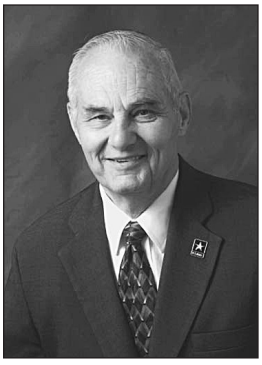
GMOs, Glyphosate & Tomorrow

Distinguished Professor, Scientist Reveals Growing, Multi-Faceted Problems in Glyphosate & Crops Created to Survive It



Don Huber, Ph.D.

Seeds evolved for millions of years before humans invented corporate agribusiness. Genetic selection to improve crops began only when people invented farming. Early on, there was a vast germ pool from which to select differences in vigor, growth, quality characteristics, yield or disease resistance. Even after years of extensive selection and later blending into hybrids by diligent researchers during the past century, most of this inheritance is unpatentable and therefore useless as a source of power or corporate-style profit.

Genetic engineering to modify crops exists because most of the world's farmers depend on seeds, and as a novel way to manipulate genes it offered inviolate proprietary control. Two traits account for practically all of the genetically modified crops grown in the world today. One deploys herbicide-tolerance enabled by a glyphosate-insensitive form of the EPSPS gene coding (key to this GMO is the soil bacterium Agrobacterium tumefaciens*). The other uses insect-resistance due to one or more toxin genes derived from the soil bacterium* Bacillus thuringiensis.

It is the former that concerns us here, for without glyphosate, the biotech industry would be an orphan, all dressed up with nowhere to go. Glyphosate, often known as Roundup® after the popular Monsanto product but available in many guises since its patent expired in 2000, is the partner GMOs must bring to the dance. It is a broad-spectrum herbicide that ingeniously ties up nutrient access rather than killing unwanted plants directly. It was heralded for many years as a relatively benign replacement for the horrific, dioxin-based herbicides of the past. The figures don't lie; GMOs drive glyphosate sales.

Enter Don Huber, a plant pathologist of 50 years standing, now Emeritus Professor at Purdue University and enjoying an active post-academic life. Huber is an international authority on nutrient deficiency diseases of plants and is particularly well situated to comment on glyphosate as it functions through nutrient tie-up, not inherent toxicity.

Recently his retirement turned hyperactive when a letter he wrote to Secretary of Agriculture Tom Vilsack leaked out. Although much of the mainstream media ignored it, the letter was an immediate sensation. Huber — not coincidentally a speaker at the 2010 Acres U.S.A. Conference — informed Vilsack that a new infectious agent had been discovered. It is "widespread, very serious, and in much higher concentrations in Roundup Ready (RR) soybeans and corn," he wrote. He appealed to the secretary for help with resources and research capability.

The letter unleashed a storm of alarm and denial, and as Huber tells below, the USDA is looking into the matter despite its recent ill-advised approval of genetically modified alfalfa.

We asked him to comment on his recent letter (see pages 54-55) and share his own thoughts and opinions on this ubiquitous farm chemical.

— Chris Walters

ACRES U.S.A. How does glyphosate differ from herbicides that were popular before it came along?

DON HUBER. There are a number of ways that glyphosate is different from most other herbicides. Most of our herbicides are mineral chelators that act to physiologically immobilize a specific mineral nutrient that is required for a specific critical enzyme. When that physiological pathway is shut down, the weed or the plant it's applied to dies. Glyphosate also is a chemical chelator that can grab onto mineral nutrients and immobilize them physiologically so they're no longer available for those physiologic functions that they regulate. The difference with glyphosate is that it is not specific to just one mineral nutrient, but immobilizes many of them and doesn't affect a primary mechanism to cause death by itself. It merely turns off the plant's defense mechanisms so that soil-borne fungi that would normally take weeks to months to damage a plant can kill it in just a few days after glyphosate is applied. When they use the glyphosate-tolerant technology, they insert another gene that keeps that plant's defense mechanism going somewhat so you can put the glyphosate directly on the crop plant without having it killed. But the technology doesn't do anything to the glyphosate, which is still tying up mineral nutrients. Anytime you put the gene in, you reduce the nutrient efficiency of the plant, though not to the point that it destroys the ability of the plant to survive. It does leave it physiologically impaired.

