Nebraska Soybean Board
FINAL Research Report Form

DS VB 6/4/2019

Note: Submit this report no later than 90 days after the NSB-funded project officially terminates.
This post-project 90-day time-frame will allow the Lead PI time to complete any final data analysis and a final technical report, plus the drafting of any articles for submission to scientific journals. Note that this completed report will be provided to the curator of a national database of State, Region, and USA Soy checkoff funded projects.

Project # and Title: 1729: Impact of Dicamba drift on Non-Dicamba soybeans

Principal Investigator: Stevan Knezevic

Co-PI's & Institutions:

Project Date (Including Extension): 04/30/2017 ***to*** 04/30/2019 ***(example: mm/dd/yyyy to mm/dd/yyyy)***

Total Budget for Project: $ 122,576.00

1. Briefly State the Rational for the Research:

Control of glyphosate resistant weeds with dicamba has been encouraging, and has resulted in an increasing adoption of the DT-soybeans. However, the off-target movement of dicamba-based products to non-DT soybeans and other broadleaf crops has become a significant concern. Negative impact of dicamba on non-DT soybean may vary with dicamba rate, soybean type, and soybean growth stage at the time of drift occurrence.

2. Research Objectives (copy from project, but keep in a brief bullet format):

1. To establish baseline data on the injury of potentially sensitive crops (eg. non-DT soybeans) to six micro-rates of Dicamba herbicide (Xtendimax and Engenia).

2. To collect photos of injury symptoms (time-lapse photography) in order to develop educational materials and power-point presentations that can be disseminated to farmers through traditional and web-based technologies.

3. General Approach Used and (if applicable) the Nebraska Test Locations:

Field trials were conducted in 2017 and 2018 at Haskell Ag Lab, Concord, NE. The study was laid out as a split-plot treatment design with 6 micro rates of dicamba products (Clarity, Engenia and XtendiMax), 3 application times (soybean growth stages) in a RCB experimental design with 4 replications. In 2017, the dicamba rates included: 0, 1/10; 1/50; 1/100; 1/500; and 1/1000 of the standard product label rate for DT types. In 2018, the dicamba rates included: 0, 1/10; 1/100; 1/1000; 1/5000; and 1/10000 of the standard product label rate. Plots had four rows of each soybean types (Round-up Ready, Liberty-Link, Conventional, and Dicamba-Tolerant serving as a check). To simplify visuals of the amount of the rates on a per acre basis, the 1/10th of the label rate is equivalent to 3 tablespoons, 1/100th is a 1 teaspoon, 1/500 is 1/5th of a teaspoon and 1/1000 is 1/10th of a teaspoon applied over a size of football field (1 acre).
The three application times were: (1) second expanded trifoliate (V2), (2) just before flowering (V7/R1) and (3) full flowering (R2). Visual evaluation of injuries was conducted at 7, 14, 21, and 28 days after treatment (DAT). Soybean morphological development measurements included plant heights, number of branches, days to canopy closure (for V2 and V7/R1 only), days to flowering (for V2 only), number of flowers (V2 and V7/R1), and days to maturity. Yields of all soybean types were harvested.

4. Describe: Deliverables & Significance Attained for Each Research Objective:

Results from this project were used to develop a variety of deliverables, which included: scientific manuscripts, posters and oral presentations for professional Weeds Science Society conferences, extension articles published in Crop Protection Clinics, Wed-Based Crop Watch, Trade Journals and Local Newspapers. Also, whole series of Power-Point presentations were developed and delivered during many extension programs across Nebraska over last 3 years. Set of time-lapse videos are also developed and shared with Soybean Board members.

The list of significant learnings from the project included:

1. Roundup Ready, Liberty-Link, and Conventional soybeans were equally sensitive to all tested micro-rates of Clarity, Engenia and XtendiMax.

2. When micro-rates were increased, crop growth parameters were significantly impacted, including: reductions in plant height by 4-12”, alterations in branching pattern, delayed days to canopy closure by 7 to 14 days, and delayed flowering by up to 12 days, and reduced flower numbers by as much as 92%, delayed dates of physiological maturity from 11-24 days, and most importantly reductions in soybean yield. The negative impacts were dependent on application date with the soybean growth stage; with V7/R1 stage being the most dicamba sensitive.

3. As for visual injuries, all dicamba products injured non-DT soybean varieties in a similar fashion. Visual injuries ranged from 20-90% across all products and application times. The observed injuries were visible in the form of: leaf cupping, curling and twisting of stem (epinasty), stunted shoot, swollen nodes and necrosis. Additional symptoms such as flower abortion, swollen nodes and curling pods were observed when dicamba was applied at V7/R1 or R2 stage.

4. Describe: Deliverables & Significance Attained for Each Research Objective (continued):

4. Yield of all non-DT soybeans were significantly affected by all tested dicamba products irrespective of application time. Yields of Conventional, Liberty-Link and Roundup-Ready soybeans ranged from 50-60bu/A in non-sprayed control plots. (for details, see Technical Report or individual Year-End Reports)).

5. Yield losses varied from 5% - 90% depending on the dicamba dose and application time. In 2018, Engenia doses of 0.02-0.05, 0.04-0.07 and 0.01-0.04 oz/A reduced yield by 5% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, depending on the crop growth stage of Engenia application. XtendiMax doses of 0.02-0.08, 0.02-0.05 and 0.02-0.07 oz/A reduced yield by 5% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, also depending on the crop growth stage of exposure. The V7/R1 was the most sensitive stage to both herbicides and all three soybean types.

6. Others scientists across USA also reported similar soybean responses to dicamba in their studies. They all reported doses of dicamba that are similar to the ones we have calculated in our study. For example, the dose that can cause 5% yield reductions ranged from 0.3g (1/1800) to 1.9g = 1/300 of the label rates. To help visualize such small amounts of dicamba, those rates are equivalent to about 1/10 to 1/2 of the teaspoon (1 teaspoon = 5g). These results clearly demonstrated that non-DT soybeans are were sensitive to low-rates of Engenia and XtendiMax, hence, efforts must be made to avoid drift of dicamba onto non-DT soybeans or any sensitive crops

5. List where the Project Research Results/Findings were Publicized:

- Presented 14 posters in 2017 and 6 posters in 2018 at North Central Weeds meetings.
- Presented 1 talk at International Plant Science Conference in Rome.
- Presented 2 posters and 1 talk in 2018 at the WSSA meetings in New Orleans.
- Presented 2 posters in 2018 at the Western Society of Weeds in Denver.
- Total of about 20 Power Point presentations for use during UNL-Extension Meetings, Hasker Harvest Days, Crop Consultants Meetings, and Farm Shows, which are attended by farmers, crop consultants, and Ag folks in general.
- Multiple articles in UNL Web-based Crop-Watch Newsletter and local papers (Norfolk, Wayne)
- 2 published Manuscripts: Osipitan, O.A., Scott, J.E., Knezevic, S.Z. (2019). “Glyphosate-Tolerant Soybean Response to Microrates of Dicamba Based Herbicides”. Agrosystems Geoscience and Environment, 2:1-8.

Knezevic, S.Z., Osipitan, O.A., Scott, J.E. (2018). “Sensitivity of Grape and Tomato to Micro-rates of Dicamba-Based Herbicides”. Journal of Horticulture, 45: 229.

Note: The above boxes will automatically accomodate for your text inputs; HOWEVER, the Final Report comprised of the above listed items must be kept to THREE PAGES. A Technical Report of no more than TEN PAGES (preferably fewer) can be appended to this report.
Submit both reports as a single PDF with this file name format: #XXX > FINAL > Project Title > PI last name

Please email this completed form to the Agriculture Research Division (jmonaghan2@unl.edu) based on the reporting schedule given to you. If you have any questions, please call the ARD at 2-2045 or Victor Bohuslavsky at the Nebraska Soybean Board Office at (402) 432-5720.

