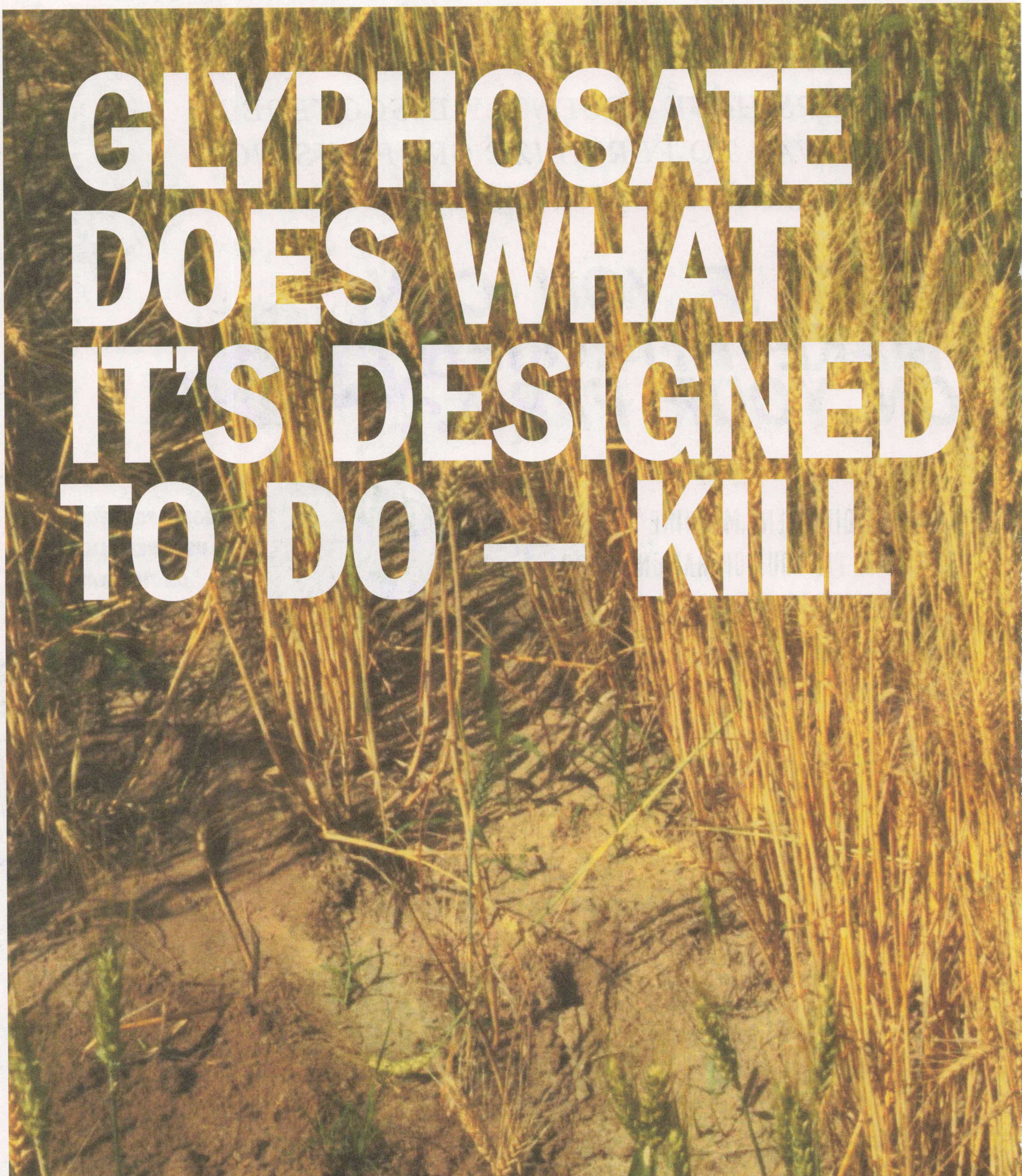
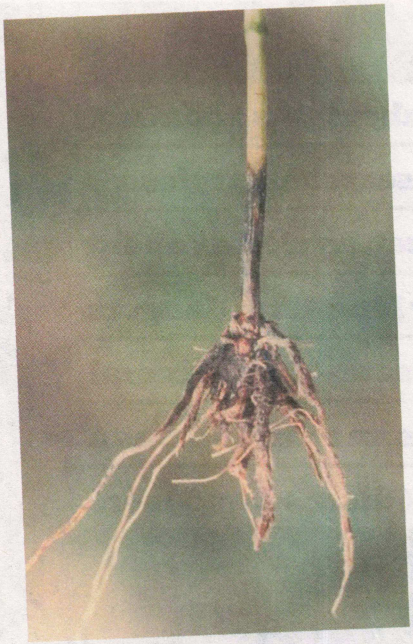
GLYPHOSATE DOES WHAT IT'S DESIGNED TO DO — KILL



Dr. Don Huber talks about his career as a researcher, professor and Army officer, as well as about the many long-term dangers of glyphosate — as a mineral chelator, as an antibiotic, as a cause of plant disease, and more

Glyphosate use increases the risk of take-all in wheat.

