Comments on the Arkansas State Plant Board's Proposal to Restrict Dicamba Use

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EXECUTIVE SUMMARY AND INDEX TO KEY FINDINGS

Center for Food Safety (CFS) is a public interest organization that supports sustainable agriculture and has for many years warned of the adverse effects of the Xtend crop system, including dicamba drift damage. We fully support the Plant Board's proposal to prohibit use of dicamba herbicides after April 15th for the 2018 crop season.

Monsanto's attempt to characterize northeastern Arkansas as "aberrational" for the scale of dicamba crop injury it has experienced flies in the face of record-high complaint levels in states across the country. In fact, high complaint levels in northeastern Arkansas are fully explained by its unusually high concentration of soybean and cotton cultivation and other factors, without need to blame farmers or others (Section 3).

Close examination of Monsanto's volatility testing reveals: 1) The vast majority was not even conducted on XtendiMax; 2) Extensive reliance on largely meaningless "humidome" tests and flawed modeling based on them; and 3) Extremely few field tests, with those few that were done subject to serious defects and limitations. In sum, Monsanto's testing obscured rather than illuminated the real world impacts that its Xtend crop system would have (Section 5.1, Appendix 1).

Field studies by independent agronomists at the University of Arkansas and elsewhere show clearly that new dicamba formulations like XtendiMax are (nearly) as volatile as old versions, with lesser volatility directly after application but equivalent or greater volatility at later time points up to three days after application (Section 5.2).

The evidence for volatility as a major cause of dicamba injury is overwhelming, and includes the frequent observation of uniform symptoms across large fields, drift at long distances (> 1 mile) from the nearest application, and injury occurring to soybeans that are upwind of the application site (Section 5.3).

While Monsanto disputes "atmospheric loading" of dicamba as an unsubstantiated theory, three decades of Canadian research have definitely established this phenomenon as fact. It is conservatively estimated that nine-fold more dicamba enters the atmosphere in Arkansas than in Canada, proportional to use (Section 5.4, Appendix 2).

None of the alternative modes of dicamba injury hypothesized by Monsanto – dicamba contamination of tanks, putative contamination of other herbicides with dicamba, illegal use of old dicamba formulations, or improper use of new dicamba – come anywhere close to accounting for the many millions of acres injured by the herbicide. Monsanto presents little or no credible evidence to support any appreciable role for these alternative modes (Section 6).

Accounting for the increase in planting of Xtend crops from 2016 to 2017, Arkansas officials received nearly five times more dicamba injury complaints in 2017 than would have been expected based on 2016 figures, despite the widespread introduction and use of "low volatility" Engenia (Section 6.3).

There is overwhelming evidence of frequent and widespread vapor drift injury to sensitive crops in Arkansas and many other states even with label-compliant use of XtendiMax and Engenia (Section 7.0).

The XtendiMax label is complex, confusing and contradictory. Some sections appear to prohibit dicamba use whenever a "sensitive crop" is at some unspecified distance downwind of the application site, while others state that downwind buffer zones of a 110 or 220 feet are protective of those same sensitive crops (Section 8.1).

XtendiMax label restrictions dramatically shrink permissible spraying periods such that it becomes extremely difficult to effectively control weeds (Section 8.2).

The new XtendiMax label for 2018 is doomed to failure because it fails to include any provisions to address the herbicide's volatility. Moreover, the additional restrictions mirror those imposed by Missouri in 2017, which proved entirely ineffective at reducing drift injury (Section 8.3).

Dicamba injury caused serious yield losses in 2016, and is certain to do so in 2017. Yield losses depend on numerous factors, including the timing and rate of dicamba drift exposure, the number of exposure events, the crop and crop variety, and weather conditions following the exposure event(s). Average yields may mask losses experienced by individual growers with dicamba-injured crops, especially with good weather conditions this year. Agronomists warn that despite decades of research, these complicating factors make it impossible to predict yield losses from dicamba injury symptoms (Section 9.0).

Many farmers with dicamba-injured soybeans now feel compelled to grow Xtend varieties to protect against drift damage. This means forced payment of the premium for Xtend seeds; loss of premia in the case of non-GMO or organic growers who feel compelled to switch to Xtend; and the fundamental loss of the right to grow the crop of one's choice. Of course, the choice of "defensive adoption" is not available to farmers who grow sensitive crops other than soybeans (Section 10.1).

The dicamba drift debacle was entirely predictable based on the known volatility of dicamba and its use pattern in the context of the Xtend crop system. Numerous warnings from farmers, scientists and public interest groups over a period of seven years were ignored (Section 10.2).

The Xtend crop system was approved due to the outsize influence of Monsanto and other pesticide-seed companies on regulators and weed scientists, and the "desperation" of some farmers who believe they have no alternative to control problematic weeds. The dicamba debacle is a case study in what happens when American agriculture is turned over to unethical pesticide-seed suppliers (Section 10.3).

While some believe that the Xtend crop system is a necessary tool in the struggle to control herbicide-resistant weeds, in fact there is already evidence of growing or full-blown dicamba resistance in impactful weeds like Palmer amaranth, waterhemp and kochia. Like other herbicide-resistant crops, the Xtend system drives rapid evolution of resistance, and represents a lose-lose proposition from the perspective of both drift damage and resistant weeds (Section 10.4).

The dicamba debacle is due to both dicamba's volatility, and more importantly its post-emergence use in the Xtend system when surrounding crops are more susceptible to damage and higher temperatures exacerbate volatility. Future herbicide-resistant crop systems will cause substantial drift injury due to these systemic factors, even with herbicides less volatile than dicamba (Section 10.5).

Monsanto's attack on University of Arkansas weed scientists as "not disinterested" researchers should be rejected out of hand. University weed scientists regularly assess and recommend herbicide and seed products, including Monsanto's, as a normal part of their jobs. In contrast, Monsanto has a long record of scientific misconduct and producing junk science in promoting and defending its products, which accords quite well with its entirely insupportable arguments in this Petition and its broader "product defense" campaign with respect to Xtend and XtendiMax products (Section 10.6).

1.0 INTRODUCTION

Center for Food Safety (CFS) submits these comments regarding the Arkansas Plant Board's proposal to prohibit the use of dicamba herbicide after April 15th for the 2018 crop year. CFS is a public interest organization that supports sustainable agriculture and opposes harmful agricultural technologies. CFS has extensive experience in the field of herbicide-resistant crops and their impacts, and has for many years warned of the adverse effects of the Xtend crop system, including the dicamba drift damage that has afflicted farmers in Arkansas and many other states. We fully support the Plant Board's proposed dicamba restrictions, and applaud the state for defending the interests of its farmers.

2.0 OVERVIEW OF MONSANTO'S PETITION

Monsanto argues that Arkansas' partial ban on dicamba use is overly broad, because most crop damage has occurred in a confined area of the state, and in a limited time frame. The state's partial ban is said to to be "arbitrary" because Monsanto's data supposedly demonstrates that "low-volatility" dicamba produced by it and other companies could not be responsible for the dicamba injury observed in Arkansas, while explanations offered by independent scientists are contradicted by science. Monsanto then claims that dicamba damage is due to illegal use of older, more drift-prone dicamba formulations; contamination of other herbicides with dicamba; improper use by farmers; and the weather. Monsanto attacks the integrity of University of Arkansas weed scientists whose research and recommendations helped inform the state's action. The company claims further that restricting dicamba use would cause rather than prevent yield loss for Arkansas farmers, and that the state should have considered alternative solutions. The petition calls on Arkansas to overturn its partial ban and permit season-long use of Monsanto's XtendiMax and other "low volatility" dicamba formulations in 2018 and beyond.

3.0 IS MASSIVE DICAMBA DRIFT INJURY IN ARKANSAS REALLY AN "ABERRATION"?

A critical claim in Monsanto's petition is that Arkansas' experience represents an "aberration" in an otherwise "successful" rollout of the dicamba-resistant crop system everywhere else in the country in 2017.[1] This contention must be rejected out of hand. Many states other than Arkansas have experienced record numbers of dicamba crop injury complaints, with official complaint numbers approaching 3,000 and affected crops exceeding 3 million acres (Figures 1 and 2). In any case, Arkansas has a duty to adopt dicamba restrictions to protect Arkansas farmers, period, regardless of how it compares to other states.

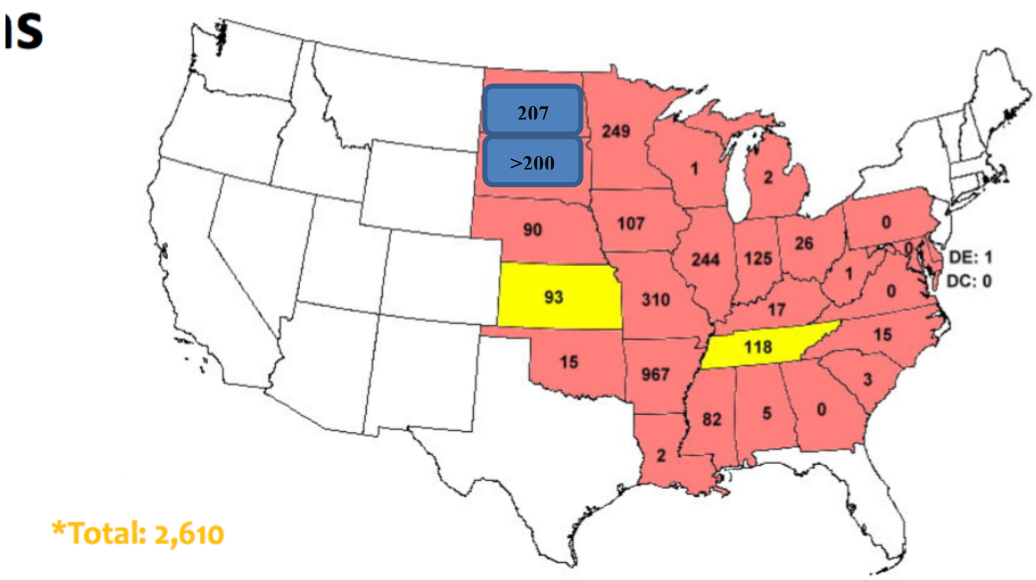

Figure 1: Official dicamba-related injury investigations as reported by state departments of agriculture as of September 15, 2017 (AAPCO 2017, Figure 2). South Dakota updated from 105 to >200 complaints based on AP (2017). North Dakota updated from 32 to 207 complaints based on ND DoA (2017). The additional 270 complaints in ND and SD yield a new total of 2,880 complaints.

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[1] While dicamba-resistant cotton and soybeans have been grown on a limited basis since 2015 and 2016, respectively, EPA first registered "low-volatility" dicamba formulations for use on dicamba-resistant crops for the 2017 crop season. Thus, 2017 is the first year both elements of the system were available.

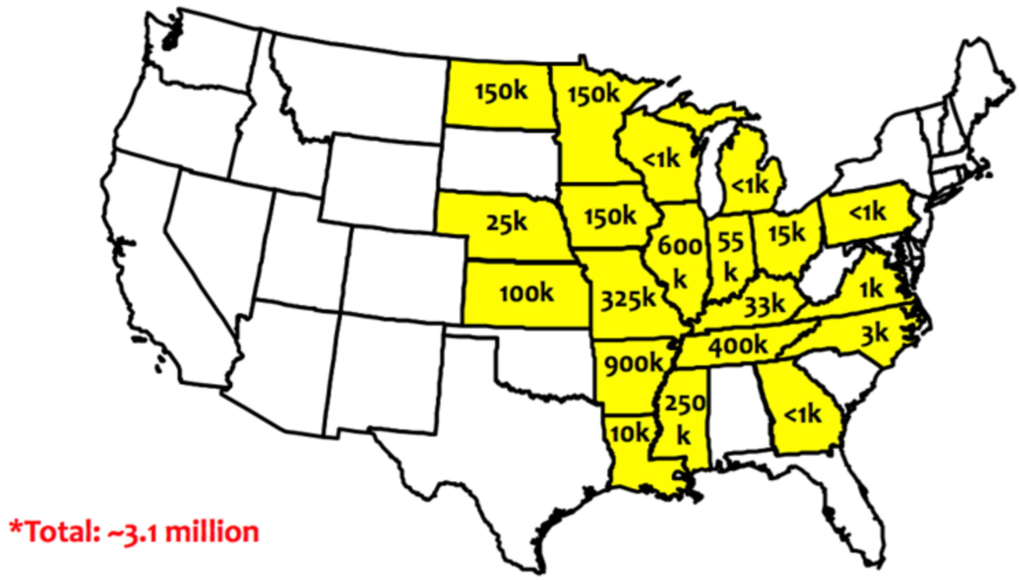

Figure 2. Estimates of dicamba injured soybean acreage as reported by state extension weed scientists (as of August 10, 2017) (Bradley 2017c).

3.1 Dicamba Injury Outside of Arkansas

<u>Mississippi</u>

"Honestly, I don't know how many growers I've heard from and how many fields I've looked at. I quit keeping track — it's just an endless stream. As of (June 27), we had 32 official complaints and more had come in. I'm having trouble wrapping my mind around the scale of what's happening. … I'm talking to guys who say it's [dicamba injury] on all the [soy]beans they're checking."

Jason Bond, Mississippi State University (Bennett D. 2017a)

<u>Tennessee</u>

"It's so widespread it's kind of overwhelming. In some areas if a crop isn't dicamba-tolerant it's showing [dicamba drift injury] symptoms. … in two weeks we have as many complaints in 2017 as we had in all of 2016 … Really, what's happening here is the mirror image of what's happening across the river [in Arkansas and the Missouri Bootheel]. We're in this together."

Larry Steckel, University of Tennessee (Bennett D. 2017a)

Missouri
"In my opinion, we have ***never*** seen anything like this before; this is not like the introduction of Roundup Ready or any other new trait or technology in our agricultural history."

