Glyphosate, Soil Fungi, and Dry Bean Crops: Examining Risks and Resilient Alternatives

Author: Jennifer R. Depew, R.D.
Affiliation: H_6-FDC Research Initiative, **Email:** LymanForestPress@proton.me

Date: January 29, 2026

Core Thesis: Fungal pathogens are a key concern for producers of garbanzo beans, black-eyed peas, and other pulses. Emerging research suggests that the long-term use of glyphosate-based herbicides may be undermining soil health in ways that promote these very fungi, creating a cycle of risk for crop integrity, farm economics, and safety.

Abstract

The cultivation of dry beans (pulses)—faces persistent threats from soil-borne fungal pathogens such as *Fusarium* and *Aspergillus*, which compromise yield, seed quality, and food safety through mycotoxin contamination. This paper examines an emerging and self-reinforcing risk cycle: the widespread agricultural use of glyphosate-based herbicides, both on genetically modified crops and as a pre-harvest desiccant on pulses, appears to undermine soil health in ways that promote these fungi. We review evidence that glyphosate persists in soils, disrupts beneficial microbial communities, chelates essential minerals, and selectively favors pathogenic fungi, thereby increasing crop susceptibility and contamination risk. Further, we outline the cascading consequences for farm economics, worker safety, and consumer health, including the potential for dietary and inhalation exposure to mycotoxins. In response to this systemic challenge, we propose a shift toward regenerative strategies that rebuild soil resilience. Special attention is given to the potential of edible sumac (*Rhus coriaria*)—a source of antifungal polyphenols such as gallic acid and ellagitannins—as a low-cost, dual-purpose biocontrol agent. When integrated as a hedgerow and/or as a soil amendment made from the leaves, sumac may suppress pathogenic fungi while providing an additional revenue stream. This paper argues that reducing dependency on glyphosate, especially as a desiccant, and adopting ecological alternatives like sumac can break the cycle of fungal proliferation, enhance crop integrity, and align pulse production with evolving market and safety expectations.

Keywords: glyphosate, dry beans, fungal contamination, *Fusarium*, *Aspergillus*, soil microbiome, mycotoxins, regenerative agriculture, *Rhus coriaria*, biocontrol.

1. Introduction: The Pulse Producer's Dilemma

For a grower or processor of dry beans—whether it's garbanzos destined for hummus, black-eyed peas for a hearty stew, or any of the countless other pulses that nourish the world—the silent threat lurking beneath the soil surface is all too familiar. Fungal pathogens, particularly various species of *Fusarium*, are more than just an agronomic nuisance; they are a persistent adversary to profitability and quality.

The battle often begins unseen, with the fungus attacking root systems or colonizing seeds. The result can be stunted stands, premature plant death, or seeds that appear outwardly sound but carry the pathogen within. At harvest, the toll becomes clear: reduced yields, shriveled or discolored beans, and the ever-present risk of mycotoxin contamination—invisible, stable compounds that can jeopardize food safety, trigger regulatory scrutiny, and erode consumer trust. A single field with elevated mycotoxins can compromise an entire production Lot, turning a season's work into a financial loss.

Conventional wisdom points to management strategies like crop rotation, fungicide applications, and resistant varieties. Yet, despite these tools, the challenge persists and, in some regions, seems to intensify. This leads to a critical, and perhaps uncomfortable, question for the modern producer:

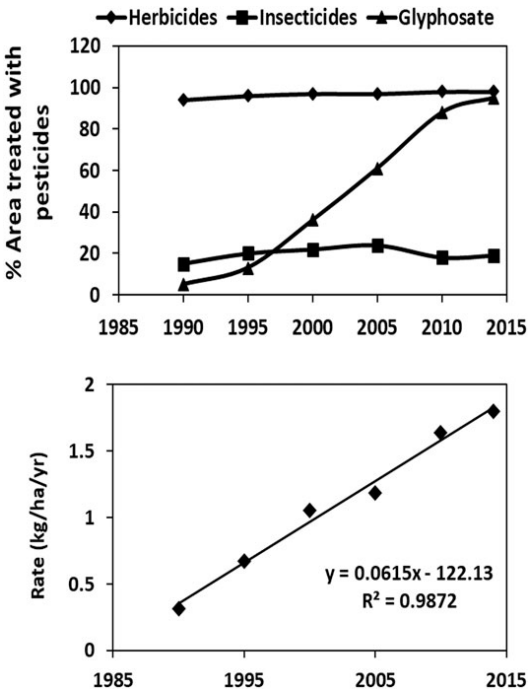
> **Could a tool we rely on for efficiency and weed control be subtly undermining our efforts against fungal contaminants?**

Specifically, could the widespread use of glyphosate herbicide—not only for field clearance but also, pertinently, as a pre-harvest desiccant on crops like lentils, peas, and garbanzos—be contributing to the problem it's meant to help manage… reduced yield due to biosystem competitors?

Emerging science suggests this widespread use of glyphosate herbicides on GMO crops or as a desiccant for other crops, may be altering the foundational ecology of the soil in ways that favor pathogenic fungi, creating a cycle where the solution to one problem inadvertently is fueling another—burning up beneficial soil bacteria that otherwise would keep soil fungus in check. This introduction of a synthetic amino acid analog can chelate essential minerals, reducing mineral bioavailability for the crops and for the beneficial soil microbes. This paper explores the connection between our chemical crop management choices and the biological resilience of our crops, serving to frame a dilemma that sits at the heart of sustainable pulse production and the heart of the home—traditional home-cooked bean soups and stews.