Final Report

Impact of Dicamba Drift on Non-Dicamba Soybeans

Dr. Stevan Knezevic; sknezevic2@unl.edu; *University of Nebraska*

Introduction: Control of glyphosate resistant weeds with dicamba has been encouraging, and has resulted in an increasing adoption of the DT-soybeans. However, the off-target movement of dicamba-based products to non-DT soybeans and other broadleaf crops has become a significant concern. Negative impact of dicamba on non-DT soybean may vary with dicamba rate, soybean type, and soybean growth stage at the time of drift occurrence.

Study objectives: (1) To establish baseline data on the injury of potentially sensitive crops (eg. non-DT soybeans) to six micro-rates of Dicamba herbicide (Xtendimax and Engenia). (2) To collect photos of injury symptoms (time-lapse photography) in order to develop educational materials and power point presentations that can be disseminated to farmers through traditional and web based technology.

Results: Roundup Ready, Liberty-Link, and Conventional soybeans were equally sensitive to all tested micro-rates of Clarity, Engenia and XtendiMax. When micro-rates were increased, crop growth parameters were significantly impacted, including: reductions in plant height by 4-12", alterations in branching pattern, delayed days to canopy closure by 7 to 14 days, and delayed flowering by up to 12 days, and reduced flower numbers by as much as 92%, delayed dates of physiological maturity from 11-24 days, and most importantly reductions in soybean yield. The negative impacts were dependent on application date with the soybean growth stage; with V7/R1 stage being the most dicamba sensitive.

As for visual injuries, all dicamba products injured non-DT soybean varieties in a similar fashion. Visual injuries ranged from 20-90% across all products and application times. The observed injuries were visible in the form of: leaf cupping, curling and twisting of stem (epinasty), stunted shoot, swollen nodes and necrosis. Additional symptoms such as flower abortion, swollen nodes and curling pods were observed when dicamba was applied at V7/R1 or R2 stage.

Yields of all non-DT soybeans were significantly affected by all tested dicamba products irrespective of application time. In 2017, Conventional, Liberty-Link and Roundup-Ready soybeans yielded 58, 60, 60 bu/A in non-sprayed control plots. In 2018, the non-sprayed Conventional, Liberty-Link and Roundup-Ready soybeans yielded 56, 47, and 69 bu/A respectively.

In 2017, Engenia rate of 1/10 (1.28 oz/A) lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans from 58, 60, 60 bu/A in non-sprayed plots to 24, 22, and 27 bu/A, respectively, in plots sprayed at V2 stage. The same rate of Engenia lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans to 18, 15 and 25 bu/,A, respectively, when sprayed at R2. Spraying Engenia at the 1/10 rate further lowered yields to 3, 2 and 4 bu/A for Conventional, Liberty-Link and Roundup-Ready soybeans respectively, when sprayed at V7/R1 soybean stage. In 2018, Engenia sprayed at V2 stage with

1/10 (1.28 oz/A), soybeans yielded 33, 31, and 51 bu/A, respectively. The 1/10 rate of Engenia, when applied at R2, lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans further to 11, 14 and 17 bu/A, respectively. Yields were further lowered to 10, 6, and 12 bu/A respectively, when Conventional, Liberty-Link and Roundup-Ready soybeans were sprayed with Engenia at V7/R1 stage.

In 2018, XtendiMax rate of 1/10 (2.2 oz/A) lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans from 51, 43 and 63 bu/A to 37, 28 and 48 bu/A, respectively, when sprayed at V2 stage. The 1/10 rate of XtendiMax lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans to 20, 10 and 21 bu/A, respectively, when sprayed at R2. Spraying XtendiMax at the 1/10 rate drastically lowered yields to 8, 3 and 16 bu/A for Conventional, Liberty-Link and Roundup-Ready soybeans, respectively, when sprayed at V7/R1 soybean stage.

In 2018, the 1/100 of the labels rates reduced the soybean yields to 40-58 bu/A when applied at the V2 stage. For instance, 1/100 of label rate of Engenia reduced yields to about 50 bu/A in Conventional, 40 bu/A in Liberty-Link, and 63 bu/A in Roundup-Ready soybean. The same rate applied at V7/R1 stage reduced yields to about 40 bu/A in Conventional, 36 bu/A in Liberty-Link and 47 bu/A in Roundup-Ready soybean. The 1/1000 of dicamba label rate also caused reduction in the non-DT-soybeans yields. For example, in Roundup-Ready soybeans, the 1/1000 of label rate applied at V7/R1stage reduced yields from 69 to 62 bu/A with Engenia and from 68 to 62bu/A with XtendiMax.

Yield losses varied from 5% - 90% depending on the dicamba dose and application time. In 2017, Engenia dose of 0.12-0.33, 0.16-0.41 and 0.18-0.37 oz/A reduced yield by 50% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, depending on the crop growth stage of Engenia application. The V7/R1 was the most sensitive stage to Engenia in Conventional and Roundup-Ready soybeans as 0.12 oz/A reduced yield by 50%. In 2018, Engenia doses of 0.02-0.05, 0.04-0.07 and 0.01-0.04 oz/A reduced yield by 5% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, depending on the crop growth stage of Engenia application.

In 2017, XtendiMax dose of 0.16-0.69, 0.27-0.68 and 0.25-0.77 oz/A reduced yield by 50% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, depending on the crop growth stage of XtendiMax application. The V7/R1 was the most sensitive stage to XtendiMax in Liberty-Link and Roundup-Ready soybeans as 0.18-0.25 oz/A reduced yield by 50%. In 2018, XtendiMax doses of 0.02-0.08, 0.02-0.05 and 0.02-0.07 oz/A reduced yield by 5% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, also depending on the crop growth stage of exposure. The V7/R1 was the most sensitive stage to both herbicides and all three soybean types.

Discussion and Conclusion:

The results from this study clearly showed that all non-DT soybeans tested (Conventional, Liberty-Link and Roundup-Ready) were very sensitive to micro-rates of Clarity, Engenia and XtendiMax.

The yield losses varied with the doses and application time. The 5% yield loss is utilized to illustrate potential for yield losses, which is equivalent to about 3 bushel/acre assuming a 60 bushel/acre common yields). It is reasonable to determine such level of yield differences consistently across years and locations despite the natural variability in field experimentations. The range of doses that reduced yields by 5% varied from 0.01 to 0.07 oz/A (0.3 to 1.9g ae/ha) across all herbicides, application times and soybean types (Table 12). The lowest rates of 0.3-0.56 g/ha were calculated for V7/R1 stage and to highest rates of 1.4 – 1.9 g ae/ha for V2 and R2 stages. The 0.3g equals 1/1800 while 1.9g = 1/300 of the label rates.

Others also reported similar soybean responses to dicamba in their studies. Robinson et al. (2013) estimated that a dicamba rate less than 1/1000 of the label rate caused 5% yield loss across growth stages. He estimated that 0.14 and 0.24 g ae ha^{-1} of dicamba was required to cause 5% soybean yield loss when applied at V2 and R2 stage respectively. Meanwhile, Foster and Griffin (2018) showed that 0.6 to 4.4 g ae ha^{-1} of dicamba caused 1% - 9% yield loss when applied at V3/V4 stage and 2% - 17% yield loss when applied at R1/R2 stage. An earlier meta-analysis by Egan et al. (2014) using six different studies suggested that approximately 4% yield loss was caused by 5.6 g ae ha^{-1} (1/100 of label rate) of dicamba when applied at vegetative stages

Similarly, Kniss (2018) in his meta-analysis reported that 5% yield loss threshold was calculated across various growth stages. For example, at early vegetative stage (V1-V3), 5% yield loss could be caused by 1.9 g ae ha^{-1} (1/295 of the label rate), while at late vegetative stages (V4-V7), 5.7 g ae ha^{-1} (1/98 of the label rate) could cause 5% yield loss. The reproductive stage (R1-R2) required the least amount (0.89 g ae ha^{-1}, equivalent to 1/629 of the label rate) of dicamba to cause 5% yield loss. However, there were differences in the estimated doses for 5% yield loss among the individual studies used in the meta-analysis. For example, at early vegetative stage, Anderson et al. (2004) suggested 1.6 g ae ha^{-1} (1/350 of label rate) of dicamba caused 5% yield loss, while Johnson et al. (2012) suggested 2.2 g ae ha^{-1} (1/254 of label rate) of dicamba for the same level of yield loss. At reproductive stage, Griffin et al. (2013) suggested 0.15 g ae ha^{-1} (1/3733 of label rate) caused 5% yield loss, while Soltani et al. (2016) suggested 0.16 g ae ha^{-1} (1/3500 of label rate) caused the same level of yield loss.

