Weed Science Research Summary 2019

West Central Research, Extension and Education Center

North Platte, Nebraska

TABLE OF CONTENTS

Weed Science

Title: Large-scale off-target movement assessment of dicamba in Nebraska.

Authors: Guilherme S. Alves, Kasey Schroeder, Jeff Golus, Greg R. Kruger

Objectives: Evaluate off-target movement (OTM) of dicamba when applied according to label directions under large-scale field conditions in Nebraska.

Results: During the air samplings after application, temperature inversions occurred overnight with stronger gradients in the two nights following the application. Results indicate that secondary movement of dicamba occurred causing injury on soybeans, probably due to the high temperatures (over 33° C) and temperature inversion on the next two days after application. The injury level decreased as the downwind distance increased, reaching 31 and 50% of injury on covered and non-covered plants, respectively, at 15 m from the sprayed area. Flux calculations had a similar tendency for detecting greater dicamba flux during the days and lower flux during the nights. Dicamba was detected in the air samples up to 56 h after application. Regardless of cause, farmers and applicators should be cautious of nearby sensitive crops and weather conditions during and up to 3 days after dicamba applications in order to mitigate spray drift and its consequences.

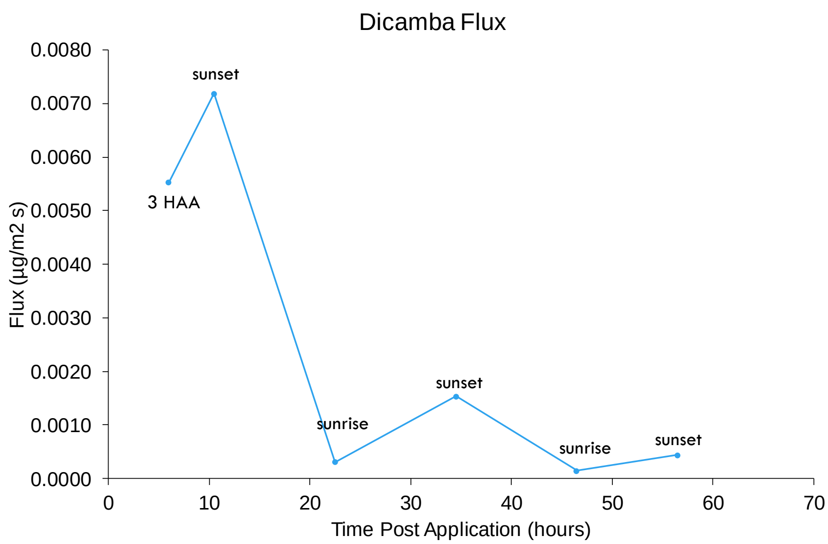


Figure 1. Flux from dicamba off-target movement up to 56 h after application (HAA).

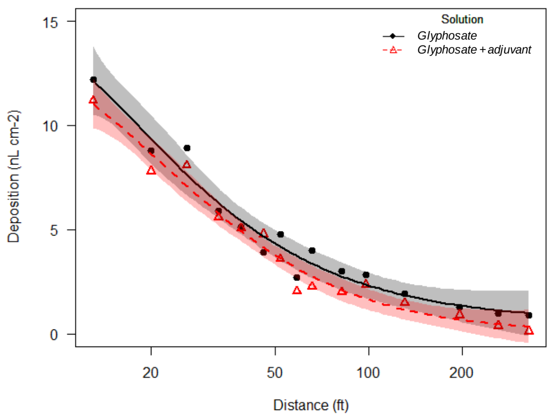
Title: Spray drift from aerial application in South Dakota

Authors: Guilherme S. Alves, Kasey Schroeder, Arthur F. T. Duarte, Daniel A. Doretto, Greg R. Kruger

Objectives: Quantify spray drift from aerial application of glyphosate tank-mixed with a drift-reducing adjuvant.

Results: Glyphosate solution tank-mixed or not with the drift-reducing adjuvant produced similar spray drift. During the applications, temperature and relative humidity were 43 F and 81%, respectively. Wind speed ranged from 5.2 to 8.3 mph. Future research needs to be conducted using different flight speeds, nozzle types, pressures, and meteorological conditions.

Figure 1. Air Tractor 802A aircraft used to spray glyphosate tank-mixed with a drift-reducing adjuvant in South Dakota.



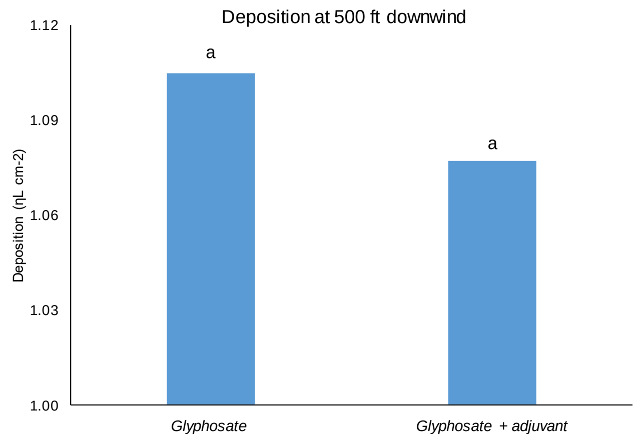


Figure 2. Deposition of rhodamine dye on Mylar cards (left) and monofilament lines (right) from an aerial application of glyphosate. Shaded areas represent the 95% confidence intervals. Bars with the same letter do not differ using Tukey's test at $\alpha = 0.05$.

Title: Dicamba spray drift as influenced by wind speed and nozzle type

https://www.cambridge.org/core/journals/weed-technology/article/dicamba-spray-drift-as-influenced-by-wind-speed-and-nozzle-type/5DF3E93D072A22E7F98C118430F27057

Authors: Guilherme S. Alves, Greg R. Kruger, João Paulo A. R. da Cunha, Denise G. de Santana, Luís André T. Pinto, Frederico Guimarães, and Milos Zaric

Objectives: Evaluate drift from dicamba applications through flat-fan nozzles, under several wind speeds in a wind tunnel.

Results: The air induction TTI nozzle produced the lowest percentage of dicamba drift at 2.2, 3.6 and 4.9 m s^{-1} wind speeds at all distances. Dicamba spray drift from XR, TT and AIXR nozzles increased exponentially as wind speed increased, whereas from TTI nozzle drift increased linearly as wind speed increased.

Table 1. Percentage of drift at 12 m downwind from each nozzle in dicamba applications at different wind speeds using flat-fan nozzles.

	Nozzle[a,b]			
Wind speed[c]	XR	TT	AIXR	TTI
m s^{-1}	——	%	——	
0.9	0.2 a	0.2 a	0.1 a	0.1 a
2.2	2.5 c	1.8 bc	1.1 b	0.1 a
3.6	8.0 d	4.1 c	1.5 b	0.3 a
4.9	13.5 d	6.6 c	3.2 b	0.6 a
CV	26.48%			
LSD	0.9			
$F_{ws \times noz}$[d]	94.6**			

[a] Means followed by the same letter in the row do not differ using Tukey's test at $\alpha = 0.05$.

[b] Teejet Technologies, Spraying Systems Co., Wheaton,IL 62703.

[c] Abbreviations: CV, coefficient of variation; LSD, least significant difference.

[d] $F_{ws\ x\ noz}$, calculated F value for interaction between wind speed and nozzle; **significant at $\alpha = 0.01$.

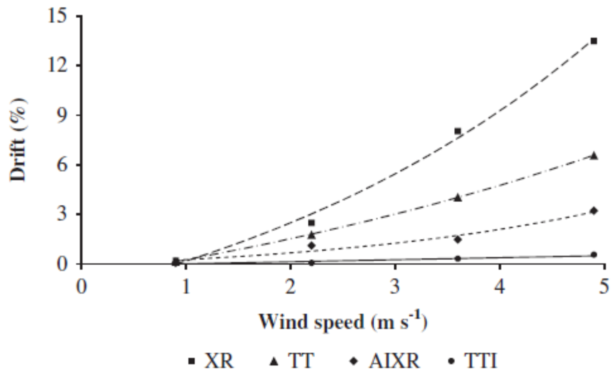


Figure 1. Effect of wind speed on dicamba drift collected 12 m downwind from applications made through different nozzle types in a wind tunnel.

Title: Spray drift and droplet spectrum from dicamba sprayed alone or mixed with adjuvants using air-induction nozzles

http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-204X2018000600693

Authors: Guilherme S. Alves, Greg R. Kruger, and João Paulo A. R. da Cunha

Objectives: Evaluate the spray drift and droplet spectrum of dicamba applied alone or with potential drift-reducing adjuvants, using air-induction flat fan nozzles.

Results: Droplet spectrum and dicamba drift depended on the interaction between spray composition and nozzle type. Polymer and ammonium sulfate increased droplet size in all nozzle types, which may reduce drift to nearby crops.