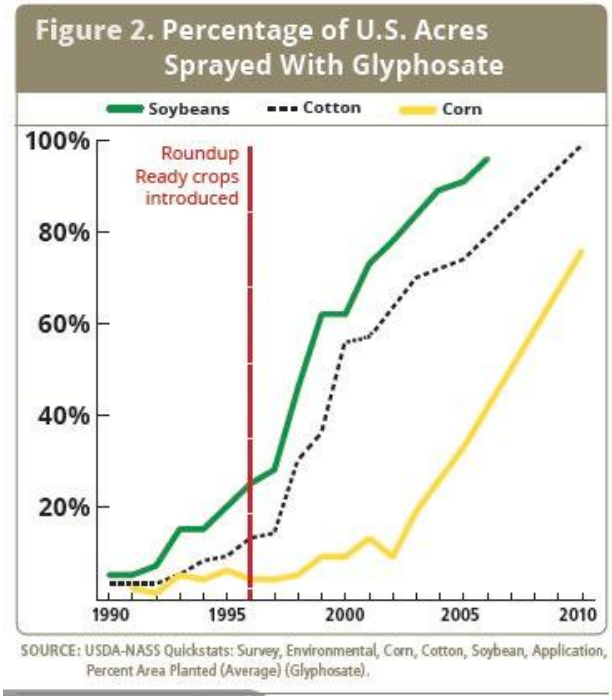
1.1 Glyphosate Herbicide and GMO Crop Timeline

Glyphosate herbicides were introduced in 1974, patented by Monsanto, and use was limited with a gradual increase in acreage of application on soybeans, cotton and corn until the later introduction of genetically modified versions of the crops to be tolerant of glyphosate's inhibition of the shikimate pathway which is used to make aromatic amino acids and lignan for seed coats. Root tips, also rich in lignan, seem particularly vulnerable to increased soil accumulation of glyphosate, however, even in the GMO crops.



"**FIGURE 1**. Increase in agricultural area treated with glyphosate (in comparison with total herbicides and insecticides) and in application rate on GR soybeans in the USA between 1990 and 2014 extracted from the United States Agricultural Statistics Service (NASS) website. http://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys." (van Bruggen, et al., 2021)

The introduction of genetically modified soy, cotton and corn to be glyphosate tolerant led to a rapid escalation in acres with Roundup Ready GMO crops, nearing 100% of soy and cotton and ~ 75% of corn, by the year 2010. See Figure 1. Increase in agricultural area treated with glyphosate (in comparison with total herbicides and insecticides)... between 1990 and 2014 (USDA-NASS, cited by van Bruggen, et al., 2021) and Figure 2. Percentage of U.S. Acres Sprayed with Glyphosate (USDA-NASS Quickstats).



"Figure 2. Percentage of U.S. Acres Sprayed With Glyphosate." Source: USDA-NASS Quickstats: Survey, Environmental, Corn, Cotton, Soybean, Application, Percent Area Planted (Average) (Glyphosate). (USDA-NASS, 2012; USDA-NASS, 2014)

Fungal risk to crops may be increasing regionally even if the crop is not treated directly with a glyphosate containing herbicide. Soil and groundwater may accumulate glyphosate leading to soil microbiome shifts even for crops that aren't treated with glyphosate-based herbicides or as a desiccant.

USDA-NASS QuickStats provides data on pesticide use, including glyphosate applications on corn, cotton, and soybeans, measured as the percent of area planted treated with the active ingredient.

- **Corn**: In 2021, **76%** of corn acres planted in Minnesota received glyphosate applications. Nationally, glyphosate is the most widely used herbicide on corn, with usage consistently high across years. (MDA-PFMD, 2022)
- **Cotton**: In 2021, glyphosate was applied to **74%** of cotton acres planted in Minnesota. The use of glyphosate on cotton is primarily through herbicide-resistant varieties. (USDA-NASS, 2021)
- **Soybeans**: In 2021, **59%** of soybean acres planted in Minnesota received glyphosate applications. (MDA-PFMD, 2022) Nationally, glyphosate is the dominant herbicide on soybeans, with usage exceeding 90% in recent years. (USDA-NASS, 2021)

These figures are derived from the Agricultural Chemical Usage, 2021 Corn, Cotton, and Rice Summary, accessible via USDA-NASS QuickStats under the program: Survey, Sector: Environmental, Group: Field Crops, Commodity: Corn, Cotton, or Soybean. Data are reported per active ingredient, with estimates in parent acid equivalents. (USDA-NASS, 2021)

2. The Soil Science: How Glyphosate Persists and Disrupts Soil Balance

- **Environmental Concern**: Glyphosate accumulates in soil over seasons more than anticipated and has been found in ground water and rain water, leading to regional accumulation. (van Bruggen, et al., 2021)
- **Soil Balance Mechanism**: Glyphosate acts as a broad-spectrum antimicrobial, suppressing beneficial bacteria and fungi that normally keep pathogenic fungi in check. (Rushton, et al., 2015)
- **Mineral Chelation**: Beneficial minerals bind with glyphosate leaving less mineral uptake for the crop plant or beneficial microbes, and leaving the crop with a lower ratio of minerals compared to traditionally grown crops. While overall yield may seem improved, the food itself is nutritionally depleted … more calories grown, but with less mineral content per calorie.

The USDA-NASS graphic (Figure 2) tells a story of increasing agricultural reliance and use of glyphosate-based herbicides. Over the last two decades, glyphosate has become the cornerstone of weed management for major crops like corn, cotton, and soybeans. In states like Minnesota, well over half of all acres planted to these staples are treated with it annually. The use as a desiccant adds more acres of wheat, oats, legumes and peas, and other crops. This widespread, repeated use of a synthetic amino acid over decades has revealed an unforeseen consequence: glyphosate doesn't always disappear from the ecosystem as quickly as expected.

Research now indicates that this molecule can persist in soil and water, binding to particles and accumulating over successive growing seasons. It is in the soil microbiome, the complex, living matrix of the soil, that glyphosate's most profound impact may be unfolding. As a broad-spectrum antimicrobial, its purpose is to disrupt a key metabolic pathway (the shikimate pathway) found in plants and many microorganisms. While the engineered "Roundup Ready" GMO crop-plant is shielded, the rest of the soil's inhabitants are not so lucky. Genetic drift to weeds is an added risk leading to

glyphosate resistant weeds that need additional herbicide applications costing more time and money and adding to a soil burden of potential toxins to beneficial microbes.