All of the above examples are similar to the doses that caused 5% yield loss in our study (0.3g – 1.9 g ae ha^{-1}), therefore, in conclusion, Clarity, Engenia and XtendiMax had very similar effects on the growth and development of all non-DT soybeans. Soybean yields were affected by exposure to dicamba at all three growth stages, and the most sensitive stage was V7/R1. The range of doses that can cause soybean yield reductions ranged from 0.3g (1/1800) to 1.9g = 1/300 of the label rates. To help visualize such small amounts of dicamba, those rates are equivalent to about 1/10 to 1/2 of the teaspoon (1 teaspoon = 5g). These results clearly demonstrated that non-DT soybeans are were sensitive to low-rates of Clarity, Engenia and XtendiMax, hence, efforts must be made to avoid drift of dicamba onto non-DT soybeans or any sensitive crops.

Key references (please see Technical Report for list of references):

Final Technical Report

(2017 - 2018)

Project Title:

Impact of Dicamba Drift on Non-Dicamba Soybeans

Investigator:

Dr. Stevan Knezevic

Professor of Integrated Weed Management

University of Nebraska

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402-404-0175

Introduction: Control of glyphosate resistant weeds with dicamba has been encouraging, and has resulted in an increasing adoption of the DT-soybeans. However, the off-target movement of dicamba-based products to non-DT soybeans and other broadleaf crops has become a significant concern. Negative impact of dicamba on non-DT soybean may vary with dicamba rate, soybean type, and soybean growth stage at the time of drift occurrence.

Study objectives:

(1) To establish baseline data on the injury of potentially sensitive crops (eg. non-DT soybeans) to six micro-rates of Dicamba herbicide (Xtendimax and Engenia).

(2) To collect photos of injury symptoms (time-lapse photography) in order to develop educational materials and power point presentations that can be disseminated to farmers through traditional and web based technology.

Study procedures:

Field trials were conducted in 2017 and 2018 at Haskell Ag Lab, Concord, NE. The study was laid out as a split-plot treatment design with 6 micro rates of dicamba products (Clarity, Engenia and XtendiMax), 3 application times (soybean growth stages) in a RCB experimental design with 4 replications. In 2017, the dicamba rates included: 0, 1/10; 1/50; 1/100; 1/500; and 1/1000 of the standard product label rate for DT types. In 2018, the dicamba rates included: 0, 1/10; 1/100; 1/1000; 1/5000; and 1/10000 of the standard product label rate. Plots had four rows of each soybean types (Round-up Ready, Liberty-Link, Conventional, and Dicamba-Tolerant serving as a check).

The three application times were: (1) second expanded trifoliate (V2), (2) just before flowering (V7/R1) and (3) full flowering (R2). Visual evaluation of injuries was conducted at 7, 14, 21, and 28 days after treatment (DAT). Soybean morphological development measurements included plant heights, number of branches, days to canopy closure (for V2 and V7/R1 only), days to flowering (for V2 only), number of flowers (V2 and V7/R1), and days to maturity. Yields of all soybean types were harvested.

A four parameter log-logistic regression equation was used to model the relationship between dicamba micro-rates, and soybean growth, and yield variables. The regression analyses helped to estimate the dicamba micro-rate at which a certain level of injury or yield reduction could be predicted. Mean values were collected for variables which regression analyses were not possible.

A series of time-lapse cameras (3 herbicides x 3 application timing x 3 herbicide rates) were utilized to record soybean injury per day (10:00 am – 3:00 pm), for 28 days after the date of the spray treatment (DAT).

Results

Roundup Ready, Liberty-Link, and Conventional soybeans were equally sensitive to all tested micro-rates of Clarity, Engenia and XtendiMax. When micro-rates were increased, crop growth parameters were significantly impacted, including: reductions in plant height by 4-12", alterations in branching pattern, delayed days to canopy closure by 7 to 14 days, and delayed flowering by up to 12 days, and reduced flower numbers by as much as 92%, delayed dates of physiological maturity from 11-24 days, and most importantly reductions in soybean yield. The negative impacts were dependent on application date with the soybean growth stage; with V7/R1 stage being the most dicamba sensitive.

1. Visual Injury:

All dicamba products injured non-DT soybean varieties in a similar fashion. Visual injuries ranged from 20-90% across all products and application times. The observed injuries were visible in the form of: leaf cupping, curling and twisting of stem (epinasty), stunted shoot, swollen nodes and necrosis. Additional symptoms such as flower abortion, swollen nodes and curling pods were observed when dicamba was applied at V7/R1 or R2 stage. The leaf and stem injury appeared within 7 to 14 days after treatment (DAT). For example, the soybeans treated at V2 stage with the highest rate (1/10 of the label rate) had highly visible injuries that lasted throughout the entire growing season. While those treated with the lower rate (1/1000 of the label rate) had observable leaf injury for 30 days. The greatest visual injury by the dicamba micro-doses was generally observed when applied at V2 and V7/R1 stage. The 1/10 of the label rate of Engenia or XtendiMax caused as much as 80% injury 21 days after treatment; whereas, at R2 stage the injury was about 65%. Across all tested products and soybean type, V7/R1 required the least amount of any of the dicamba product to cause 50% injury, suggesting that V7/R1 was the most sensitive stage to application.

2. Yield:

Yield of all non-DT soybeans were significantly affected by all tested dicamba products irrespective of application time. In 2017, Conventional, Liberty-Link and Roundup-Ready soybeans yielded 58, 60, 60 bu/A in non-sprayed control plots. In 2018, the non-sprayed Conventional, Liberty-Link and Roundup-Ready soybeans yielded 56, 47, and 69 bu/A respectively.

In 2017, Engenia rate of 1/10 (1.28 oz/A) lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans from 58, 60, 60 bu/A in non-sprayed plots to 24, 22, and 27 bu/A, respectively, in plots sprayed at V2 stage. The same rate of Engenia lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans to 18, 15 and 25 bu/,A, respectively, when sprayed at R2. Spraying Engenia at the 1/10 rate further lowered yields to 3, 2 and 4 bu/A for Conventional, Liberty-Link and Roundup-Ready soybeans respectively, when sprayed at V7/R1 soybean stage. In 2018, Engenia sprayed at V2 stage with 1/10 (1.28 oz/A), soybeans yielded 33, 31, and 51 bu/A, respectively. The 1/10 rate of Engenia, when applied at R2, lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans further to 11, 14 and 17 bu/A, respectively. Yields were further lowered to 10, 6, and 12 bu/A respectively, when Conventional, Liberty-Link and Roundup-Ready soybeans were sprayed with Engenia at V7/R1 stage.

In 2017, XtendiMax rate of 1/10 (2.2 oz/A) lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans from 58, 61 and 63 bu/A in non-sprayed plots to 25, 27 and 33 bu/A, respectively, in plots sprayed at V2 stage. The same rate of XtendiMax lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans to 11, 20 and 26 bu/A, respectively, when sprayed at R2. Spraying Engenia at the 1/10 rate further lowered yields to 3, 2 and 5 bu/A for Conventional, Liberty-Link and Roundup-Ready soybeans, respectively, when sprayed at V7/R1 soybean stage.