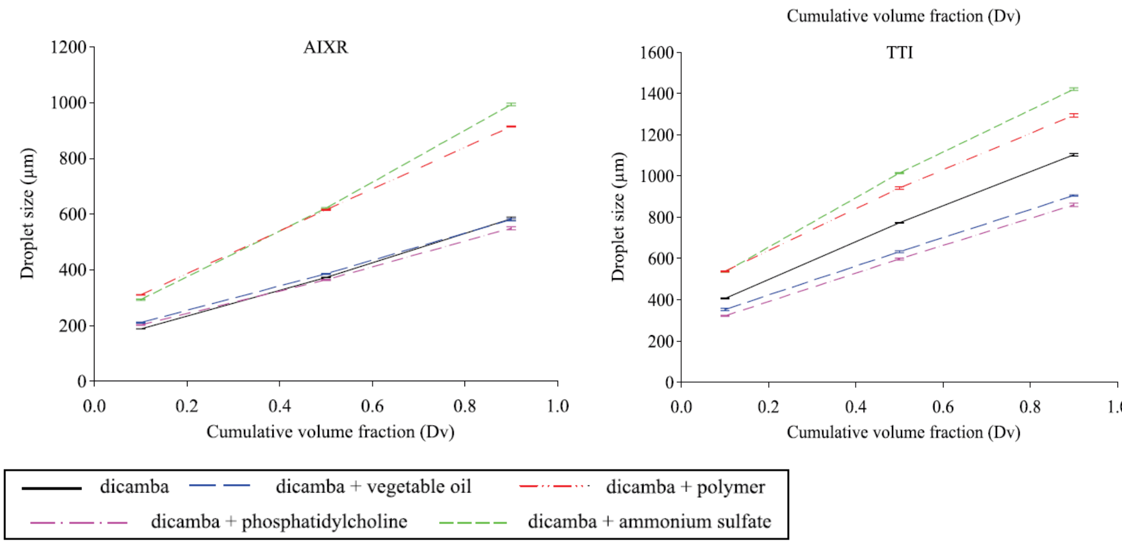


Figure 1. Droplet diameter below with the cumulative volume fraction ($D_{v0.1}$, $D_{v0.5}$, $D_{v0.9}$) produced through different nozzle types in applications of dicamba alone and with adjuvants.

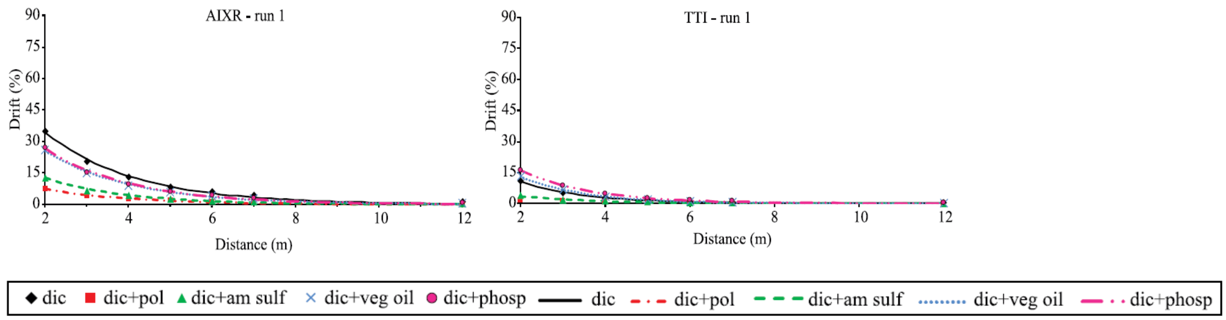


Figure 2. Drift curves from applications of dicamba alone, or with adjuvants, through different nozzle types in wind tunnel. Dic - dicamba; pol - polymer; am sulf -ammonium sulfate; veg oil - vegetable oil; phosp - phosphatidylcholine.

Title: Spray drift from dicamba and glyphosate applications in a wind tunnel

https://www.cambridge.org/core/journals/weed-technology/article/spray-drift-from-dicamba-and-glyphosate-applications-in-a-wind-tunnel/B470F201A56D611EE59D26252876CC08

Authors: Guilherme S. Alves, Greg R. Kruger, João Paulo A. R. da Cunha, Bruno C. Vieira, Ryan S. Henry, Andjela Obradovic, and Mica Grujic

Objectives: Evaluate the effects of dicamba with and without glyphosate sprayed through standard and air induction flat-fan nozzles on droplet spectrum and drift potential in a low-speed wind tunnel.

Results: Dicamba droplet spectrum and drift depended on the association between herbicide solution and nozzle type. Dicamba alone produced coarser droplets than dicamba + glyphosate when sprayed through air induction nozzles. Drift decreased exponentially as downwind distance increased and it was reduced using air induction nozzles for both herbicide solutions.

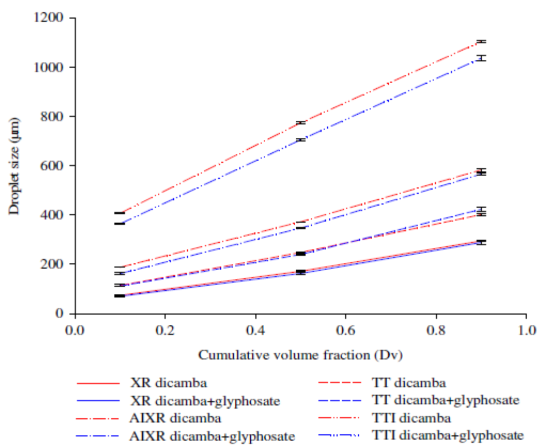


Figure 1. Droplet diameter for the cumulative volume fraction (Dv0.1, Dv0.5, Dv0.9) of two herbicide solutions sprayed with four different nozzle types.

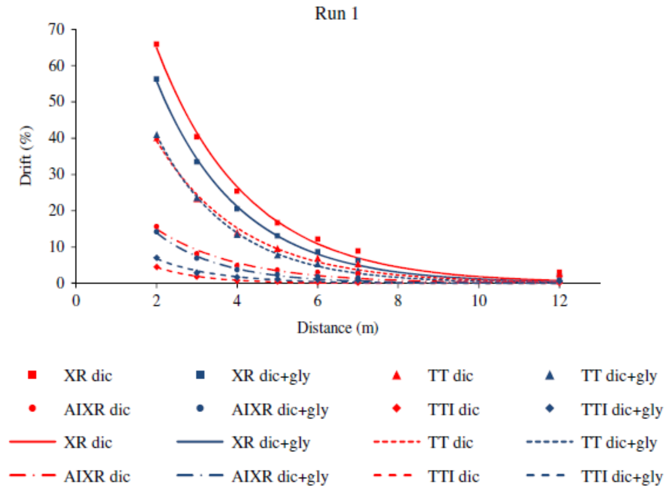


Figure 2. Percent drift in dicamba (dic) and dicamba plus glyphosate (dic + gly) applications made using four different nozzle types.

Title: Dicamba-tolerant soybean dose-response to isoxaflutole exposure

Authors: Karina Beneton, Guilherme S. Alves, Daniel A. Doretto, Arthur F. T. Duarte, Ana Clara Gomes, Greg R. Kruger

Objectives: Evaluate the effects of sublethal rates of isoxaflutole on non-HPPD-tolerant soybean at different growth stages.

Results: Soybean yield following isoxaflutole applications at both stages were similar up to 5.3 g ha^{-1}. When compared to untreated soybeans, 6.4% yield reduction was observed on average using the lowest two rates. These results suggest that sprayer tanks must be appropriately cleaned following isoxaflutole applications, especially if the equipment is also used in areas with non-HPPD-tolerant soybean. In addition, drift reduction technologies (DRTs) should be used while spraying isoxaflutole close to areas cultivated with HPPD-sensitive soybeans, especially early in the season. Future research needs to be conducted to evaluate the most appropriate DRTs for isoxaflutole applications in order to reduce injury to non-HPPD-tolerant crops.

Table 1. Yield of non-HPPD-tolerant soybean exposed to sublethal rates of isoxaflutole at three development growth stages.

Rate (g ai ha^{-1})	Growth stage					
	V3		R1		R5	
	---------------------kg ha^{-1}---------------------					
1.1	4682	a	4886	a	4954	a
2.6	4736	a	4741	a	4575	a
5.3	4338	ab	4798	a	4190	b
7.9	4273	b	4848	a	4013	b
15.8	4232	a	4514	a	3629	b
31.5	3501	b	4276	a	3142	b
105.0	35	c	2198	b	2801	a

Means followed by the same letter in the row do not differ using Tukey's test at $\alpha = 0.05$.