The result is a quiet revolution in the soil microbiome. Beneficial bacteria and fungi—the species that fix nitrogen, improve soil structure, and, critically, compete against or suppress pathogenic fungi—are particularly vulnerable to loss of the shikimate metabolic pathway. Loss of the beneficial competitors to fungal species creates an ecological vacuum, no one left to defend the land from fungal dominance. Into this void step tougher, often harmful, organisms. Among them are *Fusarium* species, fungi that are naturally more tolerant of glyphosate and now face less competition from bacteria or more beneficial fungi that cannot tolerate the glyphosate. The chemical treatment intended to clear the field of weeds is also inadvertently *preparing the soil* for a fungal takeover.

2.1 Glyphosate herbicides negatively impact beneficial soil fungi and nitrogen-fixing bacteria.

- **Beneficial Fungi:** Glyphosate significantly inhibits arbuscular mycorrhizal fungi **(AMF)**, which are crucial for plant nutrient and water uptake. (Nivelle, et al., 2018); Francis) Studies show that even low concentrations (as low as 1 part per million of Roundup) can reduce AMF growth and colonization. Glyphosate also disrupts the symbiotic relationship between plants and fungi, impairing the fungi's ability to support plant health and protect roots from pathogens like Fusarium. (Francis)
- **Nitrogen Fixers:** Glyphosate harms nitrogen-fixing bacteria (such as Rhizobium and Bradyrhizobium) and other beneficial microbes involved in nitrogen fixation. (Sibalekile, et al., 2025; Singh, et al., 2020; Kepler, et al., 2020 Nivelle, et al., 2018; Craven, et al., 2018; Friedlander, 2017; Francis; Soil Assoc.) It can reduce nodule formation and the overall nitrogen fixation process. Research indicates that glyphosate reduces nitrogen fixation at concentrations as low as 2 parts per million, with effects lasting up to 120 days after application.

While some studies suggest minimal or transient effects on microbial communities at standard field rates, the weight of evidence indicates that glyphosate disrupts essential soil microbial functions critical for plant health and soil fertility. (Craven, et al., 2018; CSANR.WSU, 2016)

This leads to a crucial and often overlooked point for pulse producers: the risk is not confined to fields where glyphosate is sprayed directly. The chemical's mobility means it

can affect nearby fields or accumulate regionally in watersheds. A farmer growing non-GMO, glyphosate-free garbanzos could still be facing elevated fungal pressure if their soil's natural defenses have been depleted by years of adjacent or prior use. The problem is systemic, rooted in the very health of the soil food web.

3. Exploring Solutions: Rebuilding Defense with Biology

Faced with this cycle, the path forward isn't simply to abandon tools, but to actively rebuild soil resilience. Crop rotation away from continuous Roundup Ready systems is a vital first step, allowing microbial communities to recover. The most promising long-term strategies, however, may involve working with nature's own chemistry to restore balance.

This is where an ancient, edible plant offers a strikingly modern solution: **the sumac shrub** (*Rhus* spp.).

Moving beyond the initial idea of sedum, sumac—specifically the magenta-red berries used to make the tart, lemony seasoning za'atar—presents a compelling case. Research in viticulture has demonstrated that extracts from sumac species exhibit strong antifungal activity, particularly against *Fusarium* strains that plague grapes. The principle is one of **allelopathy**: the plant produces natural biochemicals to defend itself against soil-borne diseases.

For a dry bean producer, this opens a fascinating possibility. Could sumac, planted as a perennial hedgerow, cover crop, or strategic intercrop, act as a living fungicide? Its root exudates and decomposing leaf litter could continuously replenish the soil with antifungal compounds, creating a hostile environment for pathogens like *Fusarium* and a supportive one for beneficial microbes. As a bonus, it's a non-toxic, drought-resistant plant that produces a harvestable, marketable spice crop—turning a cost center (soil treatment) into a potential secondary revenue stream.

Implementing this requires careful sourcing of clean plant material and on-farm trials to adapt the concept to legume production systems. Yet, the logic is elegantly aligned with the problem: countering a persistent chemical imbalance with a persistent biological solution. It represents a shift from treating symptoms with short-term chemistry to cultivating long-term health through ecological intelligence.

3. The Cascading Consequences: From Soil to Safety

Indirect risks may negatively impact soil microbes and bees, larger species and humans through increased risk for fungal illness or more pathogenic bacterial infections. Research on health risks of glyphosate herbicides have tended to be short in time span and focused on limited indicators of harm. (van Bruggen, et al., 2021)

> "More detailed studies showed reductions in specific genera or species as well as biological processes after glyphosate application. Plant growth promoting rhizobacteria and beneficial intestinal bacteria often are negatively affected, while pathogenic bacteria and fungi are enhanced. Such shifts in microbial community composition have been implicated in enhanced susceptibility of plants to *Fusarium* and *Rhizoctonia*, of birds and mammals to toxic *Clostridium* and *Salmonella* species, and of bees to *Serratia* and Deformed Wing Virus. In animals and humans, glyphosate exposure and concentrations in urine have been associated with intestinal diseases and neurological as well as endocrine problems, but cause-effect relationships need to be determined in more detail." (van Bruggen, et al., 2021)

3.1 Crop Risk of Aspergillus species in Dry Beans

Aspergillus species are common contaminants of dry beans and pose a significant food safety risk due to their potential to produce mycotoxins.

Aspergillus ochraceus is frequently found in dried beans and is a known producer of ochratoxin A (OTA), a nephrotoxic, hepatotoxic, and carcinogenic mycotoxin. It thrives in dried foods like beans, nuts, and oilseeds: arabica coffee beans, (Maman, et al., 2021). Kidney beans had the highest fungal presence of OTA in a study of 7 types with 52 samples, (Hitokoto, et al., 1981). Optimal growth of OTA occurs between 24–31°C with water activity (aw) of 0.95–0.99. (Asperigillus ochraceus, ScienceDirect)

Dried beans are a staple food in Brazil, with 70% of the population consuming them daily, making mycotoxin contamination a major public health concern. A study by Cordeiro, et al., (1995), confirmed OTA production occurred in all five types of Brazilian dry beans that were inoculated with *A. alutaceous* (now considered *A. ochraceus*) and incubated at 25°C for 28 days, with levels of ochratoxin A reaching about 200 mg/kg dry beans (*Phaseolus vulgaris* L.). Removal of the seed coat was associated with increased OTA suggesting the seed coat has a protective or inhibitory effect on fungal growth or OTA production, (Cordeiro, et al., 1995)

The shikimate pathway is necessary for production of aromatic amino acids which play a key role in the plant's production of lignans within the seed coat, (van Bruggen, et al., 2021), potentially giving another mechanism of action for increased vulnerability to fungal

pathogens when glyphosate herbicides are used on the crop or are over accumulated in soil and ground or rain water.