ACRES U.S.A. Before glyphosate-tolerant genes were introduced, how did farmers cope with the danger of possibly killing the crop plant?

HUBER. They took care of their weed control before planting or before the crop emerged. Back then, there weren't too many herbicides that you could apply directly to the plant. We had a few, 2,4-D and a few others, that were semi-selective and very effective against broadleaves, which have a different physiology than grass plants. A similar thing with Tordon. You can put Tordon right on a grass pasture and it will kill the broadleaf weeds for three or four years. It has pretty good residual activity, but grass looks like you'd just fertilized it when you got rid of all of those broadleaved weeds.

ACRES U.S.A. The innovation that gave glyphosate its market clout had to do with concentrating the whole arsenal into one weapon? No more multiple herbicides?

> "Any time you have a single gene in so many different crops, especially a gene that impacts the normal resistance and defense mechanism in the plant, and you spread that same vulnerability across so many plants, you should anticipate a high level of vulnerability."

HUBER. There was selective activity in our herbicides. Glyphosate on plants without the new gene inserted has a very broad-spectrum effect so that all weeds are affected. They're all killed by the soil fungi. It's not quite analogous, but you could say that what you're doing with glyphosate is you're giving the plant a bad case of AIDS. You've shut down the immune system or the defense system.

ACRES U.S.A. How does glyphosate's immobility as a strong metal chelator or nutrient chelator translate into the long-term effects of glyphosate buildup after years of steady use?

HUBER. As long as it's bound very tightly with those mineral elements it is not available or not in an active form for plant damage. If there is something that happens to break that binding then it can again be released and available for root uptake and plant damage. It depends on how long it survives in the soil and that will depend on two primary factors. Soil pH is a big factor in stability and the other is clay content. The higher the pH, the less stable it is, and the higher the clay content, the more stable it will be. In a high-clay soil it may survive for a number of years. In water solution it can degrade fairly rapidly and not have a lot of residual activity. I think that's probably one reason why the French Supreme Court ruled two years ago that it would be fraud to claim biodegradability of glyphosate in soil — because it's not always really predictable. For some soils it can survive for a long period of time, and in others it may have a much shorter period. With the information that's currently available, it's not really possible to have a good predictable figure. We do know that even though it's immobilized rapidly in most soils it can then be reactivated or desorbed and reactivated to damage future crops.

ACRES U.S.A. What must happen to reactivate it?

HUBER. One of the things that's recently been shown to do this is to apply phosphorus fertilizer on the crop. From a nutritional standpoint, it can actually desorb the glyphosate so that it's again reactivated as an active chemical for plant uptake and damage.

ACRES U.S.A. Has this been demonstrated by researchers to impact the crops when it's desorbed?

HUBER. Yes. That can be quite damaging to the crop and actually limit uptake of nutrients required by the crop as much as 60 to 70 percent, and that's pretty much across the board. Most elements will be reduced around 60 percent and a few of them in the 70 percent range. In this way the plant can be placed under a

fairly significant nutrient deficiency even though the nutrients may be in the soil — the plant can't utilize them because of glyphosate's toxicity.

ACRES U.S.A. Have your colleagues found similar impacts?

HUBER. Yes. A number of soil microbiologists are all reporting the same type of impact on the soil biology. One paper mentions that it's a very powerful herbicide, but also a very potent biocide. It's a little bit selective in that it stimulates some soil organisms and is very toxic to other organisms. It's toxic to your legume module bacteria for nitrogen fixation, also quite toxic to the organisms that make manganese and iron available for plant uptake, and those are critical nutrients. It stimulates the soil pathogens that do the killing from a weed control standpoint, but it also stimulates some so that you're essentially making a super-pathogen to kill a weed. Then you leave that super-pathogen in the soil, which also attacks other plants later on in the rotation.

ACRES U.S.A. The letter you sent to Secretary of Agriculture Tom Vilsack in January, not surprisingly, is being attacked on a number of fronts. Since the pathogen that has been discovered hasn't been detailed in a journal, its existence has been questioned. How was this pathogen discovered, who did the research, and is research being readied for publication?