WILLIAM M. BROWN, JR., WIKIPEDIA



A wheat root affected by take-all

Acres U.S.A. You've been speaking at the Acres U.S.A. conference for years, but people probably don't know your whole background. You taught at Purdue, but where did you actually grow up?

Don Huber. I grew up in Arizona and in Idaho on dairy farms, after World War II. We wanted to expand and didn't feel like the opportunities were there at the time in Arizona for either good land or water supply. So, we moved the dairy from Arizona to Idaho. As a freshman in high school, I rode a freight train with my father for six days, right before Christmas, to arrive in Idaho with a hundred head of heifers and four or five milk cows, to start our dairy in Idaho. I got well acquainted with those cows, being boxed up for six days with them. We had five cows milking while we were feeding calves, trying to move as much of the genetic stock as we could to start our new dairy in Idaho.

Acres U.S.A. And then where did you go to college? Did you do ROTC, or how did you get into the Army?

Huber. I enlisted in the Idaho National Guard out of high school, toward the end of the Korean War. I joined an aviation engineer unit as a private and had the opportunity to work in the shop doing maintenance on heavy equipment. Our responsibility was building emergency landing strips and facilities to support the Air Force and the Army.

I went to the University of Idaho through ROTC and got my commission and also a master's degree at the University of Idaho. I was assigned to a special Army Reserve research and development unit that was just established at Washington State University while I was working on my master's. Our responsibility was to develop the recovery plan in the event of a nuclear attack. That's where I really gained an education in plant physiology and nutrient relationships. Sylvan Wittwer and all the top physiologists, MDs and veterinarians were pulled together for this special unit. I just happened to be the young person that could run errands and provide a little input.

It was more of a learning process for me at the time. It's where I learned about the interaction between plants and fallout materials — recovery times and interactions between strontium, for example, and essential nutrients. We were trying to discover the things that we would need to do to maintain the basic functioning of a society in the event of a nuclear attack. It was a prime time in my career and a prime subject for us at the time, in the Cold War — to have the plan developed in the event that we needed to use it.

Acres U.S.A. What were some of the results from that? What is the plan for soils that are saturated in radioactive isotopes?

Huber. That's what they're going through with their plans in Ukraine right now. When the war's over, how do you recover? You have contaminated soils from all the military chemicals, but in their event, they still have Chernobyl. You dig six feet down the foxhole, and you still have very high exposure to some radioactive materials in close proximity to the 1986 meltdown event.

When Chernobyl happened, one of the things USDA and State Department were concerned about was how to provide food for everybody who was contaminated downwind from the meltdown. The problem isn't just the area of the reactor. Of course, one of the first thing you do is to get potassium iodine pills and get your level up so that you can protect against some of the adverse interactions that would come about from the fallout materials. We thought initially that those soils may be uninhabitable for up to 300 years. But that's not realistic at all — that's just panicking. It's actually a very hot radioactive area for 10 or 12 years, or 20 years. But then you get out farther

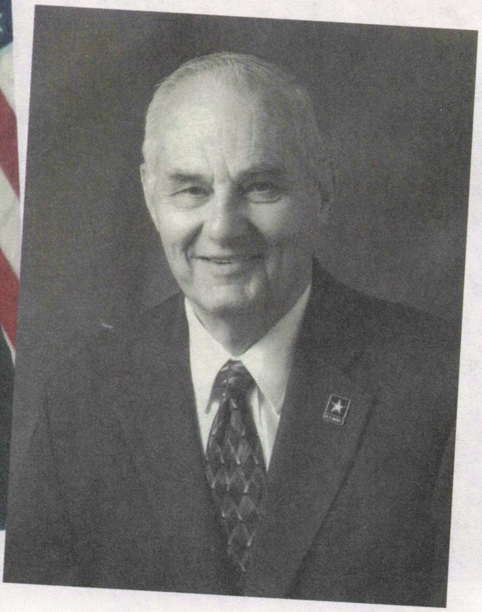


PHOTO COURTESY OKLAHOMA STATE UNIVERSITY away from that source and it starts becoming more manageable. You look at Hiroshima and Nagasaki after the atomic bomb, and they're both thriving cities now.