Kevin Bradley, University of Missouri (Bradley 2017a)

Minnesota
"…as I complete my 32nd summer in Minnesota, I have never experienced any herbicide-induced injury problem as extensive nor as consistent, on both the state and national scale, in expressing symptoms, as my experiences this summer."

Jeff Gunsolus, University of Minnesota (Gunsolus et al. 2017)

Hard data support this expert testimony. For instance, Missouri has received four-fold more dicamba drift injury complaints thus far in 2017 than the combined total of drift injury complaints for ***all*** pesticides in a typical year (Figure 1).[2] In Illinois, more pesticide drift complaints have been received this year (through the end of August) than in the past three years combined, and 65% of them were attributed to dicamba. Tennessee growers reported as many dicamba drift episodes in a two-week period of June as in all of 2016 (Bennett D. 2017a).

Monsanto treats these official numbers as defining the scope of the problem, slicing and dicing them in clever ways to stigmatize Arkansas. However, those who are tasked with investigating dicamba injury episodes – like University of Missouri's Kevin Bradley and Carrie Leach of the Office of Indiana State Chemist – estimate that 9 of 10 affected farmers do not file official complaints (Quinn & Unglesbee 2017; Unglesbee 2017a). One reason is reluctance to damage relations with their dicamba-spraying neighbors (Loux & Johnson 2017). This suggests that the official numbers shown in Figures 1 and 2 represent only a fraction of actual complaints and damage. Assuming the 1 in 10 ratio supported by two knowledgeable experts, it is possible that on the order of 30 million acres of crops grown by over 20,000 farmers have been injured by dicamba. This would represent an astounding one-third of the 89.5 million acres of soybeans grown in 2017, not to mention numerous other crops, trees and shrubs.

Nevertheless, Monsanto's Rob Fraley dismisses this devastating drift injury as par for the course: "There's always a few challenges in launching new technology" (Parker 2017). Like

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[2] See Figure 1 for 310 dicamba injury complaints in Missouri this year (through 9/15/17). For 75-80 overall pesticide drift complaints in the typical year, see Gray (2016a).

his colleagues in the weed science community, Andrew Thostenson, a pesticide specialist with the North Dakota State Extension Service, sees things quite a bit differently:

> "We are in unprecedented, uncharted territory. We've never observed anything on this scale in this country since we've been using pesticides in the modern era" (Unglesbee 2017a)

3.2 Dicamba Injury in Arkansas

Monsanto argues not only that Arkansas is an outlier, but that dicamba injury was unusually high – "aberrational" – in only eight counties, while dicamba-resistant crops were grown "successfully" in 80% (33 of 41) Arkansas counties. With this divisive framing, the company attempts to paint a picture of a minority of "bad actors" in a few counties who cause drift problems by breaking the rules, versus the majority of "good" farmers in most counties who are using the technology appropriately. Blame is thus deflected from Monsanto's products onto farmers, with the implication that better training and enforcement will ameliorate drift.

However, this framing is highly misleading. In fact, Arkansas' nearly 1,000 dicamba injury complaints are distributed very much as one would expect based on the acreage planted to soybeans and cotton in those 41 counties. This is evident in Figure 3, which juxtaposes a county-by-county map of dicamba injury reports with a USDA map illustrating where soybeans and cotton are grown in the state. Just as one would expect, the complaints are concentrated in counties of intensive soybean and cotton production, and tail off sharply in counties that grow very little of these crops.

Figure 4 demonstrates the same point with hard numbers, showing that dicamba complaints by county increase with combined acres of soybeans and cotton harvested in those counties. Three things stand out. First, the majority of counties that grow very little soybeans and cotton (< 100,000 acres combined) experienced either no injury complaints, or at most a few, as one would expect. Second, dicamba injury reports climb disproportionately with county area planted to both crops, beginning with area in excess of about 100,000 acres. Third, dicamba injury is particularly pronounced in those counties that grow both soybeans and a significant proportion of the state's cotton (Figure 3). Finally, nowhere else in the country does one find such concentrated production of cotton and soybeans (Figure 5), which likely translates to greater amounts of dicamba applied per unit area, and hence greater potential for drift damage.

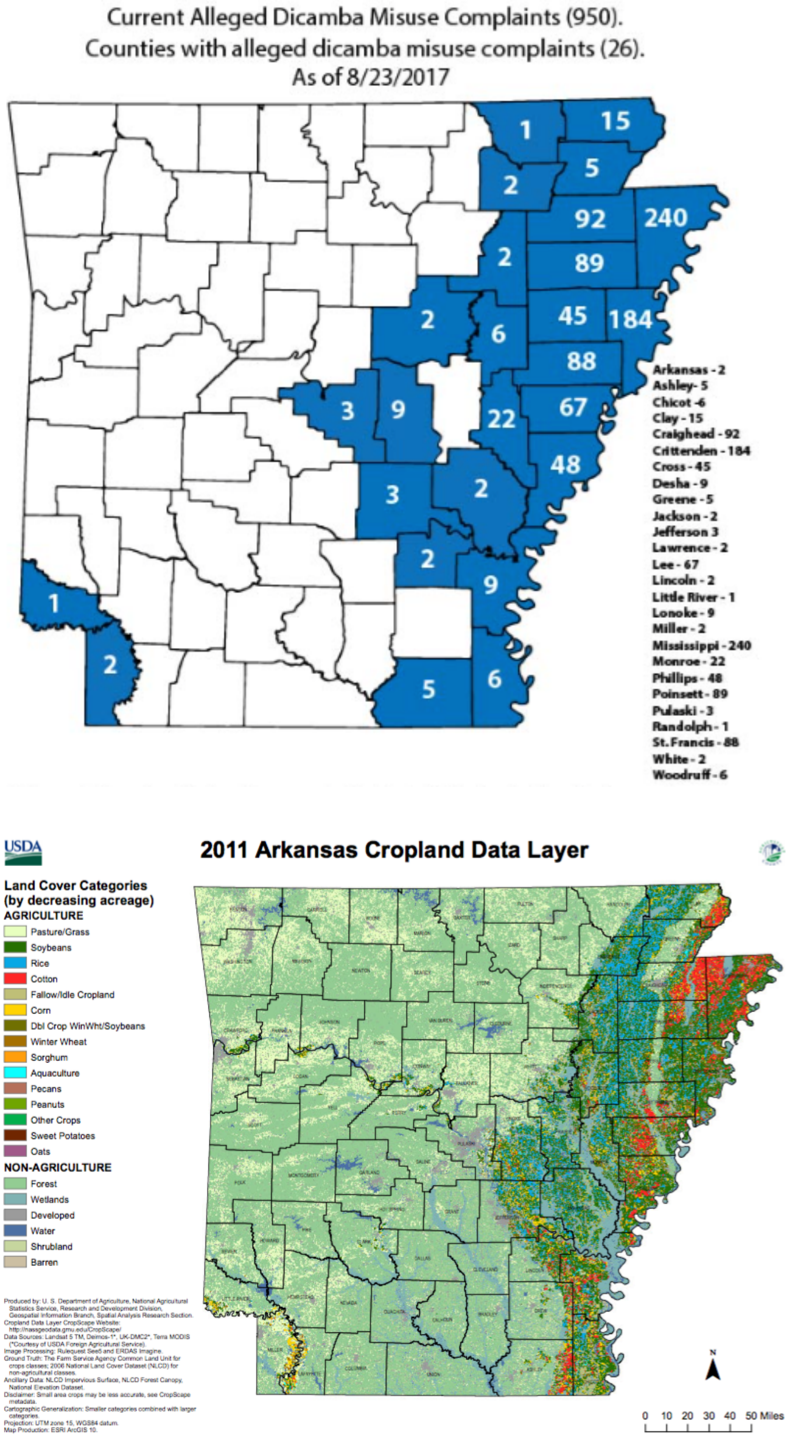

Figure 3. Comparison of counties with dicamba complaints and Arkansas cropland data layer map showing where soybeans and cotton are most intensively grown.

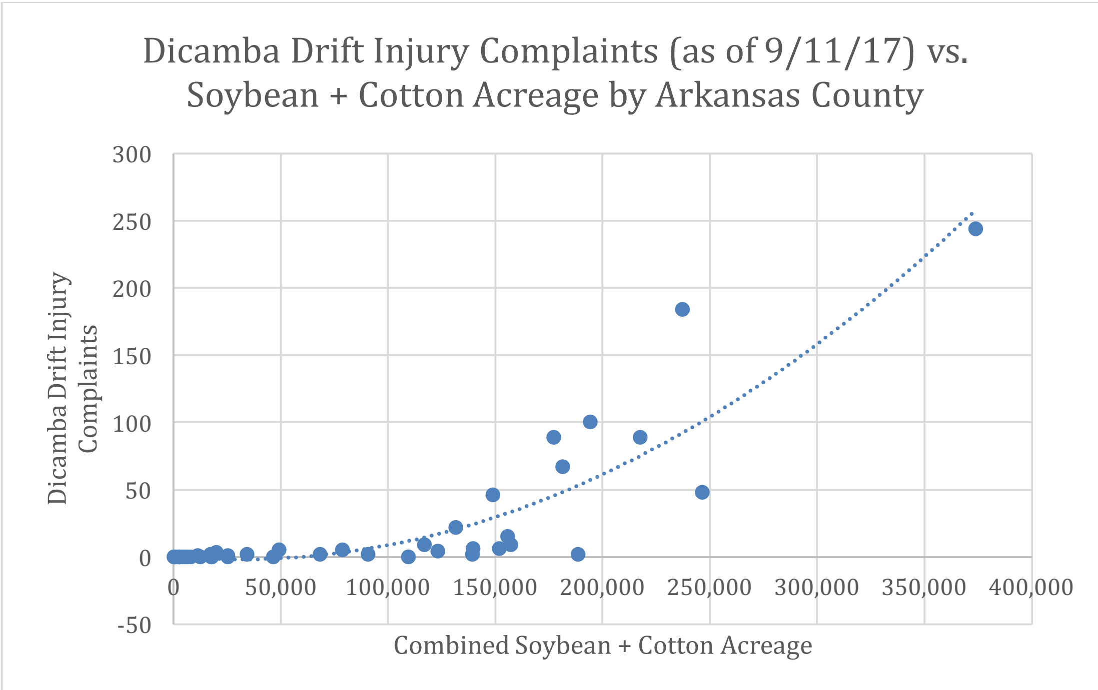

Figure 4. Each dot represents an Arkansas county where soybeans are grown. For each county, the x-axis shows combined soybean & cotton acreage, while the y-axis shows the number of dicamba drift injury complaints. Counties with few complaints also had little soybean/cotton production, while dicamba injury increases dramatically where these crops are intensively grown. County acreage data are harvested acres as reported in the latest USDA Census of Agriculture (2012), which was used because more recent USDA NASS survey data did not provide acreage data for as many counties.

Another significant factor not accounted for in the discussion above is the higher concentration of Xtend soybeans and cotton in the Arkansas Delta region that encompasses the eight counties, and the correspondingly more intensive use of dicamba.

Table 1: Adoption of Xtend Soybeans and Cotton (2017)

	National (millions of acre)				Arkansas (millions of acres)				MO Bootheel (millions of acres)		
	Total	Xtend	**% Xtend**		Total	Xtend	**% Xtend**		Total	Xtend	**% Xtend**
Soybeans	89.5	20	**22%**		3.55	1.5	**42%**		0.875	0.57	**65%**
Cotton	12.6	5	**40%**		0.45	0.3	**67%**		0.3	0.24	**80%**

Sources: Total planted acres from USDA National Agricultural Statistics Service. Xtend acres nationally and in Arkansas are Monsanto estimates. MO Bootheel estimates from Bradley (2017b).

Table 1 shows that Arkansas farmers' adoption rates of Xtend soybeans and cotton are nearly double and 70% higher, respectively, than the national average. Adoption rates in the Arkansas Delta counties are still higher, and are likely similar to those reported for the adjacent Missouri Bootheel counties, since these areas are where the herbicide-resistant weeds (particularly Palmer amaranth) that drive adoption of the Xtend system are most problematic (Bradley 2017b, slide 19). This means proportionally greater use of dicamba, and hence more potential for drift damage, than in other soybean and/or cotton-growing areas with adoption rates closer to the national average.

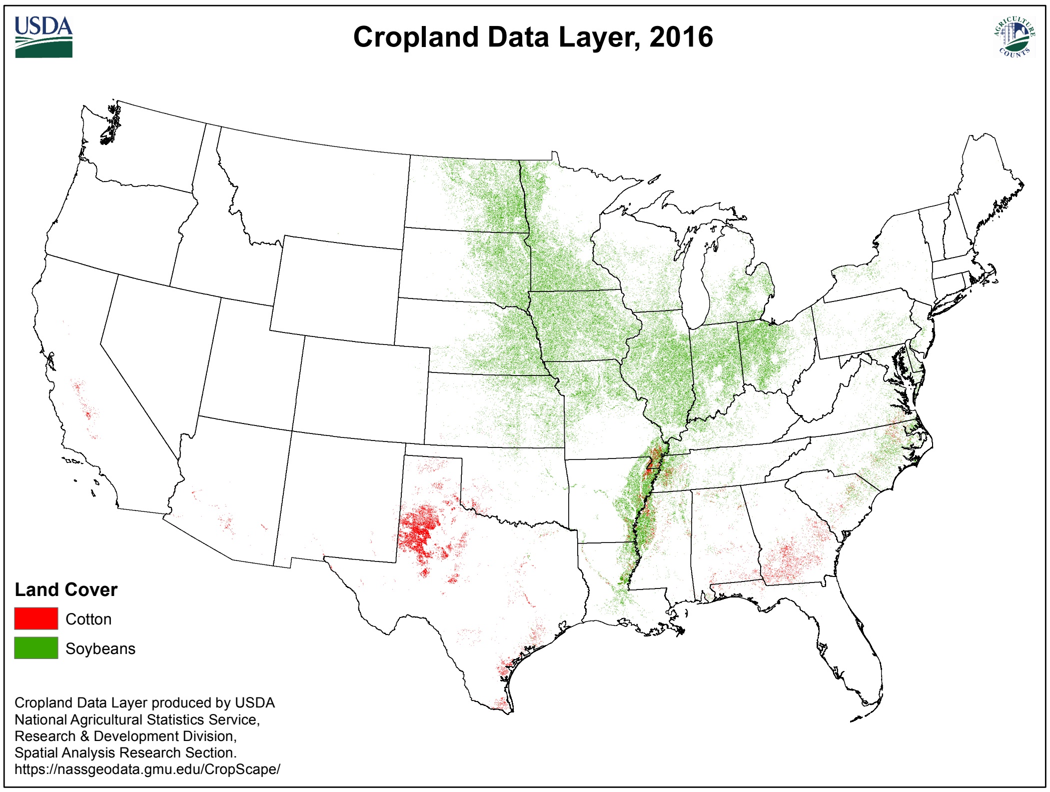

Figure 5. Cropland Data Layer map from USDA's National Agricultural Statistics Service, showing the intensity of soybean and cotton production in the U.S. Courtesy of Avery Sandborn, USDA NASS, created 9/27/16.