HUBER. The letter to the Secretary wasn't for public dissemination. It was a request for help. It was meant to bring to his attention the things that many of us are seeing out in the field, both from the veterinarians and animal producers as well as agronomists, plant pathologists and our crop producers. I wanted to bring the situation to his attention and request help so we could move the science along faster than we can individually. It's because of the seriousness of the situation that many growers are experiencing. The work to date has been very well done, very scientifically conducted, but there is still much to do. Much of it hasn't been published on the animal side, but Koch's-postulates — the scientific criteria used to establish a cause-effect relationship — have been completed, and much of the science on the animal side has been done. That's not a concern or a question. The veterinarians have been very thorough. They split their samples, sent them to a number of different labs to rule out all of the other known causes of those conditions, and when they check for this new organism that's what they find. They find it with cattle and pigs and horses and poultry. So it has a pretty broad host range. In trying to identify how the animals were being infected, they began looking at the feed and found that soybean meal was just loaded with it. They also find it in silage and corn products. Any fermented product seems to encourage this organism. It's also a very good synergist with other pathogens. The Fusarium fungus that causes Sudden Death Syndrome (SDS) is very compatible with this new organism. Another interesting thing is that it appears very compatible with Clavibacter that causes Goss' wilt of corn as well as other bacteria. Over the past two years we've had extensive SDS and Goss' wilt epidemics and that's where we really see the higher titer with this organism. The two diseases and the newly discovered pathogen appear to be very synergistic. This new organism may be an opportunist that is able to take advantage of a weakened condition and then really move forward.

> "It's not quite analogous, but you could say that what you're doing with glyphosate is you're giving the plant a bad case of AIDS. You've shut down the immune system or the defense system."

ACRES U.S.A. What is "higher titer?"

HUBER. Higher population. Just a lot more of it. It seems to grow better for possibly a higher infection potential.

ACRES U.S.A. Is this the first appearance of this pathogen in nature? Or is it something that was there all along, waiting for discovery?

HUBER. We're fairly convinced it's something that's always been there, very benign, not really a problem until we changed something that has either increased its virulence or its opportunity. I think the research to date would indicate that it's probably more a change in the susceptibility of the crops, in the population of the pathogen, and in the potential for animal infection. There are many organisms new to science that have been around forever. Which is something you see with the prions. We didn't know they existed either until we had to look a lot further to find an answer to a problem, and then they were discovered. This organism was discovered pretty much the same way. When they rule out all other known sources, then the veterinarians just kept looking and found this one, and then verified it as the cause by doing Koch's postulates. Then they took it a step further to find out: where was it coming from? How are the animals getting it? That led them to check the feed and they found it there. In science you go from one thing to another, sometimes in a process, and you don't necessarily stop and publish each little bit that is found until you have a better understanding of how it all fits together. In agriculture we're really talking about a system; we're not talking about silver bullets.

ACRES U.S.A. People have an easier time understanding single-factor analysis and silver bullets, but that's not how it works in nature, is it?

HUBER. We're talking about how parts of this system interact and fit together. That's been the real emphasis in this research, not how to get that publicity and meet the popular demand by publishing each little bit of information. You try to get enough research so you can really understand its scope and

what its impact is in the overall production system. That's really my plea to the Secretary in that letter — we need resources and we need some commitment of those resources and personnel that are available to the Secretary but aren't available to each individual scientist. It was for alerting him to the problem so he would be interested, as he has been, in passing it on to those who would be able to provide additional resources. We need to understand how it fits into the overall ecological scheme and agricultural production system.

ACRES U.S.A. Despite the recent rapid approval of genetically modified alfalfa, do you find a silver lining in indications that USDA resources or commitment are forthcoming?

HUBER. Well, I certainly hope so.

ACRES U.S.A. This pathogen doesn't have a name. What do you call it?

HUBER. That's been a bit of a stumbling block. In the letter I called it a microfungus. That was a mistake, because when you think of a microfungus you automatically think of a mold-type organism, and it certainly isn't that. It's many thousands of times smaller than a mold, much smaller than a bacterium — approximately the size of a virus. It's in that category, except that it self-replicates and can be passive.

ACRES U.S.A. But it is certainly not a virus?