But you need to have that plan so that you can be prepared. It's similar to what we're doing now — we have a recovery plan for crops — a national plant disease recovery program. I had the privilege of chairing it for a few years, and I served on it for a number of years. We made a plan for animal diseases and also one for humans. We had a recovery plan in place for COVID — for a pandemic viral situation. It had been rehearsed. We had people lined up, and we had facilities and alternate facilities all lined up. And we still have, according to some of the people working on the human recovery plans, 63 or so million doses of hydroxychloroquine sitting in pre-staged areas so that we wouldn't disrupt the normal medical needs of the communities and country. With COVID, all of that apparently was totally ignored, and we did exactly the opposite of all of our training and all of our experience from the swine flu epidemic, or from the concerns about an epidemic, back in the '70s. All of that information, for some reason, was totally discarded and ignored.

But I had that privilege of working on and learning from that project and learning from some of the top physiologists and medical personnel too, spread over my military career. That in many ways paralleled my academic career. My military assignments were in the chemical and biological warfare units on a recovery defense research program.

Acres U.S.A. Were you National Guard or Reserves this whole time, or did you do any time on active duty?

Huber. I was commissioned in surface-to-air missile systems. My active duty was very short, because they trained us in the Nike Ajax surface-to-air missile system, and I was the last class that went through that program. They shifted over to the Hercules, a larger missile system than the Ajax, and the Army asked if there was anything else I wanted to do for my six-year obligation, and I said I'd like to go on for a Ph.D since I had that opportunity available at Michigan State University.

So, the Army assigned me as a Reserve officer to the biological labs at Edgewood and Fort Detrick, Maryland, working with biochemists and microbiologists. My research at Michigan State for my Ph.D. in plant pathology was on biological control of soil-borne plant pathogens and paralleled my Army work.

In 1969, when President Nixon unilaterally closed out our chemical and biological warfare programs, I was shifted officially from artillery surface-to-air missile systems to the medical service branch. For a few years, I was with the U.S. Army Medical Intelligence and Information Agency, but eventually all of the medical intelligence programs for all of the services were brought under one umbrella to form the Armed Forces Medical Intelligence Center, based at Fort Detrick.

For eight years I was the commander of a Strategic Medical Intelligence detachment. I had 12 professionals in the unit, and we all had specific assignments for DIA or for the surgeon general, or general military assignments from the Joint Chiefs of Staff, to develop those strategic plans and programs. I retired after 42 years of reserve and active service as associate director of the Armed Forces Medical Intelligence Center.

Acres U.S.A. How much overlap was there between your Ph.D. work, or your teaching work at Purdue, and your defense work? A lot of it was classified, but to what degree did that inform the research that you did during that time and since?

Huber. I stayed on as a contractor for some time and continued a lot of that research. It was similar to what I was doing — maybe different organisms, different entities, but similar principles from an epidemiological and disease control standpoint.

Acres U.S.A. When did you first learn about glyphosate? Did you first hear about it as an herbicide, or as an antibiotic, or as a chelator, or all of the above?

Huber. I first became aware of glyphosate when some of my research plots followed the plots of our weed scientist in the 1973-74 period. He was looking at this new miracle herbicide at least two years before it was commercialized, to see its applicability and to get familiar with it.

These were corn or soybean plots, and then we'd follow up with a wheat crop after that in Indiana. And every time wheat was grown on a plot where glyphosate had been applied, you could pick out those plots fairly accurately by the increase in disease. We were seeing several diseases increased, but take-all on wheat was one that I had focused on for 25 or 30 years. We don't have good resistance to it. We don't have any chemicals that are really effective to control it. So it's primarily a management issue.

I was looking at research that had been published for over 100 years, since take-all's first identification in Australia. It's a fungal root and crown rot that's common in all soils throughout the world. It's a ubiquitous organism, but it also causes probably the greatest losses — even more consistently than rust on cereals.

I'd had several grad students who were interested in soil ecology, and we had identified the mechanism that was involved when you have increased disease following certain crop sequences. We determined that the pivotal point from a disease standpoint was the availability of manganese. Manganese is a micronutrient requirement in the Shikimate pathway for lignification and plant cell wall formation. It's also very critical in photosynthesis and energy production. When you have anything that interferes with the Shikimate pathway, you have increased disease. If something is tying up any of the micronutrients that are involved — manganese, cobalt, copper, zinc — you get that interference.