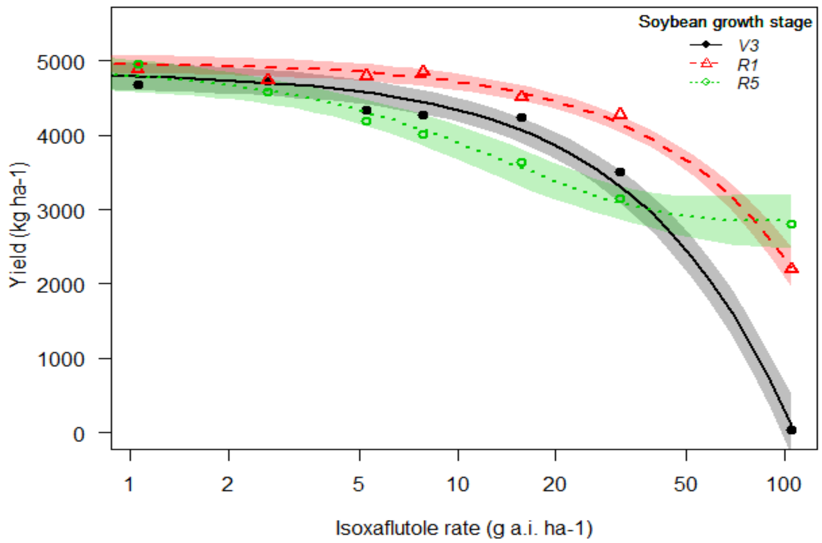


Figure 1. Dose-response curves for non-HPPD-tolerant soybean yield exposed to sublethal rates of isoxaflutole at three development growth stages. Shaded areas represent the 95% confidence intervals.

Title: Weed control from dicamba plus glufosinate as affected by drift-reducing adjuvants and carrier volume

Authors: Arthur F. T. Duarte, Guilherme S. Alves, Bruno C. Vieira, Kasey Schroeder, Greg R. Kruger

Objectives: Evaluate weed control from dicamba plus glufosinate tank-mixed with different drift-reducing adjuvants using two carrier volumes and nozzle types.

Results: Applications made through TTI1104 and ULD12004 nozzles resulted in similar biomass reduction (94%) for commom waterhemp. By adding Strikezone® to the herbicide solution, kochia control increased 17% using TTI nozzle compared with ULD nozzle. No differences were obtained using other adjuvants. Greater kochia control was obtained using Serenity® Plus compared with Reign® and OnTarget® sprayed through TTI nozzle. Results suggest that c. waterhemp and kochia control were not affected by reducing the carrier volume in dicamba plus glufosinate applications. Drift-reducing adjuvants had influence on weed control depending on the weed species and nozzle type. Further research needs to be conducted to evaluate more nozzle types and weed species.

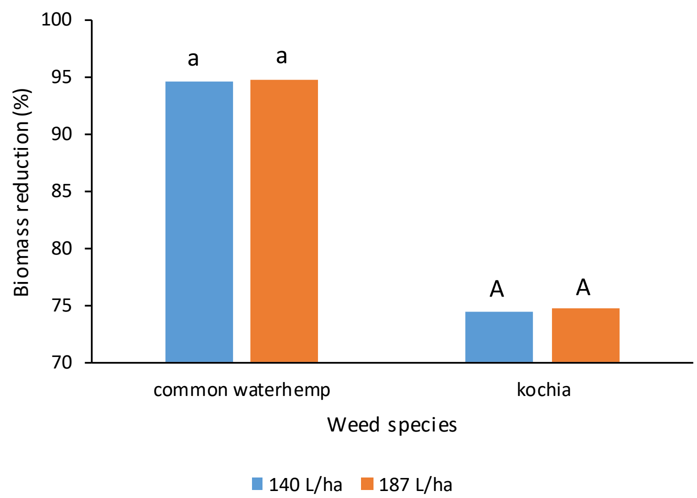


Figure 1. Biomass reduction of c. waterhemp and kochia treated with dicamba plus glufosinate solutions using two carrier volumes. Bars with the same letter do not differ using Tukey's test at α = 0.05.

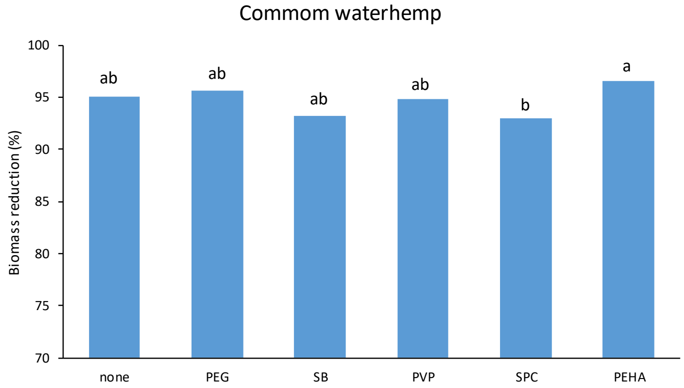


Figure 2. Biomass reduction of c. waterhemp treated with dicamba plus glufosinate (none) and tank-mixed with different adjuvants. PEG - Intact®; SB - OnTarget®; PVP - Reign; SPC - Serenity® Plus; PEHA - Strikezone®. Bars with the same letter do not differ using Tukey's test at $\alpha = 0.05$.

Title: Injury and symptomology caused by simulated drift of dicamba-containing herbicides on soybean

Authors: Rosa S. Ynfante, Guilherme S. Alves, Bruno C. Vieira, Jeffrey A. Golus and Greg R. Kruger

Objectives: Evaluate the effect of simulated dicamba drift on non-dicamba soybeans cultivars.

Results: There was no significant interaction between cultivar, herbicide and rate. Diflexx® caused higher biomass reduction across cultivars when compared to other herbicides. The cultivars Credenz CZ2601LL and Hoegemeyer 2511NRR showed to be more sensitive to dicamba for having the highest biomass reduction. On the other hand, Asgrow A3253 demonstrated to be less sensitive to dicamba.

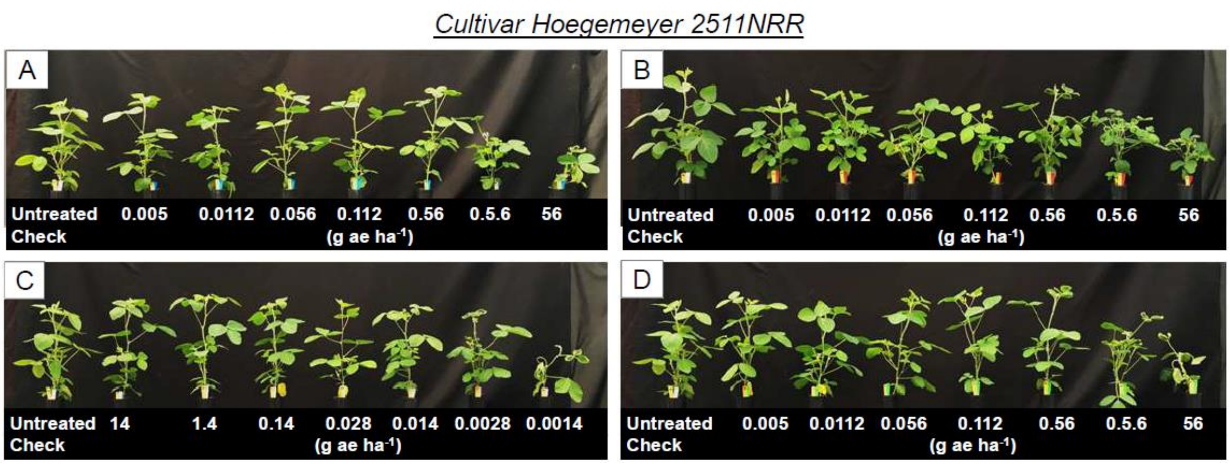


Figure 1. Soybeans injury in response to seven sublethal rates of Diflexx® (A), Xtendimax™ (B), Status® (C) and Engenia® (D).

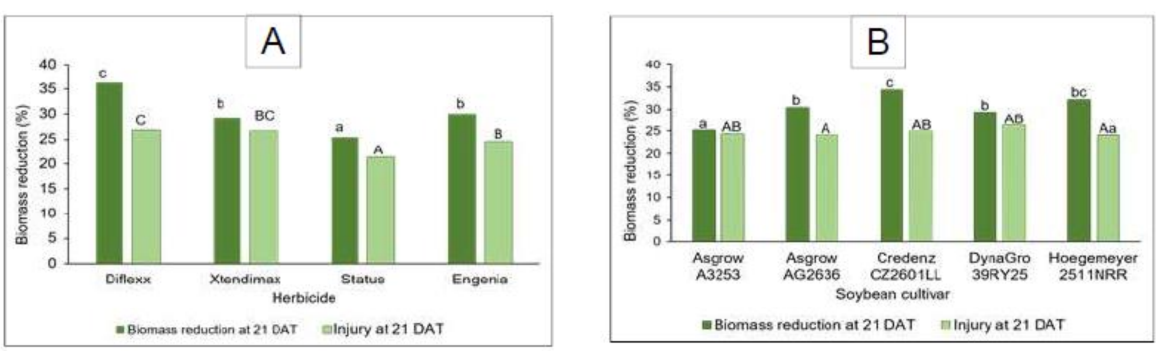


Figure 2. Biomass reduction and visual injury at 21 days after treatment caused by dicamba-containing herbicides across cultivars (A) formulations (B). Bars with the same letter do not differ using Tukey's test at α = 0.05.