Other factors that explain the larger number of official complaints in Arkansas vs. more northern states include:

1) Higher temperatures that promote greater volatilization;

2) A substantially longer planting period, which means that dicamba is applied over a longer time frame, creating greater potential for fields to be drifted on repeatedly; and
3) An extremely flat topography, which promotes greater vapor drift (Hartzler 2017).

In conclusion, there is nothing aberrant about either Arkansas or the eight hardest-hit counties, and Monsanto's numbers games provide no evidence to support blaming growers for dicamba damage in the state. More farmers suffered crop injury in those counties because that's where Monsanto's GMOs were most heavily grown, and dicamba most intensively sprayed. Contributing factors include Arkansas' climate and topography, which are more conducive to volatilization than conditions in more northern states.

Is the Arkansas Plant Board's proposed dicamba restriction "overbroad," as Monsanto claims? We do not believe so. Restrictions on a county-by-county basis would be unwise for several reasons. First, the number of dicamba injury complaints in various counties in a single year (2017) are not necessarily predictive of the future. For instance, a county with no or few complaints this year may experience local weather or other conditions that promote more drift in the next. Second, Xtend soybean acres and thus the volume of dicamba applied to them are expected to double or more in 2018 nationally (Unglesbee 2017a), and thus presumably in Arkansas, likely leading to more complaints even in counties with few this year. Third, any exemption scheme would rightly be viewed as unfair by growers, creating dissension in the agricultural community. Finally, enacting such a scheme would necessarily involve sensitive decisions about what level of dicamba drift injury is acceptable. Yet whether an injured grower resides in a county with many or few complaints is immaterial to his or her situation.

4.0 VOLATILITY VS. SPRAY DRIFT

Dicamba has long been recognized as an extremely volatile herbicide (Behrens & Lueschen 1979; Hagar 2017a). Volatilization occurs when an herbicide, hours to several days after it has been applied, evaporates from the soil and plant surfaces to hang in the air above the field. The volatilized herbicide can then drift long distances (miles) to damage neighboring crops. This sort of drift (sometimes called vapor drift) is an issue primarily with more volatile herbicides like dicamba and 2,4-D, and is distinct from spray drift, which can occur with virtually any herbicide while it is being applied. Most spray drift (also called physical or particle drift) occurs when it's windy; whereas still conditions, high temperatures, and temperature inversions promote volatilization.

Volatility is particularly feared because vapor can drift for miles, is often difficult to trace back to the source, can occur days after application, and is not amenable to control. In contrast, spray drift tends to damage only adjacent fields, can usually be traced, and mitigation is more often possible through proper application practices and enforcement. As University of Arkansas weed scientist Jason Norsworthy put it: "I can fix physical drift. I cannot fix a volatility issue" (ARK DTF 2017, p. 139).

5.0 WHETHER OLD OR NEW, DICAMBA IS HIGHLY VOLATILE

Dicamba-resistant crops were viewed with great trepidation from the very start, because of both dicamba's volatility and the greater drift injury threat posed by its use in the context of the Xtend crop system.

Critics, including the Center for Food Safety, warned of precisely the impacts that are now being experienced, for three basic reasons. First, dicamba would be used much more extensively and intensively than ever before. Second, dicamba would be applied later in the season, when neighboring crops had leafed out and were susceptible to being injured. Third, later applications would take place when temperatures were higher, exacerbating volatilization and hence crop injury (CFS 2014, p. 39).

Monsanto and BASF sought to quell these concerns by developing supposedly "low-volatility" dicamba formulations (Xtend and Engenia, respectively) specifically for use with these crops.[3] They assured the EPA and the world that they had done extensive tests proving that their formulations could be safely used without causing appreciable crop injury via volatility.

5.1 Trust Us, We're the Experts

In the petition, Monsanto discusses "evidence" that supposedly demonstrates this. At first glance, this evidence seems impressive – 1,200 controlled tests and dozens of field studies carried out from 2009 to 2012 (Petition, pp. 6-8, 14-15). However, read further and you learn that virtually all of these studies were conducted by Monsanto itself, raising obvious conflict of interest concerns. A still closer look reveals that the vast majority of tests were not even conducted on XtendiMax, but rather on already approved versions of dicamba (e.g. Banvel, Clarity), on "forerunners of Roundup Xtend" – a premix of dicamba and glyphosate that to this day has not been registered for use on Xtend crops – or other experimental precursors (see below). These results obviously do not tell us anything definitive about the volatility of XtendiMax.

[3] DuPont has a third formulation, brand name FeXapan, which is equivalent to XtendiMax.

Another issue is the entirely unrealistic conditions under which many of these tests were conducted. Monsanto refers to laboratory-based "humidome" studies (Petition, p. 7), "which involve[] spraying and then covering flats of soil with a plastic dome, then pulling air through the dome [for 24 hours] to expedite and better measure the volatilizing process" (Grassi 2012). Monsanto relied very heavily on humidome testing for its assessment of XtendiMax's volatility, as did EPA (ARK DTF 2017, Appendix C; EPA 2016a). This test deviates in so many ways from reality – the infinitesimal area sprayed, the spraying of soil rather than plant surfaces, the artificially "expedited" volatilization process, the perfectly controlled and static environmental conditions, the unrealistically low 40% relative humidity[4] – that the results are meaningless as predictors of dicamba's real-world vapor drift impacts. As Jason Norsworthy put it: "the humidome data we have seen up to this point is not correlated well with what we have seen in the field" (ARK DTF 2017, p. 149).

Nevertheless, the humidome test results served as "inputs for extensive computer modeling (using standard EPA models) to predict and evaluate the potential impacts from volatility from the application of XtendiMax" (Petition, p. 7; EPA 2016a). This is bad enough. Still worse, the volatility model used by EPA – known as PERFUM (**P**robabalistic **E**xposure and **R**isk Model for **FUM**igants) – was not developed by EPA scientists, but rather by two employees of Exponent, Inc.,[5] a polluter defense firm notorious for taking industry money to manufacture uncertainty about the hazards of even the most indisputably toxic compounds, including perchlorate (thyroid disease), atrazine (prostate cancer), various pesticides (Parkinson's disease), beryllium (often fatal chronic beryllium disease), asbestos (cancers of the lung & larynx and other lung diseases), and hexavalent chromium (lung cancer) (Michaels 2008). Whether because of a model biased by pesticide industry contractors, meaningless humidome input data, or some combination of these and other

[4] A Monsanto representative conceded that the humidome tests were run at 40% relative humidity rather than the much higher level characteristic of summers in Arkansas in order to avoid condensation, which created problems with the humidome tests (ARK DTF 2017, pp. 156-157). Many professional pesticide applicators in Illinois noted that high humidity (as well as high temperatures) exacerbated drift issues with dicamba (IFCA 2017).

[5] See https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment#atmospheric. The link under PERFUM (Atmospheric Models section) leads to a webpage of Exponent, Inc. (https://www.exponent.com/experience/probablistic-exposure-and-risk-model-for-fumigants/?pageSize=NaN&pageNum=0&loadAllByPageSize=true), which explains that EPA's standard model was developed by Exponent's Richard Reiss and John Griffin, with funding provided by the Arysta LifeSciences Corporation, which among other products sells dicamba to European farmers under the brand name Kalimba. http://www.arystalifescience.eu/category/9.

factors – EPA's eventual prescription of a mere 110-foot downwind buffer to protect against volatilization damage was disastrously inadequate.

Field studies generally provide data more relevant to real-world conditions, but Monsanto conducted very few of them (Dewey 2017). The one field study described by Monsanto not only involved dicamba formulations other than XtendiMax,[6] but they were sprayed on tiny, 0.06 acre (50' x 50') plots that could not possibly simulate the effects of commercial-scale use on farms hundreds to thousands of acres in size (Petition, p. 14).

The only volatility field trials involving XtendiMax that Monsanto mentions in the petition took place in 2015 in Texas and Georgia (Petition, pp. 7, 23-24). These trials, too, were extremely small (merely a few acres), and were biased in a number of respects to mask or downplay XtendiMax's volatility (see Appendix 1).

Nowhere does Monsanto even attempt to account for the effects of spraying vastly greater quantities of dicamba over time and space at commercial scale. After listening to a lengthy and highly technical presentation by a Monsanto representative, a member of the Arkansas Dicamba Task Force [TF] posed a simple question, which was answered by Monsanto regulatory field scientist Tom Moore [TM] (ARK DTF 2017, p. 164):

> TF: Can you show us, since you can model this, then surely you have modeled what effects you would see if you sprayed this [XtendiMax] over thousands of acres, instead of just a few acres. Can you show us that?
>
> TM: Yeah. So that's not…. that's not something that we've modeled.

Tellingly, Monsanto expressly prohibited independent testing of XtendiMax's volatility prior to its commercialization in 2017, while BASF permitted only limited testing on Engenia (Dewey 2017). The reason given by Monsanto – to avoid any delay in EPA registration (i.e. approval) – begs an obvious question. Why would independent tests on XtendiMax's volatility cause EPA to withhold or delay approval? Clearly, Monsanto feared that testing by university scientists would reveal greater volatility than the company's own data that EPA relied upon – an entirely justified fear, as we discuss below. By retaining total control over such testing, Monsanto and BASF were allowed to "cherry-pick the data available to regulators" (Dewey 2017). This would involve throwing out results unfavorable to the companies' products, one form of fraud.

[6] Old dicamba formulations Banvel and Clarity, as well as "two proprietary low-volatility experimental dicamba-containing mixtures."

5.2 Science Speaks for Itself

What have independent weed scientists found? First, there is broad agreement in results from the Universities of Missouri, Tennessee and Arkansas that the new dicamba formulations can volatilize and drift to other fields as long as 3 days after application (Dewey 2017).[7] This has been demonstrated in two ways. Direct measurements of dicamba in the air above treated fields reveal that over time, there is no statistical difference between the volatility of older formulations[8] and the new "low-volatility" XtendiMax and Engenia. While older formulations tended to volatilize to a greater extent immediately after application, the new dicamba products continued to volatilize up to 72 hours after application (Horstmeier 2017a).

The other method used to assess volatility is to place indicator soybean plants at set distances from a sprayed plot. These plants are covered for the first half-hour after application,[9] which shields them from spray drift. They are then uncovered, and subsequent damage is attributable to volatility. Two field trials by the University of Arkansas weed scientists revealed that both old (Sterling Blue) and new (XtendiMax) dicamba formulations volatilized to damage indicator soybeans plants for the length of the experiment (3 days). XtendiMax caused similar levels of damage as Sterling Blue – slightly less in one test, and slightly more in the second (Figure 6). Kevin Bradley of the University of Missouri conducted similar tests in which he compared the most volatile form of dicamba (Banvel) to Engenia and XtendiMax. While Banvel caused the most volatility damage to indicator plants at all time points up to 72 hours, XtendiMax was very close behind, followed by Engenia (Figure 7).

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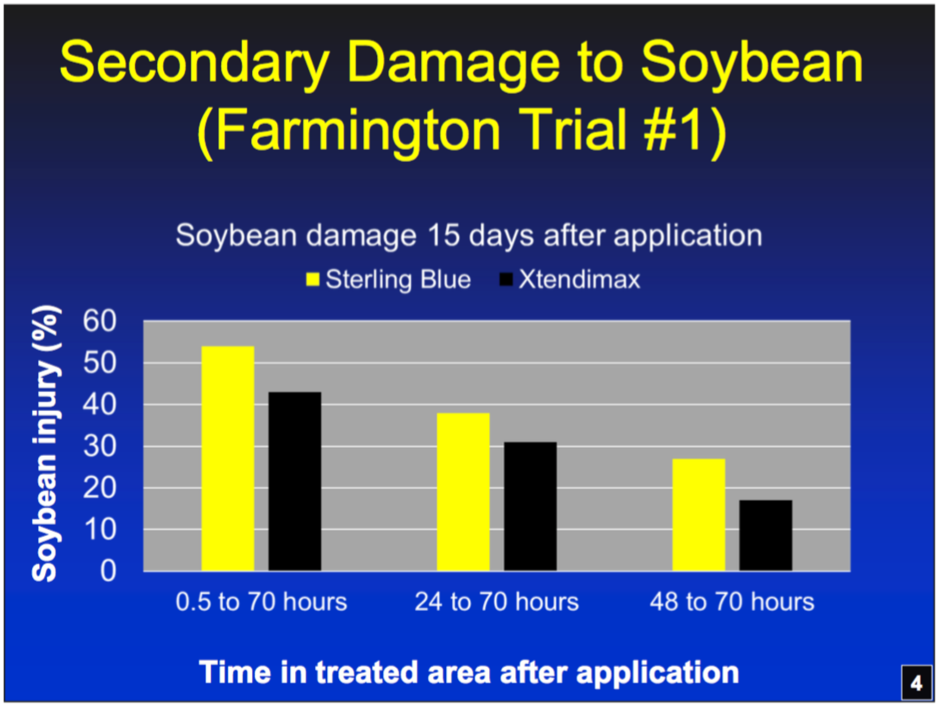
[7] This directly contradicts Monsanto's claim in the petition that the University of Arkansas' findings are on outlier (Petition, p. 24).

