2017 Survey of Nebraska Soybean Farmers’ Adoption of Xtend Technology and Off-Site Dicamba Movement

Rodrigo Werle\*, Amit J. Jhala, Robert Klein, Christopher A. Proctor, and Jennifer Rees

First and third authors: University of Nebraska-Lincoln, West Central Research and Extension Center, 402 West State Farm Road, North Platte, NE 69101; second and fourth authors: University of Nebraska-Lincoln, Department of Agronomy and Horticulture, 68583 Plant Science Hall, Lincoln, NE; fifth author: University of Nebraska-Lincoln, Southeast Research and Extension Center, 2345 Nebraska Avenue, York, NE; \*corresponding author: rodrigo.werle@unl.edu

Abstract

Keywords

Introduction

Dicamba (3,6-dichloro-o-anisic acid) is a benzoic acid regularly referred as auxin or growth regulator herbicide. In past 50 years, dicamba was an important component of weed management in corn, wheat, turfgrass, pastures, and rangeland (Keelin and Abernathy 1988, Schroeder and Banks 1989, Spandl et al. 1997, Wehtje 2008). The development of herbicide tolerant traits through genetic modification allowed application of dicamba on soybeans (Behrens et al. 2007). Available for growers in 2017, dicamba tolerant soybean varieties (e.g., Xtendimax® Technology) will offer a new option for controlling broadleaf weed species in soybeans fields (Johnson et al. 2010, Vink et al. 2012).

Weeds have permanently been a major challenge in cropping-systems, and herbicide resistant weeds dramatically increased in the past 20 years (Heap 2017). For example, waterhemp (*Amaranthus tuberculatus* var. *rudis*) populations infesting soybean fields have evolved resistance to ALS-, EPSPS-, and PPO-inhibitor herbicide site-of-action (SOA) groups in Nebraska (Vieira et al. 2017), Heap 2018. These three SOA are the only herbicide alternatives for postemergence (POST) waterhemp control in soybeans. Therefore, complexity of waterhemp management in soybeans is likely to increase with less herbicide options. As part of future solutions, POST-application of dicamba in tolerant soybean varieties might be a valuable tool for combating glyphosate-resistant and other troublesome weeds in Nebraska and/or elsewhere.

The expected high adoption of dicamba tolerant soybeans technology in Nebraska raised awareness of the un-intended movement of dicamba particles on sensitive vegetation. The dicamba herbicide has high vapor pressure (e.g., easily capacity to volatilize) (Behrens and Lueschen 1979); therefore, dicamba application in certain environmental conditions (e.g., high wind speed or temperature inversion) might cause injury on sensitive crops. Micro-rates of dicamba damaging crops is well documented in grapes, soybeans, vegetables, and cotton (Griffin et al. 2013, Mohseni-Moghadam et al. 2016, Mohseni-Moghadam and Doohan 2015). Despite a new dicamba formulations to reduce volatility, dicamba injury in sensitive soybeans varieties was reported across the north-central US in 2017.

In Nebraska, the total area for soybean production in 2017 was estimated at 2.3 million hectares (USDA, 2018). The majority (>95%) of soybean varieties planted were herbicide tolerant (glyphosate and glufosinate), but conventional and organic varieties are also growing in the state. In 2017 was the first year of dicamba tolerant soybeans in Nebraska (e.g., EPA approval of seed commercialization and POST-emergence application of dicamba); therefore, it is necessary more information regarding soybean farmers perspective of this technology. Survey is a useful method to obtain knowledge or perception of a situation or fact (Givens et al. 2009, Rankins et al. 2005, Webster and Macdonald 2001). For example, a survey showed that < 82% and < 50% of pesticide applicators from Missouri are aware that temperature and vapor pressure influence herbicide volatilization, respectively (Bish and Bradley 2017). Therefore, the broadcast dicamba (or auxin herbicides) application might require more training than other herbicides.