Title: Spray drift from mesotrione and isoxaflutole through different nozzle types

Authors: Andrea Rilakovic, Guilherme S. Alves, Bruno C. Vieira, Greg R. Kruger

Objectives: Investigate spray drift effects on sensitive crops during POST-applications of mesotrione and isoxaflutole through three nozzle designs in a wind tunnel.

Results: Grasses and broadleaves had similar biomass reduction downwind when both herbicides were sprayed through TTI nozzle. When using XR and AIXR nozzles, greater biomass reduction was observed for soybean compared to sorghum. Regardless of crop, mesotrione and isoxaflutole resulted in similar plant biomass reduction across nozzles. Drift decreased exponentially as downwind distance increased.

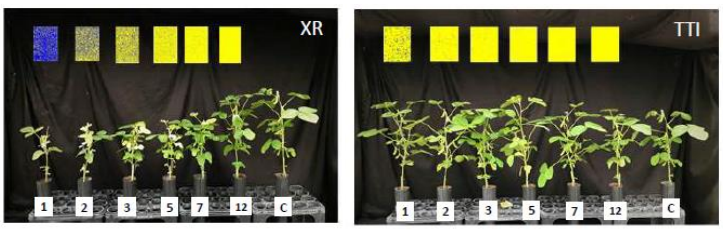


Figure 1. Visual injury at 28 DAT from HPPD herbicide applications through flat-fan nozzles from 1 to 12 m downwind.

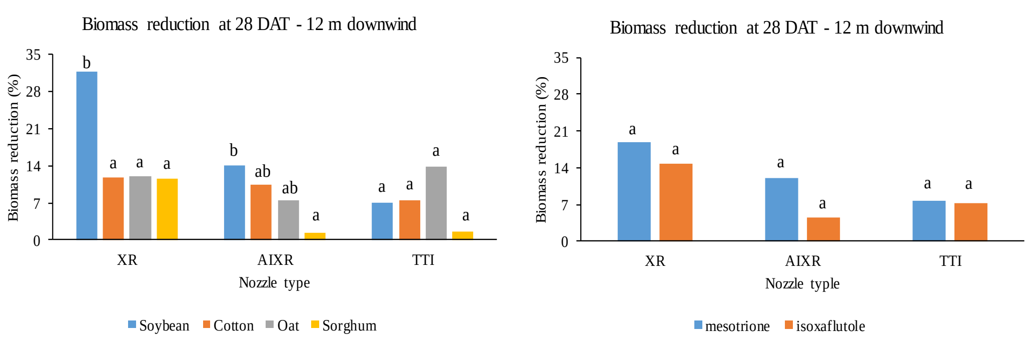


Figure 2. Plant biomass reduction at 28 DAT through flat-fan nozzles within crop (left) and within herbicide (right) at 12 m downwind distance. Bars with the same letter within nozzle do not differ using Tukey's test at $\alpha = 0.05$.

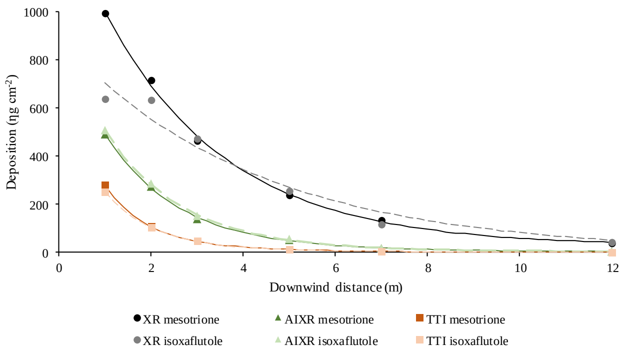


Figure 3. Drift deposition curves from applications of mesotrione and isoxaflutole through different nozzle types in a wind tunnel.

Title: Effect of Adjuvant Rates on Dicamba Physicochemical Properties and its Correlation with Droplet Size.

Authors: Gabrielle de Castro Macedo, Jesaelen Gizotti de Moraes, Vitor Muller Anunciato, Glenn Obear, Frank Sexton, and Greg R. Kruger

Objectives: During the application of herbicides the deposition of the product on non-target areas should be avoided. Drift reduction technologies aim to eliminate the movement of small droplets to non-target organisms. Factors as droplet size, application pressure, nozzle design, and adjuvants can increase spray droplet size and decrease drift. The addition of adjuvants can improve herbicide deposition, retention, absorption and may alter the physicochemical properties of the spray solution. Therefore, the objectives of this research was to assess the combinations of dicamba with several adjuvant concentrations on their influence in droplet size, density, viscosity, and surface tension.

Results:

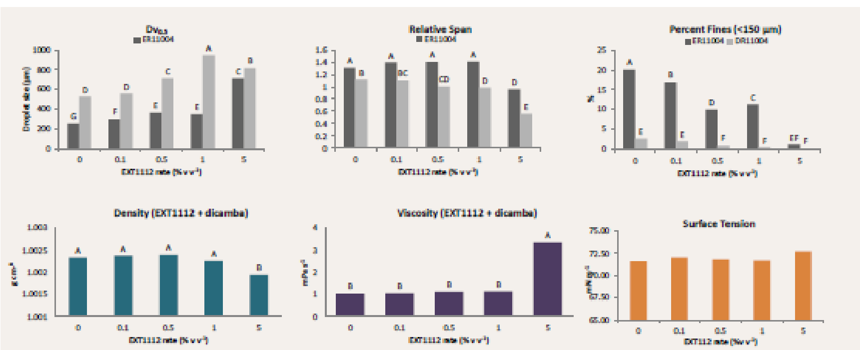


Figure 1. $D_{V0.5}$, Relative Span, percent fines (<150 µm), density, viscosity, and surface tension of dicamba tank-mixture with EXT1112 in several rates. Means followed by the same letter are not different ($p<0.05$).

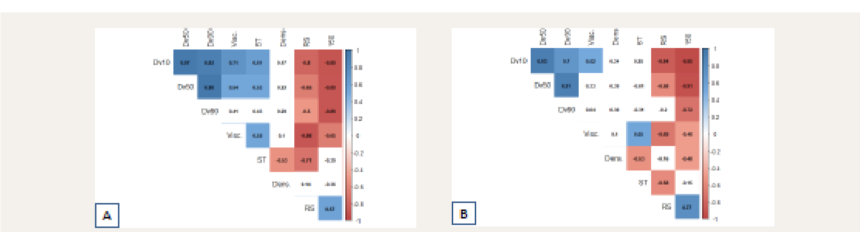


Figure 2. Pearson correlation index for $D_{V0.1}$, $D_{V0.5}$, $D_{V0.9}$ (µm), viscosity (mPa s^{-1}), density (g cm^{-3}), percent fines (<150 µm), surface tension (mN m^{-1}), and relative span. Measurements were taken from water, dicamba, and dicamba in tank-mixture with EXT1112 (0.1, 0.5, and 5% vv^{-1}). Droplet size information were obtained for ER11004 (A) and DR11004 (B) nozzles. Blue cell have positive correlation between

variables ($p<0.05$), whereas red cells have negative correlation between variables ($p<0.05$). White cells do not have significant correlation ($p>0.05$) between variables.

Increased adjuvant concentration resulted in increased droplet size for both nozzles with adjuvant concentrations up 1% v v^{-1}. Percent fines (<150 µm) reduction occurred with the addition of adjuvant in all concentrations. The drift potential reduction was greater when using DR11004 nozzle and adjuvant concentrations higher than 0.5% v v^{-1}. Solution density decreased when 5% v v^{-1} of adjuvant was used with dicamba, whereas the opposite occurred with viscosity. The surface tension was not changed by the treatments. Viscosity was not a good predictor for drift reduction. Reduction in percent fines and relative span occurred even with smaller concentrations of the adjuvant, whereas droplet size increased. Correlation among droplet size and physicochemical properties was investigated using Pearson correlation index using R software (GGally package) ($p<0.05$). Viscosity had a positive correlation with droplet size and surface tension. Viscosity had a negative correlation with relative span and percent fines. Moving forward with formulations and adjuvants development, we need to be aware that there are complex interactions that exist and they need to be thoroughly investigated to optimize pesticide applications.

Title: Herbicide drift exposure leads to reduced herbicide sensitivity in Amaranthus spp.

Authors: Bruno Canella Vieira, Joe D. Luck, Keenan L. Amundsen, Rodrigo Werle, Todd A. Gaines, Greg R. Kruger

Funding: CAPES (Brazil), Nebraska Agricultural Experiment Station with funding from the Hatch Multistate Research Capacity Funding program from the USDA National Institute of Food and Agriculture.