But we realized that manganese was the most important of these. Manganese is a very deficient element in many of our soils today, and soybeans have a high requirement for manganese. In 1994, the first crop that was genetically engineered to tolerate glyphosate came out. There's a major effect, from a disease standpoint, when you use a compound like glyphosate, which chelates minerals like manganese.

Now, the information that was available in 1974 was that glyphosate worked very specifically — that it only inhibited one enzyme, and that was the EPSPS enzyme, at the top of the Shikimate pathway. Glyphosate would shut down EPSPS, and that would affect the whole pathway. My interest in glyphosate was because of that increase in disease severity. And of course, with FIFRA [Federal Insecticide, Fungicide and Rodenticide Act] regulations, if a chemical increased disease, it wasn't supposed to be registered, or there would be limitations on registration.

Glyphosate affected the Shikimate pathway. Of course, from a registration standpoint, they said it can never be toxic to humans or mammals be-

cause we don't have a Shikimate pathway in our cells. Of course, we know that's not true for microorganisms in our gut — it is toxic to us. But for registration, they said, "We don't need to do any toxicology studies because it can never be toxic to mammals."

Acres U.S.A. Did you realize at that point, or had you already known, that glyphosate was a chelator and an antibiotic as well? Or was that something that you had to discover that they weren't advertising?

Huber. I had to go back and ask, "Well, what's this chemical really doing? What's its herbicidal mode of action?" Guri Johal had joined our

Glyphosate makes farming easier — but at the cost of mineral chelation, the degradation of soil biology and increased risk of disease.

staff as a molecular biologist and plant pathologist, and in about 1984 he looked at glyphosate and showed that it was a chelator, and its mode of action as a herbicide was to increase disease severity. You can't kill a plant with glyphosate in sterile soil; it has to be a field soil or have fungi and bacteria in it. You can stunt a plant, but you can't kill it with glyphosate unless you have those soil-borne pathogens there.

I started looking at what was different with this material compared to other herbicides. Why were we seeing the increase in take-all if it wasn't doing something to manganese? Because everything else, if it increased take-all, would be chelating or tying up manganese — or would be toxic to the organisms that make manganese more available in the soil.

Everything that was known at the time fit that central focus point. Glyphosate affected the Shikimate pathway and wasn't supposed to be toxic — it was only supposed to inhibit one enzyme — but it was giving us a large increase in disease severity. We then realized that Stauffer Chemical Company had patented it as a mineral chelator in 1964. It had been used to clean steam pipes and boilers and sold as a mineral chelator, especially for manganese and other plant essential elements.

I started setting up my own research to satisfy that curiosity — to ask, does glyphosate really fit the model that we had been building for 20 years, or is there something we had missed? And it still fits the model very well, as far as the chelating.

Now, as far as its antibiotic activity, that became apparent very early because we were also doing a lot of soil ecology studies, with the manganese cycle and nitrogen cycle especially. Glyphosate would increase the oxidizing organisms that make manganese less available. In fact, there's about a twelvefold increase in

CHAFER MACHINERY, FLIKR

population of the oxidizers and about a tenfold reduction in the organisms that can reduce it. Glyphosate as an antibiotic was fairly specific from a functional standpoint relative to mineral nutrition.

And then in 2000, Monsanto — who I did a lot of cooperative work with for a number of years — patented glyphosate as an anti-parasite and antibiotic compound. They recognized that it had that activity. They didn't report any negative activity, as I remember, against beneficials. But it turned out that it has a very dramatic effect against beneficial microorganisms, and a very dramatic effect in increasing virulence of the parasitic pathogenic group of organisms. Bob Kremer then followed up on that and did some excellent research showing that increase in virulence and infectivity in the presence of glyphosate and the deleterious effects against beneficials — nitrogen-fixing organisms, hormone producers, and other organisms that we rely on in agriculture for providing nutrients to plants.

Acres U.S.A. When GMO technology came along in the '90s, were you more opposed to it because of the actual genetic alterations or because it enables more use of glyphosate and other herbicides? Is one of those factors worse than the other?