In 2017, the 1/50 and 1/100 of the labels rates reduced soybean yields by 13-16 bu/A when applied at the V2 stage. For example, 1/100 of label rate of Engenia reduced yields by about 14 bu/A in Conventional, 16 bu/A in Liberty-Link, and 13 bu/A in Roundup-Ready soybean. The same rate applied at V7/R1 stage reduced yields by about 26 bu/A in Conventional, 18 bu/A in Liberty-Link and 26 bu/A in Roundup-Ready soybean. Yields were also reduced even with "very low" exposures of 1/500 and 1/1000 of the label rate. For example, the 1/1000 of label rate of Engenia applied at V2 stage reduced yields by about 4 bu/A in Conventional, 2 bu/A in Liberty-Link, and 4 bu/A in Roundup-Ready soybean. The same rates applied at V7/R1 stage reduced yields by 11 bu/A in Conventional, 3 bu/A in Liberty-Link and 8 bu/A in Roundup-Ready soybean.

In 2018, XtendiMax rate of 1/10 (2.2 oz/A) lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans from 51, 43 and 63 bu/A to 37, 28 and 48 bu/A, respectively, when sprayed at V2 stage. The 1/10 rate of XtendiMax lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans to 20, 10 and 21 bu/A, respectively, when sprayed at R2. Spraying XtendiMax at the 1/10 rate drastically lowered yields to 8, 3 and 16 bu/A for Conventional, Liberty-Link and Roundup-Ready soybeans, respectively, when sprayed at V7/R1 soybean stage.

In 2018, the 1/100 of the labels rates reduced the soybean yields to 40-58 bu/A when applied at the V2 stage. For instance, 1/100 of label rate of Engenia reduced yields to about 50 bu/A in Conventional, 40 bu/A in Liberty-Link, and 63 bu/A in Roundup-Ready soybean. The same rate applied at V7/R1 stage reduced yields to about 40 bu/A in Conventional, 36 bu/A in Liberty-Link and 47 bu/A in Roundup-Ready soybean. The 1/1000 of dicamba label rate also caused reduction in the non-DT-soybeans yields. For example, in Roundup-Ready soybeans, the 1/1000 of label rate applied at V7/R1stage reduced yields from 69 to 62 bu/A with Engenia and from 68 to 62bu/A with XtendiMax.

3. Yield losses:

In 2017, Engenia dose of 0.12-0.33, 0.16-0.41 and 0.18-0.37 oz/A reduced yield by 50% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, depending on the crop growth stage of Engenia application. The V7/R1 was the most sensitive stage to Engenia in Conventional and Roundup-Ready soybeans as 0.12 oz/A reduced yield by 50%. In 2018, Engenia doses of 0.02-0.05, 0.04-0.07 and 0.01-0.04 oz/A reduced yield by 5% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, depending on the crop growth stage of Engenia application (Figure 1, Table 1).

In 2017, XtendiMax dose of 0.16-0.69, 0.27-0.68 and 0.25-0.77 oz/A reduced yield by 50% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, depending on the crop growth stage of XtendiMax application. The V7/R1 was the most sensitive stage to XtendiMax in Liberty-Link and Roundup-Ready soybeans as 0.18-0.25 oz/A reduced yield by 50%. In 2018, XtendiMax doses of 0.02-0.08, 0.02-0.05 and 0.02-0.07 oz/A reduced yield by 5% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, also depending on the crop growth stage of exposure. The V7/R1 was the most sensitive stage to both herbicides and all three soybean types (Figure 1, Table 1).

Discussion and Conclusion:

The results from this study clearly showed that all non-DT soybeans tested (Conventional, Liberty-Link and Roundup-Ready) were very sensitive to micro-rates of Clarity, Engenia and XtendiMax.

Visual injury caused by all three dicamba products ranged from 20-80%. Soybean exposure to dicamba just before flowering resulted in the greatest soybean injury and greatest yield losses. Types of soybean injuries ranged from: leaf cupping at V2 and V7/R1 spraying, epinasty (curly stems) at V2, V7/R1 and R2 timings; abortion of flowers at V7/R1; and swollen nodes and curly pods at R2 timing.

Soybean height was reduced by 10-85% across all dicamba micro-rate and the growth stages of dicamba application. Reduction in soybean height delayed canopy closure when sprayed at V2 stage, while there was no complete canopy closure when sprayed at V7/R1 stage. From practical standpoint, the reduced soybean height, and delayed (or no) canopy closure could potentially reduce soybean competitive ability against weeds. Delayed flowering and maturity caused by the micro-rates of dicamba, delayed harvest till later part of the season, thereby potentially subjecting the soybeans to early frost damage.

The yield losses varied with the doses and application time. The 5% yield loss is utilized to illustrate potential for yield losses, which is equivalent to about 3 bushel/acre assuming a 60 bushel/acre common yields). It is reasonable to determine such level of yield differences consistently across years and locations despite the natural variability in field experimentations. The range of doses that reduced yields by 5% varied from 0.01 to 0.07 oz/A (0.3 to 1.9g ae/ha) across all herbicides, application times and soybean types (Table 12). The lowest rates of 0.3-0.56 g/ha were calculated for V7/R1 stage and to highest rates of 1.4 – 1.9 g ae/ha for V2 and R2 stages. The 0.3g equals 1/1800 while 1.9g = 1/300 of the label rates.

Others also reported similar soybean responses to dicamba in their studies. Robinson et al. (2013) estimated that a dicamba rate less than 1/1000 of the label rate caused 5% yield loss across growth stages. He estimated that 0.14 and 0.24 g ae ha^{-1} of dicamba was required to cause 5% soybean yield loss when applied at V2 and R2 stage respectively. Meanwhile, Foster and Griffin (2018) showed that 0.6 to 4.4 g ae ha^{-1} of dicamba caused 1% - 9% yield loss when applied at V3/V4 stage and 2% - 17% yield loss when applied at R1/R2 stage. An earlier meta-analysis by Egan et al. (2014) using six different studies suggested that approximately 4% yield loss was caused by 5.6 g ae ha^{-1} (1/100 of label rate) of dicamba when applied at vegetative stages

Similarly, Kniss (2018) in his meta-analysis reported that 5% yield loss threshold was calculated across various growth stages. For example, at early vegetative stage (V1-V3), 5% yield loss could be caused by 1.9 g ae ha^{-1} (1/295 of the label rate), while at late vegetative stages (V4-V7), 5.7 g ae ha^{-1} (1/98 of the label rate) could cause 5% yield loss. The reproductive stage (R1-R2) required the least amount (0.89 g ae ha^{-1}, equivalent to 1/629 of the label rate) of dicamba to cause 5% yield loss. However, there were differences in the estimated doses for 5% yield loss among the individual studies used in the meta-analysis. For example, at early vegetative stage, Anderson et al. (2004) suggested 1.6 g ae ha^{-1} (1/350 of label rate) of dicamba caused 5% yield loss, while Johnson et al. (2012) suggested 2.2 g ae ha^{-1} (1/254 of label rate) of dicamba for the same level of yield loss. At reproductive stage, Griffin et al. (2013) suggested 0.15 g ae ha^{-1} (1/3733 of label rate) caused 5% yield loss, while Soltani et al. (2016) suggested 0.16 g ae ha^{-1} (1/3500 of label rate) caused the same level of yield loss.

All of the above examples are similar to the doses that caused 5% yield loss in our study (0.3g – 1.9 g ae ha^{-1}), therefore, in conclusion, Clarity, Engenia and XtendiMax had very similar effects on the growth and development of all non-DT soybeans. This was evident by measuring various growth and development parameters, including final yields. Soybean yields were affected by exposure to dicamba at all three growth stages, and the most sensitive stage was V7/R1. The range of doses that can cause soybean yield reductions ranged from 0.3g (1/1800) to 1.9g = 1/300 of the label rates. To help visualize such small amounts of dicamba, those rates are equivalent to about 1/10 to 1/2 of the teaspoon (1 teaspoon = 5g). These results clearly demonstrated that non-DT soybeans are were sensitive to low-rates of Clarity, Engenia and XtendiMax, hence, efforts must be made to avoid drift of dicamba onto non-DT soybeans or any sensitive crops.

