Yellow Rain: Filling in the Gaps

The U.S. case on mycotoxin weapons is persuasive now, although experts still see flaws in the evidence

For many, the laboratory results released by the State Department on 13 May were the long-awaited "conclusive evidence" that what Secretary of State Alexander Haig had said 8 months earlier was true: that Communist forces in Southeast Asia are using outlawed toxic weapons to terrorize tribal villagers. Blood and urine samples taken from victims of an artillery attack in Kampuchea were found to contain the organic toxin T2 and its metabolite HT2. This is the fungal poison that Haig named last fall when he accused the Soviets of violating the rules of modern warfare. Chemical and biological weapons are banned by the 1925 Geneva Protocol and the 1972 Convention on Biological Weapons. Haig said that the Soviets were supplying and perhaps dispensing T2 toxin—along with other poisons—for use in "Yellow Rain" attacks on remote areas in Kampuchea, Laos, and possibly Afghanistan.

With this news, the government seems to have won over American popular opinion, but it still meets skepticism from scientists demanding a more rigorous standard of proof. Specialists in T2 toxin told *Science* that they were perplexed by several aspects of the news release, particularly by the report of T2 in victims' blood weeks after an attack. The phenomenon has never been observed in test animals.

Government officials respond by saying that, given our ignorance about toxin weapons and the difficulty of collecting data in Southeast Asia, we are lucky to have any proof that T2 is present. They believe that it is quibbling to focus on technical inconsistencies in the data when so much else remains unchallenged. This may be a form of special pleading, but it is a fault more than matched by the defects in the official Soviet statement on Yellow Rain (see box, p. 32).

Haig's original indictment of the Soviets, released last fall in Bonn, was widely perceived as flawed (*Science*, 2 October 1981, p. 34). The State Department has labored since then to shore up its case. Some of the gaps have been filled with new information, some with conjecture.

Frederick Celec, the Air Force officer at the State Department who heads the effort to collect data on Yellow Rain, argues that the skeptics from the beginning have taken too narrow a view. He was clearly abashed by the reluctance of American scientists to rally behind the government's cause. The mistake, he claims, has been to focus too closely on individual pieces of the puzzle and thereby to miss the general pattern. In his view, the testimony of thousands of victims, the corresponding reports from Communist defectors, and the handful of chemical samples make the case complete.

The importance of the chemical evidence, and its ambiguity, should not be underestimated, however. For if the weapons contain "riot control agents" or herbicides, the United States does not have as strong a position. United States troops used such materials in Vietnam, although the herbicides were not targeted for use on people. But if the aerosol truly contains T2, and if the Soviets have supplied it, the outcome could be devastating. In proving that the Soviets violated international treaties, the evidence could undermine the minimal degree of trust needed for future arms control agreements with the Soviets.

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Sharon Watson, a U.S. Army toxicologist and the government's chief technical expert on Yellow Rain, argues as Celec does that it is a mistake to judge the evidence from Southeast Asia according to standards applied in American laboratories. The conditions on the battlefront are very different from those in the agricultural labs where civilians study T2, Watson says. Her view tends to negate all but military research. Nevertheless, Watson claimed in testimony before the Senate Armed Services Committee on 22 March that several disinterested experts "agree with our interpretation of the data."

The only expert who has been called upon to vouch for the government's data is Chester Mirocha, a plant pathologist at the University of Minnesota. Mirocha, regarded as the nation's most skilled analyzer of the trichothecene family of toxins, has run analytical tests on dozens of samples forwarded by the State Department. The trichothecenes are produced by a fungus that commonly grows on wheat and corn in the United States. T2 is the most easily detected of the group of trichothecenes allegedly used in Southeast Asia. Mirocha has found significant quantities of these toxins in samples of water, vegetation, rock scrapings, blood, and urine—all collected from battle areas in Kampuchea and Laos.

Mirocha has testified about his research, but other scientists are not eager to join the debate just yet. There are several reasons. Information on Mirocha's laboratory work has not yet been published. Mirocha says he plans to publicize the details at the meeting of the International Union of Pure and Applied Chemists in Geneva this September.

In interviews with a dozen specialists* in trichothecene toxins, *Science* found that most of these experts are willing to believe the State Department's case, yet at the same time they are uneasy about some of the technical claims that do not match their own experience. In general, they admire Mirocha's research, feeling, as one said, that "If Mirocha says it's true, I believe it." Nevertheless, they question the government's claims on the following points.