[8] There are two "older" formulations of dicamba. The older of the two is the dimethylamine salt (DMA) of dicamba (e.g. Banvel), which is roughly twice as volatile as the diglycolamine salt (DGA) of dicamba (e.g. Clarity, Sterling Blue). See Mueller et al. (2013).

[9] Alternately, the indicator plants are transferred from a greenhouse to the field one-half hour after spraying.



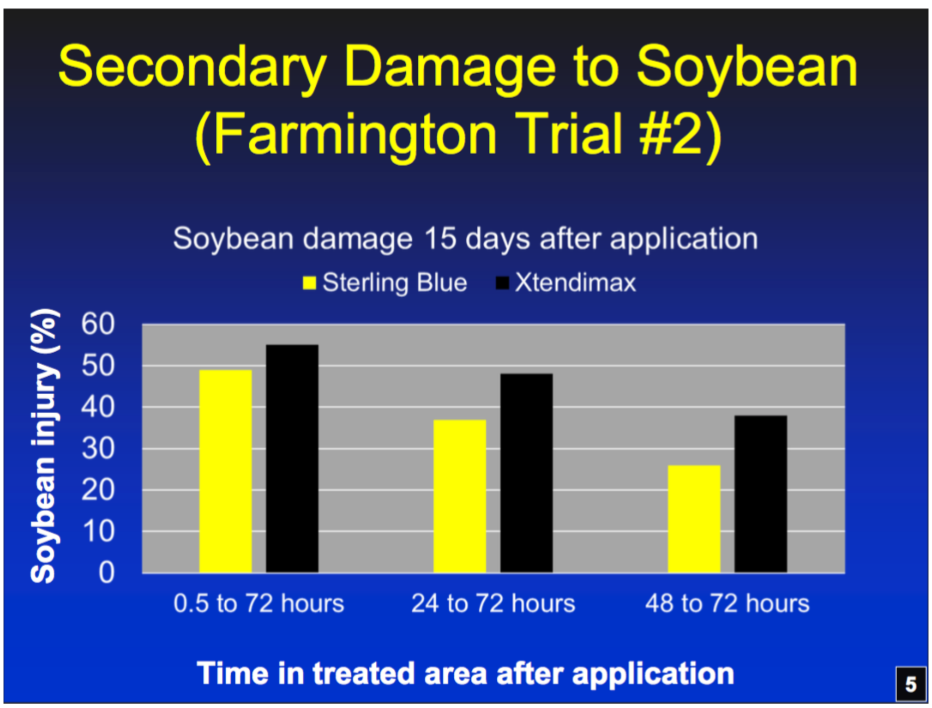


Figure 6: From J.K. Norsworthy, T. Barber, B. Scott. Dicamba: What do we know? PowerPoint presentation (ARK DTF 2017, Appendix B, slides 19-24. Secondary damage is from volatilization of dicamba.

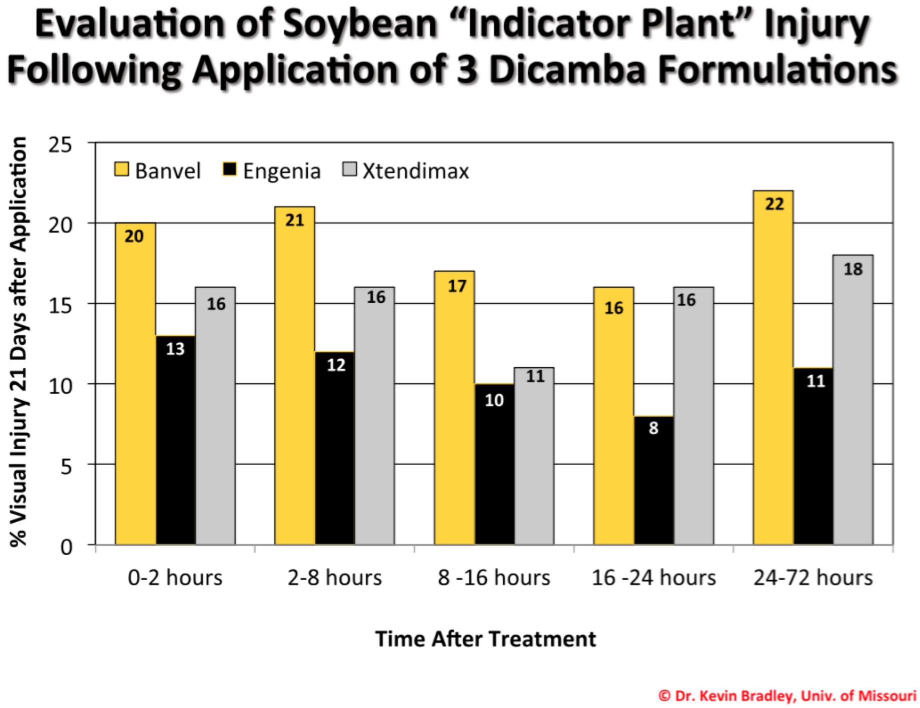


Figure 7: Damage to sensitive soybeans caused by three different dicamba formulations: Banvel, Engenia and XtendiMax. From: Bradley (2017b).

5.3 Dicamba Volatilization in the Field

These independent test results entirely contradict the claims of Monsanto and BASF,[10] and they are amply supported by observations of dicamba damage in farmers' fields. We know this because spray drift and volatilization cause distinctly different patterns of injury. Two signature symptoms of volatility are crop injury occurring at great distances (up to several miles) from the nearest sprayed fields, and uniform damage across even large fields. In contrast, spray drift travels much shorter distances, and causes more severe damage along the edge of a field nearest to where the spraying operation took place, with a rapid tailing off of injury symptoms with increasing distance (i.e. towards the center of the field). This is common knowledge among experts (Loux & Johnson 2017).

Ohio agronomists report "an alarmingly high number of fields [that] seem to show that we have more offsite movement due to volatility than we thought would happen based on past

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[10] Monsanto claims that XtendiMax reduces volatility by 90% vs. Clarity, and by 99% vs. Banvel, based on the humidome tests discussed above (Smith 2017a). BASF claims that Engenia is "up to 90 percent less volatile than other forms of dicamba" (Gray 2017a).

experience with dicamba use in corn and the development of lower volatility formulations of dicamba products labeled for use in Xtend beans" (Loux & Johnson 2017). Kevin Bradley of University of Missouri concurs: "The majority of fields I've been in are injured from one end to the other with no discernable difference in soybean symptomology. This suggests problems with off-site movement through volatility" (Gullickson 2017a). Speaking to his observations of dicamba volatility in Tennessee, weed scientist Larry Steckel is even more emphatic: "This is landscape level redistribution of that herbicide. It's 200-acre or larger fields covered pretty uniformly. I've never seen anything like it" (Smith 2017b). Many similar reports from other weed scientists could be cited.

There are also numerous reports of dicamba injury occurring over great distances, another indicator of volatilization. To give just a few examples. In Missouri, Dr. Bradley reported that "[d]icamba appears to be moving miles" (Gullickson 2017a). In Arkansas, Jason Norsworthy reported uniform symptoms indicative of vapor drift two to three miles from the nearest Xtend field (ARK DTF 2017, pp. 139-140), while the editor-in-chief of a major farm journal spoke to farmers who reported dicamba damage up to three and even five miles from the nearest sprayed field (Horstmeier 2017b).

In a survey, 85% of professional pesticide applicators in Illinois reported dicamba injury to soybeans in fields that were NOT downwind of the dicamba application site, and were often upwind of it. They cited this as evidence of volatility and vapor drift, noting that shifting winds and inversions in the period after the application were likely responsible; and ranked volatility as the most frequent cause of dicamba crop injury (IFCA 2017, pp. 7, 10).

Based on these three mutually supportive lines of evidence, Kevin Bradley modestly sums up the consensus of weed scientists who have investigated dicamba injury complaints as follows:

> "…many university weed scientists like myself believe this [volatility] is one of the major routes by which off-target movement of dicamba has occurred, because our air sampling data, field volatility studies, and field visits indicate that to be the case" (Bradley 2017a)

How does Monsanto respond to these field observations? By simply ignoring them. In the petition, the company pretends that the only reports of "uniform symptomology" indicative of dicamba volatilization occurred in the eight "aberrant" Arkansas counties that are the obsessive focus of its concern throughout the petition, and then blames causes other than volatility for these episodes (Petition, p. 16). As detailed above, this amounts to a flat denial of an enormous body of evidence collected by weed scientists across America that definitively establishes product volatility as a major route of dicamba crop injury.

5.4 Dicamba in the Atmosphere

Clearly, volatilization of dicamba is the only way to explain many cases of uniform injury across large fields, often at great distances from the nearest spraying operation. This in turn simply could not have occurred without substantial amounts of dicamba entering the atmosphere and drifting off-site in areas where the Xtend crops are sprayed. One term that scientists use to describe this well-known phenomenon is "atmospheric loading," or accumulation of a substance in the air (ARK DTF, Appendix B, slide 29). Monsanto, however, denies that dicamba accumulates in the atmosphere, maintaining that this explanation for observed crop injury is "contradicted by science." The company cites two sentences of a single non-Monsanto document – a review of dicamba by the European Union – in support of its position (Petition, pp. 13-15).

Monsanto entirely ignores thirty years of research that directly contradict its views. Studies in the Canadian Prairies, where dicamba has long been sprayed on wheat and other cereal crops, have consistently detected dicamba in the air, in rainfall, and in atmospheric deposits.[11] In weekly summer testing for five herbicides conducted from 1984 to 1987, atmospheric deposits of dicamba were detected in over half (58%) of the samples. This was second in frequency only to 2,4-D (67% detection rate), which was used in over eight-fold higher quantities than dicamba in the area where the testing took place (Waite et al. 1995; for eight-fold greater use of 2,4-D, see Waite et al. 1992, a prior publication based on the same monitoring).

Another study found that dicamba concentrations measured at different altitudes (1, 10 and 100 meters) at a single site, and at two sites 35 kilometers apart, were similar, providing evidence for "regional atmospheric transport" of dicamba (Waite et al. 2005).[12] In the same Canadian study, scientists used air concentrations to estimate the "atmospheric loading" of dicamba (precisely the phenomenon that Monsanto claims is "contradicted by science"). At peak concentrations in early July, it was estimated that 207 kilograms (456

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[11] Atmospheric deposits occur when an airborne substance – like volatilized dicamba – falls back to earth. Such deposition is measured by setting out containers to capture rainfall (which washes many airborne herbicides out of the air) and herbicide-laden particles – wet and dry deposits, respectively.

[12] It should be noted that in its Georgia and Texas field trials, Monsanto measured dicamba concentrations in air samples taken no higher than 1.5 meters above the soil surface (Petition, Exhibits 26-1 and 27-1, respectively).

lbs.) of dicamba were present in the atmosphere over the agricultural zone of the Canadian Prairies.

Rainfall in Alberta, Canada was found to contain dicamba at concentrations sufficient to injure sensitive plants (Hill et al. 2002a). The five highest dicamba levels found in this monitoring study fell within a range of 1/6830 to 1/2440 of the standard field rate of 0.56 kg/ha, which easily exceeds the dicamba concentration – as little as 1/30,000 of the field rate (Barber 2017a) – that induces injury symptoms in soybeans. The study also found that dry beans and tomato plants incurred leaf damage and weight reductions when treated with water containing the maximal concentrations of dicamba and three other herbicides detected in rainfall over the course of the study.

How do these Canadian findings relate to the situation in Arkansas? First, we conservatively estimate that ***dicamba was applied on average nine times more intensively in the ten Arkansas counties[13] with the highest complaint figures than in the Canadian study*** discussed above (Waite et al. 1995), in which dicamba was routinely detected in the form of atmospheric deposition (see Appendix 2). Second, other Canadian studies show that the amount of dicamba applied locally or regionally correlates (as one might expect) with concentrations in the air and/or the amount deposited from the atmosphere (Hill et al. 2002b; Messing et al. 2013). Thus, because new dicamba volatilizes to nearly the same extent as the older formulations used in the Canadian studies (see section 5.2, Figures 6 & 7), one would expect nearly an order of magnitude more dicamba coming to earth in Arkansas than in the Canadian study area.

In short, there are undoubtedly considerable amounts of dicamba entering the atmosphere in the Arkansas Delta and wherever the Xtend crop system is intensively used. Dicamba use in Canada has been sufficiently high to pose potential risks to sensitive crops, like soybeans, dry beans and tomatoes. Because deposition scales with usage, it is not surprising that the much more intensive use of dicamba in the Arkansas Delta has caused such devastating crop injury there and in many other states. Conversely, much of the observed dicamba crop injury simply could not have occurred if Monsanto's humidome and other testing accurately predicted real-world impacts.

6.0 PASSING THE BUCK

Clearly, volatilization of dicamba has been a major cause of the epidemic levels of dicamba injury to non-target plants in the 2017 crop season, in Arkansas and many other states.

[13] Mississippi, Phillips, Crittenden, Poinsett, Craighead, Lee, St. Francis, Clay, Cross and Monroe.

Monsanto has shown considerable creativity in finding alternative explanations, deflecting blame from its products onto farmers, other pesticide manufacturers, and even the weather. In this section, we critically assess those explanations and the evidence presented for them (Petition, pp. 16-19).