Key references:

1. Anderson, S.M., Clay, S.A., Wrage, L.J., Matthees, D. (2004). “Soybean Foliage Residues of Dicamba and 2,4-D and Correlation to Application Rates and Yield”. *Agron. J.*, 96:750-760

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4. Griffin, J.L., M.J., Stephenson, D.O., Miller, D.K., and Boudreaux, J.M., (2013) “Soybean Response to Dicamba Applied at Vegetative and Reproductive Growth Stages”. *Weed Technology*, 27:696-703

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6. Robinson, A.P., Simpson, D.M., Johnson, W.G. (2013). “Response of Glyphosate-Tolerant Soybean Yield Components to Dicamba Exposure”. *Weed Science*, 61:526-536

7.Soltani, N., Nurse, R.E., Sikkema, P.H. (2016). “Response of Glyphosate-Resistant Soybean to Dicamba Spray Tank Contamination during Vegetative and Reproductive Growth Stages” *Can. J. Plant Sci.*, 96:160-164

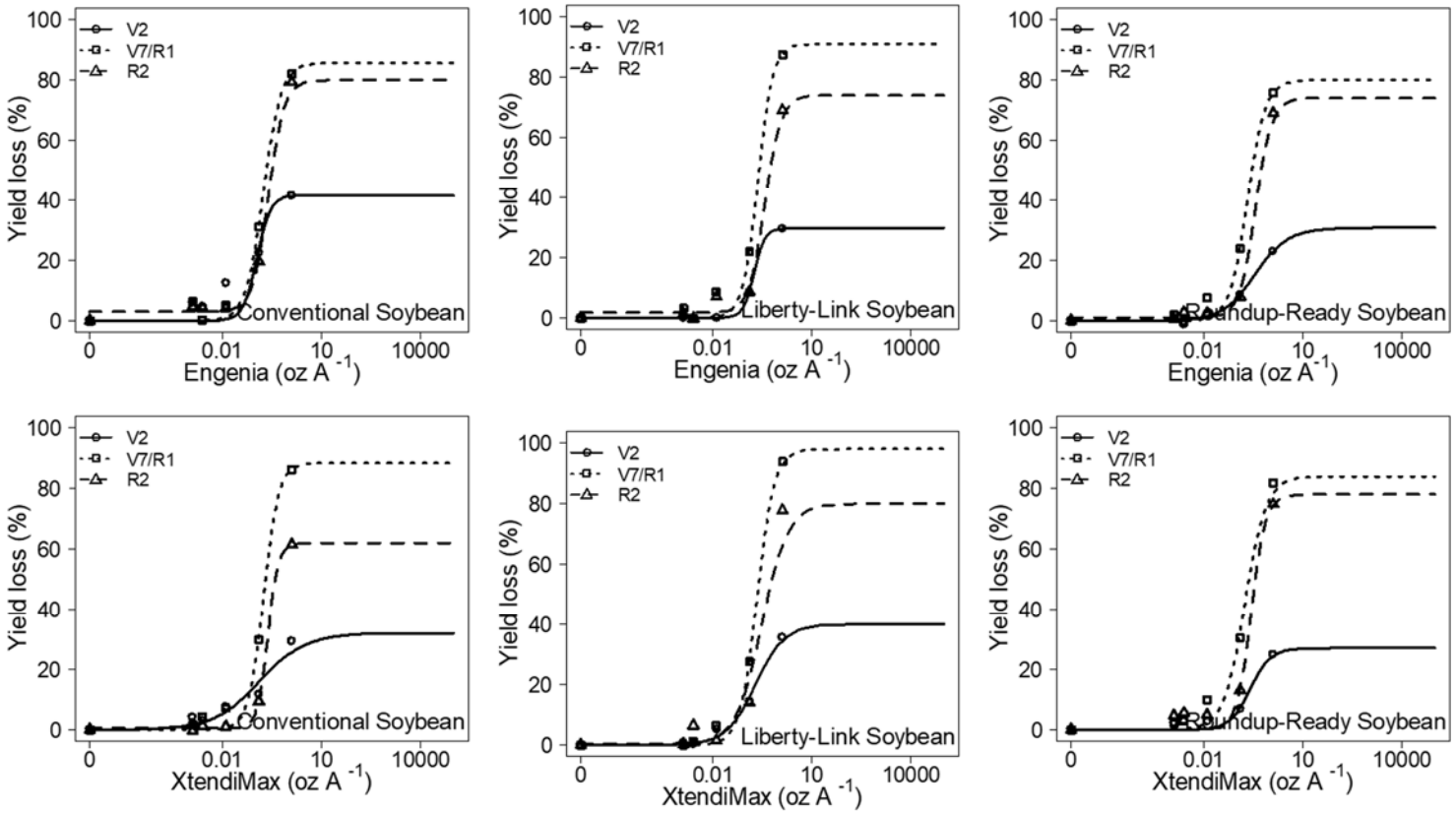

Figure 1. Yield loss in Conventional, Liberty-Link and Roundup-Ready soybeans as caused by micro-rates of dicamba products at 28 DAT for three growth stages in 2018.

Table 1: Dose of Engenia and XtendiMax in oz/acre or g ae/ha that resulted in 5% yield loss (ED5) of Conventional, Liberty-Link and Roundup-Ready soybeans sprayed at three growth stages in 2018

		Engenia	XtendiMax
		Oz/acre or g/ha	Oz/acre or g/ha
Conventional	V2	0.03 (0.01) or 0.84g	0.02 (0.001) or 0.56g
	V7/R1	0.02 (0.002) or 0.56g	0.04 (0.003) or 1.1g
	R2	0.05 (0.007) or 1.4g	0.08 (0.01) or 2.2g
Liberty-Link	V2	0.06 (0.07) or 1.7g	0.05 (0.001) or 1.4g
	V7/R1	0.04 (0.008) or 1.1g	0.02 (0.01) or 0.56g
	R2	0.07 (0.01) or 1.9g	0.02 (0.0004) or 0.56g
Roundup Ready	V2	0.04 (0.004) or 1.1g	0.07 (0.03) or 1.9g
	V7/R1	0.01 (0.006) or 0.3g	0.02 (0.001) or 0.56g
	R2	0.03 (0.005) or 0.8g	0.05 (0.01) or 1.4g

Standard error in parenthesis; 1oz=28g.

Yearly Report - 2018

Project Title:

Impact of Dicamba Drift on Non-Dicamba Soybeans

Investigator:

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Introduction:

Control of glyphosate resistant weeds with dicamba has been encouraging, and has resulted in an increasing adoption of the DT-soybeans. However, the off-target movement of dicamba-based products to non-DT soybeans and other broadleaf crops has become a significant concern. Negative impact of dicamba on non-DT soybean may vary with dicamba rate, soybean type, and soybean growth stage at the time of drift occurrence.

The majority of soybean acreage are still planted to non-DT varieties. During 2017 and 2018 season there were many dicamba drift complaints. For example, the Nebraska State Department of Agriculture received over 90 complaints of dicamba drift onto non-DT soybeans with an estimated impact on 60,000 affected acres in 2018. In addition, there were over a thousand complaints across Midwestern region. It is known that fine-sized dicamba spray droplets have tendency not only to drift with any air movement (even very slow wind), but also to move off target when fine aerosol droplets remain suspended during air temperature inversions (defined as air temperatures near the soil or canopy surfaces that are cooler than those higher up), high humidity, and little or no wind. These suspended tiny aerosol-size dicamba droplets may not evaporate for some time, and thus can drift from the target site, especially in the first 36 hours after application. This drift can travel onto nearby fields with various dicamba-sensitive crops including non-DT soybeans.

Study objectives:

(1) To establish baseline data on the injury of potentially sensitive crops (eg. non-DT soybeans) to six micro-rates of Dicamba herbicide (Xtendimax and Engenia).