This survey will serve as a documentation on famers perspective in the first years of dicamba tolerant-soybeans technology adoption in Nebraska. This documentation will aid … which might help to evaluate …..…. Therefore, the objective of this study was to …

**MATERIAL AND METHODS**

A survey was developed to investigate Nebraska farmers’ perspective on dicamba use and Xtend technology during the 2017 growing season, first year of the full launch of the Xtend technology in the United States (Table 1). To reach a representative audience, the survey was conducted in two formats; Table 1: i) hard-copies were handed out during the 2017 Soybean Management Field Days (which has more than 400 participants), held at four major soybean growing areas of Nebraska (August 08-11, 2017 at North Platte, Ord, Auburn, and Tekamah, respectively); and ii) online using SurveyMonkey ([www.surveynokey.com](http://www.surveynokey.com)) linked to University of Nebraska-Lincoln (UNL) CropWatch website (central resource for UNL Extension information on crop production and pest management; [www.cropwatch.unl.edu](http://www.cropwatch.unl.edu)). The online survey was available from August 18 through September 18, 2017. For consistency in data entry, results from the hard copies from the field days were entered in the online system by a student. All results were exported from SurveyMonkey as an Excel file with the answers to each question in separate columns.

The survey comprised three sections (Table 1). Questions in the first section focused on demographic information such as county, whether they own a sprayer and spray their herbicide programs, and number of soybean hectares, Xtend soybean hectares, Xtend hectares sprayed with dicamba in 2017 and expected for 2018. The second section of the survey was designed to collect data from farmers who adopted the Xtend technology and sprayed dicamba during the 2017 growing season. Respondents were asked questions about selected dicamba product, use of additional tank mix products (which allowed us to investigate whether their dicamba application led to injury in neighboring soybean fields and if the technology helped improve weed management). The results of this section allowed us to investigate the reliance (EXTRAPOLATE THE INFORMATION) on dicamba for POST-emergence weed control. The third section of the survey focused on injury observed in non-Xtend soybeans. Farmers were asked questions pertaining to dicamba injury patterns, whether an official complaint was filed with the Nebraska Department of Agriculture ([www.nda.nebraska.gov](http://www.nda.nebraska.gov)), and what they believed was the main cause for dicamba injury (tank-contamination, physical drift, volatilization, temperature inversion) and whether it was the results from dicamba applied in Xtend soybeans or corn.

Survey data were sorted and analyzed using the *sort*, *filter*, and *count* function of Excel. For most questions, results are presented in two fashions: i) percentage of answers and ii) number of hectares represented. The total number of respondents and hectares for all pertinent questions are included in the results. Not every respondent answered every question. Results from specific trends we were trying to investigate were only extracted from respondents that answered all pertinent questions. For instance, when trying to estimate whether Xtend hectares are expected to increase in 2018, only answers from respondents that completely answered survey questions 2 and 3 (Table 1) were used.

**RESULTS**

***Demographic information***

Survey results were obtained from 312 farmers from 60 Nebraska counties, representing a total of 77,855 hectares of soybeans grown in 2017 (Figure 1). Sixty three percent of the answers representing 44,620 hectares (57% of total hectares) were obtained during the Soybean Management Field Days. The remaining answers (43%, representing 33,235 hectares [43% of total hectares]) were obtained online. According to USDA-NASS (2017), Approximately 2,3 million hectares of soybeans were planted in Nebraska in 2017; therefore, the results of this survey represent approximately 3.4% of the total area planted in the state. Nonetheless, the major soybean areas in Nebraska was covered in this survey (Figure 1).