Other *Aspergillus* species identified in Brazilian dry beans from 14 cities, include *A. flavus* (aflatoxin producer), *A. niger* (fumonisin producer), and *A. westerdijkiae*, which may also produce OTA. Notably, no ochratoxin A biosynthesis genes were found in any of the 87 isolates tested, suggesting that OTA production may be rare or absent in the studied strains despite the presence of *A. ochraceus*. While *Aspergillus* species were prevalent in Brazilian dry beans, the primary mycotoxin gene risks identified were for **aflatoxins** from *A. flavus* and **fumonisins** from *A. niger*, with **ochratoxin A** gene presence being less consistently observed despite the presence of *A. ochraceus*. (dos Santos-Ciscon, et al., 2019)

The 2019 study by Cordeiro, et al., (1995) found that aflatoxin biosynthesis genes were present in 17 out of 39 *A. flavus* isolates, while fumonisin genes were detected in all *A. niger* isolates.

3.2 Human Health Risks include Farm and Production Staff and Consumers

- **Safety of Farm and other Workers:** There is risk of inhaling fungal spores (e.g., *Aspergillus*) during harvest/processing, evidenced by respiratory illness statistics. Protective respiratory masks may be advisable for staff working with dry beans, nuts and oilseeds.
- **Consumer Safety:** Dietary glyphosate residue on foods may have direct negative health impacts for neurotoxic and metabolic effects or digestive symptoms and may also have indirect negative effects from gut dysbiosis leading to negative overgrowth of fungus or toxic bacterial species in the gut microbiota.
- **Inhalation of Mycotoxins by Workers or Customers:** An aerosolized risk of residual mycotoxins on thin plastic packaged dry beans or nuts may be a health concern for the store employees and customers shopping near areas where the plastic packages were handled and displayed.

Inaccurate diagnosis of Aspergillus as a cause of deadly lung conditions may be leading to a false sense of this being a minor problem as pneumonia, asthma, or viral infections are more commonly thought to be causal in respiratory failure.

> "Few cases of Aspergillus lung infections resulting in death have been recorded, but possibly only because pneumonia, asthma or viral infections are assumed to be the cause of death when respiratory failure occurs. A fungus growing in the lungs has not been considered as a cause of death by most physicians. Nor does death

always occur, as the *Aspergillus niger* mold growing in the lungs might just cause a persistent cough and respiratory discomfort."

- *Dust Study is There More to the Story on GMO's?*, FarmandRanchFreedom.org.

"From 1980 through 2014, more than 4.6 million Americans died from a range of chronic respiratory illnesses, the researchers reported. While the risk was pegged at 41 deaths for every 100,000 people back in 1980, it rose to nearly 53 out of every 100,000 by 2014, representing a nearly *31 percent* spike over 35 years."

- Respiratory Disease Death Rates Have Soared, Sept. 29, 2017, WebMD.com.

Toxicity studies of chemicals focus on acute and/or cancer risks and glyphosate studies have also focused on shorter time lengths rather than chronic risks from low level exposure. Several research teams have shown that indirect effects involving shifts in the human microbiome may be a significant concern.

"Despite various potential negative side effects of GBHs for human beings and the environment (van Bruggen et al., 2018), the European Union authorized glyphosate use for five more years in 2017, but POEA-containing herbicides were prohibited (European Commission, 2017; Rueda-Ruzafa et al., 2019). Since that time, many additional scientific papers have been published on potential side effects of glyphosate and GBHs on plants and animals. Several of those papers have indicated that indirect effects on plant and animal health through changes in the associated microbiomes may be more important than direct effects on plant and animal physiology (Kiefer et al., 2021; Miyazaki et al., 2019; Motta et al., 2020)." (van Bruggen, et al., 2021)

4. The Systemic Challenge: Glyphosate in the Agricultural System

The glyphosate dilemma has become woven into the fabric of modern industrial agriculture since ~ 1974. Its foundation is the widespread adoption of genetically modified "Roundup Ready" soy, corn, and cotton. These crops enabled simple, broad-spectrum weed control, driving glyphosate to become the most-applied herbicide in history. This systemic reliance is the primary engine for the soil accumulation and microbial disruption previously discussed and presence in ground water and rain water … even "organic" products tested for glyphosate residue generally have been found to contain the synthetic amino acid derivative.

However, for producers of dry beans, there is a second, more direct point of entry: the practice of using glyphosate as a pre-harvest desiccant.

This application is a matter of logistics and economics. On crops like lentils, peas, garbanzos, and black-eyed peas, glyphosate is applied to kill and uniformly dry the plants, facilitating a quicker, more efficient harvest. This is a critical risk-management tool in regions with short harvest windows or unpredictable fall moisture.

Yet, this practice introduces profound contradictions and risks that directly impact a pulse producer's bottom line and market access:

- **The "Non-Desiccant" Desiccant:** Glyphosate is not a true contact desiccant like diquat. It is a systemic herbicide that requires 14-21 days to work, demanding precise timing at physiological maturity. Application errors can shrink yield and seed size *and* increase the likelihood of higher residue levels in the harvested bean.
- **Direct Residue Load:** This application places the chemical directly on the edible seed close to harvest, making residues on the final food product a near certainty. While regulators set "tolerances," the court of public opinion and discerning buyers are increasingly setting their own standards at zero tolerance and choosing to buy products meeting organic labeling standards.
- **The Market Barrier:** This is the critical business takeaway. Major buyers, particularly in premium, organic, and EU export markets, are increasingly rejecting crops treated with glyphosate as a desiccant. Its use can be a direct barrier to certification and a lucrative contract. As you found, it is often prohibited for seed crops due to germination concerns—a clear signal of its biological impact on the very vitality of the seed.