Huber. It depends on the individual, I guess, and what their exposure is. But our whole concept of genetics that we'd had before had to be pretty much discarded with genetic engineering. When you start sequencing, all of a sudden you realize that it's not a gene-for-gene concept or a gene-for-function concept — it's a spatial relationship in the genetic material that determines the function. You realize that when you're changing that spatial relationship between genetic materials — between nucleotides — that is what determines the functionality of the genetics. You're doing some major changing spatially when you insert new genetic material or delete it.

If you're editing, you're essentially deleting that material from a functional relationship. And it's not just one entity that's changed; you may select for one entity, as they did with the Roundup-ready GMOs — but that's just one of maybe 1,400 or 1,500 other changes that occur in that transformation because of the change in spatial relationship. When you look at genetics, you have to look at it like a Rubik's Cube. You change one thing and you change the other faces in that cube.

Really, when you look at tomography — how nuclear material is really spaced — it's more like a big ball of yarn. All of those contact points, or all of those spatial relationships, are changed. We have no idea what those new proteins are really doing. We know that they're a critical element from a toxicity standpoint.

With genetic engineering, you have to realize that you can never duplicate something. You don't get the same thing. Monsanto demonstrated that with their Bt genetics (A10) — you may produce the same Cry toxins, and the Bt effect may be similar with two or three different genetic combinations, but if you look at the whole picture, there may be 1,400 or 1,500 changes with one, and the same number with another one, but they're not the same 1,400 or 1,500 changes.

There's all kinds of opportunities for very serious effects, especially from a chronic standpoint. I had some access to some of Monsanto's studies that were later published, and you see that change. They cut the testing period down from a two-year period — the life expectancy on the rats — to three or four months. "It's not an acute toxin, so it's okay. It's substantially equivalent." Well, there's no such thing as substantially equivalent in the biological environment.

The biological warfare approaches and research that some of our adversaries were doing focused on nitrogen-protein, amino-acid types of compounds — peptides, CHAT peptide-type things. And you look at the toxins that we know, and many of them are peptide related and nitrogen related. With genetic engineering, we have hundreds of them occurring that we have never seen before. They're all synthetic; they're all new compounds. I have some serious concerns about genetic engineering without some safety studies. There's negative potential there. The other question is, once it's there, how do you get rid of it? You can contaminate the entire germ plasm base very

quickly and not recover.

Glyphosate is a very broad-spectrum mineral chelator that functionally immobilizes eight or nine critical elements that are essential elements for plant growth. And nobody wants to compensate for them. A researcher at Kansas State pretty much lost his job as a result of publishing his research on Roundup-ready soybeans requiring two and a half to three times more manganese than the normal wild-type parent. He published his data so his growers would realize that if you're going to use this technology, make sure you compensate for the missing mineral requirements.

Levels of manganese that are required with glyphosate treatment of soybeans are very toxic to the wild type of beans. And yet it takes two-and-a-half to three times that much manganese, from a functional standpoint, in the Roundup-ready soybeans. When he published his research, the outcry from the companies and others was severe enough that he had to publish a letter of apology for publishing his science. He said he didn't understand the unintended consequences of letting people know how to keep their crops healthy and functional. And then eventually he moved on from the position. There are three or four other examples of people who lost their jobs because they said, "I'm just reporting what I'm seeing."

The problem is both from a direct effect of glyphosate, as a mineral chelator, and the effect then on physiological processes that would provide resistance or tolerance to disease. And genetic engineering permits the increased usage of the material that compounded the direct effects.

Acres U.S.A. You've said that 20 percent of glyphosate that's sprayed ends up going into the soil. That has to be part of what makes it so effective.

Huber. Yes, it's systemic. You don't have to have thorough coverage, like we did with other contact herbicides, and you can put it on at any time. You aren't restricted to just the dry period before planting. You can put it on over the crop whenever you get around to it, rather than having to do it at a specific time. But it's systemic, so it bioaccumulates in the plant in the meristematic tissues and in the reproductive tissues.

I was working with Malcolm Sumner and a number of others in Central America on glyphosate in sugarcane, and six hours after putting glyphosate on 12-foot high sugarcane stalks as a desiccant, there was more than a hundred times more glyphosate in the stalk tissue, where the sugar was accumulating and the minerals were accumulating, than was required to chelate and immobilize all of the unbound essential minerals.

So, it very quickly mobilizes throughout the plant. You can read it on the bottle — it says that glyphosate gets the roots. And that's another concern because it moves freely into the root system. You have a little zinc deficiency created as a result of that chelation effect. In that six-hour period with the sugarcane, 94 percent of your manganese and iron disappear from a functional standpoint in the plant, and about 35 percent of your zinc.

