GLYPHOSATE AND WHEAT, OFTEN NOT A GOOD MIX

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Glyphosate has been used in just about all forms of production agriculture for 40 years or more, but yet there are new things to learn about glyphosate almost everyday or a new allegation against glyphosate use makes the headlines somewhere almost everyday
For example, for years we discussed almost academically the specter of glyphosate-resistant weeds.

Now, glyphosate-resistant weeds are a reality and are having an impact on production agriculture.
So here is roadmap of where I’m heading today ...
I’ve got about 70 minutes of your undivided attention, so let me give you an idea what we’re going to talk about today:

1. Glyphosate history
2. Basic Chemistry of glyphosate, including:
   A. Biochemical Mode of Action
   B. Environmental fate
      1). Plant and soil persistence
      2). Behavior in the soil
3. Glyphosate and wheat
   A. Label uses in wheat culture
   B. Unintentional use (drift and contamination)
   C. Wheat residue sampling for glyphosate
   D. Remediation of glyphosate impacted wheat
Glyphosate history
Glyphosate History:

1. Initial patent issued to Stauffer Chemical; chelating agent, conversion of phosphinic acid to phosphonic acid
2. During development called MON2139, patent issued in 1969
3. Herbicidal activity discovered
   Monsanto scientist John Franz
3. Original Roundup herbicide released in 1974, contained the isopropylamine salt of glyphosate, water and a polyoxyethylene-alkylamine (POEA) surfactant
Chemistry of glyphosate:
Glyphosate chemistry ...

Glyphosate is a “zwitterion”
  ... carries both a positive and negative charge as do all amino acids
  ... If you took chemistry back when I did, you would have called zwitterions “dipolar”
Phosphonic acid group

Amino group

Carboxylic acid group

Phosphonic acid group
Environmental fate of glyphosate

AIR:
The vapor pressure of glyphosate is very low, virtually no glyphosate is lost via volatilization. In fact, glyphosate will partition into water versus air.

WATER:
Glyphosate is very soluble in water, approximately 11,600 ppm. Glyphosate is also stable in water over a range of different pH’s from PH 3 through PH 9 at 35 degrees C (95 degrees F).
**Glyphosate Environmental Fate**

**Soil:**
Soil ½ life: 3 – 144 days, even years in some instances; standard published value is about 45 days

“Irreversibly absorbed to soil particles and is not biologically available under relevant environmental conditions”

... most of the time
Once in contact with the soil, glyphosate is either bound to the soil particles or remains unbound in the soil solution.
Whether glyphosate is bound or unbound to the soil particles, impact degradation in the soil.

Unbound glyphosate degrades rapidly at a steady state...

Across most soils about 1% of the applied glyphosate is unbound and degrades rather rapidly.
Bound glyphosate degrades much slower in the soil, still at a steady state, but much slower than unbound glyphosate.

Primarily because it is difficult for microorganisms to adsorb bound glyphosate across cell membranes.
What else can impact glyphosate soil adsorption??

1. Soil texture/SOM/CEC
2. Soil phosphate level itself ...

   Glyphosate, apparently has to compete for the same specific soil binding sites with inorganic phosphate ... so, the higher the PO$_4$ level in the soil, the more glyphosate may remain unbound in the soil solution ... potentially “available” for plant uptake
Some research greenhouse studies under carefully controlled conditions have suggested that glyphosate may be “remobilized” with the addition of P fertilizers (back into the soil solution)

Don’t panic yet ...  
It not quite that simple
Plant roots *can* take up glyphosate from the soil solution, but that usually does *not* occur.
Regardless of whether glyphosate is unbound in the soil solution, bound to soil particles, or in plant tissue when it is metabolized (broken down), the first stable product will be AMPA. Glyphosate to AMPA is a one molecule for one molecule reaction.
AMPA IS MORE PERSISTANT IN THE SOIL THAN THE PARENT GLYPHOSATE MOLECULE IS, WHY ??

1. AMPA may bind tighter to the soil particle than glyphosate does, so it is harder to desorb AMPA than glyphosate.

2. AMPA is less likely to permeate the cell walls or membranes of soil microorganisms, so it is not readily taken up.
Glyphosate microbial decomposition is both aerobic and anaerobic

aerobic

anaerobic

Oxygen

Atomic Number: 8
Atomic Mass: 16
<table>
<thead>
<tr>
<th>Sample number</th>
<th>Glyphosate residue (ppm)</th>
<th>AMPA residue (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;0.010</td>
<td>0.071</td>
</tr>
<tr>
<td>2</td>
<td>&lt;0.010</td>
<td>0.042</td>
</tr>
</tbody>
</table>
Glyphosate persistence

PLANT TISSUE:

1. Glyphosate can be very persistent in plant tissue (1 year or more), resides in the vacuole of the cell

2. Reduction in residue levels may be a function of growth dilution as well as metabolism of glyphosate to AMPA

3. Metabolism of glyphosate very species dependent
1. More than just inhibiting aromatic amino acid synthesis
2. Sub-lethal dosages can cause PGR type symptoms
There are four essential aromatic amino acids that plants synthesize:

1. Phenylalanine
2. Tryptophan
3. Tyrosine
4. Histidine
Lets define the term “aromatic”

A long time ago, chemists decided to breakdown all organic (carbon containing) compounds into two groups:

Aliphatic (fatty)
Aromatic (fragrant)
The definition now is that in order to be considered “aromatic” it must contain benzene molecule or compounds that resemble benzene in terms of chemical behavior.
Aromatic amino acids get their names from the “aromatic” rings in their structures.