First, it should be noted that Monsanto frames this entire discussion in a transparently dishonest way. The company pretends that dicamba injury indicative of volatilization is ***only*** an issue in the eight hardest hit Arkansas counties, and that it simply has not occurred anywhere else in the state or the country. As we have seen in the previous section, this is entirely untrue. However, this framing – the supposed "extreme localization" of volatility-like injury in the Arkansas Delta – is exploited for two ends: 1) To pin the blame on "aberrant" Arkansas farmers and others; and 2) To argue that additional training and enforcement will solve the problem, making the proposed partial ban unnecessary.

6.1 Tank contamination

Monsanto explains that herbicide retailers sometimes prepare customized mixes of herbicides for farmers, and that the mixing tanks must be thoroughly rinsed between loads to prevent carryover. The company's theory is that if dicamba had been mixed in load A, insufficient rinsing afterwards could result in dicamba traces in a subsequent load B consisting of non-dicamba herbicides that are sprayed on crops that are dicamba-sensitive, resulting in injury that resembles that from volatilization.

What evidence does Monsanto present to support this theory? None. Instead, the company presents hearsay – reports that it "was recently made aware of" according to which a single herbicide retailer discovered "a defective valve that had released dicamba into other herbicide products, resulting in dicamba symptomology in several fields in an unidentified state" (Petition, p. 17). First, this is not evidence for the theory it is supposed to illustrate: tank mix contamination due to incomplete rinsing. Even on its own terms, the alleged episode is obviously suspect without considerably more detail on the source of the report, the parties involved, level of contamination, location of affected fields, etc. Even if eventually confirmed, a "defective valve" resulting in injury to "several fields" cannot possibly explain epidemic dicamba injury.

6.2 Dicamba contamination of glufosinate

Monsanto claims that dicamba contamination of other herbicides, sprayed on non-dicamba-resistant crops, could also explain volatility-like injury. The contamination in this case would be due to "insufficient segregation" of dicamba and other herbicides at the herbicide processing facility (Petition, pp. 17-18). As evidence for this possibility, Monsanto claims that its own tests revealed dicamba contamination of several lots of generic glufosinate, a competing herbicide, and that these results were confirmed by an independent laboratory. The Exhibit 5 to the Petition that supposedly confirms this is nothing more than a letter to the Arkansas Secretary of Agriculture identifying the glufosinate brands that Monsanto claims were contaminated with dicamba. No test results were included.

A representative of Nufarm flatly rejected Monsanto's charge that its Cheetah brand of glufosinate was tainted with dicamba. In a presentation to the Arkansas Dicamba Task Force, he reportedly provided results from multiple tests, some by third parties, that showed no signs of dicamba contamination in his company's product, and demanded that Monsanto retract its charge (Bennett D 2017b).

Monsanto also charged that Interline, another generic glufosinate product, was tainted with dicamba, and initially refused to share its test results with the manufacturer, United Phosphorous, Inc. (UPI). Subsequent third-party tests contradicted Monsanto's results; Interline does not contain dicamba. This is not surprising, since "UPI does not manufacture, formulate or sell any dicamba products," and thus UPI has no dicamba to "segregate" from glufosinate. UPI's Bob Kostic found "Monsanto's circulation of vague information about testing Monsanto claimed to have performed to be very irresponsible" (Kostic 2017)

Glufosinate can only be sprayed directly on glufosinate-resistant, LibertyLink crops (e.g. soybeans and cotton). If dicamba contamination of glufosinate were a significant cause of crop injury, then one would expect LibertyLink soybeans to be disproportionately affected relative to other soybean types (e.g. Roundup Ready, non-GM). Monsanto presents no evidence to this effect, and we are not aware of any.

6.3 Illegal use of older dicamba herbicides

Monsanto suggests that illegal use of older dicamba formulations might be responsible for volatility damage, but presents no credible evidence to support this theory. First, Monsanto says that BASF maintains it has not sold enough Engenia in Arkansas to treat the 1.8 million acres of dicamba-resistant crops that Monsanto says were grown in the state in 2017 (Petition, p. 18).[14] BASF made a similar claim in an email to a journalist (Mulvany 2017), implying that old dicamba made up the difference. However, there is no indication

[14] Arkansas never approved XtendiMax, making Engenia the only new dicamba formulation that could be legally applied to dicamba-resistant crops in the state prior to the 120-day ban instituted on 7/11/17.

that BASF accounted for the perhaps substantial number of farmers who purchased Xtend seed without using Engenia, purely to prevent dicamba drift damage to their crops (see Section 10.1). It is also unclear whether or not BASF factored in planned Engenia applications that were not made in consequence of Arkansas' 120-day ban on all dicamba use, which went into effect on July 11th (Begemann & Skiles Luke 2017). Both of these factors could easily account for some or all of the "shortfall" in Engenia sales claimed by BASF based on Monsanto's Xtend seed sales estimate. Finally, to our knowledge there is no independent source to verify either BASF's claims about sales of Engenia or Monsanto's regarding sales of Xtend seeds in Arkansas.

Second, Monsanto refers to a single report of illegal aerial application of dicamba in Mississippi County, Arkansas (Petition, p. 18, citing Exhibit 35). However, Exhibit 35 is merely a "Request for Investigation Information" form, and clearly shows that this episode has ***not*** been confirmed (as Monsanto falsely claims); and that the "suspected pesticide" at issue could be 2,4-D rather than dicamba. Because aerial application of any dicamba herbicide, including Engenia or XtendiMax, would likely cause crop injury, this suspected misuse incident does not provide any evidence to support illegal use of old dicamba.

However, a comparison of dicamba complaint numbers in 2016 and 2017 provides strong evidence ***against*** Monsanto's theory. Arkansas officials received 32 complaints of crop injury involving dicamba in 2016 (Miller 2017), all of them necessarily attributable to old dicamba formulations.[15] Even if one assumes that ***all*** Xtend crop growers in Arkansas illegally used old dicamba in 2017, then one would expect only 200 dicamba complaints rather than the nearly 1,000 that were actually recorded (Figure 1).[16] The fact that Arkansas has experienced nearly five times ***more*** dicamba complaints this year, ***despite the introduction and widespread use of BASF's Engenia,*** suggests that "low volatility" dicamba is responsible for at least as much crop injury as older versions, if not more. And these data also accord much better with the volatility findings and observations of independent scientists (Sections 5.2 to 5.4) than with those of Monsanto (Section 5.1).

Finally, a survey of agrichemical retailers and applicators in Illinois found that fully 89% believed that illegal use of old dicamba was ***not*** a major contributor to dicamba injury to soybeans in their state (IFCA 2017, p. 13). Illinois was one of the hardest-hit states, second

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[15] Because Engenia only became available in Arkansas in 2017 and XtendiMax was never approved there.
[16] National Xtend crop acreage grew by 6.25-fold from 4 million acres in 2016 to 25 million acres in 2017. If one assumes an equivalent rise in Xtend acreage in Arkansas, and complaints scaling up with acres planted, then one would expect 6.25 * 32 complaints in 2016 = 200 complaints in 2017. For Monsanto's 2016 estimate (3 million acres of Xtend cotton and 1 million acres of Xtend soybeans), see Gray (2016a).

only to Arkansas in dicamba-injured soybean acreage (Figure 2). There is no credible reason to believe that old dicamba played any more of a role in off-target injury in Arkansas than in Illinois.

6.4 Monsanto presents no data on alleged farmer misuse of new dicamba

Monsanto claims that three-fourths of "hundreds" of reports of off-target movement of XtendiMax it has investigated in states outside of Arkansas have involved label violations, but fails to provide any firm numbers or supporting evidence whatsoever (Petition, p. 19). The same holds for the "more than a thousand" cases of XtendiMax drift damage it reported more recently (Charles 2017a).

The real story here is the thousand-plus cases of XtendiMax drift injury, because it directly contradicts the company's assertion that the Xtend system has been "successfully" deployed everywhere else in the country except the Arkansas Delta.

Monsanto and BASF have each made one submission to the EPA about complaints they have received regarding off-site movement of their dicamba products (Bamber 2017). Monsanto made the BASF report available as Exhibit 19 to its Petition, but for some reason failed to provide its own submission.

BASF's report contains brief descriptions of 195 "individual incident reports … pursuant to FIFRA §6(a)(2) for Engenia™ Herbicide, EPA Reg No. 7967-345." The descriptions are based on site visits by BASF field staff (see Petition, Exhibit 19).[17] Monsanto should publically release its corresponding raw data to allow others to assess off-site movement of its XtendiMax herbicide, as requested by state pesticide control officers and independent scientists.[18] DuPont should do likewise with drift injury complaints associated with its FeXapan. The additional complaints reported to registrants would likely push the total number of official dicamba injury reports above 4,000 nationally.

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[17] Incident reports to BASF imply that the complainants blamed Engenia drift as the cause of injury to their crops, although BASF says its staff "could not always obtain the identity of the registered product alleged to be associated with the incident." The incidents cover investigations conducted over a two-month period, from May 24th to July 21st, in states across the country.

[18] See Bamber (2017), citing AAPCO President Troy Cofer: "…the states and EPA should be informed of the number of investigations they [registrants] are working on and the conclusions of the registrants' own investigations." Dave Scott, Pesticide Administrator of the Office of the Indiana State Chemist, notes Indiana's estimate that only 1 of 10 reports of dicamba injury actually reach his office. "Underreporting of symptoms impacts the state's ability to fully discern the problem."

7.0 NEW DICAMBA CAUSES DRIFT INJURY, TOO

The farm press is full of testimonials concerning crop injury that occurs even when new "low volatility" dicamba is applied properly, in accordance with all label instructions.

> "Last year [2016] I didn't have any issues. This year it's an epidemic. These weren't what I call cowboys using the old versions of dicamba. These were people using the right stuff the right way. … I don't feel that this technology can be successfully used. Our heat, humidity and topography are highly conducive to off-target movement."
>
> **Tom Burnham, Arkansas farmer (Gray 2017a)**

> "Today, we've talked to many farmers who did everything by the book, paid attention to all label requirements, and still damaged neighbors' crops, trees and lawns not just across the fence, but a mile, 3 miles, even 5 miles away. I'm talking about farmers in North Dakota and Minnesota, not just in the humid Delta."
>
> **Greg Horstmeier, Editor-in-Chief, DTN Progressive Farmer (Horstmeier 2017b)**

> "Some guys are doing it absolutely right by the label and management and still ending up with dicamba on a neighbor's crops through volatility."
>
> **Robert Goodson, University of Arkansas (Bennett C 2017a)**

> "All the calls I've had this year, these are people that are spraying the newly approved products." … "I have visited and talked with many farmers and applicators who have done it right and still experienced movement of dicamba away from the direction of the prevailing wind at application."
>
> **Kevin Bradley, University of Missouri (Gray 2017a)[19]**

> "Some of it is bizarre. There are growers who managed applications entirely by the book and still hurt a neighbor's soybeans. Sometimes I can't offer a grower any explanation. I'm seeing growers who wanted to do it right and so they followed every line of the label. It still got away from them."
>
> **Jason Bond, Mississippi State University (Bennett C 2017a)**

When Jeremy Wolf, an Illinois farmer, experienced dicamba injury to his soybeans, he determined that a neighbor's spraying was the source of his problem. However, the neighbor had applied Engenia to his Xtend soybeans according to label requirements, including the right nozzles, buffers, wind speeds and anti-drifting agents. Yet Wolf's

[19] Note that movement against the prevailing wind is a strong sign of volatility, whereas spray drift follows the wind.

soybeans were injured to such an extent that he is now seriously considering planting all corn next year (CSB 2017).[20]

Lawrence Sukalski applied dicamba to 1,500 acres of Xtend soybeans in southern Minnesota and northern Iowa. He followed the label instructions to the letter, including requirements for proper herbicide mixing, spray pressure and buffer zone. Even so, two of his neighbors contacted him about dicamba injury to their soybeans. "It should have been OK, but it wasn't. It's a puzzle," he said (Meersman 2017). Many more such reports could be listed.

No one denies that illegal use of old dicamba, improper use of the new formulations, and tank mix contamination could be responsible for some cases of dicamba injury. Where new dicamba manufacturers part ways from everyone else in the agricultural community is in blaming essentially ***all*** cases on some form of misuse, whereas weed scientists and farmers regard misuse as a relatively minor component of the problem, and volatility as one of the "major routes" of dicamba crop injury. Kevin Bradley sums up the consensus well:

> "I have yet to hear any manufacturer of the approved dicamba products say that volatility is one of the possible ways that dicamba has moved away from its intended target in 2017 … To say that all of these problems have occurred due to physical drift, tank contamination, or temperature inversions but not volatility is, in my opinion, disingenuous at best." (Bradley 2017a)

Larry Steckel of University of Tennessee agrees:

> "After visiting hundreds of dicamba-drifted RR [Roundup Ready], LL [LibertyLink] and conventional soybean fields that easily have totaled over 30,000 acres, I can say with certainty that many of the reasons I have heard recently from upper management in Monsanto are NOT the cause of all these dicamba injured broadleaf plants across west Tennessee.
>
> I cannot imagine the hundreds of thousands of acres of non dicamba tolerant (DT) soybeans in Tennessee that have shown dicamba injury could be due to contamination of Liberty jugs with dicamba, calcium deficiency, Dual Magnum burn, and/or surfactant burn. Nor do any of those reasons explain the dicamba injury I have seen in a vineyard, gardens, trees in parks and back yards.......even my backyard" (Steckel 2017a)

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[20] Unlike soybeans, corn is tolerant of dicamba.

Aaron Hager is deeply troubled by the misinformation being spread by dicamba manufacturers, which is "unlike anything I've experienced during my 24-year tenure at the University of Illinois" (Hager 2017a). He takes particular exception to "unprofessional and unethical" blanket claims that dicamba injury will not reduce yield.