HUBER. Not by our current definition.

ACRES U.S.A. Could your theory be summarized thusly — this is not the result of a mutation in an existing pathogen, rather, a change in the conditions has caused an existing pathogen to multiply and become a problem, with pathways being created that were not common in the past?

HUBER. Right. The organism appears to be prominent in the environment but new to science. On a much larger scale, it would be like when they bred the Texas male-sterile gene into corn. We got away with it for a few years. Then all of a sudden we realized we had an organism out there that was new to science with the Southern corn leaf blight epidemic of 1970-71. We'd previously had that experience with the Victoria gene in oats.

ACRES U.S.A. Can you name some of the researchers who are involved? Specifically who discovered the pathogen?

HUBER. No. Because there's no need for them to have the harassment or be inundated the way I've been. We've got too much work to do.

ACRES U.S.A. But you can vouch for them?

HUBER. They are very well-established scientists. There's no need to attack everybody else, and that's exactly what happens when you come up with something that's new.

ACRES U.S.A. In other words, naysayers are assured that there is more than one person involved with this research, they're reputable people, the results are going to be published as soon as they're available, and these plant and animal afflictions are not going away?

HUBER. Clavibacter survives in corn residue for three to four years at least so if we continue to do the same things, we should anticipate the same result. There's research that shows that when you apply formulated glyphosate to a glyphosate-tolerant corn plant that normally is resistant, some hybrids become fully susceptible to that organism. Glyphosate can nullify the genetic resistance for Clavibacter just like it can sugar beets for Rhizoctonia or Fusarium in same plants.

ACRES U.S.A. What other results do you anticipate?

HUBER. High infertility and abortions in animals fed with corn and soybean feeds containing high populations of this organism.

ACRES U.S.A. Some of your critics reject the whole idea that sudden plant death and spontaneous cattle abortions are even an increasing problem.

HUBER. It isn't a universal phenomenon, just as most disease outbreaks can be limited. I think the criticism goes against the statistics though. If you look at the USDA's anticipated yield on corn that they put out in August, and then subtract the actual yields reported in January, you come up with almost a billion bushels less, even though we had near ideal conditions for harvest. Where did those billion bushels go? All you have to do to document that there was a short crop last year is look at the price. We're no longer talking about $3 per bushel corn, we're talking about $6 per bushel. That's not from increased ethanol use, that's from a major shortage in the crop produced. How do you get soybeans from $5 up to $12? You have a short crop because you have an inelastic supply/demand relationship in agriculture. I think the figures document that. In some areas they didn't have those problems this year as some had last year, and that's because environmental conditions are also important for disease.

ACRES U.S.A. Just to get it on the record, after you sent your letter to Vilsack, someone else leaked it?

HUBER. Right. It was not intended as a public document. My request to the Secretary was for the help we needed to get resources, and also to ask him to delay any decision on the Roundup Ready alfalfa until some things could be checked out. One reason is that we were seeing a marked increase in susceptibility to Goss' wilt in previously Goss' wilt-resistant corn. Critical research was needed to document the epidemiology of this new organism.

ACRES U.S.A. What has your experience been over the last decade or so with the availability of research funds for questions like this in the United States?

HUBER. Funding for applied research is hard to come by and publishing in this area can also be difficult. I know from the International Symposium on Glyphosate that they had to find a journal publisher outside this country to publish the research data and symposium proceedings. It's pretty hard to get it published in the States. There are also

Letter Sent to Secretary Vilsack by Dr. Huber That Was Leaked

January 16, 2011

Dear Secretary Vilsack:

A team of senior plant and animal scientists have recently brought to my attention the discovery of an electron microscopic pathogen that appears to significantly impact the health of plants, animals, and probably human beings. Based on a review of the data, it is widespread, very serious, and is in much higher concentrations in Roundup Ready (RR) soybeans and corn — suggesting a link with the RR gene or more likely the presence of Roundup. This organism appears NEW to science.

This is highly sensitive information that could result in a collapse of US soy and corn export markets and significant disruption of domestic food and feed supplies. On the other hand, this new organism may already be responsible for significant harm (see below). My colleagues and I are therefore moving our investigation forward with speed and discretion, and seek assistance from the USDA and other entities to identify the pathogen's source, prevalence, implications, and remedies.

