreaks and crop management problems to extreme weather and pest infestations to worry about, how seriously do growers and plant scientists take the potential threat of anticrop bioterrorism? No one's laughing down at the American Farm Bureau Federation, which calls itself the “voice of agriculture.” Stewart Truelsen, director of broadcast services for the federation, describes a fictitious scene in the online article “America's Achilles' Heel: Food Supply” in which “Slobodan Milosevic pounded his fist on his desk and looked up at the generals standing before him. ‘If only we could find a way to retaliate against the U.S. civilian population for what their military is doing to us,’

he said. A scientist standing behind the generals edged his way forward and said, ‘Maybe I can help. I am a plant pathologist.’”

Writes Truelsen, “This scene never took place that we know of, but it's hardly farfetched. . . . Think about it for a minute. A major disruption of our food supply would be more devastating than an oil embargo and it would be totally unexpected and unprecedented. Americans are so used to finding supermarket shelves stocked with food they wouldn't know what to do if our corn, wheat, and soybean crops were destroyed. These commodities are used in so many food products, and to feed livestock, that there wouldn't be much to eat without them.”

Most people know something about the danger to people of biological weapons; fewer realize the potential dire effects of using pathogens to cause a food-crop epidemic or contaminate the food supply.

According to Norman Schaad, a phytobacteriologist in the Foreign Disease-Weed Science Research Unit within the U.S. Department of Agriculture's Agricultural Research Service, the U.S. agriculture infrastructure is susceptible to disease outbreaks resulting from bioterrorism. Says Schaad, "As members of the plant science community, we are aware of the risk and feel it's important to interact with other scientists and agencies in a cooperative effort to review the issues." A symposium titled "Plant Pathology's Role in Anti-Crop Bioterrorism and Food Security," held in August 1999 during the joint American Phytopathological Society (APS) and Canadian Phytopathological Society (CPS) annual meeting in Montreal, Canada, brought together plant pathologists, military intelligence officers, and criminal experts to discuss anticrop bioterrorism with speakers from federal agencies, universities, and the private sector. "It was," Schaad says, "the first international symposium held to raise the awareness of experts in the agricultural scientific community," and the first meeting to urge plant pathologists to help develop science-based defense measures against anticrop bioterrorism.

Experts who spoke at the meeting suggested that being prepared for an anticrop attack would present a strong deterrent. Possible strategies for preparing for such an attack include developing a global electronic system to track new and emerging plant pathogens and rapid diagnostic tests to identify anticrop attacks in their early stages. Highlights of the symposium and links to related materials are featured on the Crop Biosecurity page of the APS Web site located at <http://www.scisoc.org/>. Topics featured on the site include historical perspectives on bioterrorism, identification and "fingerprinting" of pathogens, risk assessment, ground surveillance, and protection of infrastructure.

New and Emerging Diseases

Many factors contribute to what appears to be an increase in new and emerging plant pathogens. No one knows the exact causes, but in nearly all likely scenarios—climate changes, disrupted ecosystems, new releases of genetic material, contaminated seeds, increased international air travel and trade, pesticide-induced chemical resistance, and increased use of transgenic crops—people play a role.

Pathogens can be classified into five categories, according to scientists at the Department of Plant Pathology at North Carolina State University in Raleigh: new (pathogens detected in the last five years), emerging (pathogen incidence has increased in the last 20 years), reemerging (previously

controlled pathogens associated with chemical resistance or changes in management or cultivars), threatening (pathogens not reported or limited in distribution in the United States), and chronic/spreading (pathogens known longer than 20 years and causing increased concern). The APS Web site offers a list of plant pathogens believed to be suitable for use as weapons. Among these are viruses (such as banana bunchy top virus and Fiji disease virus, which attacks sugarcane), fungi (such as *Tilletia indica*, which causes the wheat disease Karnal bunt), and bacteria (such as *Liberobacter* spp. and *Xanthomonas campestris*, both of which attack citrus fruits).