(2) To collect photos of injury symptoms (time-lapse photography) in order to develop educational materials and power point presentations that can be disseminated to farmers through traditional and web based technology.

Study procedures:

Field trials were repeated in 2018 at Haskell Ag Lab, Concord, NE. The study was laid out as a split-plot treatment design with 6 micro rates of dicamba products (Engenia and XtendiMax), 3 application times

(soybean growth stages) in a RCB experimental design with 4 replications. In 2018, the dicamba rates included: 0, 1/10; 1/100; 1/1000; 1/5000; and 1/10000 of the standard product label rate. Plots had four rows of each soybean types (Round-up Ready, Liberty-Link, Conventional, and Dicamba-Tolerant serving as a check). To simplify visuals of the amount of the rates on a per acre basis, the $1/10^{th}$ of the label rate is equivalent to 3 tablespoons, $1/100^{th}$ is a 1 teaspoon, 1/500 is $1/5^{th}$ of a teaspoon and 1/1000 is $1/10^{th}$ of a teaspoon applied over a size of football field (1 acre).

The three application times were: (1) second expanded trifoliate (V2), (2) just before flowering (V7/R1) and (3) full flowering (R2). The V2 timing was to simulate potential drift at an early stage of soybean growth, which is expected time for earliest applications of dicamba products. The second and third timing was to simulate potential drift at the later stages of soybean growth, reflecting variable planting times. For, example some fields might be planted earlier, some later, thus these two timings would simulate potential drift among neighboring fields around flowering time. Visual evaluation of injuries was conducted at 7, 14, 21, and 28 days after treatment (DAT). Soybean morphological development measurements included plant heights, number of branches, days to canopy closure (for V2 and V7/R1 only), days to flowering (for V2 only), number of flowers (V2 and V7/R1), and days to maturity. Yields of all soybean types were harvested.

A four parameter log-logistic regression equation was used to model the relationship between dicamba micro-rates, and soybean growth, and yield variables. The regression analyses helped to estimate the dicamba micro-rate at which a certain level of injury or yield reduction could be predicted. Mean values were collected for variables which regression analyses were not possible.

A series of time-lapse cameras (3 herbicides x 3 application timing x 3 herbicide rates) were utilized to record soybean injury per day (10:00 am – 3:00 pm), for 28 days after the date of the spray treatment (DAT).

Results from 2018 season

In general, results from 2018 were similar to those of 2017. Both, Engenia and XtendiMax had similar effects on soybeans. Soybean growth parameters were affected with the increased micro-rates of dicamba. For example, there was reductions in plant height, delay in canopy closure, reduction in flower number,

delay in physiological maturity, and loss of soybean yield. Of all growth stages, the V7/R1 stage was the most sensitive to dicamba.

1. Visual Injury:

There was an increase in visual injury ratings with increased dicamba micro-doses (Figure 1, Table 1). The observed injuries were visible in the form of: leaf cupping, curling and twisting of stem (epinasty), stunted shoot, swollen nodes and necrosis. Additional symptoms such as flower abortion, swollen nodes and curling pods were observed when dicamba was applied at V7/R1 or R2 stage. The leaf and stem injury appeared within 7 to 14 days after treatment (DAT). For example, the soybeans treated at V2 stage with the highest rate (1/10 of the label rate) had highly visible injuries that lasted throughout the entire growing season. While those treated with the lower rate (1/1000 of the label rate) had observable leaf injury for 30 days. The greatest visual injury by the dicamba micro-doses was generally observed when applied at V2 and V7/R1 stage. The 1/10 of the label rate of Engenia or XtendiMax caused as much as 80% injury 21 days after treatment; whereas, at R2 stage the injury was about 65%. Across all tested products and soybean type, V7/R1 required the least amount of any of the dicamba product to cause 50% injury, suggesting that V7/R1 was the most sensitive stage to application.

2. Yield:

In 2018, Dicamba similarly affected soybean yields like in 2017, irrespective of application time. The early flowering (V7/R1) stage was consistently the most sensitive stage to dicamba exposure. The non-sprayed Conventional, Liberty-Link and Roundup-Ready soybeans yielded 56, 47, and 69 bu/A respectively. However, when the same soybeans were sprayed at V2 stage with 1/10 (1.28 oz/A) of Engenia rate, they yielded 33, 31, and 51 bu/A, respectively. The 1/10 rate of Engenia, when applied at R2, lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans further to 11, 14 and 17 bu/A, respectively. Yields were further lowered to 10, 6, and 12 bu/A respectively, when Conventional, Liberty-Link and Roundup-Ready soybeans were sprayed with Engenia at V7/R1 stage (Table 2).

XtendiMax rate of 1/10 (2.2 oz/A) lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans from 51, 43 and 63 bu/A to 37, 28 and 48 bu/A, respectively, when sprayed at V2 stage. The 1/10 rate of XtendiMax lowered yields of Conventional, Liberty-Link and Roundup-Ready soybeans to 20, 10 and 21 bu/A, respectively, when sprayed at R2. Spraying XtendiMax at the 1/10 rate drastically

lowered yields to 8, 3 and 16 bu/A for Conventional, Liberty-Link and Roundup-Ready soybeans, respectively, when sprayed at V7/R1 soybean stage (Table 2).

The 1/100 of the labels rates reduced the soybean yields to 40-58 bu/A when applied at the V2 stage. For instance, 1/100 of label rate of Engenia reduced yields to about 50 bu/A in Conventional, 40 bu/A in Liberty-Link, and 63 bu/A in Roundup-Ready soybean. The same rate applied at V7/R1 stage reduced yields to about 40 bu/A in Conventional, 36 bu/A in Liberty-Link and 47 bu/A in Roundup-Ready soybean.

The 1/1000 of dicamba label rate also caused reduction in the non-DT-soybeans yields. For example, in Roundup-Ready soybeans, the 1/1000 of label rate applied at V7/R1stage reduced yields from 69 to 62 bu/A with Engenia and from 68 to 62bu/A with XtendiMax (Table 2).

3. Yield Loss:

Similarly to 2017 data, dicamba herbicides caused significant yield losses across all three soybean types. Yield losses were significantly influenced by both herbicides to the levels of as high as 55 bushels/acre. For example, Engenia doses of 0.02-0.05, 0.04-0.07 and 0.01-0.04 oz/A reduced yield by 5% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, depending on the crop growth stage of Engenia application (Table 3). Similarly, an XtendiMax doses of 0.02-0.08, 0.02-0.05 and 0.02-0.07 oz/A reduced yield by 5% in Conventional, Liberty-Link and Roundup-Ready soybean respectively, also depending on the crop growth stage of exposure. The V7/R1 was the most sensitive stage to both herbicides and all three soybean types (Figure 2, Table 3).

In grams of dicamba's acid equivalent per hectare, the above rates ranged from 0.3g/ha to 1.9g/ha, which are equivalent to 1/1800 to 1/300 of the label rate. To help visualize such amount of dicamba, such rates are equivalent to about 1/10 or 1/2 of the teaspoon per acre (teaspoon = 5g).

Discussion and Conclusion:

The results from this study clearly showed that all non-DT soybeans tested (Conventional, Liberty-Link and Roundup-Ready) were very sensitive to micro-rates of Clarity, Engenia and XtendiMax.

Visual injury caused by all three dicamba products ranged from 20-80%. Soybean exposure to dicamba just before flowering resulted in the greatest soybean injury and greatest yield losses. Types of soybean injuries ranged from: leaf cupping at V2 and V7/R1 spraying, epinasty (curly stems) at V2, V7/R1 and R2 timings; abortion of flowers at V7/R1; and swollen nodes and curly pods at R2 timing.