Objectives: While the introduction of herbicide tolerant crops provided growers new options to manage troublesome weed species, the widespread adoption of these herbicides increased the risk of herbicide off-target movement towards sensitive areas. The impact of herbicide drift towards sensitive crops is extensively investigated in the literature, however scarce information is available on the consequences of herbicide drift towards other plant communities neighboring agricultural landscapes. Troublesome weed species are often abundant in field margins and ditches surrounding agricultural landscapes, and herbicide drift exposure could be detrimental to long-term weed management as numerous weed species evolved herbicide resistance following recurrent applications of low herbicide rates. The objective of this study was to evaluate if glyphosate, 2,4-D, and dicamba spray drift exposure could result in *Amaranthus* spp. reduced herbicide sensitivity.

Results: The study results demonstrate that herbicide drift exposure rapidly selected for weed biotypes with reduced herbicide sensitivity over two generations. Preventing the establishment of resistance prone weeds on field margins and ditches is an important management strategy to delay herbicide resistance. Weed management programs should consider strategies to mitigate near-field spray drift, and suppress troublesome weed populations on field borders in agricultural landscapes.

Further work on the project: Additional studies are necessary to investigate the molecular basis of the sensitivity shifts found in the *Amaranthus* spp. following recurrent herbicide drift selection in this study. This study is currently under review for publication. The following links provide access to research papers related to this project:
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0220014
https://onlinelibrary.wiley.com/doi/abs/10.1002/ps.4781

Figure 1. Herbicide drift study conducted in the low speed wind tunnel with waterhemp (Amaranthus tuberculatus), Palmer amaranth (Amaranthus palmeri), and drift collectors (Mylar cards) positioned at different downwind distances from the nozzle.

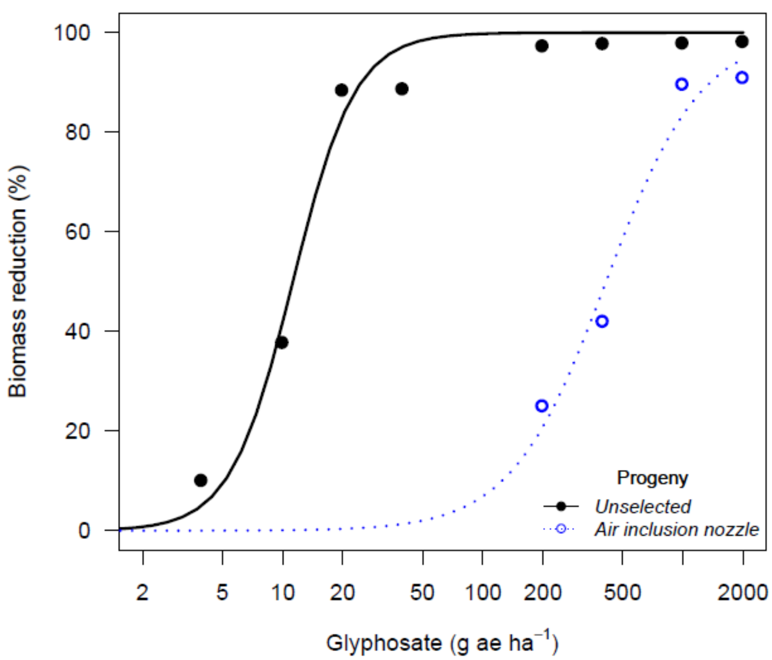


Figure 2. Biomass reduction for Palmer amaranth population (P_2) from Perkins County (NE) following recurrent selection to glyphosate spray drift at 30 days after treatment in the glyphosate dose response study.

Title: 2019 Impact of Adjuvants on Rainfastness in Sugar Beets.

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Authors: Vinicius Velho, David Mattler, Jeffrey A. Golus, Barbara Vukoja, Greg R. Krueger

Objectives: The success of a chemical product does not rely only on its toxicity on the target, but also on a series of variables such as retention, persistence, and fundamentally the technology of application used. Using adjuvants when spraying can optimize physicochemical characteristics of the spray solution and increase efficiency. One of the factors for a successful application is the retention of the active ingredient on the leaf despite adverse environmental factors such as rain. The objective of this study was to evaluate adjuvants influence on application rainfastness in sugar beets leaves.

Results: The results indicate that rain amount ($p < 0.0001$) and adjuvant ($p = 0.0821$) influenced PTSA rainfastness. Plants submitted to no rain had the higher amount of PTSA and the amount of rain received was proportional to the wash off. Also, it is possible to notice that Sticker 1 sprayed alone retained the biggest amount of PTSA on the leaves, but when sprayed in a tank mixture with Sticker 2 suffered a big lost in efficacy. All other treatments do not manifest statistical difference from the check after being exposed to rain.

Table 1: Quantities of PTSA (Mg/cm^2) recovered after rain without adjuvants.

Rain(mm)	PTSA(mg/cm^2)
0	3.8363 a
12.7	0.1851 b
25.4	0.0919 b
50.8	0.4058 b

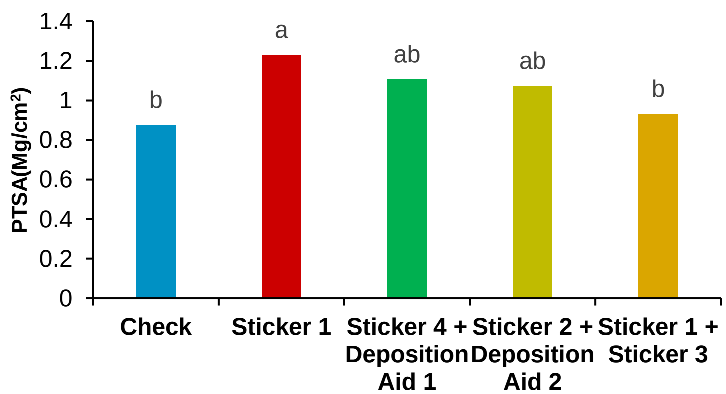


Figure 1: Quantities of PTSA (Mg/cm^2) recovered after rain with adjuvants.

Title: Effect of Adjuvants Associated with Herbicide Tank-mixtures on Weed Control

Authors: Ely Anderson, Jeffrey A Golus, Bruno C Vieira, Greg R Kruger

Objectives: Resistant weeds are becoming a large problem in agriculture, and with it are bringing many challenges to farmers across the United States. Adding multiple modes of action in a tank solution could help solve this issue. Glufosinate mixed with dicamba or 2,4-D could help with resistant weeds by giving us two modes of action in a given tank solution. The overall weed control of these herbicides mixed together could be enhanced with the addition of an adjuvant. Adjuvants have been shown to be beneficial to herbicides in tank solution when looking at translocation, efficacy, and many other categories. Research was conducted to better understand the interactions between unformulated glufosinate mixed with 2, 4-D (Enlist One) or dicamba (Xtendimax) alone and in tank solution with two different adjuvants on common waterhemp (*Amaranthus tuberculatus (moq.) J. D. Sauer*), velvetleaf (*Abutilon theophrasti Medik*), and common lambsquarters (*Chenopodium album L.*).

Results: Results show that adding either adjuvants resulted in greater overall weed control compared to having glufosinate alone across all species. Adding an adjuvant to Xtendimax alone or glufosinate with Xtendimax on common lambsquarters increased overall control compared to both treatments alone. Across all weed species there were no statistical differences when observing Enlist One with either adjuvant or Enlist one with glufosinate and either adjuvant. Overall, this study concludes that adding either adjuvant to unformulated glufosinate increased the overall weed control across all species.

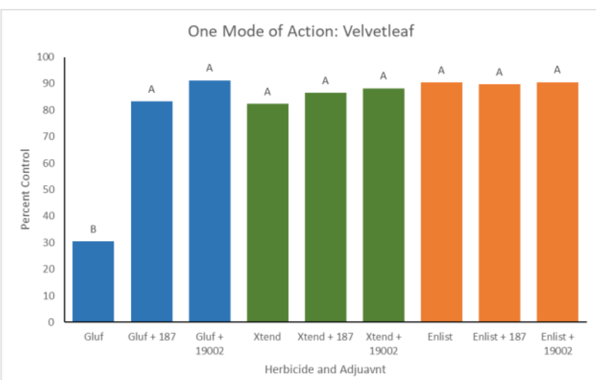


Figure 1: Velvetleaf control associated with different tank mixtures

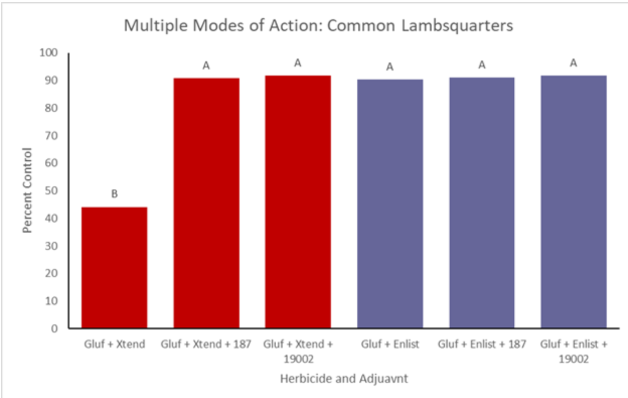


Figure 2: Common lambsquarters control associated with different herbicide tank mixtures

Title: Influence of Adjuvants Associated with Glufosinate and Glyphosate Tank-mixtures on Weed Control.