We are informing the USDA of our findings at this early stage, specifically due to your pending decision regarding approval of RR alfalfa. Naturally, if either the RR gene or Roundup itself is a promoter or co-factor of this pathogen, then such approval could be a calamity. Based on the current evidence, the only reasonable action at this time would be to delay deregulation at least until sufficient data has exonerated the RR system, if it does.

For the past 40 years, I have been a scientist in the professional and military agencies that evaluate and prepare for natural and manmade biological threats, including germ warfare and disease outbreaks. Based on this experience, I believe the threat we are facing from this pathogen is unique and of a high risk status. In layman's terms, it should be treated as an emergency.

A diverse set of researchers working on this problem have contributed various pieces of the puzzle, which together presents the following disturbing scenario:

Unique Physical Properties

This previously unknown organism is only visible under an electron microscope (36,000X), with an approximate size range equal to a medium size virus. It is able to reproduce and appears to be a micro-fungal-like organism. If so, it would be the first such micro-fungus ever identified. There is strong evidence that this infectious agent promotes diseases of both plants and mammals, which is very rare.

Pathogen Location & Concentration

It is found in high concentrations in Roundup Ready soybean meal and corn, distillers meal, fermentation feed products, pig stomach contents, and pig and cattle placentas.

Linked with Outbreaks of Plant Disease

The organism is prolific in plants infected with two pervasive diseases that are driving down yields and farmer income — sudden death syndrome

continued on next page

some hazards to publishing if you're a young researcher doing research that runs counter to the current popular concepts. A lot of research on safety of genetic engineering is done outside of this country because it's difficult to gain access to the materials, or the statements you have to sign to have access to those materials state that you won't publish without permission of the supplier. I think the 26 entomologists who sent their letter to EPA in 2009 stated it aptly when they said that objective data wasn't available to the EPA because the materials haven't been available to them or that they're denied the opportunity to publish their data.

ACRES U.S.A. Has there been a chilling effect on the availability of funds to do the research in this country?

HUBER. The entomologists asked that they not be publicly identified by name because they were dependent on outside sources for funding and there isn't a lot of funding available for this type of research anymore so that's certainly a major impediment. You have to have funding to get graduate students working on it and if you have the graduate students, then you can get publications out to make it possible for you to get tenure and promotion.

ACRES U.S.A. Is the Ignacio Chapela affair a good example of the impact this can have on a young researcher's career?

HUBER. There are scientists who have experienced a situation where their career became very short or they had to change paths in order to survive and stay in the system.

ACRES U.S.A. Have you received any response from Secretary Vilsack?

HUBER. I didn't anticipate a direct response. I kind of thought I might receive a "We received your letter" note like you get back from your Congressman, but I have been contacted by USDA personnel in response to the letter. I've been cooperating and working with them in that area. I wanted to be able to do that in a more detailed manner than you can put in a letter, so in the

letter I merely highlighted the concerns, the things that we were seeing and that we could document. I've been able to provide information for them to go forward in their investigations.

ACRES U.S.A. Then you're confident that the research component of the USDA is looking into it with great interest, not just brushing it aside?

HUBER. I believe they are at this point.

ACRES U.S.A. If the letter had not been made public, if it had gone through channels as you expected, do you think you might have gotten a more proactive response from Vilsack?

HUBER. It might have been easier for him to do that. I don't know. I have a good working relationship with a number of those people in the USDA, and they have the charge to respond to this kind of concern. They can't do it overnight; it takes a little time to get up to speed. Leaking of the letter didn't make it easier for them. It probably made it a little more difficult just because then you get a lot of pressure coming in from all different directions. But it may have moved the process along perhaps a little quicker than it might otherwise.

ACRES U.S.A. Are you personally acquainted with Secretary Vilsack or Assistant Secretary Kathleen Merrigan?

HUBER. No, I'm not. I've worked very closely for a long time with the actual scientists and people doing the work. I have a great deal of respect for a lot of those people.

ACRES U.S.A. What was the major focus of your work during the years before you became a retired, or emeritus, professor?