The yield losses varied with the doses and application time. The 5% yield loss is utilized to illustrate potential for yield losses, which is equivalent to about 3 bushel/acre assuming a 60 bushel/acre common yields). It is reasonable to determine such level of yield differences consistently across years and locations despite the natural variability in field experimentations. The range of doses that reduced yields by 5% varied from 0.01 to 0.07 oz/A (0.3 to 1.9g ae/ha) across all herbicides, application times and soybean types (Table 2). The lowest rates of 0.3-0.56 g/ha were calculated for V7/R1 stage and to highest rates of 1.4 – 1.9 g ae/ha for V2 and R2 stages. The 0.3g equals 1/1800 while 1.9g = 1/300 of the label rates.

Others also reported similar soybean responses to dicamba in their studies. Robinson et al. (2013) estimated that a dicamba rate less than 1/1000 of the label rate caused 5% yield loss across growth stages. He estimated that 0.14 and 0.24 g ae ha^{-1} of dicamba was required to cause 5% soybean yield loss when applied at V2 and R2 stage respectively. Meanwhile, Foster and Griffin (2018) showed that 0.6 to 4.4 g ae ha^{-1} of dicamba caused 1% - 9% yield loss when applied at V3/V4 stage and 2% - 17% yield loss when applied at R1/R2 stage. An earlier meta-analysis by Egan et al. (2014) using six different studies suggested that approximately 4% yield loss was caused by 5.6 g ae ha^{-1} (1/100 of label rate) of dicamba when applied at vegetative stages

Similarly, Kniss (2018) in his meta-analysis reported that 5% yield loss threshold was calculated across various growth stages. For example, at early vegetative stage (V1-V3), 5% yield loss could be caused by 1.9 g ae ha^{-1} (1/295 of the label rate), while at late vegetative stages (V4-V7), 5.7 g ae ha^{-1} (1/98 of the label rate) could cause 5% yield loss. The reproductive stage (R1-R2) required the least amount (0.89 g ae ha^{-1}, equivalent to 1/629 of the label rate) of dicamba to cause 5% yield loss. However, there were differences in the estimated doses for 5% yield loss among the individual studies used in the meta-

analysis. For example, at early vegetative stage, Anderson et al. (2004) suggested 1.6 g ae ha^{-1} (1/350 of label rate) of dicamba caused 5% yield loss, while Johnson et al. (2012) suggested 2.2 g ae ha^{-1} (1/254 of label rate) of dicamba for the same level of yield loss. At reproductive stage, Griffin et al. (2013) suggested 0.15 g ae ha^{-1} (1/3733 of label rate) caused 5% yield loss, while Soltani et al. (2016) suggested 0.16 g ae ha^{-1} (1/3500 of label rate) caused the same level of yield loss.

All of the above examples are similar to the doses that caused 5% yield loss in our study (0.3g – 1.9 g ae ha^{-1}), therefore, in conclusion, Clarity, Engenia and XtendiMax had very similar effects on the growth and development of all non-DT soybeans. This was evident by measuring various growth and development parameters, including final yields. Soybean yields were affected by exposure to dicamba at all three growth stages, and the most sensitive stage was V7/R1. The range of doses that can cause soybean yield reductions ranged from 0.3g (1/1800) to 1.9g = 1/300 of the label rates. To help visualize such small amounts of dicamba, those rates are equivalent to about 1/10 to 1/2 of the teaspoon (1 teaspoon = 5g). These results clearly demonstrated that non-DT soybeans are were sensitive to low-rates of Clarity, Engenia and XtendiMax, hence, efforts must be made to avoid drift of dicamba onto non-DT soybeans or any sensitive crops.

Key references:

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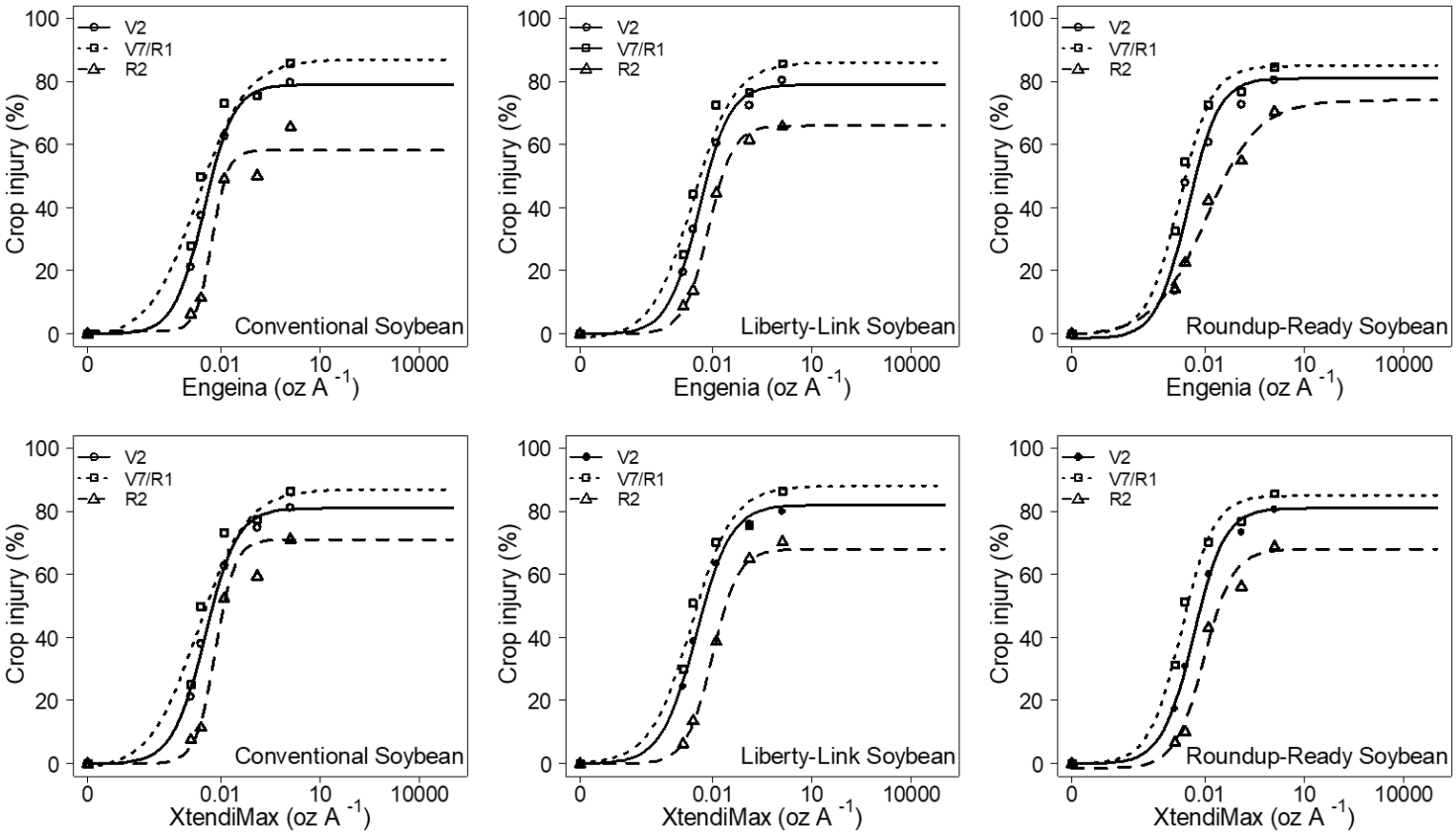

Figure 1. Conventional, Liberty-Link and Roundup-Ready soybean injury caused by micro-rates of dicamba products at 21 DAT for three growth stages in 2018.