According to 277 participants, 68,796 soybean hectares were planted in 2017 and 63,768 hectares are expected to be planted in 2018 (a 7% reduction in soybean hectares expected for 2018 when compared to 2017). According to 299 participants, 13,994 out of 74,948 soybean hectares were planted with Xtend soybeans (19% of total hectares) in 2017. When evaluated on a per farm basis, 20% was the average number of hectares planted to Xtend soybeans in 2017 (ranging from XX to 100%; data not shown). According to 210 participants, the amount of Xtend hectares will likely double in 2018 in Nebraska. 27,813 out of 55,154 hectares are likely to be planted to Xtend soybeans (50% of total hectares). On a per farm basis average, producers will likely plant 52% of their soybean hectares with Xtend soybeans. When asked how many Xtend soybean hectares were treated with dicamba in 2017, 109 farmers indicated that 11,113 out of 13,817 were (80%). On a per farm basis, an average of 73.4% of their hectares were treated (ranging from XX to XX%). In 2018, 86 farmers indicated that 17,375 out of 19,169 hectares will be sprayed with dicamba (89% of total hectares) with an average of 87.5% hectares expected to be treated on a per farm basis. These results indicate that the soybean hectares planted with the Xtend technology and sprayed with dicamba will significantly increase in 2018. Similar trend is observed with Xtend technology in other US states (Reference). The manufacturer is expected nearly 16.2 million hectares of dicamba soybean varieties in 2018, which is approximately half of total soybean grown in the US (Monsanto). In general, growers are willing to adopt herbicide genetic modified crops with herbicide tolerance traits than other technologies (e.g., insecticide and fungicide traits) (Fernandez-Cornejo et al. 2014, Perry et al. 2016, Service 2007). For example, glyphosate tolerant crops were the most adopted technology in the history of modern agriculture (Dill et al. 2008, Duke and Powles 2008). Ten years after introduction of glyphosate tolerant soybean varieties, over 95% of soybean hectares in the US was treated with glyphosate (Benbrook 2016, Bonny 2008).

When asked whether they own a sprayer and spray their herbicide programs, 65% of respondents (total response = 218) reported they do. In terms of acreage, 71% of the hectares surveyed were sprayed by the farmer (out of a total of 51,950 hectares). When sorting the data and evaluating whether those who sprayed dicamba in Xtend soybeans in 2017 own a sprayer (total of 90 answers), 71% of respondents reported they do, representing 81% of the hectares surveyed (total of 12,154 hectares). These results indicate the importance of pesticide application training, particularly application of the new auxin formulations in Xtend soybeans, to non-commercial applicators. A survey showed the necessity of training and need for more regulations on dicamba application in Missouri (Bish and Bradley 2017). Moreover, the environmental protection agency (EPA) and manufacturers agreed with label changes and restrictions for dicamba application for the growing season of 2018. Some the regulations included specific application training, reduction in the time of day for dicamba application, wind speed, and application time of the year.

***Xtend technology and sprayed dicamba during the 2017 growing season***

*Nozzle selection – application related*

Regarding dicamba formulation, 55%, 38% and 7% of total hectares represented in the survey (11,664 hectares; 86 responses) were treated with Xtendimax, Engenia, and Fexapan herbicides, respectively. On a per farm basis, 58%, 37%, and 5% of respondents used Xtendimax, Engenia, and Fexapan, respectively. No farmer indicated the use of a non-labeled dicamba formulation (e.g., Banvel, Clarity, etc.) in Xtend soybeans during the 2017 growing season.

Complete responses from 89 farmers representing a total of 11,862 Xtend soybean hectares sprayed with dicamba were selected to investigate tank-mix product used alongside dicamba in Xtend soybeans POST-emergence applications. When asked whether glyphosate was tank-mixed with dicamba, 82%, 15% and 3% of respondents reported yes, no and not sure, respectively, which represented 84%, 15% and 1% of total hectares. When asked whether a POST-emergence herbicide other than glyphosate was tank-mixed with dicamba, 28%, 57%, and 15% said yes, no and not sure, respectively, which represented 29%, 59%, and 12% of total hectares (89 responses and a total of 11,862 hectares). ACCase inhibitors (WSSA Group 1; e.g., clethodim) followed by PPO inhibitors (WSSA Group 14; e.g., fomesafen) were the main answers (data not shown). When asked whether an herbicide with soil residual activity was added to the tank mix with dicamba, 25%, 53% and 22% of farmers reported yes, no, and not sure, respectively, which represented 27%, 52% and 21% of total hectares. Long-chain fatty acid inhibitors (Group 15; e.g., acetochlor, *S*-metolachlor, and dimethenamid-P) were the predominant answer