Authors: Ely Anderson, Jeffrey A Golus, Bruno C Vieira, Susan Sun, Greg R Kruger

Objectives: Resistant weeds are becoming a growing issue in present day agriculture. This situation brings new challenges and strategies on how to manage weeds that have become resistant overtime. Multiple modes of action in a tank solution could slow down resistance. With this in mind, research was conducted in the University of Nebraska at the Pesticide Application Technology Lab located in North Platte, NE to investigate the interactions of unformulated glufosinate and unformulated glyphosate (Touchdown Hi-Tech), alone and in tank solution with two adjuvants in controlling five weed species.

Results: Results show that adding an adjuvant to glufosinate increases overall weed control across all species except for common waterhemp.

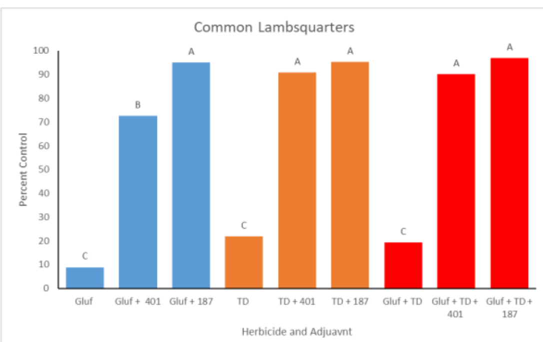


Figure 1: Weed control on common lambsquarters based on herbicide and adjuvant tank solutions.

This research also concludes that adding either adjuvant to a Touchdown Hi-Tech tank solution increases overall weed control except for common waterhemp and velvetleaf. Mixing glufosinate and Touchdown Hi-Tech with either adjuvant 187 or 401 also increased overall control of barnyard grass, large crabgrass, and common lambsquarters when compared to glufosinate and touchdown alone in solution. This portion of the study shows that we can overcome the antagonism of glufosinate mixed with glyphosate when using unformulated products and different adjuvants in these tank solutions. Overall adding an adjuvant to a tank solution of glufosinate alone or glufosinate with Touchdown increased weed control depending on the weed species.

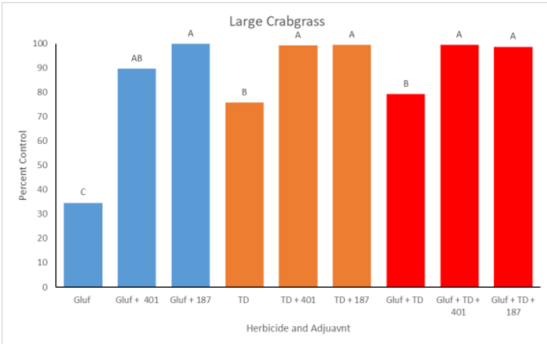


Figure 2: Weed control on large crabgrass based on herbicide and adjuvant tank solutions.

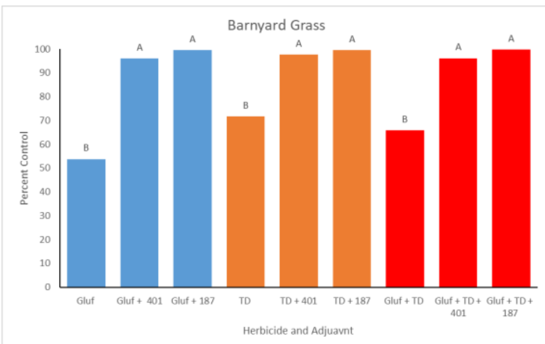


Figure 3: Weed control on barnyard grass based on herbicide and adjuvant tank solutions.

Title: Influence of Glufosinate and Dicamba in Tank-Mixtures on Weed Control

Authors: Pedro H. A. Correa, Gabrielle C. Macedo, Jesaelen G. Moraes, and Greg R. Kruger

Objectives: The aim of this study was to investigate weed control when using dicamba and glufosinate in tank-mixture.

Results: Velvetleaf: glufosinate (590 g ai ha^{-1}) in combination with 70, 140, 280, and 560 g ae ha^{-1} of dicamba provided a higher control, with no significant differences among these treatments. Palmer amaranth: Great control (>85%) was observed regardless of the treatment, with the exclusion of glufosinate in its lower rates (74 and 37 g ai ha^{-1}) in absence of dicamba suggesting a plant regrowth. Green foxtail: As dicamba has no activity in grasses, all treatments containing 140 g ai ha^{-1} of glufosinate or more provided a desired control (>85%) of green foxtail.

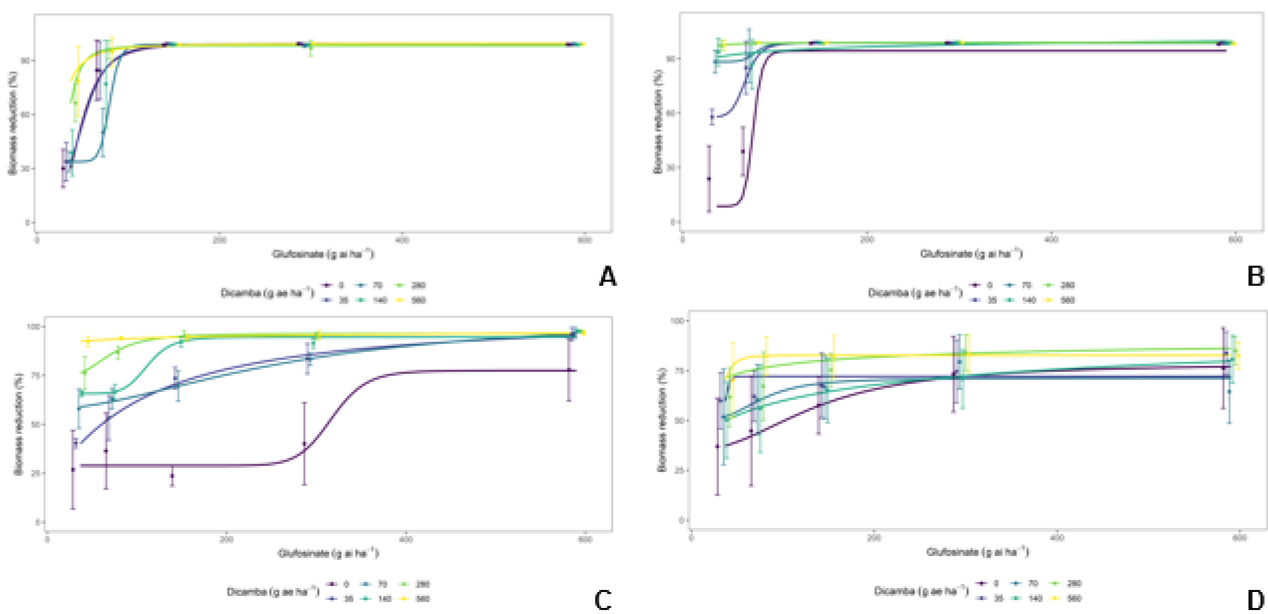


Figure 1. Dose-response curves of glufosinate tank-mixed with dicamba in several rates. (A) Green foxtail; (B) Palmer amaranth; (C) velvetleaf, and (D) kochia.

Further work on the project: Addition of adjuvants such as DRAs and its possible improvement in weed control. Testing of different nozzles and its possible effect in deposition and weed control. Testing glufosinate and dicamba tank-mixtures with adjuvants and its effects in crops.

Title: Herbicide Efficacy as Influenced by Nozzle for UAV Applications

Authors: Trenton Houston, Clint W. Hoffmann, Jeffrey A Golus, Bruno C Vieira, Greg R Kruger

Objectives: Identify nozzle/carrier volume/herbicide combinations that will be suitable for sUAV (small unmanned aerial vehicle) pesticide application platforms for the control of kochia (*Bassia scoparia* (L.) A. J. Scott). Evaluate the efficacy as influenced by herbicide (carfentrazone-ethyl, mesotrione, glufosinate, dicamba, glyphosate, and unformulated glyphosate), at two carrier volumes (2.3 L ha^{-1} and 93.5 L ha^{-1}) through four nozzles (AITX8002, AIXR11002, TXR8002, and XR8002).