- How is it possible, several wondered, that T2 could be found in blood samples taken from victims so long after an alleged toxin attack? The State De-

*In addition to Mirocha and Matthew Meselson of Harvard, the scientists interviewed (identified by university or other affiliation) were J. Bamburg (Colorado State), W. Buck and S. Swanson (Illinois), A. Ciegler (U.S. Department of Agriculture), F. S. Chu (Wisconsin), C. W. Hesseltine (U.S. Department of Agriculture), F. Hoerr (Auburn), Paul Nelson (Pennsylvania), G. Osweiler (Missouri), J. Rosen (Rutgers), E. B. Smalley (Wisconsin), W. Sorenson (National Institute of Occupational Safety and Health), and R. Wyatt (Georgia).

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partment's release of 13 May described blood and urine samples collected at two intervals, 24 hours and 18 days after the attack on Tuol Chrey, Kampuchea, on 13 February. Experiments at the University of Illinois have shown that the half-life of T2 in cattle and swine is about 10 minutes when injected intravenously. Within hours, the T2 is undetectable, although the metabolite HT2 may still be present. Within a day, no traces of T2 remain. How, then, did T2 continue to circulate in the Kampucheans' blood for 18 days?

Celec agrees that the recent State Department finding is "astounding" in its novelty. Mirocha offers a variety of explanations. He says the T2 may bind in some undiscovered way to proteins in the body, only to be released over a period of days. No one has found evidence for this in animals, although there is a report that another fungal toxin (ochratoxin) binds to proteins and thus achieves a 3-day half-life in the body. Alternatively, Mirocha suggests that the Kampucheans were exposed continuously to T2, perhaps from small deposits in the hair or lungs. He adds that the combination of T2 and other poisons

The Soviet Elephant Grass Theory

On 21 May, the Soviet mission to the United Nations issued a 19-page critique, "Chemical and Bacteriological (Biological) Weapons," written by "experts from the U.S.S.R. Academy of Sciences, the U.S.S.R. Ministry of Health, and other competent Soviet organizations." It is meant to be a rebuttal of the "disinformation" given out by the U.S. Department of State. But it may prove embarrassing to its authors, at least in scientific circles, for its conjectures are extravagant. The chief of these is that the United States is responsible for introducing fungal toxins to Southeast Asia.

The Soviet paper does make an important concession at the outset: it agrees that T2 and other toxins allegedly used in weapons have been found in Southeast Asia. However, the Soviets maintain that the toxins are produced naturally by the fungus *Fusarium* which they say thrives in the environment where the alleged attacks have occurred. American agricultural experts say this simply is not true. Paul Nelson, a plant pathologist at Pennsylvania State University and one of the world's foremost catalogers of *Fusarium*, describes the Soviet explanation as "science fiction."

According to the Soviet account, the T2 toxin in Laos and Kampuchea got there in the following way. It all began, the Soviets say, when U.S. troops sprayed herbicides in Vietnam in the 1960's, killing large swaths of forest. Napalm fell on the dead wood, igniting large forest fires and scorching the soil at temperatures of 120°F. This produced "the complete destruction of soil microflora and microfauna and their nutrient medium." The sterile areas were then "artificially seeded (from the air) with elephant grass, a malignant, long-rooted, polyspermous weed which cannot be put to any practical use." The grass provided a good breeding ground for new fungi, including *Fusarium*, some varieties of which produce T2 and other toxins. Because competitor fungi had been wiped out by napalm, *Fusarium* burst into life, rapidly colonizing the new environment and releasing clouds of spores into the air. Prevailing winds from the Gulf of Siam blew the spores into Kampuchea and winds from the South China Sea swept them into Laos.

The report ends with a suggestion that much of Southeast Asia is now threatened with biological poisons because the United States has been plotting since 1955 to infect the area with *Fusarium*. It concludes: "These facts reveal the hidden truth of who was really responsible for the mycotoxicoses in Southeast Asia. The military leaders of the United States are the true guilty parties."

Nelson, who has cataloged more than 6000 isolates of *Fusarium*, 300 of them toxin-producers, has never come across any reference to a toxin-producing *Fusarium* in Vietnam, Laos, or Kampuchea.