Complete responses from 63 farmers representing a total of 9,098 Xtend soybean hectares sprayed with dicamba indicated that 11%, 48%, 3%, 8%, 17%, 2% and 11% sprayed dicamba alone, with glyphosate, with a POST-emergence other than glyphosate, with glyphosate and another POST-emergence, with glyphosate and a soil-residual product, with glyphosate plus another POST and a residual product, respectively. In terms of hectares surveyed, 14%, 44%, 1%, 8%, 18%, 3%, and 13% were sprayed with the aforementioned tank-mixes, respectively. When asked whether the Xtend technology and dicamba application improved weed management in soybeans, 93% of farmers responded yes, representing 95% of total hectares surveyed (76 responses and a total of 10,882 hectares of Xtend soybeans sprayed with dicamba).

It is well documented the benefits of PRE-applied herbicide mixtures for controlling problematic weeds and protecting soybean yields in Nebraska (Oliveira et al. 2017). However, our results indicate that the weed management strategy on dicamba soybean varieties is likely to have less diversity of herbicide SOA. It is expected high reliance on dicamba alone for the management of troublesome weeds (e.g., waterhemp, Palmer amaranth, horseweed, giant ragweed, kochia, etc.), which have evolved resistance to glyphosate. In the past, less diversity of herbicides and dependence on glyphosate in cropping systems resulted in the rapid increase of glyphosate-resistant weeds (Heap, 2018). The dramatic evolution of herbicide resistant weeds in the US was part of the reasons for launching synthetic auxin-tolerant traits in crops (dicamba and 2,4 D). These new herbicide-tolerance traits will offer alternatives for controlling problematic weeds in Nebraska. However, the potential shift of single-based herbicide weed management strategy (e.g., glyphosate to synthetic auxin herbicides) might raise awareness of the long-term use of the auxin technology. As to date, 34 weeds species have already evolved resistance to auxin herbicides (Busi et al. 2017), including kochia (Cranston et al. 2001) and waterhemp (Bernards et al. 2012).

***Dicamba injury in non-Xtend soybeans***

Farmers were asked whether their dicamba application in Xtend soybean field injured neighboring non-Xtend soybean fields and 18%, 73% and 9% responded yes, no, and not sure, respectively (total of 92 answers). Those who observed injury in neighboring fields were asked what they believed was the cause of injury and 69%, 23% and 8% responded volatilization, physical drift, and temperature inversion (total of 13 answers).

Survey respondents were asked whether they observed dicamba injury in non-Xtend soybeans and 51% responded yes (total of 211 answers).

From those who reported complete responses, 50% observed injury. Farmers reported 6,164 injured hectares out of a total of 46,515 hectares (13%; total of 172 answers).

Those who observed dicamba injury in their non-Xtend soybeans, 53% observed injury in the entire field whereas 47% reported injury on the edges of the field (total of 85 answers). Those who observed injury on the edges of the fields, 33%, 39% and 28% reported the injury pattern to be odd-happed, severe near edge, and uniform, respectively (n=18). Those who observed injury in the entire field, 4%, 21% and 75% reported the injury pattern to be odd-happed, severe near edge, and uniform, respectively (n=28).

Farmers who observed dicamba injury in non-Xtend soybeans were asked whether they filed an official complaint with the Nebraska Department of Agriculture (NDA) and 7% responded yes and 93% no. The average injury acreage size of those who filed an official complaint with NDA was 179±35 (6 answers) and for those who did not was it 135±77 hectares (80 answers). Therefore, there was not a clear correlation between injury size and likelihood of filing an official complaint with the NDA.