- Phenylalanine
- Tryptophan
- Tyrosine

Indole
Glyphosate’s biochemical mode of action is to inhibit one step in the biosynthesis of three of the four essential aromatic amino acids via the shikimic acid pathway.
To inhibit aromatic amino acid synthesis glyphosate inhibits just one enzyme:

5-enolpyruvoylshikimate-3-phosphate synthase

(EPSPS)
The aromatic amino acid Histidine, is not derived from the shikimic acid pathway and is not impacted by glyphosate
When a susceptible plant is exposed to glyphosate, the shikimic acid pathway is blocked and shikimic acid begins to accumulate like water behind a dam.
Shikimic acid accumulation in susceptible plant tissue

Alfalfa

![Bar graph showing shikimic acid accumulation in control and treated alfalfa tissues. The treated tissue shows a significant increase in shikimic acid content compared to the control.](image-url)
Shikimic acid or shikimate, (“ate” suffix means acid)

Shikimate is the starting material for “Tamiflu”
When a susceptible plant is exposed to glyphosate, symptomology may not be readily apparent for at least 3 – 5 days after exposure and complete plant death may not occur for up to two weeks or more.

But biochemically, things began to happen within the exposed wheat plant within an hour or so of exposure to glyphosate.
Glyphosate symptoms in wheat:

Symptom intensity from the same rate of glyphosate will vary year to year, may also vary between varieties, time of exposure, response to other plant stresses, etc.
No real visual symptoms, outside the area of suspected drift pattern, but 0.017 ppm residue
More to the wheat story

Some slight to moderate symptomology

Residue:
0.039 ppm

Chlorosis
Stunting
Reduced vigor
Slight necrosis
Closer to target field

Moderate to severe symptomology

Residue: 0.428 ppm

Severe chlorosis
Poor vigor
More necrosis
In a susceptible plant like wheat, glyphosate inhibits the shikimic acid pathway, which accounts for about 35% of the biomass of most plants.
At sub-lethal rates glyphosate acts like a PGR

Deformed heads, head-trapping, etc. are often the result of wheat exposure in the "joint" stage. FS 6 - 10
What else can cause a head trapping symptom in wheat??
What else can cause deformed heads in wheat besides glyphosate?

1. 2,4-D, MCPA, other PGR’s
   A. Too high a rate
   B. Late application (boot stage)
2. Cold temperature
3. 2,4-D, et al and cold temperatures
1. Glyphosate probably has no greater potential for drift than any other pesticide (esters potential exception)

2. Use is so great, if only had a 0.1% error rate, still a staggering potential for mishaps

3. The larger the application, the greater potential for off target movement
Droplet size, pressure, air speed ??

Wing Tip Vortices

Nothing seems to be hitting the ground ... !!
Probability of off target movement increases with the size of the application.
Residue sampling issues, whether glyphosate or not
Why are you taking the samples ... ??

1. Scientific curiosity
2. Diagnostic (why is the crop acting this way ?)
3. Potential food/feed residue issue
4. Other ...
Residue sampling issues, not necessarily unique to glyphosate ...

1. Clean and sanitary (you, your equipment and even your vehicle)
2. Sample suspected least to most
3. Untreated or background sample
4. Sample containers
5. If plant, what plant part?
6. If soil, how deep?
7. Soil companion samples?
Soil contaminated with *glyphosate* residue can impact foliar residue levels.

**Effect of Washing Wheat Foliage Samples**

Residue (ppm)

As Collected | Washed

- **Glyphosate**
- **AMPA**

![Graph](image-url)
1. Tap Water
2. Distilled Water
3. Air Dry and pat with paper towels
Glyphosate grain residue at harvest

Wheat plants exposed to low rates (drift) of glyphosate after emergence in the fall

EPA tolerance for glyphosate residue in grain is 30 ppm

EPA tolerance for forage, fodder and straw is 100 ppm
Glyphosate grain residue and test weight considerations

Glyphosate Residue Impact on Test Weight

\[ y = -5.418x + 61.952 \]

\[ R^2 = 0.3299 \]
y = -1.5907x + 12.412
R² = 0.1039

Glyphosate Residue Impact on Crude Protein
Remediation of *glyphosate* impacted fields:

1. Fertility and pest management
2. Water management (if irrigated)
3. Re-seeding or over-seeding
4. Over-seeding, with what?
Case in point: over-seeding S WWW with S W SW ... Good idea ??
What does it cost on a per acre basis to over-seed an impacted winter wheat field??

Use the note cards you were given.

You can identify yourself if you choose, if so, put down you contact information.

You can remain anonymous if you choose also.
As a young man, I was a combat engineer with the 101st Airborne Division, so in parting may I say ....
... that’s all folks, I’m outta here ... !!