HUBER. For 50 years my research was focused heavily on the biology and control of soilborne pathogenic fungi, microbial ecology, biological control, microbial interactions and host-parasite physiology — trying to understand resistance and susceptibility from a physiological standpoint. I was heavily involved in the whole development of nitrification inhibitors, and also in identifying nutrient pathways in corn, soybeans and wheat. I served as one of the editors of the American Phytopathological Society's book on mineral nutrition and plant disease, which came out in 2007. I initially got involved with glyphosate thinking that when glyphosate-tolerant soybeans were released it would probably be a win/win situation for a lot of our growers who didn't want to make a separate trip across the soybeans to meet the nutritional demands for manganese. If they could just add manganese as a tank mix, it would be a pretty good time to remedy the manganese deficiency we

(SDS) in soy, and Goss' wilt in corn. The pathogen is also found in the fungal causative agent of SDS (Fusarium solani fsp glycines).

Implicated in Animal Reproductive Failure

Laboratory tests have confirmed the presence of this organism in a wide variety of livestock that have experienced spontaneous abortions and infertility. Preliminary results from ongoing research have also been able to reproduce abortions in a clinical setting.

The pathogen may explain the escalating frequency of infertility and spontaneous abortions over the past few years in US cattle, dairy, swine, and horse operations. These include recent reports of infertility rates in dairy heifers of over 20%, and spontaneous abortions in cattle as high as 45%.

For example, 450 of 1,000 pregnant heifers fed wheatlage experienced spontaneous abortions. Over the same period, another 1,000 heifers from the same herd that were raised on hay had no abortions. High concentrations of the pathogen were confirmed on the wheatlage, which likely had been under weed management using glyphosate.

Recommendations

In summary, because of the high titer of this new animal pathogen in Roundup Ready crops, and its association with plant and animal diseases that are reaching epidemic proportions, we request USDA's participation in a multi-agency investigation, and an immediate moratorium on the deregulation of RR crops until the causal/predisposing relationship with glyphosate and/or RR plants can be ruled out as a threat to crop and animal production and human health.

It is urgent to examine whether the side-effects of glyphosate use may have facilitated the growth of this pathogen, or allowed it to cause greater harm to weakened plant and animal hosts. It is well-documented that glyphosate promotes soil pathogens and is already implicated with the increase of more than 40 plant diseases; it dismantles plant defenses by chelating vital nutrients; and it reduces the bioavailability of nutrients in feed, which in turn can cause animal disorders. To properly evaluate these factors, we request access to the relevant USDA data.

I have studied plant pathogens for more than 50 years. We are now seeing an unprecedented trend of increasing plant and animal diseases and disorders. This pathogen may be instrumental to understanding and solving this problem. It deserves immediate attention with significant resources to avoid a general collapse of our critical agricultural infrastructure.

Sincerely,

COL (Ret.) Don M. Huber
Emeritus Professor, Purdue University
APS Coordinator, USDA National Plant Disease Recovery System (NPDRS)

The Basics

Micronutrients are regulators, inhibitors and activators of physiological processes, and plants provide a primary dietary source of these elements for animals and people.

. . . Lost yield, reduced quality, and increased disease are the unfortunate consequences of untreated micronutrient deficiency. The shift to less tillage, herbicide resistant crops and extensive application of glyphosate has significantly changed nutrient availability and plant efficiency for a number of essential plant nutrients. Some of these changes are through direct toxicity of glyphosate while others are more indirect through changes in soil organisms important for nutrient access, availability, or plant uptake. . . .

— From Abstract of "Ag Chemical and Crop Nutrient Interacts Current Update" by Don M. Huber, Emeritus Professor, Purdue University

saw in a number of areas in Indiana, and they could get the weeds controlled at the same time. It only took one trial to realize that it wouldn't work, because glyphosate immobilized the manganese that we were trying to make available for the plant. The last 15-16 years were primarily devoted to understanding and finding ways to remedy the nutrient inefficiency that the technology and the chemistry was imposing on the plant. Of course that brought me right back to looking at a lot of those soil-microbial interactions that are so essential to making nutrients available to plants to start with.

ACRES U.S.A. How does that relate to the current pathogen?