Dicamba producers appear to believe that an extraordinary number of farmers are negligent, law-breaking and cynically dismissive of the welfare of their neighbors and community. Otherwise, they would accept the overwhelming evidence proving that dicamba drift damage occurs even when all the rules are followed, and own up to the defects in their products that bear a large part of the blame for the dicamba debacle. By deflecting blame onto farmers, they hope to avoid financial responsibility for the harms their products have caused to so many of their customers.

8.0 IS DICAMBA LABELING THE SOLUTION…. OR THE PROBLEM?

8.1 A Complex, Confusing and Contradictory Label

A pesticide label is a legally binding document that prescribes precisely how and under what conditions the product may be "safely" used. The many hazards posed by new dicamba formulations necessitated an extraordinary range of restrictions, resulting in a label 4,550 words long. According to Iowa agronomist Bob Hartzler: "[t]he restrictions on these [new dicamba] labels is unlike anything that's ever been seen before" (Polansek & Plume 2017).

In the case of XtendiMax, these restrictions are complex, confusing and in part contradictory. For instance, application is prohibited during a temperature inversion, a condition in which cold surface air is trapped beneath a layer of warm air that increases the potential for drift to vulnerable fields. The label states that inversions are "common on evenings and nights with limited cloud cover and light to no wind." However, "their presence can [also] be indicated by ground fog." When it is not foggy, they "can also be identified by the movement of smoke from a ground source or an aircraft smoke generator." An inversion "will often dissipate with increased winds (above 3 mph) or at sunrise when the surface air begins to warm (generally 3º F from morning low)" (XtendiMax Label 2016).[21]

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[21] This discussion relates to the XtendiMax label issued on 11/15/16 that was in effect throughout the 2017 crop season. It was superseded on October 12, 2017 by a new label that is discussed in Section 8.3.

It’s hard to argue with Missouri farmer Hunter Raffety, who said: “You have to be a meteorologist to get it exactly right” (Polansek & Plume 2017). The cost of demanding that farmers make decisions better left to weather experts could be quite high. In Missouri, temperature inversions occur at least one-half to two-thirds of the days in June and July, and they typically persist for 8-10 hours from evening to early morning (Bradley 2017a).

Application is also prohibited when wind speeds exceed 15 mph. However, the limit drops to 10 mph when the wind is blowing toward “non-target sensitive crops.” A downwind buffer of either 110 or 220 feet (for 0.5 and 1.0 lb./acre application rates, respectively) is required to protect “sensitive areas.” This unsprayed “buffer zone” is the distance from the last treated row to the closest downwind edge of any sensitive crop. This might seem straightforward. Yet other sections of the label appear to impose ***absolute*** restrictions unconnected with the protective buffer zone just described. For instance, the label warns farmers:

> “**DO NOT APPLY this product when the wind is blowing toward adjacent commercially grown dicamba sensitive crops, including but not limited to, commercially grown tomatoes and other fruiting vegetables (EPA crop group 8), cucurbits (EPA crop group 9), and grapes” [boldface in original].**

Does this mean the 110-foot downwind buffer is NOT protective, after all? Is a farmer prohibited from spraying if the downwind, dicamba-sensitive crop is ¼, ½, 2 or 10 miles away? What other crops besides tomatoes, cucurbits and grapes are included in this prohibition?

Similarly confusing, the label instructs farmers [also in boldface] to “**consult sensitive crop registries to identify any commercial specialty or certified organic crops that may be located near the application site.”** Once again, is the 110-foot buffer zone protective of some sensitive crops (which ones?) but not protective of “specialty or certified organic crops”? How “near” is “near the application site”? What is a “sensitive crop registry” and how does this direction relate to others on the label?

These are just a few examples. It is doubtful if even a lawyer could reconcile these conflicting instructions in any logical way. Whatever their intent, there is a risk that these additional, vague restrictions may be exploited by Monsanto as a pretext to evade responsibility for dicamba crop damage even when the ***explicit*** rules (e.g. 10 mph wind speed limit, 110’ downwind buffer zone) are followed to the letter.

8.2 The Label is Too Restrictive to Accommodate Real World Constraints

The same restrictions that make the label so confusing also dramatically shrink permissible spraying periods such that it becomes extremely difficult to effectively control weeds.

According to University of Tennessee weed scientist Larry Steckel, the labels for XtendiMax, FeXapan and Engenia are "almost impossible" to follow:

> "Following them [the labels] as they are now is a Herculean task. Talk about threading the needle – you can't spray when it's too windy. You can't spray under 3 miles per hour. You got to keep the boom down – there are so many things. It looks good on paper, but when a farmer or applicator is trying to actually executed that over thousands of acres covering several counties, it's almost impossible" (see Smith 2017b).

Many other experts subscribe to this view.

> "Those in the know, and by that I mean those who will acknowledge there actually is a problem, say at least some of the damage is due to the impossibility of spraying all the acres needed in proper weather conditions. There just aren't enough perfect spraying days" (Horstmeier 2017b).

Purdue University agronomists decided to look at this question empirically. They examined hourly weather data for West Lafayette, Indiana, to reconstruct precisely when XtendiMax or FeXapan could or could not have been sprayed in compliance with the label in the 2017 crop season (for the following discussion, see Ikley & Johnson 2017 and Unglesbee 2017b). Their analysis also accounted for practical constraints (rainfall making fields too muddy to permit spraying operations). They found that XtendiMax could ***not*** be sprayed in accordance with the label in the West Lafayette area on nearly half (13) of the days in both June and July. Label-complaint use was only possible for 46% and 36% of the ***hours*** in June and July, respectively, including night-time hours.

The Purdue agronomists also assessed permissible spraying hours under emergency rules issued by the State of Missouri on July 13th after it lifted a dicamba ban imposed only July 7th (Plume 2017, Begemann 2017). The Missouri rules prohibit spraying after 3 pm and before 9 am, because temperature inversion conditions promoting off-target movement are very common in the early evening and night hours; and impose a limit of 10 mph rather than 15 mph to mitigate spray drift.

These additional restrictions drastically reduced permissible spraying periods. In fact, the agronomists found that dicamba could have been legally sprayed for ***"only 49 hours in June, including a 12-day period where we only had 2 hours to apply the approved products."*** Thus, in this scenario dicamba could be sprayed during less than 6% of the hours in the month of June, and for all practical purposes could not be sprayed at all for nearly two weeks. June is when many spraying operations take place in Indiana. The agronomist found this result "alarming," in part because it "almost guarantees" that particularly damaging weeds like waterhemp and Palmer amaranth would become too big to effectively control, and in fact exceed the 4-inch height limit for spraying that is prescribed on the product label.

8.3 EPA's Additional Restrictions Will Not Help

EPA recently announced a new label with additional restrictions on the use of XtendiMax and other dicamba formulations (see EPA 2017a and XtendiMax Label 2017). Dicamba is now a "restricted use pesticide" (can only be applied by certified applicators or those under their supervision); the maximum wind speed at application is reduced from 15 to 10 mph; application is prohibited from sunset to sunrise; tank clean-out language is included on the label to prevent cross-contamination; and there are various new record-keeping requirements. Do these additional restrictions represent "workable solutions" that will prevent a repeat of the dicamba debacle next year, as EPA Administrator Scott Pruitt appears to believe? (EPA 2017a).

No, almost certainly not. A major reason is that EPA has ignored volatility. In an article about the new labels, University of Tennessee weed scientist Larry Steckel is unambiguous about this: "[n]one of the changes address volatility of the new formulations" (Steckel 2017b). Another reason is that EPA's new restrictions closely mirror those instituted by the State of Missouri (Begemann 2017, see Section 8.2), and the Missouri rules have entirely failed to prevent or even reduce dicamba crop injury. First, a farmer with fields in both Arkansas and the adjoining Missouri Bootheel reported that "every acre" of his Missouri soybeans incurred damage after the new Missouri rules were implemented, whereas his fields in Arkansas (where a July 11th ban remained in effect) escaped damage, with the exception of fields near the state border (Gray 2017b). Second and more importantly, this farmer's experience was not exceptional. Fully half or more of Missouri's dicamba injury complaints were recorded ***after*** the emergency rules took effect (for 134 dicamba complaints through 7/6/17, see Bradley 2017b; for 310 complaints in Missouri through 9/15/17, see Figure 1). EPA's additional restrictions are no more likely to reduce dicamba injury in 2018 than Missouri's in the latter half of this season. It is hard to argue with Steve Smith of the Save Our Crops Coalition – who warned of the hazards of the Xtend crop system seven years ago – who said "EPA failed agriculture miserably" with its ineffectual new label restrictions (Smith S 2017).

When the use of a product is so hazardous that even the most stringent restrictions do not provide for safe use in many real-world scenarios, then this is probably a good sign that it never should have been approved in the first place.

9.0 DOES DICAMBA INJURY REDUCE YIELDS?

In the petition, Monsanto cherry picks, and takes entirely out of context, a single study on a single Missouri farmer's field to falsely suggest that this year's massive dicamba injury will not adversely impact yields.[22]

In fact, there have been numerous studies on this subject. What this research has found is that whether and to what extent dicamba injury results in yield losses depends on a host of issues that differ dramatically from field to field and farmer to farmer. Important factors include the crop's sensitivity to dicamba, the number and timing of dicamba exposures, the drift rate, the crop variety, and the growing conditions after the exposure event(s). Thus, the months that often pass between dicamba injury and harvest time are fraught with fear and uncertainty for affected farmers.

The extreme sensitivity of soybean to dicamba, coupled with its huge acreage, have made it the focal point of concern. But practically all broadleaf (non-grass family) plants are susceptible to dicamba. Damage has been reported to tomatoes, watermelon, cantaloupe, grapes, pumpkins, peas, organic vegetables and tobacco, not to mention residential gardens, trees and shrubs (Bradley 2017b, Smith 2017b and Bamber 2017). Missouri farmer Bill Bader is struggling to save his farm in the face of huge yield losses from dicamba injury to thousands of his peach trees: many have defoliated limbs, others walnut-sized peaches not worth the picking (Gray 2016b, Smith 2016).

The 2016 season provides some guideposts for the much worse situation this year. Larry Steckel reports that Tennessee soybean fields exposed multiple times to dicamba drift experienced 40% yield losses (see Smith 2017b). Mark Beaird of Missouri likewise experienced yield losses of about one-third on his soybeans that were hit multiple times by

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[22] Petition, pp. 26-27. In citing an article about the study (Ward 2017), Monsanto strategically omits the subtitle: "Here's a look at yield loss from a dicamba drift event in one Missouri field," and further omits mention of the key issue stated in the first sentence: "No weed scientist can walk out into a field today, look at dicamba injury and tell you what the yield loss will be in that field, says Kevin Bradley, University of Missouri Extension weed scientist."

dicamba drift, with estimated losses just shy of six figures (Gray 2016c). University and industry experts predicted that Curtis Storey would suffer 50% yield reductions in parts of his soybean fields in Arkansas (Bennett C 2017b).

Reduced yield is equally certain this year for many farmers. John Weiss of Arkansas anticipates up to 50% yield losses on his soybeans (Gray 2017c). Jason Norsworthy of University of Arkansas is certain that there will be substantial yield losses in Mississippi and Crittenden Counties this year, and has seen fields so damaged they will not yield even 5 bushels per acre (versus a typical harvest of 50 bushels/acre or more). Multiple dicamba exposures are common. "Anyone that's been in Northeast Arkansas, it wasn't one hit, it wasn't two, it was multiple hits, three, four hits" (ARK DTF 2017, pp. 142-143).

Lesser injury levels will also reduce yield in many cases, but prediction is extremely difficult. Speaking to dicamba injury to soybeans from Engenia drift, University of Illinois' Aaron Hager warns: "Don't believe the advice you may hear about the crop being okay at harvest time. What do you base that on? We don't understand [what] the exposure level is here. ***We have 50 years of data showing predictability effect is not that good.*** You have to remember this is a dose-dependent response" (CSB 2017). Even on a single farmer's fields, variable injury levels will yield different outcomes. For instance, David Wildly of Arkansas reports dicamba injury to all of his thousands of acres of soybeans, with "[a] third of those acres [ ] hit hard enough to reduce his harvest" (Charles 2017b). Perry Ostomo of North Dakota predicts that soybeans severely injured by drift of Engenia will produce just 5-10 bushels per acre (versus typical yields of 30 or more) (Pates 2017).

One rule generally holds. Extremely low levels of dicamba drift can reduce crop yields when the plant is exposed during its reproductive phase, while higher levels are generally required during the prior vegetative stage of growth. Because dicamba is applied later in the season on Xtend crops than is otherwise possible, it makes sense that these "post-emergence" applications are more likely to have yield-lowering effects on injured crops. However, even this rule of thumb does not always hold true. Research at the University of Arkansas has shown that determinate soybean varieties suffer greater yield loss when exposed at late vegetative growth stages than during the reproductive phase (Barber 2016).

Growing conditions from the drift event(s) to harvest time are also important. Excellent weather conditions in both Tennessee and Arkansas this year are highly favorable to optimal soybean yields, and should help injured soybeans recover somewhat (for Tennessee, see Smith 2017b; for Arkansas, see ARK DTF 2017, p. 143). While this is hopeful news for affected farmers, it may also obscure the yield impacts of dicamba injury in several ways. First, assuming soybeans injured this year recover to have decent yields thanks to excellent weather, who is to say yields would have not been still higher if they had not been exposed to dicamba? Second, we must guard against interpreting any weather-induced recovery ***this year*** as a guide to potential dicamba effects in future years, when less favorable growing conditions could result in greater yield deficits for dicamba-injured soybeans.

Another critical issue is how average outcomes obscure individual losses. If excellent growing conditions this year boost average yields – at the national, state or even county level – this says nothing about whether dicamba injury has lowered yields for individual growers. High average yields are no solace to those many farmers who will most certainly experience yield losses.