Results: Overall, the results indicate that the smaller droplet producing nozzles paired with low volume applications had the best level of control. Mesotrione, carfentrazone-ethyl, and glyphosate applications at 2.3 L ha^{-1} resulted in greater biomass control compared to applications at 93.5 L ha^{-1}, with the XR and TXR nozzles being the most effective nozzles. Glufosinate had better levels of control at 93.5 L ha^{-1} , but also showed the same level of control at 2.3 L ha^{-1} when paired with the XR nozzle. Herbicides such as glufosinate, glyphosate, dicamba, and mesotrione had collapsed patterns when applied at 2.3 L ha^{-1}, mainly with AITX and AIXR nozzles. Overall, there were many herbicide, nozzle, and carrier volume interactions that influenced efficacy levels with carrier volume being the most important. sUAV applications have potential, but nozzle/herbicide interactions can result in poor control. sUAV applications are feasible with current herbicides and nozzles.

Further work on the project: Future research will include field research that tests the efficacy of the products/herbicides/nozzles that were tested in this project. Application parameters need to be standardized for each sUAV type. Application height, speed, deposition, and swath width will also need to be tested to fully understand UAV pesticide application.

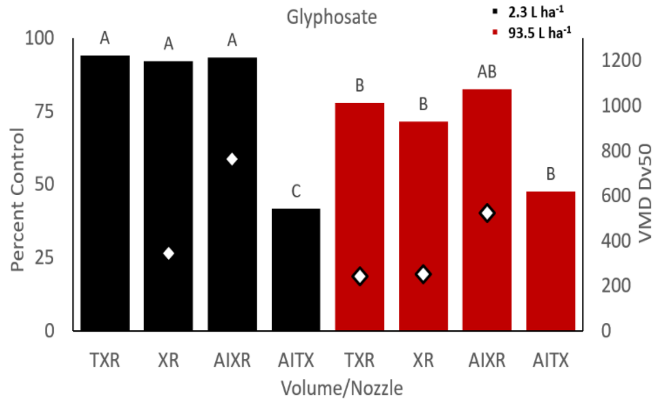


Figure 1: Kochia control by glyphosate. Application volumes at 2.3 L ha^{-1} provided better efficacy across TXR, XR, and AIXR nozzles than applications at 93.5 L ha^{-1}, with exception of the AITX nozzle which had fan development issues at 2.3 L ha^{-1}.

*If VMD value is missing, measurements could not be made.

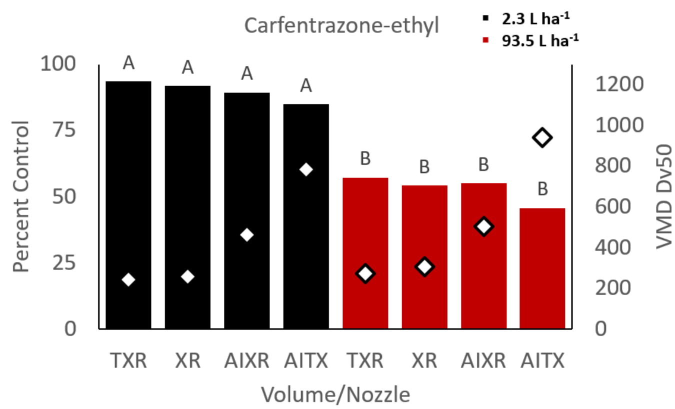


Figure 2: Kochia control by carfentrazone-ethyl. Application volumes at 2.3 L ha-1 provided the better efficacy across all nozzles than applications at 93.5 L ha-1.

*If VMD value is missing, measurements could not be made.

Title: Potential Nozzles and Herbicides for a UAV Pesticide Application

Authors: Trenton Houston, Clint W. Hoffmann, Jeffrey A Golus, Guilhereme S Alves, Barbara Vukoja, Bruno C Vieira, Greg R Kruger

Objectives: Evaluate herbicide efficacy as influenced by four different nozzles (TeeJet: AITX8002, AIXR11002, TXR8002, and XR8002) at two different carrier volumes (2.3 L ha^{-1} and 93.5 L ha^{-1}) and six herbicides (glyphosate, unformulated glyphosate, glufosinate, carfentrazone-ethyl, dicamba, and mesotrione). Identify nozzle, carrier volume, herbicide combinations that result in acceptable efficacy levels on common waterhemp (*Amaranthus tuberculatus* (Moq.) J. D. Sauer) by a sUAV (small unmanned aerial vehicle) pesticide application.

Results: The study results indicate that nozzles producing smaller droplets paired with 2.3 L ha^{-1} provided the best control levels in general. Carfentrazone-ethyl had better control at 2.3 L ha^{-1} across all nozzles tested. Dicamba and mesotrione control were not influenced by nozzle type and carrier volume. With the exception of the XR nozzle, glufosinate applications at 93.5 L ha^{-1} had better control compared to applications at 2.3 L ha^{-1}. Failure of control was from the poor fan formation out of TXR, AIXR, and AITX nozzles at 2.3 L ha^{-1}. Formulated glyphosate applied at 2.3 L ha^{-1} provided the best control for the TXR, AIXR, and XR nozzles, whereas applications with the AITX nozzle at 2.3 L ha^{-1} had issues with spray pattern resulting in poor performance. At 2.3 L ha^{-1} proper fan formation was not achieved with AITX and AIXR nozzles. The data reveals that sUAV pesticide applications can provide effective control levels with current formulations and nozzles, but the different combinations need to be tested for the adaptation of the technology.

Further work on the project: Future research will include field research that tests the efficacy of the products/herbicides/nozzles that were tested in this project. Application height, speed, deposition, and swath width will also need to be tested to fully understand UAV pesticide application.

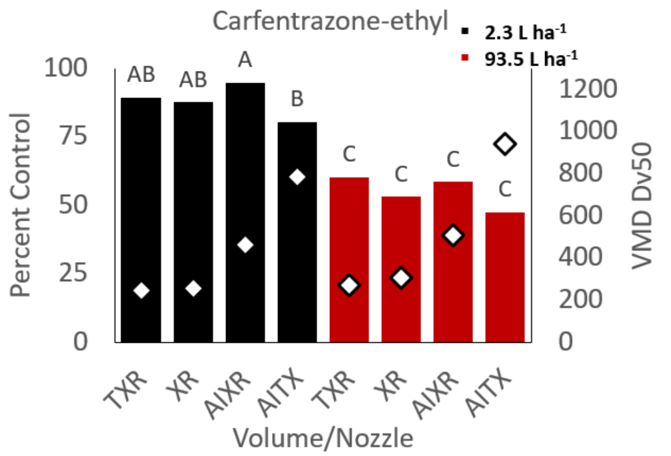


Figure 1: Common waterhemp control by carfentrazone-ethyl. Application volumes at 2.3 L ha^{-1} provided the better efficacy across all nozzles than applications at 93.5 L ha^{-1}.

*If VMD value is missing, measurements could not be made.

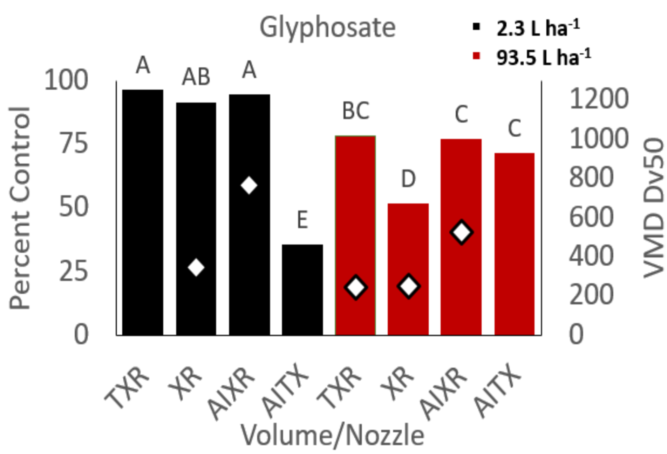


Figure 2: Common waterhemp control by glyphosate. Application volumes at 2.3 L ha^{-1} provided the better efficacy across TXR, XR, and AIXR nozzles than applications at 93.5 L ha^{-1}. Poor control at 2.3 L ha^{-1} with the AITX nozzle was from poor fan development.

*If VMD value is missing, measurements could not be made.

Title: Use the adjuvant to enhance weed control by glufosinate herbicides

Authors: Estefania G. Polli, Greg R. Kruger

Objectives: This study was conducted in the greenhouse conditions at the PAT Lab to investigated the influence of non-commercial Exacto® adjuvants on the performance of two glufosinate herbicides (Liberty 280-SL® and Interline®) on common lambsquarters (*Chenopodium album*). Plants (12 in) were sprayed in a spray chamber calibrated to deliver 15 GPA at 40 psi. The herbicide dose used was 16 fl oz ac^{-1}.