Fusarium grows in every part of the world, Nelson says, but seems to produce strong toxins only in cold and temperate climates. There are only two species that produce T2 and the other toxins that the U.S. claims were used in weapons. These fungi occur normally in cold areas such as the upper midwestern United States, Canada, and Siberian Russia. Nelson says he has never seen or read about either of them occurring in a tropical climate. There is a third species that grows in semiarid tropical climates, such as Australia, and may produce a toxin. Nelson says that he would be "very skeptical that it would grow in Southeast Asia." The toxin it produces has not been analyzed, and Nelson doubts that it is T2.

Russians have done much of the pioneering research on the varieties of *Fusarium* that produce T2. They became involved at the close of World War II, Nelson says, because as many as 1 million people may have been poisoned by infected grain. The problem was traced to a *Fusarium* fungus in wheat that had been left in the field during the winter.

According to Nelson, the world's most lethal strain of *Fusarium* lives in the laboratory of Abraham Joffe at the Hebrew University in Jerusalem. Joffe studied *Fusarium* toxins in Russia during the 1940's and brought fungus specimens with him when he emigrated to Israel. He will not give live samples to anyone, although he has licensed the production of T2 to a company in Israel. Its only legitimate use is for agricultural and toxicological research.

The Soviets' United Nations report relies on three sources to buttress its claim that toxigenic *Fusarium* fungi thrive in Southeast Asia, most importantly a British text published in 1971, *Genus Fusarium*. Nelson, who knows the author, says the book makes no mention of a toxigenic *Fusarium* in Southeast Asia.

Nelson is baffled as well by the Soviet elephant grass theory of infection. First, he says, it is impossible to sterilize soil as described in this report; certainly napalm would not do the job. Second, *Fusarium* spores dry out and die when they are airborne for long. The fungus would not travel as rapidly as the Soviets have hypothesized. Nelson does not challenge the fact that some variety of *Fusarium* might live in Southeast Asia. The important question, he says, is whether it would produce a toxin. He thinks not.

—ELIOT MARSHALL

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with chemicals in the aerosol may have damaged the normal processes of elimination. These were theories, not explanations.

• Why does the poison used in Southeast Asia produce almost immediate vomiting, diarrhea, and convulsions, while T2 administered in the laboratory takes several hours to produce effects? Watson suggests that the disparity may be the result of different methods of intoxication: war victims inhale the poison while test animals usually ingest it in feed. In addition, Watson says, the material used in weapons is mixed with other agents, increasing its toxicity. Steven Swanson of the University of Illinois says that when animals are given a lethal intravenous dose of T2, they sometimes begin to vomit in 30 to 60 minutes. It is possible, he says, that inhaled T2 could produce similar effects in humans.

• Several scientists questioned the wisdom of putting so much emphasis on measurements of T2 that are close to the edge of the detection limit, in the range of 10 parts per billion or less. All agreed, however, that it is unlikely that Mirocha's lab had made a mistake in analyzing samples. "It is significant to get a positive for T2," one researcher said, mentioning that his own laboratory runs over 300 tests a year and rarely finds more than one or two samples containing T2.

• One plant pathologist questioned T2's value as a weapon because of its high cost. He said researchers must pay $7000 or more for a gram of the most potent variety of T2, manufactured by an Israeli scientist who brought live fungus specimens from Russia when he emigrated in the 1950's. Watson estimates that it takes 35 milligrams of T2 to kill a 70-kilogram man. Others say more is needed. However, even at Watson's rate it would take tens or hundreds of thousands of dollars worth of high-grade toxin to obliterate a village. On the other hand, a weapons builder might develop a cheap method of mass producing T2. The Soviets have developed a mycotoxin spray for use in controlling forest pests, but little is known about its composition, cost, or potency. Celec and Watson also suggest that a weapons maker might increase the potency of T2 10- to 20-fold by mixing it with solvents.