Given these many uncertainties, and the farm-threatening impacts they could have, we should not regard any level of dicamba injury as "acceptable" based on guessing games about yield impacts. This is well illustrated by the case of Charles Johnson, a Mississippi grower whose soybeans were injured in their susceptible reproductive phase. "I don't know what's going to happen because I don't know the rate that got on my beans. Yield loss is coming, but I don't know how much" (Bennett C 2017a). And he will never know for sure, even after harvest, because his soybeans were not part of any controlled experiment that would be required to answer the question.

10.0 BIG PICTURE CONSIDERATIONS

Beyond the immediate impacts discussed thus far, the dicamba debacle raises a host of more fundamental questions about the state of U.S. agriculture in the age of biotechnology.

10.1 Is Defensive Adoption a Form of Extortion?

One might think that the farmers' experiences over the past two years would generate a backlash against Monsanto's Xtend crop system. This would certainly be a fair and fitting outcome. Automobile companies must recall defective cars; meatpackers their E. coli-infested beef. The hope is that the firm's loss of revenue and reputational harm, if nothing else, will incentivize it to provide safer products in the future. But unfortunately, precisely the opposite is happening in this case. Monsanto just posted a surprise 4th quarter profit on the back of Xtend, and projects a doubling or more of Xtend soybean sales (to 40 to 50 million acres) in 2018 (Mulvany & Parker 2017, Unglesbee 2017a). All signs point to the company's new, $1 billion dicamba manufacturing plant churning out huge amounts of dicamba in years to come (Poirier 2017).[23] It's hard to think of a better example of bad behavior rewarded.

What explains this perverse outcome? Partly, it's due to the desperation of farmers who think that only dicamba can save them from increasingly difficult weed problems (discussed below). But it's also due to growers whose only interest in Xtend is to avoid crop injury of the sort described above from drift of their neighbors' dicamba.

Mark Beaird of Missouri is one. Trying to save money for his coming retirement, he felt compelled to purchase Xtend soybean seeds to avoid a repeat of the dicamba-induced yield losses he experienced in 2016 (Gray 2016c). And he is far from alone. Kevin Bradley has been University of Missouri's point person on dicamba injury. His testimony is remarkable:

> Every farmer I've visited with that's been injured, and these are famers that have done nothing wrong, they've just got drifted onto. Every single one of them has said the same thing, and that is that next year they will plant the new trait—the dicamba resistant trait— to protect themselves. I hear that terminology over and over and over and it just makes me cringe a little bit to think that farmers won't have choices. That they aren't able to plant whatever they want to plant. And that they've got to plant a dicamba resistant soybean in the future so they don't get injured (Smokey Alley 2017, par. 231).

With Xtend soybean seeds selling at a $5 to $10 per acre premium over Roundup Ready varieties (Smokey Alley 2017, par. 149), the additional forced seed expenditures are far from trivial. Even worse, non-GM and organic soybean growers who are forced to switch to Xtend are also forced to sacrifice the premia paid for non-GM or organic supplies – premia which are necessary to cover the often increased production costs of their chosen production systems. Kade McBroom, who launched a non-GM soybean processing plant last year in Missouri, was told by several of her farmer-suppliers that they may be forced to switch to Xtend soybeans to protect against dicamba drift (Roseboro 2016). David Hundley, of Ozark Mountain Poultry in Arkansas, has seen growers who used to supply him with non-GM soybeans for his poultry operation switch to Xtend soybeans for protection against drift. As a result, he is no longer able to obtain all of his non-GM soybean production from local Arkansas farmers – "being an Arkansas company that is something we strive to do each year" (Bennett D 2017b). More basically, all of these dicamba-threatened farmers are effectively being robbed of their fundamental right to plant the seed of their choice.

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[23] Scheduled for completion in 2019, when it will produce 50 million lbs. of dicamba per year.

Tom Burnham, who farms in Arkansas and the adjoining Missouri Bootheel, estimates that half of the region's dicamba-resistant crop acreage was planted by farmers solely to protect themselves from damage. It's hard to argue with his take on the situation.

> "I feel that the need to plant a technology to protect your crop from off-target movement is tantamount to extortion" (see Gray 2017a).

Some farmers believe that Monsanto was both aware of, and banked on, the boost to Xtend seed sales from defensive adoption. According to Landon Hayes:

> "[Monsanto] knew that people would buy it just to protect themselves. You're pretty well going to have to. It's a good marketing strategy, I guess. It kind of sucks for us" (see Chow 2016).

The fact that many farmers adopted Roundup Ready corn to defend against glyphosate drift from Roundup Ready soybean fields (Gunsolus et al. 2017), which Monsanto was most certainly aware of, lends credibility to this view, as does the long history of dicamba drift injury (see Section 10.2).

One of the charges in a class-action lawsuit filed by farmers against Monsanto is that the imperative of defensive adoption amounts to an illegal monopolistic practice, especially in view of Monsanto's already dominant position in markets for seeds and GM traits (Smokey Alley 2017).

Whether Monsanto intentionally exploited the drift injury-defensive adoption dynamic, or simply aggressively marketed its Xtend system to maximize profits, in blind disregard of farmers' welfare, the outcome is essentially the same: profits exacted from unwilling customers based on defective products.

10.2 The Dicamba Debacle was Entirely Predictable…

Another tragedy of the dicamba debacle is that it was an entirely predictable outcome of introducing the Xtend crop system to America's fields. In the words of Aaron Hager, crop scientist at the University of Illinois:

> "This was very predictable that this was going to happen. We've only known for 50 years that soybeans are one of the most sensitive plants to dicamba. I continue to be

amazed when people ask, 'Why is this so common?' I mean, what did people really expect?" (Hettinger 2017)

Steve Smith, Director of Agriculture for Red Gold, an Indiana-based tomato processor, issued unequivocal warnings in thoughtful testimony to Congress seven years ago:

> "I am convinced that in all of my years serving the agricultural industry, the widespread use of dicamba herbicide possesses the single most serious threat to the future of the specialty crop industry in the Midwest. … The widespread use of dicamba is incompatible with Midwestern agriculture … The introduction of dicamba tolerant soybeans is a classic case of short-sighted enthusiasm over a new technology blinding us to the reality that is sure to come" (Smith S 2010).

In 2014 comments to the U.S. Dept. of Agriculture recommending that it deny approval of Monsanto's dicamba-resistant soybeans and cotton, the Center for Food Safety (CFS) described numerous scientific studies supporting the outcome of massive crop injury from introduction of the dicamba-resistant crop system, concluding as follows:

> Monsanto and BASF have developed lower-volatility formulations of dicamba which they claim will mitigate drift damage to crops. However, whatever improvements have been made will be swamped by the massively increased use projected with introduction of dicamba-resistant crops, and the shift to later-season application under hotter conditions that promote volatilization. Even if many growers use these formulations, dicamba would drift more, and become much more prevalent in the air and the rain. Whether from local drift, regional transport, or toxic rainfall, dicamba use under the Preferred Alternative will sharply increase injury to sensitive crops (CFS 2014).

In the 1990s and 2000s, surveys of state pesticide control officers consistently ranked dicamba third (in five of six years covered by the surveys: 1996-1998, 2002-2004) among herbicides most frequently associated with drift episodes (AAPCO 1999, 2005). This is remarkable when one considers its extremely modest use over that period – just 6-11 million lbs./year. In contrast, the two leading drift culprits were used in much larger quantities: 2,4-D at around 35 million lbs./year, and glyphosate at roughly 50 million (1996-98), and 130 million (2002-2004) lbs./year.[24] What these surveys show is entirely consistent with the many expert warnings and all the other evidence discussed above:

[24] See US Geological Survey's Pesticide National Synthesis Project, which reports annual use of many different pesticide active ingredients from 1992 to 2015. Choose 2,4-D, dicamba and glyphosate at https://water.usgs.gov/nawqa/pnsp/usage/maps/compound_listing.php.

pound for pound, there is no herbicide more prone to drift and damage sensitive crops than dicamba. Only its extremely limited use, confined to pre-plant and pre-emergence applications early in the season, kept it from causing still greater problems. Xtend crops have removed those constraints, unleashing the full crop-damaging potential of this herbicide.

10.3 Then Why was the Xtend system Approved in the First Place?

Why were these warnings and data ignored? While it is beyond the scope of these comments to explore this issue in detail, the major reasons appear to be the outsized influence of Monsanto and other pesticide-seed companies on both our regulatory agencies (EPA and USDA) and the academic weed science community, as well as the "desperation" of some farmers who believe they have no alternative to the Xtend crop system.

EPA dismissed warnings out of hand, relying entirely on drift and volatility studies on XtendiMax and Engenia conducted by Monsanto and BASF, respectively, and complex modeling based on those data by its Environmental Fate and Effects Division (EFED).[25] Based on these industry studies, EPA somehow came to the conclusion that a 110-foot downwind buffer (for a typical 0.5 lb./acre application) would "reduce any potential effects from dicamba drift to off-field plants to below levels of concern as established by EFED's assessments" (EPA 2016b). The reality, as documented in these comments, is dicamba volatilizing to drift (in some cases) miles to injure entire fields hundreds to thousands of acres in size. Assuming, conservatively, that volatilized dicamba travels only a single mile (5,280 feet), EPA's buffer zone was fully 48 times smaller than it needed to be. EPA also rescinded its original determination that the buffer be omnidirectional (on all sides of the treated field), and instead restricted the buffer to downwind of the application site. This mysterious decision flies in the face of the well-known fact that vapor arising hours to days after application can easily move in any direction in the gentlest of breezes. In fact, 85% of pesticide applicators surveyed by the Illinois Fertilizer and Chemical Association who applied dicamba in 2017 said that non-Xtend soybean fields ***upwind*** of fields they sprayed were damaged (IFCA 2017, p. 7). This decision was again based on data from Monsanto. "After review of new data on volatility, EPA agrees that an omnidirectional buffer is no longer needed to address volatility concerns" (EPA 2016b).

In its assessment of whether or not to approve dicamba-resistant soybeans and cotton, USDA actually predicted that with their approval: "***Drift from herbicides will remain the***

[25] As noted in Section 5.1, pesticide industry consultants developed the volatilization model – PERFUM – used by EPA.

same or be reduced" relative to ***not*** approving them (USDA 2014, p. 22). This astoundingly wrong prediction was based, like EPA's, on flaccid acceptance of Monsanto's and BASF's overblown claims of "low volatility" for new dicamba, and the supposition that old dicamba use would increase if Xtend crops were not approved. And like the EPA, USDA dismissed a wealth of analysis and data predicting that approval would lead to widespread crop damage.

Many weed scientists have responded to the dicamba debacle quite admirably. The results of their field research directly contradict industry data, and are consistent with a wealth of real-world field observations of crop injury resulting from dicamba application. If they are to be faulted, it is for not more forcefully voicing their concerns in the years preceding commercial introduction of the Xtend system, for instance by filing comments with EPA and USDA during their review processes. Some appeared to uncritically accept dicamba manufacturers' "low volatility" claims; others were influenced by farmers' presumed "need" for the Xtend system to control glyphosate-resistant weeds generated by the Roundup Ready crop system. A third factor is the excessive reliance of the academic weed science community on pesticide industry funding (Davis et al. 2009), which often tends to inhibit criticism of those firms' products and marketing practices. This reliance, in turn, is partly attributable to the failure of state and federal governments to adequately fund research and extension services in sustainable weed control practices.

In a broad sense, the dicamba debacle is a case study in what happens when American agriculture is turned over to powerful and often unethical seed-pesticide conglomerates. Regulators and university scientists become adjuncts, their roles reduced to rubber-stamping approval of company products based entirely on company claims and data, on the one hand, and offering farmers advice on how to deal with the adverse impacts that result, on the other.

10.4 Resistant seeds and weeds

While the Xtend system has been a nightmare for many farmers, some think it brings such great weed control benefits to others that banning or further restricting it is unthinkable. What if this cost-benefit assessment is mistaken, and Xtend not only causes drift havoc, but will also worsen rather than ameliorate the problem it is marketed to solve? That is, what if Xtend is a lose-lose proposition?

Most farmers have adopted Xtend as a "new tool" in the fight against weeds resistant to glyphosate and other herbicides. However, we know by now that herbicide-resistant crop systems are particularly potent promoters of weed resistance. They encourage excessive reliance on the associated herbicide, and spraying later in the season when weeds are larger – both factors that accelerate resistance evolution. And their deployment in vast monocultures ensures that resistant weeds will emerge across huge areas. This explains why the vast majority of glyphosate-resistant weeds have arisen only since the widespread introduction of glyphosate-resistant (Roundup Ready) crop systems. Ironically, the need to control these very products of generation one GMOs has now become the overriding pretext for introduction of the Xtend system.

Before the advent of herbicide-resistant crop systems, it typically took many years for weeds to evolve resistance to an herbicide, because farmers did not rely on a single chemical for weed control. Roundup Ready crops changed that, by fostering exclusive reliance on glyphosate herbicide. Weeds resistant to glyphosate began to emerge after just three years after the introduction of Roundup Ready crops (Van Gessel 2001). And with just two seasons of limited use of the Xtend system, agronomists are already reporting weed populations that appear to be evolving resistance to dicamba as well.

In parts of both Arkansas and Tennessee, dicamba has "reduced efficacy" on farmers' most feared weed, Palmer amaranth (pigweed). In some cases, even two dicamba applications will not kill them (Bennett C 2017c, Bennett D 2017c, Steckel 2017c, Steckel 2017d). Reduced efficacy is a warning flag of evolving resistance, which is also supported by greenhouse research showing that pigweed evolves dicamba resistance after just three generations of exposure (Hightower 2016). Making matters worse, these pigweed populations are also resistant to glyphosate and several other classes of herbicide.

Neither is dicamba is very effective on Palmer amaranth's cousin, waterhemp (Spaunhorst & Bradley 2013, Hausman et al. 2016), which is especially problematic in the Midwest, and has already evolved resistance to six classes of herbicide. With the advent of Xtend soybeans, "resistance to dicamba is not a question of 'if,' but 'when'," according to University of Illinois weed scientist Aaron Hager (Hager 2016). The discovery that 2,4-D-resistant waterhemp is also tolerant of dicamba raises the troubling specter of cross-resistance to these two herbicides (Bernards et al. 2012).