Most key crops on the planet are susceptible to 10 diseases that have potential as weapons, according to a working paper by the United Nations. Three of the most damaging diseases, say the *Scientific American* authors, are wheat rust, sugarcane smut, and rice blast. Other crops at risk include corn, potatoes, many kinds of beans, fruits, coffee, and pine trees (economically important for lumber). Periodic cereal rust and smut epidemics around the world ruin crops worth hundreds of millions of dollars.

Prevention through Monitoring

Until recently, says David Huxsoll, dean of the School of Veterinary Medicine at Louisiana State University in Baton Rouge and a member of the American Society of Microbiology's Task Force on Biological Weapons Defense, "the United States has been complacent about the threat of bioterrorism." In his APS/CPS symposium presentation, "Biological Terrorism: Identifying and Protecting Our Infrastructure" (available on the APS site), Huxsoll says that it's "quite likely that terrorists will use weapons of mass destruction against the United States," directed at targets that include tourism, transportation, livestock, and crops. Even small outbreaks of exotic disease in livestock or crops, he says, could reduce production of essential foods, incapacitate the agricultural base, and, through export embargoes, remove U.S. agricultural products from the world market.

To reduce the possibility of deliberate introductions of crop pathogens as acts of terrorism, researchers must be able to fingerprint pathogens at the molecular level and discriminate between naturally occurring and deliberately introduced outbreaks. To make these determinations, they must be able to track new and emerging diseases, but there is currently no rapid international reporting system. To address the problem, several domestic and international surveillance, tracking, and reporting efforts are under way. For example, O. W. Barnett, head of the Department of Plant Pathology at North

Carolina State University, is leading an effort to prepare and update a list of new and emerging plant pathogens to be posted on the Internet at <http://www.ces.ncsu.edu/depts/ent/clinic/Emerging/vdis.htm>. Similarly, the European and Mediterranean Plant Protection Organization, an intergovernmental organization responsible for international cooperation in plant protection in Europe and the Mediterranean region, maintains a plant pathogen alert list, available on the organization's Web site at <http://www.eppo.org/index.html>, as part of its strategy against the introduction and spread of crop and forest pests.

In June 1999, the NATO workshop "BTWC [Biological and Toxin Weapons Convention] Security Implications of Human, Animal, and Plant Epidemiology" was held at the Cantacuzino Institute in Bucharest, Romania. Attendees discussed the need for epidemiology and disease reporting and ways to investigate and analyze outbreaks. A report of this meeting, as well as related reports on efforts to strengthen the BTWC worldwide are available at the Web site of the Department of Peace Studies of the University of Bradford, United Kingdom, located at <http://www.brad.ac.uk/acad/sbtwc/>.

On 20 May 1999, Dorothy Preslar, Washington Project Officer of the Federation of American Scientists (FAS), testified before the House Commerce Subcommittee on Oversight and Investigations on the adequacy of federal laws to address dangerous biological agents, including those that may be used by terrorists to attack the food production resources of the United States. The FAS, Preslar said, supports efforts to raise the level of accountability of labs in ensuring that deadly pathogens and toxins are secure from loss or theft and thus do not escape into the environment. National security and public health will be served if such agents remain in secure environments at all times and if facilities that handle them are held strictly responsible for their safe storage, proper handling, restricted access, and closely monitored transfer. Another measure suggested by the FAS includes developing and implementing detection technologies for proactive intervention against bioterrorist attacks.

Two types of strategies—preventive and responsive—can minimize the potential threat to the planet's food supplies, says Jan E. Leach, a distinguished professor of plant pathology at Kansas State University in Manhattan, in her APS/CPS symposium presentation, "Assuring Food Security: Detecting and Controlling Modified Pathogens" (available on the APS site). A preventive strategy, Leach explains, involves

understanding the structure, function, and evolution of genes involved in pathogenesis and virulence, and can highlight possible sites of genetic manipulation. A responsive strategy—identifying pathogens early, quickly, and accurately—is key to controlling disease, she says.