• Another persistent question has to do with munitions. If 5,000 to 10,000 people have been killed by toxin attacks, as the State Department alleges, why has no one been able to retrieve a piece of artillery shell, bomb, or gas cannister with traces of toxin on it? The United States now receives test samples from

USDA Research Under Fire

A ripple of anxiety spread through the Department of Agriculture (USDA) with the news that the White House was sponsoring a "small, highly focused" meeting on 14 June to talk about strategies for raising the quality of agricultural research. The meeting, held at the Winrock Conference Center in Morrilton, Arkansas, was co-sponsored by the Rockefeller Foundation. Concerns about the purpose of this gathering were sharpened by an advance report in the newsletter *Science & Government Report*, headed, "White House Aims to Shake up Agricultural R & D."

Now the meeting is over and guardians of tradition may be reassured: the outcome will not be a call to revolution but another modest proposal asking the government to spend more money on competitively awarded grants for basic research. Since there is no political support for cutting into other USDA programs to secure such funding, and since new appropriations seem unobtainable, little change is expected for now.

Because the subject is sensitive, the 15 participants* in the meeting are saying little about their recommendations. Denis Prager, a staff official in the White House Office of Science and Technology Policy, together with John Pino of the Rockefeller Foundation, will have a full report out in several weeks. In the meantime, they refer the curious to four points of agreement achieved at the meeting.

• The state agricultural experiment stations should remain highly autonomous, and their chief mission should be to deal with state needs. The experiment stations are the backbone of the federal-state cooperative research effort, receiving about one-third their funding from the USDA.

• The federal Agricultural Research Service should be granted more administrative flexibility, that is, freedom from local interests, in order to focus on topics "related to unique federal responsibilities."

• Collaboration between the state and federal research systems should concentrate on large issues of regional or national concern.

• "The basic science and research capability" of both state and federal research programs "need to be strengthened." While the conferees sought to reassure the traditionalists that the present system of "formula funding must be retained," they also noted that "additional support . . . should be substantially enhanced through competitive funding."

Ever since the publication in 1972 of the "Pound Report," a National Academy of Sciences review that sharply criticized USDA's research program as sluggish, experiment station scientists have been leery of reform proposals coming from Washington. One small innovation, the establishment of a competitive grants program funded at $15 million, caused a stir when it was launched in 1978. It was designed to interest molecular biologists in problems relating to food and animal production. The program ran into a wall of political opposition from state organizations. State officials saw it as a potential threat to their 100-year-old land grant system, which essentially divides funds along geographical and political lines. Some feared that powerful universities such as Cornell, Harvard, and the University of California would muscle in and take over agricultural research. That has not happened.

Although the land grant colleges win about half the awards from the competitive grants program, they have not been entirely convinced of its value. This program, copied after the peer review systems of the National Science Foundation and the National Institutes of Health, has had a difficult time in Congress. Each year it seems to go through a strenuous battle for survival. The White House–Rockefeller Foundation review will serve as a reminder in the midst of this struggle that problems have not changed since the 1970's: the need to encourage basic research in agriculture grows stronger each year.—ELIOT MARSHALL

*In addition to Prager and Pino, the participants were Perry Adkisson of Texas A & M, James Bonnen of Michigan State, Winslow Biggs of the Carnegie Institution, Representative George Brown, Jr. (D–Calif.), Irwin Feller of the Institute for Policy Research and Evaluation, Ralph Hardy of DuPont, James Kendrick of the University of California at Berkeley, Terry Kinney, Jr., of the Department of Agriculture, Lowell Lewis of the University of California at Berkeley, Judith Lyman of the Rockefeller Foundation, James Martin of the University of Arkansas, John Marvel of Monsanto, and Peter van Schaik of the Department of Agriculture.

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Southeast Asia at the rate of one or two a week. If these can be smuggled out, why not a piece of steel? Celec's answer is that the toxins are not always delivered by munitions; that the target areas are difficult and dangerous to visit; and that the victims' first impulse is to flee, not to collect evidence.

Some of the confusion might be cleared away if an investigative team were to survey the battle sites and conduct a thorough, independent analysis of medical and environmental samples. The United Nations (U.N.) voted in December 1980 to launch such an investigation, but progress has been slow. The U.N. staff took several months to send out invitations to serve on the inquiry. More time went by before requests to visit the battle sites went out. By the end of November 1981, the U.N. team, led by an Egyptian general, had visited refugee camps in Thailand. The next month the investigators submitted a report. It was necessarily vague, they said, because they had been denied access and assistance by the countries where toxin attacks are supposedly taking place: Afghanistan, Laos, and Kampuchea.