Kochia, a damaging weed of the Great Plains, has evolved resistance to dicamba in six states and several Canadian provinces, with most resistant to glyphosate as well.[26] Widespread deployment of the Xtend system will generate much larger populations of dicamba-resistant kochia in these regions. This development will be accelerated by introduction of

[26] Search on dicamba-resistant weeds at www.weedscience.com.

dicamba-resistant sugarbeets – which is being touted, with incredible short-sightedness, as the answer to kochia that is already resistant to glyphosate (Ellis 2017).

Pesticide-seed companies understand quite well that resistant seeds breed resistant weeds. It is no exaggeration to say that it has become their business model (Kilman 2010). The imminent introduction of 2,4-D-resistant crops by Dow is only the next logical step in the march to rendering all major field crops resistant to most major classes of herbicide (Keim 2014, CFS 2014). Agricultural herbicide use – which rose by 34%, to 564 million lbs., in the U.S. from just 2005 to 2012 (EPA 2017, Table 3.2) – will continue to surge, with increasingly negative impacts on human health and the environment.

10.5 It's Not Just the Herbicide, It's the System

It is important to emphasize that the threat posed by dicamba has as much to do with how it is used with Xtend crops as with the properties of the herbicide itself. While drift damage associated with traditional uses of dicamba has not been insignificant (Section 10.2), it pales in comparison to what is now being experienced. The vastly increased drift injury seen with the Xtend system is attributable to application later in the season, when surrounding crops are vulnerable to damage; increased vapor drift due to higher temperatures; and the increased scale of use with widespread planting. As we have seen, any volatility reductions with new dicamba (which appears to be minor, at best) have not even begun to counterbalance these system-specific factors.

Thus, it is logical to assume that the same systemic factors will generate additional problematic drift issues with weed-killers applied to future herbicide-resistant crops. Dow's 2,4-D-resistant Enlist crops raise the most immediate concerns, given 2,4-D's long history as the leading culprit in cases of drift injury (Section 10.2). However, herbicides like clomazone, atrazine and paraquat are also drift-prone (AAPCO 1999, AAPCO 2005), and their post-emergence application to crops resistant to them would also lead to substantially increased levels of drift injury.

If herbicide-resistant crop systems both increase drift damage AND foster more rapid evolution of resistant weeds, then perhaps it is time to consider safer and more sustainable alternatives to the weed management challenges facing farmers. There are certainly many techniques for managing weeds that involve much less use of herbicides, and which largely avoid the problems with herbicide drift and weed resistance (e.g. Liebman et al. 2008, Stillerman 2012).

10.6 Conflicts of Interest

Monsanto has urged the Arkansas Plant Board to disregard the views of two Arkansas weed scientists on the grounds that they have recommended the use of its competitor's products, and thus are not disinterested; and to base any decisions regarding XtendiMax on Monsanto-conducted rather than independent science. These charges and recommendations should be rejected out of hand.

It is true that Jason Norsworthy and Ford Baldwin have recommended the use of Liberty herbicide with LibertyLink crops. This is an entirely normal practice in the weed science community, much of whose work consists in company-funded herbicide efficacy trials, and recommendations to farmers regarding which herbicide and seed products to use, and how best to use them. Monsanto has benefitted enormously from positive evaluations of its products by weed scientists over the years, but this apparently does not raise conflict of interest concerns for the company.

Monsanto's recommendation that its own views and research results be preferred to those of university researchers should be weighed against the company's long history of scientific misconduct and junk science. For instance, Monsanto strongly denied widespread scientific concerns that its Roundup Ready crop system would generate glyphosate-resistant weeds when it was first being introduced, most likely to avoid any regulatory constraints on the sale of its products (Horstmeier 2017b, Freese 2010). Monsanto funded field research that was designed to provide pseudoscientific support to farm press advertisements advising farmers that they could rely entirely on glyphosate and Roundup Ready crops, every year, without risk of weed resistance (Hartzler 2004). Leading weed scientists rebuked Monsanto for this advice, which was custom-made for promoting glyphosate resistance (Hartzler et al. 2004). Monsanto's aim here was to encourage farmers already growing Roundup Ready soybeans to grow Roundup Ready corn as well (Hartzler 2003). These actions by Monsanto contributed substantially to accelerating the emergence of glyphosate-resistant weeds, which have created a market that would otherwise not exist for the Xtend crop system (Freese 2010).

Monsanto has covertly funded many academic scientists to carry its pro-GMO message to the public, and in many cases has drafted the articles that appear under the names of those ostensibly independent scientists (Lipton 2015) as well as antiregulation activists (Albarazi 2017). Monsanto funded scientists to write review articles intended to undermine the World Health Organization's finding that glyphosate is probably carcinogenic, and even exercised considerable editorial control over the tone and content of these ostensibly independent articles (Waldman, Stecker & Rosenblatt 2017; CBD 2017). Monsanto of course has a long history of scientific misconduct with respect to many of its products, from Agent Orange to PCBs.

Given the company's long record of scientific misconduct, its show of scientific rectitude in the case of dicamba cannot be taken seriously. This is all the more true given the huge chasm between what Monsanto says its research shows, on the one hand, and the results of tests undertaken by independent scientists, on the other. The fact that weed scientists' data regarding the volatility of new dicamba formulations accords much better with the real-world experiences of farmers and extension agents clinches the case against Monsanto.

Conclusion

Monsanto's petition and now lawsuit against the State of Arkansas is one tactic in the company's "product defense" campaign. Having invested nearly one billion dollars in a dicamba manufacturing facility, and still more on development of Xtend seeds, Monsanto will do whatever it takes – including junk science and blaming farmers for its own defective products – to fight any sales restrictions that would reduce its return on investment. We urge the Arkansas Plant Board to carry through with its proposed ban on the use of dicamba after April 15th for the 2018 crop season.

Appendix 1

Thoughts on Monsanto's Georgia and Texas Field Tests on the Volatility of XtendiMax

In the Petition, Monsanto briefly describes field tests it conducted to assess the volatility of XtendiMax in Georgia and Texas. The following thoughts are drawn from that discussion as well as Exhibits 26-1 to 26-15 for the the Georgia field test and exhibits 27-1 to 27-13 for the Texas field test.

1) Both trials were far too small – Georgia 3.4 acres, Texas 9.6 acres – to provide volatility results predictive of large-scale commercial use.
2) Both trials involved only a single, isolated application of XtendiMax, whereas in regions like the Arkansas Delta, XtendiMax and Engenia are sprayed by many farmers in close proximity and during limited spraying windows – creating a high potential for vapor accumulation and drift, as well as fields exposed to multiple episodes of drift.
3) Because Monsanto has long known that Xtend soybeans would account for far more acres than Xtend cotton, it obviously should have conducted volatility field tests in one or more soybean-producing states. Neither Georgia nor Texas grow appreciable amounts of soybeans (together, they accounted for less than 0.4% of the nation's soybean acreage in 2017).
4) The Georgia trial was meant to simulate early season, pre-emergence use of dicamba, while nearly all growers of Xtend crops spray dicamba post-emergence, later in the season. The atypical pre-emergence use in the Georgia trial underestimated XtendiMax's real-world volatility in several respects:
    a. The low temperature at application time reduced volatility versus what it would typically be with later season, post-emergence use, since volatility rises with temperature. Monsanto reports a temperature of just 71 F. at the time of application (on the morning of May 5th, 2015), versus an "intended" temperature of over 80 F/ in its test protocol, and typical mid-South summer temperatures in the 90s;
    b. Monsanto sprayed bare soil, while many studies have shown that dicamba volatilizes to a much greater extent when sprayed on Xtend crop plants and weeds. This is most likely due to the much greater surface area (plant leaves) that intercepts dicamba, and from which dicamba volatilizes, versus the bare soil scenario;
    c. Monsanto violated protocol by not placing soybean indicator plants at sites around the field to provide a second "bioassay" measure of dicamba damage;

while Monsanto claims the soybean plants were not deployed because they were in poor health, the more likely explanation is that the company feared the indicator plants would suffer dicamba injury that it would then have to record and explain.

5) The Texas trial was meant to simulate post-emergence use of XtendiMax on Xtend cotton, but was also biased in several respects to underestimate volatility:
   a. Monsanto sprayed Xtend cotton on June 8th, when it was very young (just 34 days into an average cotton lifespan of 130-160 days, see http://www.cotton.org/tech/ace/growth-and-development.cfm), before it could have developed much leaf tissue, meaning that most of the dicamba landed on bare soil. [Note: cotton was only 11" tall, based on positioning of air sample pumps 0.15 m above cotton canopy surface, equivalent to average sample height of 0.43 m; the difference 0.28 m = 11"). In contrast, many cotton growers spray later in the season, when cotton plants are bigger and their leaves intercept more dicamba. As discussed above, volatilization increases when plant tissue rather than (mostly) soil is sprayed. Monsanto violated the study protocol by not recording this parameter – "percent crop coverage" – likely because doing so would have revealed very little crop cover as one factor driving the low volatilization results;[27]
   b. Hotter temperatures from more typical application dates later than the trial's June 8th application date would also mean more volatilization than occurred in this trial. In fact, Monsanto predicted two to three dicamba applications per season on Xtend cotton in many areas, which would likely mean one or two applications considerably later in the season than occurred in this trial;
   c. Monsanto said the relative humidity at the time of application was a very low 23%, whereas Wundergrund places relative humidity at 50% to 55% during dicamba application;
   d. It is curious that Monsanto chose Texas as a field trial site. First, there are very few soybeans grown in Texas (only 0.2% of national acreage). Second, while Texas is the nation's largest cotton producer, its cotton growers have little need of Xtend cotton, since they have largely escaped the glyphosate-resistant weed issues (especially Palmer amaranth) that have driven cotton growers in mid-South states to adopt Xtend cotton.

[27] Monsanto Petition, Exhibit 27-1, Table 5; see also Exhibit 27-13 (p. 2), where Monsanto describes the failure to record this and other information (cloud cover and soil moisture as well as "crop percentage") as "an oversight of study personnel."

Appendix 2

Intensity of Dicamba Use in Arkansas vs. Canada

In Table 1 of their paper, Waite et al. (1992) report dicamba use in a 2,800 ha watershed that encompassed their study area for three of the years of their air monitoring study. Dicamba was applied in quantities of 67, 34 and 18 kg in the years 1984 to 1986, respectively. This translates to 0.024, 0.012 and 0.0064 kg/ha, averaged over the watershed.

We estimated dicamba use in Arkansas counties as follows. First, we calculated the percentage of overall Arkansas soybeans and cotton planted to Xtend varieties, using Monsanto figures for Xtend acreage and USDA National Agricultural Statistics Service figures for overall soybean and cotton acres planted in Arkansas. These figures are shown in Table 1: 42% of soybeans and 67% of cotton are Xtend. Second, we applied these percentages to harvested acres of soybeans and cotton in each Arkansas county from the latest Census of Agriculture (2012)[28] to arrive at county estimates of total Xtend crop acres (soybeans and cotton combined).

Third, we conservatively estimated that these Xtend acres were treated, on average, with one application of dicamba at the standard field rate of 0.56 kg/ha (0.5 lb./acre). We arrived at this estimate based on various considerations. First, Jason Norsworthy and colleagues reported that "[m]ost Xtend acres in this area (cotton & soybean) [were] treated multiple times," with "this area" comprising northeast Arkansas, the Missouri Bootheel and western Tennessee (ARK DTF 2017, Appendix B, slide 28). However, there are also reports of defensive adoption of Xtend crops, and these growers would likely not have used dicamba at all. Finally, other Xtend growers may have had to forego a planned second or third application because of the July 7th ban. Weighing these various factors, one application of the standard field rate to all Xtend crop acres seems a reasonable and conservative estimate.

[28] We would have preferred to use 2017 acreage planted figures, but the USDA's National Agricultural Statistics Service (NASS) has not yet made county-level figures available in QuikStats. We preferred the 2012 Census data over 2013 to 2016 figures from NASS surveys because the Census gives acreage figures for more counties. Arkansas soybean and cotton acreage in 2017 (3.55 and 0.45 million planted acres) was somewhat higher than the 2012 harvested acres figure used here (3.15 and 0.58 million acres), so using the 2012 figures results in an underestimate of dicamba use intensity in 2017.

The dicamba usage estimate in the preceding step was divided by the land area of the respective counties to arrive at the average amount of dicamba applied across the county (see table below).

County	County Area (hectares)	Soy+Cotton Acres Harvested	Xtend Soy+Cotton Hectares	Dicamba Use Estimate (kg)	Dicamba Use (kg/total ha)	Complaints (as of 9/11/17)
MISSISSIPPI	233,247	373,868	80,260	44,946	0.193	244
CRITTENDEN	157,927	237,037	42,736	23,932	0.152	184
CRAIGHEAD	183,167	194,164	40,460	22,657	0.124	100
POINSETT	196,422	217,507	40,662	22,771	0.116	89
SAINT FRANCIS	164,405	177,129	33,383	18,695	0.114	89
LEE	156,078	181,394	36,097	20,214	0.130	67
PHILLIPS	180,175	246,532	45,281	25,357	0.141	48
CROSS	159,642	148,836	26,030	14,577	0.091	46
MONROE	157,243	131,615	22,999	12,879	0.082	22
CLAY	165,622	155,664	29,767	16,670	0.101	15

Dicamba use is roughly 9 times more intensive in the Arkansas Delta than in the Canadian study area of Waite et al. (1992, 1995). This represents the ratio of the average use in the 10 Arkansas counties listed above (0.124 kg/ha) and the three-year average use in Waite et al. (1995) (0.0142 kg/ha).

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