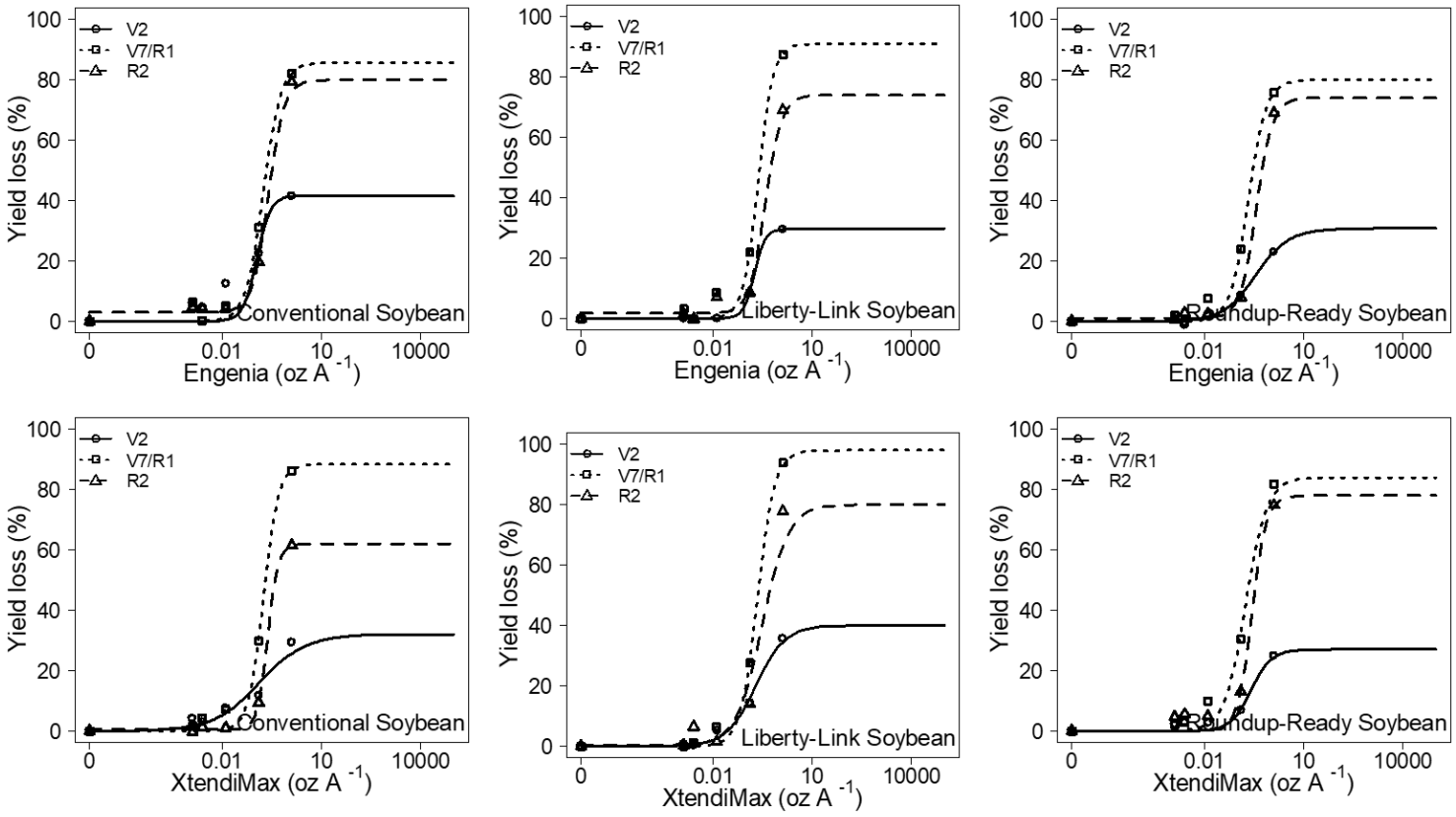

Figure 2. Yield loss in Conventional, Liberty-Link and Roundup-Ready soybeans as caused by micro-rates of dicamba products at 28 DAT for three growth stages in 2018.

Table 1: Dose of dicamba products that resulted in 50% injury of Conventional, Liberty-Link and Roundup-Ready soybeans sprayed at three growth stages in 2018

		Engenia	XtendiMax
		ED50 (SE) in oz A^{-1} for a 50% crop injury baseline	
Conventional	V2	0.0032 (0.0006)	0.0057 (0.0014)
	V7/R1	0.0005 (0.0000)	0.0037 (0.0007)
	R2	0.0054 (0.0011)	0.0123 (0.0019)
Liberty-Link	V2	0.0038 (0.0009)	0.0054 (0.0017)
	V7/R1	0.0025 (0.0004)	0.0034 (0.0005)
	R2	0.0072 (0.0006)	0.0243 (0.0086)
Roundup Ready	V2	0.0031 (0.0006)	0.0076 (0.0014)
	V7/R1	0.0017 (0.0001)	0.0029 (0.0003)
	R2	0.0110 (0.0026)	0.0270 (0.0071)

Standard error in parenthesis

Table 2: Grain yield of Conventional, Liberty-Link and Roundup-Ready soybeans as influenced by dicamba micro-rates sprayed at three growth stages in 2018

Dicamba	Soybean type	App/Stage	Grain yield (bu/A)					
			0	1/10	1/100	1/1000	1/5000	1/10000
Engenia	Conventional	V2	56 (3)[a]	33 (2)	50 (3)	49 (2)	55 (1)	51 (3)
		V7/R1	57 (3)	10 (3)	40 (2)	52 (3)	56 (3)	53 (2)
		R2	54 (2)	11 (2)	44 (3)	52 (2)	53 (4)	53 (2)
	Liberty-Link	V2	47 (2)	31 (2)	40 (3)	45 (2)	46 (2)	45 (3)
		V7/R1	45 (3)	6 (4)	36 (2)	42 (2)	46 (3)	45 (3)
		R2	45 (2)	14 (3)	40 (2)	41 (3)	44 (2)	43 (4)
	Roundup Ready	V2	69 (1)	51 (2)	63 (2)	67 (2)	67 (2)	68 (2)
		V7/R1	69 (1)	12 (1)	47 (1)	62 (1)	67 (1)	68 (4)
		R2	66 (2)	17 (3)	59 (2)	65 (1)	65 (2)	65 (2)
XtendiMax	Conventional	V2	51 (2)	37 (5)	46 (2)	48 (3)	50 (4)	50 (2)
		V7/R1	56 (3)	8 (3)	39 (3)	52 (4)	54 (3)	55 (2)
		R2	55 (2)	20 (5)	48 (4)	52 (2)	52 (3)	53 (3)
	Liberty-Link	V2	43 (3)	28 (4)	38 (4)	42 (3)	44 (2)	44 (3)
		V7/R1	48 (2)	3 (6)	33 (2)	43 (2)	47 (3)	49 (3)
		R2	48 (4)	10 (4)	40 (3)	45 (3)	43 (4)	46 (3)
	Roundup Ready	V2	63 (4)	48 (1)	57 (3)	61 (4)	63 (5)	62 (4)
		V7/R1	68 (3)	16 (4)	52 (3)	62 (1)	68 (2)	67 (1)
		R2	67 (1)	21 (4)	62 (1)	65 (1)	65 (1)	66 (1)

[a] Standard error in parenthesis

Table 3: Dose of Engenia and XtendiMax in oz/acre or g ae/ha that resulted in 5% yield loss (ED5) of Conventional, Liberty-Link and Roundup-Ready soybeans sprayed at three growth stages in 2018

		Engenia	XtendiMax
		Oz/acre or g/ha	Oz/acre or g/ha
Conventional	V2	0.03 (0.01) or 0.84g	0.02 (0.001) or 0.56g
	V7/R1	0.02 (0.002) or 0.56g	0.04 (0.003) or 1.1g
	R2	0.05 (0.007) or 1.4g	0.08 (0.01) or 2.2g
Liberty-Link	V2	0.06 (0.07) or 1.7g	0.05 (0.001) or 1.4g
	V7/R1	0.04 (0.008) or 1.1g	0.02 (0.01) or 0.56g
	R2	0.07 (0.01) or 1.9g	0.02 (0.0004) or 0.56g
Roundup Ready	V2	0.04 (0.004) or 1.1g	0.07 (0.03) or 1.9g
	V7/R1	0.01 (0.006) or 0.3g	0.02 (0.001) or 0.56g
	R2	0.03 (0.005) or 0.8g	0.05 (0.01) or 1.4g

Standard error in parenthesis; 1oz=28g.