This creates a vicious cycle for the industry: A tool used to manage harvest risk and economic efficiency may be simultaneously:

1. **Degrading soil health** and promoting fungal pathogens that threaten future yields.
2. **Leaving residues** that limit market options and consumer trust.
3. **Potentially contaminating non-sprayed fields** through soil and water movement, putting even "clean" production at a disadvantage.

The systemic challenge, therefore, is twofold: breaking free from the agronomic inertia of a ubiquitous chemical, and escaping the economic trap of a practice that can close more doors than it opens. The farmer is caught between the short-term imperative of a clean harvest and the long-term risks to soil sustainability and marketability. This untenable

position is what makes the search for alternatives not merely an environmental concern, but an urgent business imperative.

4.1 Taking a Closer Look at Glyphosate as a Desiccant for Peas or Black-eyed peas

Glyphosate herbicides are used as a desiccant on peas and Black-eyed peas, though the practice is not without controversy and specific restrictions.

- **Purpose**: Glyphosate is applied pre-harvest to kill and dry down mature Black-eyed peas, facilitating quicker and more efficient harvesting, especially in regions with unpredictable fall weather. This helps prevent equipment clogging and storage issues caused by wet crops.
- **Regulatory and Staging Guidelines**: According to agricultural guidelines, glyphosate should only be applied when the crop is at physiological maturity (typically when seed moisture is below 30%) and at least seven days prior to harvest. This timing ensures the herbicide is translocated and reduces residue levels.
- **Limitations and Risks**: Glyphosate is **not a true desiccant**—it is a systemic herbicide. It takes **14 to 21 days** to fully dry down the crop, compared to true desiccants like diquat (Reglone), which act in 4–7 days. Applying it too early can reduce seed size and yield. Grower's comments are available regarding use of glyphosate as a desiccant for peas at (thecombineforum.com).
- **Market and Certification Concerns**: Glyphosate is not approved for use on seed crops due to potential germination issues. Additionally, many buyers, especially in export markets, do not accept crops treated with glyphosate, particularly for organic or non-GMO certification. Glyphosate residues have been detected in Black-eyed peas, raising concerns about dietary exposure.
- **Alternatives**: Farmers may opt for **true desiccants** (e.g., diquat, saflufenacil) or non-chemical methods to avoid residue issues, especially when targeting premium or organic markets.

Glyphosate is used as a desiccant on Black-eyed peas but its use is regulated, delayed timing is recommended, and use of it as a desiccant has become a negative for consumers looking for product labels stating "Organic" or "No-Glyphosate Desiccant Used" due to increased concern about negative health and environmental concerns. Bee Colony Collapse or other infections in bees may be another indirect effect of the combined toxin

load of herbicides and pesticides and malnourishment from feeding on pollen from monocropped fields. (van Bruggen, et al., 2021)

---

5. Exploring Solutions: Beyond Routine Chemistry to Regenerative Principles and a Specific Botanical Ally – Sumac Leaves

Regenerative farming focuses on restoring topsoil health and ecosystem biodiversity with companion planting or mixed crop planting using hand-harvesting methods among the variety. Monocropping increases risk of pathogens becoming dominant and reduces the variety of nutrients for pollinators of the fields. Flowers planted at the edge of fields may help pollinators have a more varied diet. No-Till farming or use of cover crops may help improve the water cycle, conserve bioactive phosphorus and and reduce biosequestration of nutrients. Leaving fields fallow intermittently and allowing foraging herd animals in that field for a season was a traditional farm practice that helped soil to regenerate.

- **Mitigation:** Crop rotation (No-Till article: GMwatch.org) and organic farm management can lead to lower glyphosate residue levels than commercial produce and products that have been tested. Consumers expect their food to be toxin free and modern agricultural methods lead to accumulation of chemicals with negative health effects directly and indirectly through increased presence of higher risk bacteria and fungal species.

The agricultural No-Till system suggests glyphosate accumulation within the soil could be reduced by rotating GMO-Round-Up ready crops with non Round-Up crops. Research findings suggest the chemical glyphosate remains in the soil longer than expected, over years of time, and collecting to levels that seem to support increased fungal pathogens. Some crops (root tips in particular) are also beginning to be affected by the increased saturation of glyphosate within the soil. (No-Till, GMwatch.org, 2018)

- **A Promising Ecological Idea:** Leaves from Edible Sumac may serve as a Natural Biocontrol against harmful strains of Fungus.
    - **Follow Nature's Methods**: Even "Organic" crops could be grown with the use of a natural biocontrol—the leaves of an edible plant that contain phytonutrients that naturally suppress pathogenic fungi through natural allelopathy.

- **Powdered Sumac Leaves**: The weed like shrub could serve as a low-cost, scalable soil treatment that could be part of an integrated strategy at soil remediation.
- **Consider the Source:** While sumac grows along roadways, source clean plant material (away from highways/contaminants) and test for contaminants in the soil additive being produced from sumac leaves of bioactive species such as *Rhus coriaria* but not the smaller landscaping shrub species: *Rhus aromatica)*.

Confronting the intertwined challenges of soil degradation, fungal pressure, and chemical dependence requires a fundamental shift in management philosophy. This shift is embodied in the growing movement toward **regenerative agriculture**—a system that seeks to sustain and actively restore ecological function. Its principles—rebuilding soil organic matter, fostering biodiversity, and closing nutrient cycles—are the antithesis of the extractive, chemically reliant model that has created the glyphosate dilemma.

For the pulse producer, adopting a regenerative mindset means revisiting and modernizing traditional strategies:

- **Diverse Crop Rotations:** Breaking monoculture cycles to disrupt pathogen lifecycles and rebuild a complex soil microbiome. The No-Till article's recommendation to rotate away from Roundup Ready crops is a first, critical step.
- **Organic Management:** While not a panacea, certified organic systems legally prohibit glyphosate use, eliminating the desiccant risk and forcing a reliance on biological and mechanical weed control, which inherently supports soil life.

These practices form the essential foundation. But true regeneration also calls for innovation—finding new, old tools that work with nature's logic. This is where an ancient, edible plant steps from the traditional spice cupboard into the forefront of ecological problem-solving: Edible Sumac (*Rhus coriaria*).