Fighting Back with Research

Laboratory analysis can be cumbersome and tedious, requiring expensive equipment, special labs, and highly trained staff, and taking days or weeks to produce results. It will also be the single most critical tool needed in the event of an intentional release of anticrop pathogens. Procedures commonly used to investigate a suspected plant intoxication are described in a 1996 report by the FAS Working Group on Biological Weapons Verification titled *Report of the Subgroup on Investigation of Alleged Use or Release of Biological or Toxin Weapons Agents*. Scientists and possibly soldiers would have to collect samples of the suspected pathogen, develop and screen chemical assays, identify and validate molecules, collect toxicology data, and integrate chemical, biological, and genomic data, to name just a few parts of the likely process. In the event of an anticrop attack, no one would want to wait days or weeks for results.

Over the last decade, the pharmaceutical and biotechnology industries have led the push to automate, and thereby speed up, as many lab processes as possible. Laboratory automation entails a collection of computer-based and robotic devices and systems that help researchers work together on complex projects, speed up testing times, and improve the quality of lab products and services. In September 1999, Hewlett-Packard became the first producer of a complete commercial analytical laboratory on a computer chip—an analytical lab the size of a credit card

that's cheap, fast, and mobile. Any country that becomes a target of anticrop terrorists will need all this technology and more to avoid economic and medical disaster.

Tony Beugelsdijk, a laboratory automation and robotics expert at Los Alamos National Laboratory in New Mexico, says, "Research efforts at Los Alamos and at the National Institute of Standards and Technology have made the needed level of standardization increasingly available from instrument manufacturers." He continues, "For the first time it's possible to envision a library of chemical and biological assay functionality represented physically in hardware devices and software routines that perform tasks like extraction, thermal cycling, incubation, separation, detection, data reduction, statistical pattern recognition, and more. These could be quickly assembled into integrated systems that perform a particular assay—say, to characterize a potential biothreat agent." Beugelsdijk helped organize a two-day conference on automation in threat reduction and infectious disease research that was held in April 1999 at the National Academy of Sciences in Washington, DC.

However, characterizing the threat is only part of the solution. With the ever-increasing understanding of genetics and molecular biology, researchers on both sides of the cornfield can use transgenics to build better pathogens. This same technology could also make it possible to survive the really big biology experiment that true anticrop bioterrorism could launch. And that's what they're working toward in the Defense Science Office of the Defense Advanced Research Project Agency (DARPA), a division of the Department of Defense. The focus of DARPA's Unconventional Pathogen Countermeasures Program is to develop revolutionary broad-spectrum countermeasures versatile enough to eliminate either natural or

modified biological threats. Program strategies include defeating pathogens' ability to enter the body, identifying novel pathogen vulnerabilities based on critical molecular survival mechanisms or pathogenesis, building unique, robust vehicles to deliver countermeasures, and modulating the immune response to pathogenic microorganisms.

Examples of such new technologies include pathogen genomic sequencing, which will be used to identify molecular components of pathogens that researchers can then use to develop novel detection, diagnostic, and therapeutic strategies, and advanced consequence management strategies for bioterrorist attacks including fast and appropriate operational and medical response. DARPA's Enhanced Consequence Management Planning and Support System will coordinate the responses of civilian first responders and federal agencies and allow them to react 10 times faster. The system uses commercial hardware and software and ordinary communications technology to distribute consequence management plans, mission data, situational awareness, and patient tracking to all responding organizations during biological incidents, fires, floods, and other disasters.

Skeptics may continue to view efforts to address potential bioterrorist attacks as much ado about nothing. "For all the work that seems to have been done on biological weapons in [the 20th] century," writes Dunnigan in *How to Make War*, "no one seems to have used them." But many scientists and governments around the world are preparing for what they view as an inevitable event. To them, it's not a question of whether an anticrop bioterrorist attack will occur—it's only a question of when.

Cheryl Pellerin