The zinc deficiency alone increases root oxidation and loss of sugars and hormones and amino acids; they just flush out into the soil. That's one of the reasons we have increased disease — you're feeding pathogens and breaking dormancy with that flush of nutrition that should be going into seed production or into vegetative growth; it's all of a sudden just washed into the soil.

Glyphosate is highly water-soluble, and it's highly systemic. It may only move about a half inch in the soil, but it chelates very rapidly in the area it's exposed to. The problem, when you put it on a Roundup-ready plant, is that it's still systemic. It may not kill the plant, but anywhere that root system goes, glyphosate goes. It changes the biology, from the antibiotic effect, and changes the mineral availability — not just for a half inch or an inch, but for 20, 25 feet for alfalfa, for instance.

With glyphosate, you don't change one thing; you change everything. It's a chemical that does exactly what it was designed to do, and that's to kill.

Acres U.S.A. In the debate of whether to use glyphosate or to till, you would squarely be in the tillage camp. People are so scared of tillage destroying soil microbiology, though. How legitimate of a fear is that?

Huber. It's a lie. You cut up those fungal filaments with tillage and they multiply.

Acres U.S.A. Kind of like a rhizome for a plant or a weed?

Huber. Yes, same thing. You have a different microflora with tillage than you have with no-till. No-till is more like a climax environment. But most of our domesticated agricultural plants don't tolerate a climax environment as well.

Look at corn or sorghum. They're some of the few field crops that can grow on a continuous monocropping basis, similar to a climax ecosystem. One characteristic of a climax ecosystem is inhibition of nitrification. You don't have nitrate nitrogen in a climax system for several reasons. One is that it can't be utilized very well by a lot of the soil organisms that are part of that climax system.

The other thing is that the inhibition of nitrification is a nitrogen conservation process. The microbiome for climax will contain organisms that inhibit nitrification, or those nitrifying organisms just don't thrive in the overall environment that's there. We can modify our cultivated agricultural environment and reproduce that with a nitrification inhibitor. And we have several of those as commercial products. I worked for a number of years with nitropyrin (N-Serve), which is an excellent nitrification inhibitor. They're also very specific biologically to the nitrosomonas that convert ammonium-N to nitrite-N at rates that are used; it has no real significant effect on Nitrobacter that convert nitrite-N to nitrate-N. So, you're only stopping the first step in the conversion of ammonium to nitrate nitrogen. But we can use that process, or we can use plants to do the same thing.

In Brazil, for control of CVC — citrus-variegated chlorosis — Tuoshi Yamada worked out a system where he used Brachiaria grass, which is a good crop for inhibiting nitrification. He eliminated the glyphosate and replaced it with mulch from the Brachiaria grass, mulching it twice a year and throwing it under the citrus trees for weed control. Then, as it decomposed, it provided the nutrients for the tree from a fertility standpoint, but it also inhibited nitrification, so that he had an ammonium source of nitrogen for those trees without the conversion to nitrate nitrogen. This soil environment also favored the organisms that increased plant availability of Mn and Zn.

Corn has some inhibitory effect on nitrification — not real strong — but it's enough to be very significant for its own nutrition. It can utilize either form of nitrogen, but as you increase your yield potential, you want more ammonium because nitrate nitrogen requires a lot of sugar to reduce it to the amine form for protein and enzyme formation. You'd like to have that energy going into the seed rather than into the vegetative materials.

With no-till, you also have a tenfold increase in nitrification. You're leaching, and denitrification loss, or your volatilization losses of nitrogen, can be many times higher in no-till than they are in conventional till — in spite of how some of our logic would say that with tillage you're going to open the soil up and make it more volatile. That's not the way it is because of the biology. With no-till, you have stratification and a number of other factors; if we didn't have glyphosate, you could compensate for it through rotation.

With glyphosate, you don't see that. Its antibiotic effect works against the soil organisms — bacteria and fungi that are responsible for aggregation of polysaccharides and glomalin and all of those things that give you good soil aggregation for infiltration of water. You have to get water and oxygen to your roots. As water moves down, it pulls oxygen from the air down into the soil, and the roots benefit from that; they have to have it. With glyphosate, you kill many of those organisms that aggregate soils, such as polysaccharide-producing bacteria and mycorrhizae.

We took a soil profile in Ukraine a few months ago, and you could predict which one of those soil profiles had been under glyphosate herbicide and which ones had been under another conventional-type herbicide program, just by the changes in aggregation in the soil. A number of studies show that infiltration difference.