5.1. A Promising Ecological Tool: The Case for Sumac as a Biocontrol

Beyond its tangy flavor, sumac possesses a powerful defensive chemistry. As research confirms, extracts from *Rhus coriaria* leaves exhibit significant antifungal activity, specifically against formidable pathogens like *Botrytis cinerea* and—most pertinently—*Fusarium oxysporum*, the very agent of Fusarium wilt. The active compounds (flavonoids, tannins, and antioxidants like gallic acid) are produced by the plant as natural allelopathic defenses. (Jasso de Rodríguez, et al., 2015) An in vitro study found extract of *Rhus muelleri*

leaves at a concentration of 3363 ppm to have 50% inhibition of *Fusarium oxysporum*. (Jasso de Rodríguez, et al., 2015)

This presents a transformative opportunity in agriculture, to set nature's own biocontrol strategies at work against agricultural fungus. Imagine sumac not just as a crop, but as a strategic ecological ally integrated into the farm landscape:

- **As a Perennial Hedgerow:** Planting sumac shrubs along field borders could create a buffer zone, its root exudates and leaf litter continually replenishing the soil with antifungal compounds, reducing the inoculum pressure on adjacent bean fields.
- **As a Source of On-Farm Input:** Harvested leaves could be composted into a fungicidal soil amendment or used to create a water-extracted "tea" for targeted application.

The advantages are compelling:

- **Low-Cost & Scalable:** As a hardy, drought-tolerant perennial, it requires minimal input once established.
- **Dual-Purpose & Economically Resilient:** It produces a high-value, marketable spice crop (the berries), transforming a soil health practice into a potential secondary revenue stream, insulating the farm from commodity price swings.
- **Synergistic Health Profile:** The very gallic acid and antioxidants that suppress fungi are the same compounds studied for their human health benefits, including anticancer and antioxidant effects. This creates a powerful, holistic narrative from soil to seed to consumer health.

A Responsible and Critical Note: This proposal requires careful implementation. Not all sumac is equal. Some species, like fragrant sumac (*Rhus aromatica*), are susceptible to Fusarium wilt (Creswell, 2019), and use of their leaves might then worsen a fungal agricultural problem. Therefore, the strategy must focus on using well-characterized, disease-free *Rhus coriaria*, ideally through extracted compounds or thoroughly composted material from verified healthy plants, rather than indiscriminate planting of whole shrubs into infected soils. This underscores the need for on-farm research and collaboration with agroecologists to develop safe, effective protocols.

Sumac is not a silver bullet, but a potent component of an integrated, regenerative system. It represents a shift from battling symptoms with broad-spectrum chemistry to cultivating resilience through targeted biological intelligence. By leveraging a plant's own defenses, we can begin to repair the soil microbiome, suppress the pathogens that glyphosate

inadvertently promotes, and build a more viable, health-focused future for pulse production.

5.2 Edible Sumac Ellagitannins Are Also Protective for Human Health

Gallic acid and other ellagitannins are widespread polyphenols within popular foods and beverages including green and black tea, persimmon and pomegranate fruit and their leaves which can be used for a healing tea. Goji berries, red raspberries, and other berries and grape peels are sources and edible sumac berries can be used to make a lemony flavored tea or cold beverage and is powdered to use in small amounts individually at the dining table in Middle Eastern cuisine either alone or within the spice mix called Zataar.

Production facilities processing edible sumac berries for commercial use might add processing of the leaves for agricultural use as an additional revenue generating stream, or an agricultural company focused on developing a sumac leaf soil additive product might also process the edible magenta colored berries for human spice or beverage use or test use for farm animals, noting that it is quite potent and would be a phytonutrient additive, a 'spice' that can provide antifungal and other antimicrobial benefits to a diet. The tannin content acts as an irritant and strong diuretic in excessive quantities, leading to the need for caution and the sensible use in Middle Eastern dining as an individual additive, commonly found on dining tables as a salt shaker style container of sumac powder which adds a citrus accent and broad spectrum antioxidant benefits to a meal.

> "Gallic acid (3,4,5-trihydroxybenzoic acid, GA), a polyhydroxy phenolic compound, is abundant in natural plants such as gallnut, grapes, sumac, oak bark, green tea apple peels, grapes, strawberries, pineapples, bananas, lemons, and in red and white wine. Its antioxidative DNA-damage action has been well documented [122]. However, gallic acid induces apoptosis in several cancer cell lines by increasing ROS level and GSH depletion [123]." (Barrera, 2012)

6. Conclusion: Toward Resilient Pulse Production – From Soil Health to Shelf Integrity

- The health of the soil microbiome and mineral bioavailability is foundational to crop resilience to fungal or other pathogens.
- Reducing reliance on glyphosate, especially as a desiccant on beans, may be a critical step in breaking the cycle of fungal susceptibility and ultimately improving yield of high quality produce that is safer for food chain workers and consumers.
- Harnessing the power of ecological strategies (like sumac leaf soil additives or other cover crops and traditional farm practices) may be an economical method that

works with natural systems to ensure safe, sustainable dry bean production and more profit for producers by reduced crop losses and reduced risk of mold contamination spreading to other products.

The discovery of mold-contaminated dry beans on a store shelf is not a random event; it is the endpoint of a chain that begins in the soil. This investigation has traced that chain back to a critical, often overlooked link: the profound impact of agricultural chemistry on the living foundation of our food system.

The health of the soil microbiome is the fundamental determinant of crop resilience, seed quality, and ultimately, the safety and integrity of the bag of beans a consumer brings home.

We have seen how the systemic reliance on glyphosate—both as a pillar of GM crop systems and as a pre-harvest desiccant on pulses like garbanzos and black-eyed peas—can initiate a vicious cycle. By persisting in soil and suppressing beneficial organisms, this practice may inadvertently cultivate the very fungal pathogens, such as *Fusarium* and *Aspergillus*, that threaten yield in the field and cause spoilage and potential health risks post-harvest. The mold you encountered is a visible symptom of this invisible soil dysbiosis.