HUBER. Any time you have a single gene in so many different crops, especially a gene that impacts the normal resistance and defense mechanism in the plant, and you spread that same vulnerability across so many plants, you should anticipate a high level of vulnerability. I think that's what we're seeing.

ACRES U.S.A. What worries you about the possibility of this pathogen getting loose in alfalfa?

HUBER. A perennial crop like alfalfa can be very susceptible to a closely related common soilborne bacterium to Goss' wilt. If the technology nullifies resistance to this bacterial disease like it can for corn and it is compatible with the new organism, then you have a situation where you can compromise the crop totally because you don't have any way to get it out. With an annual crop like corn or soybean, or like we had with the Texas male-sterile gene, it was a matter of just going back to our old genetics and eliminating those with the gene from the breeding program. Once you have it implanted in the plant though, there's no way to get it out. With a perennial, insect-pollinated plant, I don't know of any way to eliminate it once it's distributed throughout an area as it could be very readily.

ACRES U.S.A. Genetic engineering is relatively new to science. Does that bring this problem to a new level of seriousness, because you can't just remove those traits? That is, the way you would if you simply stopped a hybrid program that was making something you didn't like?

HUBER. It's certainly easier to put it in than to get it out. Each time you put a foreign gene in, you're adding another stress to the plant — commonly referred to as a yield-drag aspect, which is very well documented. There's powerful technology here and usually, with a little bit of time, we can find a way to make that work more compatibly. Genetic engineering is a tool we may need for specific situations, but it's also been easy to abuse. I believe that when we start putting all of our eggs in one basket, it increases our vulnerability and potential risk factors dramatically. I believe we should try to follow scientific principles and use a lot of caution until we understand what's going on in the whole process.

ACRES U.S.A. Do you agree that genetically modified food has been unduly rushed into the American food supply?

HUBER. Someone gave the analogy of asking how many drugs that were on the market 10 years ago aren't on the market today. The reason they aren't on the market now is that new information indicated the side effects were great enough or that they weren't safe for use to start with. Certainly there is plenty of information now in the scientific literature that would raise a red flag as to the extent of use of glyphosate on everything including your concrete driveway. We've seen that re-evaluation of the safety aspects in a couple of cases put a new light on it. The Indian Supreme Court recently actually insisted on an outside laboratory to do the toxicology analysis for Bt eggplant. The independent laboratory — I believe the one they selected was in New Zealand — stated essentially that the data presented for deregulation of that crop didn't meet international standards for toxicological studies, and that their independent toxicological research found that it wasn't safe for human consumption.

ACRES U.S.A. Despite the difficulty American researchers in particular have experienced, can you now cite much data that wasn't around when GMOs were introduced?

HUBER. There's a fair amount of toxicological data indicating that there are very serious concerns with some of the products. That's also one of the things that has been looked at with infertility and spontaneous abortions. There is an increasing level of glyphosate in our food chain, and with the toxicological data that's now available, the levels are often many times the level that would send up a very serious concern from a clinical laboratory standpoint. Some of that data shows that quite low levels of glyphosate are very toxic to liver cells, kidney cells, testicular cells, and the endocrine hormone system, and it becomes important

because all of the systems are interrelated. We're finding fairly significant levels of glyphosate in manure. You have to ask how the chicken got it or how the hog or cattle got it, and of course, that's through their feed. Is it all moving through the animal or is it also into their meat and other tissues? We really don't have a lot of that data. Some of the other countries are collecting it and doing the analysis, and we're just starting to do some in this country. But for the most part it's just been considered so safe that we closed our eyes and said there's no need to do any of that work.

ACRES U.S.A. As you navigate the storm that the untimely release of your letter created, are you finding a certain amount of plain denial of the idea that glyphosate could pose serious problems?