When asked what they believed was the main cause of injury in their non-Xtend soybeans, 6%, 19%, 31%, 14%, 9%, 18%, and 4% believed it was because of tank-contamination, physical drift from dicamba application in Xtend soybeans, volatilization from dicamba application in Xtend soybeans, temperature inversion following dicamba application in Xtend soybeans, physical drift from dicamba application in corn, volatilization from dicamba application in corn, and temperature inversion following dicamba application in corn, respectively (total of 85 answers). According to results, 31% of respondents believed dicamba injury in non-Xtend soybeans came from dicamba application in corn. With widespread occurrence of Palmer amaranth in Nebraska, producers are relying more on dicamba applied later in the season for POST-emergence control in corn (personal communication). This change in use pattern of dicamba in corn for Palmer amaranth control in Nebraska and potential off-site movement needs to be further investigated.

Here we demonstrated the grower perspective on dicamba tolerant soybean varieties in Nebraska in 2017, the first year of introduction of this technology. Results showed that farmers are willing to adopt this technology as the number of soybean hectares with dicamba traits is expected to increase significantly in 2018. In Nebraska, the majority of the soybean hectares are sprayed by non-commercial applicators, which highlight the need for application training. Despite considerable number of auxin-resistant weeds worldwide, most of growers are eager to rely on POST-application dicamba for controlling weeds in Nebraska, repeating weed management strategy from the past. It remains unknown if complaints about dicamba injury on sensitive soybeans will increase in 2018. With restrict regulations and more dicamba tolerant soybean varieties growing in Nebraska, it might be expected less dicamba injury on sensitive soybean varieties. Further surveys are need for monitoring the status of the auxin-technology in Nebraska and elsewhere.



Figure 1.



Figure 2.

|  |
| --- |
| Table 1. Dicamba and Xtend soybeans survey questionnaire |
| **Demographics** |
| 1. County |
| 1. Total soybean hectares managed in 2017 and expected for 2018? |
| 1. Total Xtend soybean hectares managed in 2017 and expected for 2018? |
| 1. Total Xtend soybean hectares sprayed with dicamba in 2017 and expected for 2018? |
| 1. Do you own a sprayer and apply your herbicide programs? |
|  |
| **Dicamba application in Xtend soybeans** |
| 1. Which dicamba formulation was applied to your Xtend soybeans?   *a) XtendiMax*  *b) Engenia*  *c) Fexapan*  *d) Other* |
| 1. Was glyphosate included with the dicamba application?   *a) Yes*  *b) No*  *c) Not sure* |
| 1. Was an additional POST-emergence herbicide other than glyphosate included with the dicamba application?   *a) Yes* [which one(s)?]  *b) No*  *c) Not sure* |
| 1. Was a soil-residual herbicide included with the dicamba application?   *a) Yes* [which one(s)?]  *b) No*  *c) Not sure* |
| 1. Has weed management in soybeans significantly improved with the adoption of this technology?   *a) Yes*  *b) No* |
| 1. Did the dicamba application in your Xtend soybeans injure neighboring soybean fields?   *a) Yes* (how many injured hectares?)  *b) No*  *c) Not sure*  If Yes, what do you believe was the main cause of dicamba injury:  *a) physical drift*  *b) volatilization*  *c) temperature inversion* |
|  |
| **Dicamba injury in non-Xtend soybeans** |
| 1. Was dicamba injury noticed in your non-Xtend soybeans?   a) Yes (how many hectares?)  b) No (the survey ends here) |
| 1. Injury was observed mainly at:   a) edges of the field  b) entire field |
| 1. The injury pattern observed was:   a) uniform  b) severe near field edges  c) odd-shaped pattern |
| 1. Did you file an official complaint with the Nebraska Department of Agriculture?   a) Yes  b) No |
| 1. What do you believe was the main cause for dicamba injury in your non-Xtend soybeans? 2. Tank-contamination 3. Physical drift during application in Xtend soybeans 4. Volatilization from application in soybeans 5. Temperature inversion from application in Xtend soybeans 6. Physical drift during application in corn 7. Volatilization from application in corn 8. Temperature inversion from application in corn |
|  |