In February 1982, the team visited camps in Pakistan to collect refugees' accounts of gas attacks in Afghanistan. By then one of the original members and the technical consultant had been replaced. Some of the interview transcripts were leaked to the *Wall Street Journal*, which published them on 7 June. Although gruesome, the symptoms described by the Afghan resistance fighters do not in all cases match the descriptions collected in Southeast Asia. Some of the weapons described were different, as well.

Thus, the puzzle becomes more complex, and the U.N. team seems no closer to solving it than it was 2 years ago. Its final report is due in the fall. Some American officials are cynical about the outcome in any case, for the inquiry's ultimate administrative chief is a Soviet citizen, U.N. Under Secretary-General Viacheslav A. Ustinov. At best, the cynics believe, Ustinov is unenthusiastic. They say that he knows how to use bureaucratic inertia at the U.N. to smother unfavorable information.

The conditions do not seem to favor a quick settlement of this dispute, nor is there much hope for the kind of thorough data collection that U.S. scientists would like. This means that, for the present, people will have to rely on conjecture in deciding exactly what Yellow Rain is. However, the claim that it includes some toxic agent seems well established by the victims' testimony.—ELIOT MARSHALL

DOD Official Criticizes Export Control Policies

A senior Department of Defense (DOD) official has issued a memorandum complaining that Pentagon contract officers have sometimes been overzealous in trying to restrict the exchange of information from academic research projects. The memorandum, written on 21 May by James Wade, Jr., deputy under secretary for research and engineering, instructed the assistant secretaries of the Army, Navy, and Air Force to ensure that contract officers "avoid new or unnecessary restrictions added to university research contracts."

The DOD's policy on export controls as applied to university contracts is currently under review, Wade pointed out in his memo. But in the meantime, he wrote, "It has come to my attention that certain DOD agencies are attempting to modify university research contracts by including clauses which would serve to unnecessarily restrain the open exchange of unclassified information among members of the scientific community." Restrictions should not be placed on the publication of basic research results or on the involvement of foreign nationals in unclassified basic research, Wade noted. "Contract officers," he warned, "should not make ad hoc decisions which would aggravate and confuse an already difficult situation."

There have been a number of recent cases of contracting agencies "getting confused" and "taking matters into their own hands," according to Leo Young, director of the research and technical information office at the Pentagon, and it was these incidents that precipitated Wade's letter. One such episode, which occurred in March, involved two Air Force contracts for psychology research at the University of Illinois. The research was to be done under the direction of Emmanuel Donchin, head of the psychology department at Illinois.

"The work is pure, basic experimental psychology," Donchin says. Volunteers were to do very boring tasks for hours. Occasionally they would have to do something important. The question was, How well would they do on the important tasks?

When Donchin got the Air Force contracts for his work, he noticed a clause saying that the "technical data" under the contract may be affected by the International Traffic in Arms Regulation (ITAR), meaning that foreign nationals could not have access to the results without prior written approval and that the work could not be freely published in the open literature. Ironically, says Donchin, he himself is an Israeli citizen, the associate director of the project is British, one of his graduate students is from Italy and one is from Canada. All would need prior written approval to work on the contract.

The University of Illinois protested to the Air Force that the ITAR clause was unwarranted, and about 6 weeks later, it was removed.

The Illinois affair, says Young, illustrates how "well intentioned" contracting officers have been taking actions that "don't make sense." C. Frederick Bentley, associate director of the sponsored project office at Stanford University, says Stanford and several other universities working on very high speed integrated circuits also have protested—and eventually gotten rid of—ITAR clauses in DOD contracts. Bentley is optimistic that Wade's memo will help the universities in dealing with contract officers. "Maybe it will give us some ammunition," he says.—***Gina Kolata***

New Directors at Two Institutes

The new director of the National Institutes of Health (NIH), James B. Wyngaarden, has appointed two veterans of the research agency as directors of the institutes that specialize in arthritis and diabetes and in child health.

Wyngaarden named on 17 June Lester B. Salans as director of the National Institute of Arthritis, Diabetes, and Digestive and Kidney Diseases, whose $370-million budget is the third largest of the 11 institutes. Salans, whose appointment is effective immediately, has been acting director of the institute since October 1981.

Mortimer B. Lipsett was chosen to be the top administrator of the Nation-

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