Therefore, breaking this cycle is not merely an environmental consideration; it is a direct imperative for quality assurance and brand protection. For a producer, reducing and ultimately eliminating reliance on glyphosate desiccation is a critical step toward this goal. It addresses the root cause of fungal susceptibility, reduces direct chemical residue on the seed, and opens doors to premium markets that increasingly reject this practice. Moving away from it is a strategic decision to invest in the biological capital of the farm.

The path forward lies in embracing ecological intelligence. This means rebuilding farm systems that work with nature's own resilience. Promising strategies like integrating edible sumac (*Rhus coriaria*)—a plant with proven antifungal allelopathy—as a perennial buffer or soil amendment, exemplify this shift. It represents the kind of innovative, regenerative thinking that can suppress pathogens, enhance biodiversity, and create additional value, all while stepping away from the chemical practices that contribute to systemic risk.

The choice is clear: continue with methods that may be undermining soil health and inviting quality failures, or pioneer a transition to strategies that build resilience from the ground up. The promise of ecological strategies is not just a sustainable future, but a reliable one—ensuring that every bag of dry beans is a testament to a healthy ecosystem, not a vector for mold and disappointment. For an industry built on trust and nutrition, there is no more important pursuit.

Disclaimer: This information is being provided for educational purposes within the guidelines of Fair Use and is not intended to provide individual health care guidance.

Conflict of Interest: The author declares that no competing interests exist.

Data Availability Statement: Not applicable.

Funding: This research received no external funding. It was undertaken solely due to the author's personal interest and initiative.

Acknowledgments: This work was developed by the author with support from AI systems including DeepSeek and Brave AI. All citations and empirical claims in this work were verified against primary sources by the author. Interactions with large language models (LLMs) were used for conceptual brainstorming and drafting assistance, in strict accordance with the principle that the human researcher must act as the final verifier and authority—a necessary guardrail against the inherent confabulation tendencies of current LLMs.

References

Aspergillus fungi and current treatment options is available here: aspergillus.org.uk, http://www.aspergillus.org.uk/content/treatment-aspergillosis-and-aspergilloma

Asthma (7% in 2001 to 8% in 2009, cdc.gov) https://www.cdc.gov/vitalsigns/asthma/index.html

Barrera, G., Oxidative Stress and Lipid Peroxidation Products in Cancer Progression and Therapy., *ISRN Oncol*. 2012; 2012: 137289. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3483701/

Cordeiro, M.S.C., Amaya-Farfan, J. & Moran, P.J.S. Ochratoxin-A production in Brazilian dry beans (*Phaseolus vulgaris* L.). *Mycotox Res* **11**, 16–20 (1995). https://doi.org/10.1007/BF03192057 or https://link.springer.com/article/10.1007/BF03192057 (Cordeiro, et al., 1995)

Craven, M., Myburgh, C., Rhode, O., Saayman-Du toit, J., (2018) The effects of herbicides on soil life; Part 2: Beneficial fungi and bacteria, GRAIN/GRAAN, grainsa.co.za, October 2018, https://www.grainsa.co.za/the-effects-of-herbicides-on-soil-life-part-2-beneficial-fungi-and-bacteria (Craven, et al., 2018)

Creswell, T., (2019) Fragrant Sumac Succumbs to Fusarium Wilt, Purdue University Landscape Report, Issue 19-12, July 30, 2019, https://purduelandscapereport.org/article/fragrant-sumac-succumbs-to-fusarium-wilt (Creswell, 2019)

CSANR, (2016) Comparing effects of herbicides, fertilizers, and tillage on the soil, December 8, 2016, *Washington State University-Center for Sustaining Agriculture and Natural Resources,* csanr.wsu.edu, https://csanr.wsu.edu/comparing-effects-on-soil/ (CSANR.WSU, 2016)

dos Santos-Ciscon, B.A., van Diepeningen, A., da Cruz Machado, J., Dias, I.E., Waalwijk, C., (2019) Aspergillus species from Brazilian dry beans and their toxigenic potential, *Int. J of Food Microbiology*, 292, 2019, Pages 91-100, ISSN 0168-1605, https://doi.org/10.1016/j.ijfoodmicro.2018.12.006. or https://www.sciencedirect.com/science/article/pii/S0168160518309243 (dos Santos-Ciscon, et al., 2019)

Farm and Ranch Freedom Alliance, Dust Study is There More to the Story on GMO's?*, FarmandRanchFreedom.org*, http://farmandranchfreedom.org/gmo-side-effect-dust-study/

Francis, R., Glyphosate toxicity – impacts on the environment and non-target species, Djanbung Gardens, Permaculture College Australia, https://permaculture.com.au/glyphosate-toxicity-impacts-on-the-environment-and-non-target-species/ (Francis)

Friedlander, B., (2017) Beneficial soil bacteria face a weed-killing threat from above, *Cornell Chronicle*, September 21, 2017, news.cornell.edu, https://news.cornell.edu/stories/2017/06/aristildeglyphosate (Friedlander, 2017)

GMWatch, (2018) Glyphosate & GM Crops are Harming No-Till Soils," GMwatch.org, Jan. 10, 2018, http://www.gmwatch.org/en/news/archive/2018/18067-glyphosate-and-gm-crops-are-harming-no-till-soils

Hitokoto, H., Morozumi, S., Wauke, T. *et al.* Fungal contamination and mycotoxin-producing potential of dried beans. *Mycopathologia* **73**, 33–38 (1981). https://doi.org/10.1007/BF00443011 or https://link.springer.com/article/10.1007/BF00443011 (Hitokoto, et al., 1981)

Jasso de Rodríguez, D., Trejo-González, F.A., Rodríguez-García, R., Díaz-Jimenez, M.L.V., Sáenz-Galindo, A., Hernández-Castillo, F.D., Villarreal-Quintanilla, J.A., Peña-Ramos, F.M., (2015) Antifungal activity in vitro of *Rhus muelleri* against *Fusarium oxysporum f. sp.*

lycopersici, *Industrial Crops and Products*, 75(B), 2015, Pages 150-158, ISSN 0926-6690, https://doi.org/10.1016/j.indcrop.2015.05.048. Or https://www.sciencedirect.com/science/article/pii/S0926669015301278 (Jasso de Rodríguez, et al., 2015)