HUBER. I'm finding that a lot of people are really surprised at how many peer-reviewed scientific articles are out there to support what I'm bringing to their attention. Dr. Bill Johnson, a weed scientist at Purdue, documented in a paper he put out last summer that you can't kill a plant with glyphosate in sterile soil, but that it's the soilborne pathogens that are actually the herbicidal mode of action. What you usually hear is that glyphosate inhibits the EPSPS enzyme. Well, just inhibiting the EPSPS enzyme doesn't kill the plant — that's secondary metabolism. When you inhibit that enzyme, you shut down much of the plant's defense mechanisms against these soil-borne fungi. A lot of people aren't aware of the scientific research that's available, and I've had the opportunity to point that out — all the work of Eker, Cakmak, Ozturk, Kremer, Roemheld, Zobiole, etc., are all scientists who have germane concerns which I expressed to the Secretary. Dr. Hannah Mathers at Ohio State shows that glyphosate continues to accumulate in the perennial plant as long as the plant lives. That it continues to accumulate maybe six to eight years, and then finally reaches the level to damage cell walls. One of Dr. Mathers' papers says that this costs Ohio $6.5 million a year in lost ornamental plants through bark-cracking and winter-kill. This kind of environmental stress is because of glyphosate toxicity from the weeds that received the glyphosate since it moves out of the weeds' root system and is picked up by the ornamental or the perennial plant. Also, as that weed decomposes, it again releases glyphosate for root uptake into the adjacent plant.

About Glyphosate

Glyphosate, N-(phosphonomethyl)glycine, is the most extensively used herbicide in the history of agriculture. Weed management programs in glyphosate-resistant (GR) field crops have provided highly effective weed control, simplified management decisions, and given cleaner harvested products. However, this relatively simple, broad-spectrum, systemic herbicide can have extensive unintended effects on nutrient efficiency and disease severity, thereby threatening its agricultural sustainability. A significant increase in disease severity associated with the widespread application of the glyphosate can be the result of direct glyphosate-induced weakening of plant defenses and increased pathogen population and virulence. Indirect effects of glyphosate on disease predisposition result from immobilization of specific micronutrients involved in disease resistance, reduced growth and vigor of the plant from accumulation of glyphosate in meristematic root, shoot, and reproductive tissues, altered physiological efficiency, or modification of the soil microflora affecting the availability of nutrients involved in physiological disease resistance. . . . recommended doses of glyphosate are often many times higher than needed to control weeds . . .

— from Abstract of "Glyphosate Effects on Diseases of Plants" by G.S. Johal, D.M. Huber, European Journal of Agronomy No. 31 *(2009)*

ACRES U.S.A. Are you finding that the actual mechanism of glyphosate is widely misunderstood across the agricultural sector?

HUBER. Right. Most people just accept it as being similar to what we've had with other herbicides, where you have a primary physiological mechanism shutdown so that the chemistry actually does the killing of the plant. With glyphosate, it's only reducing the plant's ability to defend itself from soilborne pathogens. It can stunt the plant for a time before the plant recovers in a sterile soil. But in a non-sterile soil, you shut down that secondary system responsible for defense against those soil pathogens and it's like tying both hands behind the back and letting them trounce on it.

ACRES U.S.A. In your opinion, are the characteristics that led people to regard glyphosate as safer than herbicides of the past the same characteristics that now make it increasingly troublesome, a threat to the nation's agriculture?

HUBER. Yes, even more so because most of the other herbicides had a full degradation requirement on a time basis. If

you had an herbicide that would persist for four or five years, you could only apply that herbicide to a 4th or 5th of the potential acreage. That made sure there was ample time for full biological degradation to occur. With glyphosate we don't necessarily have the degradation. What we have is immobilization. Although there is some degradation that goes on, and that can be demonstrated much better in some soils than in other soils, but it's not a predictable event in many soils. Immobilized glyphosate can be reactivated in soil and be a serious problem for other crops in the rotation. When you realize how little it takes to injure a susceptible crop this is especially important — in one study it only took a 40th of a pound per acre. That's 12 grams or 4/10ths of an ounce spread over an entire acre to prevent 80-90 percent of your root-to-top translocation of the essential nutrients iron, manganese and zinc. Those three very critical micronutrients are going to affect photosynthesis as well as defense reactions and energy reactions in the plant. Glyphosate is a very powerful growth regulator chemical. Even though it can be immobilized readily, it doesn't always stay there.

Monsanto has released a "Statement About Alleged Plant Pathogen Potentially Associated with Roundup Ready Crops." View the contents at *www.monsanto.com/newsviews/Pages/huber-pathogen-roundup-ready-crops.aspx.*

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