It's rare to have a void in nature. Soil will be colonized with something. Quite often, when you have the type of biological disruption that you see with several of our chemicals — even with soil fumigation, with methyl bromide — you have a lot of organisms that are still there. There's very rapid recolonization. You have a different change, but it's not as dramatic a change as with glyphosate.

When cover crops are grown — and it's great to see them — if they're terminated with glyphosate, you've just undone everything that that cover crop had the potential to do for you.

Acres U.S.A. Dr. Laura Kavanaugh, who's an expert in third-generation DNA soil testing, says that for a lot of soils from conventional land that glyphosate's been used on, they literally can't get a reading. There's no DNA in that soil — no microbial life.

Can you talk about the new sauerkraut study you've been working on — a study that shows how to potentially help get microbe-killing chemicals like glyphosate out of the soil?

Huber. We were looking at sauerkraut juice as a way to eliminate glyphosate or to clean up the soil from residual glyphosate. We've been using glyphosate for 50 years, and even if you stop using it, you can't say, "Poof, it's gone." It's not gone. It's tying up minerals. A lot of our essential minerals are becoming deficient to the crop, and yet there are a lot of them in the soil. But they're not available, either because they're chelated, or the organisms that would normally make them available aren't there. For example, some microorganisms take oxidized manganese or oxidized iron and convert it to the Mn^2 or Fe^2 form for plant uptake and solubility.

Monica Krueger, a veterinary pathologist in Germany, demonstrated that raw sauerkraut juice in the feed

When cover crops are grown — and it's great to see them — if they're terminated with glyphosate, you've just undone everything that that cover crop had the potential to do for you.

of dairy cattle degraded glyphosate in the feed that was causing the chronic botulism that was killing many of the cows. This is a very serious problem here also, and most of our dairies just accept it and say, "Well, that's normal now." That's why you have a lot of dairy subsidies — because of poor management techniques.

We were getting some raw sauerkraut juice to see if we could follow up on Dr. Krueger's way of degrading glyphosate. If you look at the U.S. geological survey of glyphosate residues in the soil, in some places glyphosate has a half-life as long as 22 years. That's a lot of glyphosate sitting in the soil. What's it doing? Well, if it's just sitting there, it's tying up an awful lot of minerals that are essential for plant growth.

The other thing is that glyphosate and phosphate have the same binding sites in the soil. When you apply phosphate fertilizer, it can desorb the glyphosate and kill the crop. You can do everything right nutritionally and still kill a crop by desorbing residual soil glyphosate. A farm we were working with had calculated what their nutrition needed to be and had gone from 22 or 23 bushel-per-acre lentils up to 56-bushel. They then calculated what nutrients were required at those critical stages of growth to get 70 bushel. When plants were at the flowering stage, they were sampling every month and amending to bring the levels up.

On June 16, the tissue analysis showed that they were still short on phosphorus, so they made a foliar application, anticipating further growth and good green color and everything that you normally see from that application. Instead, in three days, the lentils went from a beautiful green to kind of a sick green, and in 10 days, the whole crop was dead. Rather than harvesting even the 56 bushels, they harvested seven. It was a real tragedy.

But on the sauerkraut, a sauerkraut producer had been trying to figure out why all of a sudden they had soggy sauerkraut — when they opened the fermentation vats, rather than sauerkraut it was more like applesauce. A million dollars of product had to be disposed of. This was with their organic sauerkraut, not the conventional. There wasn't any problem with the fermentation process. We checked out the salt they used, but that wasn't the problem either.

The difference was that certain fields that the cabbage was coming from would produce good-looking cabbage heads but mushy, soggy sauerkraut. All of the cabbage looked good. It was white, and the right flavors were there. They appeared to be sound and no different from cabbage from other fields.

So, we analyzed soil samples from the different production fields, and they were all similar, but there was a difference in some nutrients in the cabbage grown on them, indicating a tremendous difference in the availability of nutrients. There was plenty of copper and manganese and zinc in the ground, but the plant couldn't find it. We started asking what might cause this. The only difference between the organic and the conventional was in their fertility program, with the organic using poultry manure and the conventional using comparable rates of inorganic nutrients.