Kepler RM, Epp Schmidt DJ, Yarwood SA, Cavigelli MA, Reddy KN, Duke SO, Bradley CA, Williams MM II, Buyer JS, Maul JE. (2020) Soil Microbial Communities in Diverse Agroecosystems Exposed to the Herbicide Glyphosate. *Appl Environ Microbiol*. 2020 Feb 18;86(5):e01744-19. doi: 10.1128/AEM.01744-19. Erratum in: *Appl Environ Microbiol*. 2020 Oct 28;86(22):e02262-20. doi: 10.1128/AEM.02262-20. PMID: 31836576; PMCID: PMC7028976. https://pmc.ncbi.nlm.nih.gov/articles/PMC7028976/ (Kepler, et al., 2020)

Maman, M., Sangchote, S., Piasai, O., Leesutthiphonchai, W., Sukorini, H., Khewkhom, N., (2021) Storage fungi and ochratoxin A associated with arabica coffee bean in postharvest processes in Northern Thailand, *Food Control*, 130, 2021, 108351, ISSN 0956-7135, https://doi.org/10.1016/j.foodcont.2021.108351. https://www.sciencedirect.com/science/article/pii/S0956713521004898 (Maman, et al., 2021)

MDA-PFMD, contact: Bruening, D., 2019 Pesticide Usage on Corn and Soybeans Grown in Minnesota, *Minnesota Dept. of Agriculture Pesticide & Fertilize Management Div.,* 6-22-2022, https://www.mda.state.mn.us/sites/default/files/docs/2022-07/2019pesticideoncornsb.pdf

Nivelle, E., Verzeaux, J., Chabot, A., Roger, D., Chesnais, Q., Ameline, A., Lacoux, J., Nava-Saucedo, J.E., Tétu, T., Catterou, M., (2018) Effects of glyphosate application and nitrogen fertilization on the soil and the consequences on aboveground and belowground interactions, *Geoderma*, 311, 2018, Pages 45-57, ISSN 0016-7061, https://doi.org/10.1016/j.geoderma.2017.10.002. https://www.sciencedirect.com/science/article/pii/S0016706117312004 (Nivelle, et al., 2018)

Organic Consumers, Monsanto's Roundup Spreading Fusarium Fungus, *organicconsumers.org*, https://www.organicconsumers.org/old_articles/ge/monsanto121503.php

Rushton, S., Spake, A., Chariton, L., (2015) The Unintended Consequences of Using Glyphosate (the main ingredient in the herbicide Roundup), December, 2015, Accessed at: downloads.regulations.gov, EPA-HQ-OPP-2009-0361-3813_attachment_1 (1) (Dropbox: https://www.dropbox.com/scl/fi/c4wlcb8ginjuwr4deksli/EPA-HQ-OPP-2009-0361-3813_attachment_1.pdf?rlkey=uvmnqbqxri5r84dvz4p2i7gig&st=calh4vtr&dl=0)

Sibalekile, A., Araya, T., Castillo, H.J., Kotzé,E., (2025) Glyphosate-microbial interactions: metagenomic insights and future directions, *Frontiers in Microbiology*, 16 - 2025, ISSN:1664-302X, DOI:10.3389/fmicb.2025.1570235 https://www.frontiersin.org/journals/microbiology/articles/10.3389/fmicb.2025.1570235 (Sibalekile, et al., 2025)

ScienceDirect, Aspergillus ochraceus, https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/aspergillus-ochraceus (Asperigillus ochraceus, ScienceDirect)

Singh S, Kumar V, Gill JPK, Datta S, Singh S, Dhaka V, Kapoor D, Wani AB, Dhanjal DS, Kumar M, Harikumar SL, Singh J. (2020) Herbicide Glyphosate: Toxicity and Microbial Degradation. *Int J Environ Res Public Health*. 2020 Oct 15;17(20):7519. doi: 10.3390/ijerph17207519. PMID: 33076575; PMCID: PMC7602795. https://pmc.ncbi.nlm.nih.gov/articles/PMC7602795/ (Singh, et al., 2020)

Soil Association, The impact of glyphosate on soil health The evidence to date, https://www.soilassociation.org/media/7202/glyphosate-and-soil-health-full-report.pdf (Soil Assoc.)

Sumac - an overview, ScienceDirect Topics, *sciencedirect.com*, https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/sumac

The Combine Forum, Members, 'Desiccating Peas', *The Combine Forum*, https://www.thecombineforum.com/threads/desiccating-peas.225921/

USDA-NASS, Guide to NASS Surveys, 2021 Field Crops, https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/2021_Field_Crops/methodology.pdf

USDA-NASS , 2014 Agricultural Chemical Use Survey - Corn Highlights, May 2015, USDA-NASS No. 2015-1, https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/2014_Corn_Highlights/

USDA-NASS, 2012 Agricultural Chemical Use Survey - Soybean Highlights, May 2013, USDA-NASS, No. 2013-1, https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/2012_Soybeans_Highlights/

USDA-NASS, Guide to NASS Surveys, 2021 Field Crops, https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/2021_Field_Crops/methodology.pdf

van Bruggen A. H. C. , Finckh M. R. , He M. , Ritsema C. J. , Harkes P. , Knuth D. , Geissen V. (2021) Indirect Effects of the Herbicide Glyphosate on Plant, Animal and Human Health Through its Effects on Microbial Communities, *Frontiers in Environmental Science*, 9, 2021, ISSN:2296-665X, DOI:10.3389/fenvs.2021.763917, https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2021.763917 (van Bruggen, et al., 2021)

WebMD, Respiratory Disease Death Rates Have Soared, Sept. 29, 2017, *WebMD.com*. https://www.webmd.com/lung/copd/news/20170929/respiratory-disease-death-rates-have-soared

Wolmarans, K., & Swart, W. J. (2014). Influence of glyphosate, other herbicides and genetically modified herbicide-resistant crops on soil microbiota: a review. *South African Journal of Plant and Soil*, *31*(4), 177–186. https://doi.org/10.1080/02571862.2014.960485 or https://www.tandfonline.com/doi/full/10.1080/02571862.2014.960485 (Wolmarans and Swart, 2014)