We analyzed the poultry manure for glyphosate, which isn't typically analyzed for, but that's the only thing we could think of that could explain why the plant wasn't able to find the chelated minerals in the organic manure versus the conventional inorganic. We got samples from the manure and found a deficiency of manganese. Even iron was only about half what we'd like to see. Zinc was in the pits, and copper was in the pits. And these are elements that glyphosate chelates. And of course, the turgor and structural integrity for the cabbage cell walls comes through the Shikimate pathway, which glyphosate is recognized as shutting down. It doesn't just shut off EPSPS — it shuts down all three of the pathways for lignin formation because it requires manganese and copper for all of those enzyme systems. The whole system is compromised.

Glyphosate was carrying through the manure from the contaminated feed that the poultry were fed — the desiccated crops that were being fed to the chickens. Organic production allows manure from conventional poultry houses. But for some reason, in 2021 and 2022 there was exceptionally large residual contamination — almost 10 times what we were finding in the 2023 and 2024 manures. The carryover contamination cost the company a million dollars in lost product.

We had another project that we had just initiated, looking at how to remediate glyphosate in the soil. It was fortuitous for both projects to occur at the same time. We were able to go back to those soils, where they put the manure out with the high glyphosate contamination, and we sprayed 15 gallons of raw sauerkraut juice on them, with untreated test strips, replicated plots, etc., so that we could compare the effect of raw sauerkraut juice on the quality of the sauerkraut. We also tested a new product, an eight-organism biological cocktail designed to degrade soil residual glyphosate. We could also follow those fields in the next year's crop, which in this case was corn.

The result was that with either the sauerkraut juice or the biological cocktail, 80 to 90 percent of the residual glyphosate in the soil was fully gone. It wasn't just the first step in the degradation process to AMPA; it was fully degraded.

When we harvested the corn on the plots, we were seeing an 11.4- to 14.4-bushel yield increase by just getting rid of the glyphosate. On the silage plot, we had two-and-a-half ton increased yield on the silage. We also did a dairy study on the impact on milk production, and we found a very significant increase in milk production for silage that didn't have that residual glyphosate.

When we degraded the glyphosate, we increased the availability of manganese, iron and zinc on that ground.

Acres U.S.A. It seems so simple — stop using this product that kills soil life and chelates all of your trace nutrients — but it's so difficult to change the whole system.

Huber. Well, we're trying to. Several people tried to get the poultry people to treat their manure. In organic production you have to use the fresh manure; you can use the composted version, but composting gets rid of nitrogen. That's the whole purpose of composting from a disposal standpoint — so you can apply more material. That's why conventional growers who use high rates of compost have phosphorus and potash problems — because they no longer have to worry about limiting the application based on nitrogen. But in organic production, fresh manure is your source of nitrogen. You need the fresh material from an efficiency standpoint.

We've tried to convince them to let us set up some plots with the manure to see if we could degrade the glyphosate rather than having to degrade it after it's spread on the field and contaminates the field. It's not difficult to do if you have access to the sauerkraut juice or the cocktail; we just spray it on and then lightly harrow it and protect it from UV light. It's easy enough to do. But the better thing would be to clean up the feed or get a clean source to start with.

And then of course you have the human consumption of these products and all the other inadvertent sources through the water. And we did look at irrigation water as a possibility for contamination. That was one of the first places we looked. These organic fields have been organic for 25 years at least, some of them longer, so none of them had had herbicides directly applied to them. Anything that was there had been moved in. And of course, that's where they had the contamination — with the manure, which is permitted in organic production. But I don't think anyone realized how much there was there.

There was a seedsman who heard my presentation at Rutgers when I was there, and he came up afterward and said, "We produce a lot of seed — corn and vegetable seed on about 2,000 acres — and we do use glyphosate, but we use it very judiciously." And he said, "Do you think we ought to sample some fields?" A couple of weeks ago he sent me the results, and he said, "Now what do we do?"

There were anywhere from 1,000 to 3,000 parts per billion of glyphosate in their soils, where they thought they were "very judiciously" using it. If you're using it for 10 or 15 or 30, or even the 50, years, and if you have 30 percent clay, there's essentially no degradation taking place. The glyphosate just accumulates.

I recognized that in Indiana — that we were having a yield drag from glyphosate. What do we do with fields like that? If you get a couple hundred pounds of gypsum or calcium, and a good source of the micronutrients, down the furrow, we would see an 8 to 12-bushel increase in soybean yields — to overcome the nutrient tie up from glyphosate.

But all that does is kick the can down the road, rather than solving the problem. Eventually — like with the lentils I mentioned — you get into a situation where you have ideal conditions for desorption of some of that residual glyphosate, and that's a disaster from a financial standpoint. The best approach that is now available is to fully degrade the residual glyphosate and recapture the minerals it had tied up. ACRES