Results: Some of the adjuvants increased common lambsquarters biomass reduction up to 21 (Figure 1) and 48% (Figure 2) by Liberty 280-SL® and Interline®. However, few of them had antagonistic interaction reducing herbicidal activity.

Figure 1. Common lambsquarters biomass reduction (%) at 28 DAT with Liberty plus adjuvants.

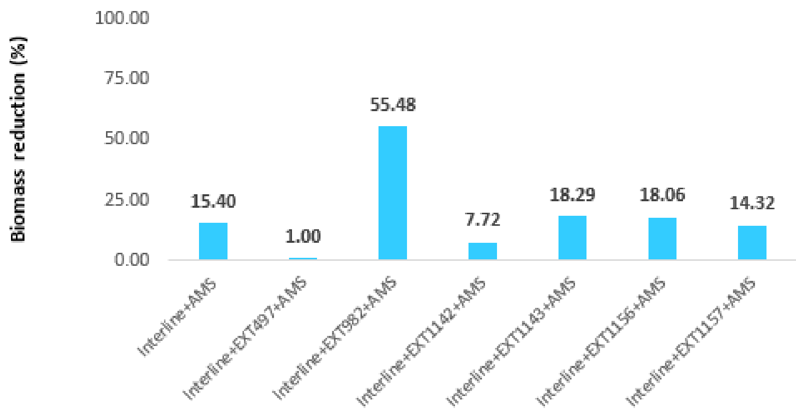


Figure 2. Common lambsquarters biomass reduction (%) at 28 DAT with Interline plus adjuvants.

Title: Use of Glufosinate, Glyphosate and 2,4-D Applied Alone or in Combination for Weed Management

Authors: Ana Clara Gomes, Gabrielle de Castro Macedo, Bruno Canella Vieira, Jeffrey A. Golus and Greg R. Kruger.

Objectives: Herbicide resistance has increased considerably in the last decade. Herbicide tolerant crops were introduced in the market providing growers new herbicide options to include into weed management programs in order to achieve satisfactory weed control and crop yield. This allowed growers to spray non-selective herbicides in post emergence applications in crops such as soybean and cotton. The Enlist™ system crops are tolerant to 2,4-D, glufosinate, and glyphosate. However, it has been reported that herbicide tank-mixtures can result in antagonistic herbicide interactions reducing weed control in some instances. Therefore, the objective of this study was to evaluate the efficacy of 2,4-D, glyphosate, and glufosinate applied alone and in tank-mixture on Palmer amaranth (*Amaranthus palmeri*) and kochia (*Bassia scoparia*) using two different nozzles.

Results: Overall, solutions containing 2,4-D had better control on Palmer amaranth as the population had glyphosate resistant biotypes. For kochia, glufosinate alone, glufosinate + 2,4-D, and glufosinate + glyphosate provided satisfactory control (>75%). Overall, the glyphosate, 2,4-D, and glufosinate tank-mixture solution did not perform as expected, suggesting possible antagonistic interactions, especially on Kochia. Additional studies are necessary to understand herbicide tank-mixture interactions in controlling herbicide resistant weeds.

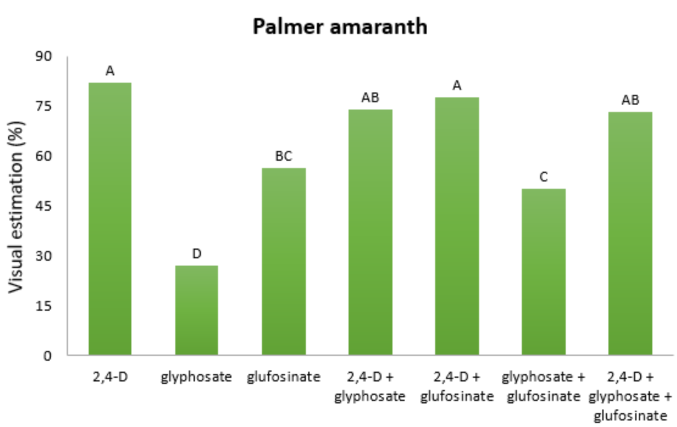


Figure 1. Visual injury at 21 days after application caused by different herbicides solutions. Means followed by the same letter are not different ($p < 0.01$).

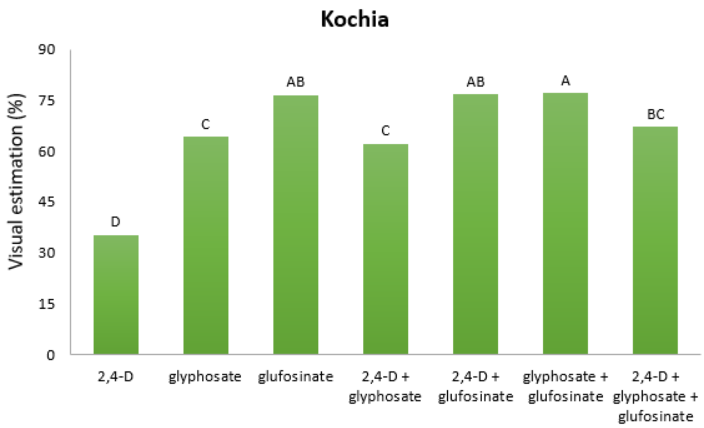


Figure 2. Visual injury at 21 days after application caused by different herbicides solutions. Means followed by the same letter are not different ($p < 0.01$).

Title: Interactions of Clethodim and Dicamba on Glyphosate-resistant Volunteer Corn Control

Authors: Daniel de Araujo Doretto, Gabrielle de Castro Macedo, Pedro H. Alves Correa, Karina Beneton, Vitor M. Anunciato, Jeffrey A. Golus and Greg R. Kruger

Objectives: Glyphosate-resistant volunteer corn (*Zea mays*) is a common weed escape in soybean fields, as corn is grown in rotation with soybean in much of the Midwest. Volunteer corn can reduce soybean yield through competition, cause problems with harvest, host insects and diseases, and contaminate soybean at harvest. There is limited information on the efficacy of tank-mixtures of clethodim and dicamba on volunteer corn control. The objective of this study was to evaluate the effects of clethodim and dicamba tank-mixture on volunteer corn control different heights, with and without the use of non-ionic surfactants.

Results: Antagonistic interaction between herbicides was observed and clethodim efficacy was reduced when sprayed at lower rates in mixtures with dicamba. The addition of NIS and DCFRA increased volunteer corn control. The highest dose of SelectMax (16 fl oz/a + XtendiMax 22 fl oz/a) overcame the antagonism and provide an adequate control (> 80% of biomass reduction), but only on small plants (12 inches). Results indicate that cutting the rate of clethodim is not a good strategy for management of volunteer corn. Timeliness is critical for the success of this tool in the field as volunteer corn is not a conventional weed.

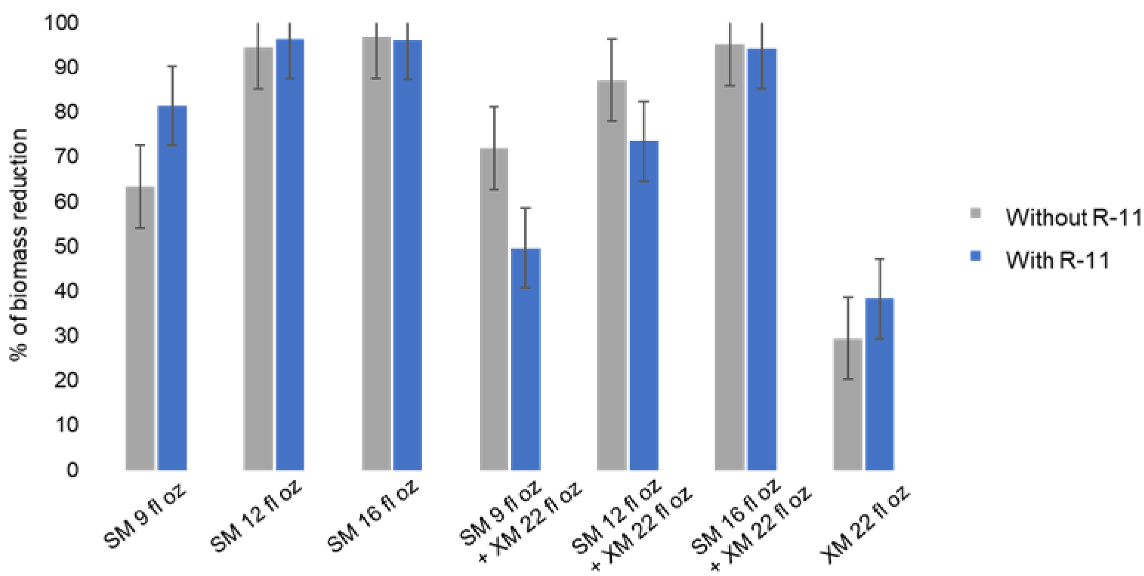


Figure 1: Biomass reduction from plants sprayed at 12 inches.

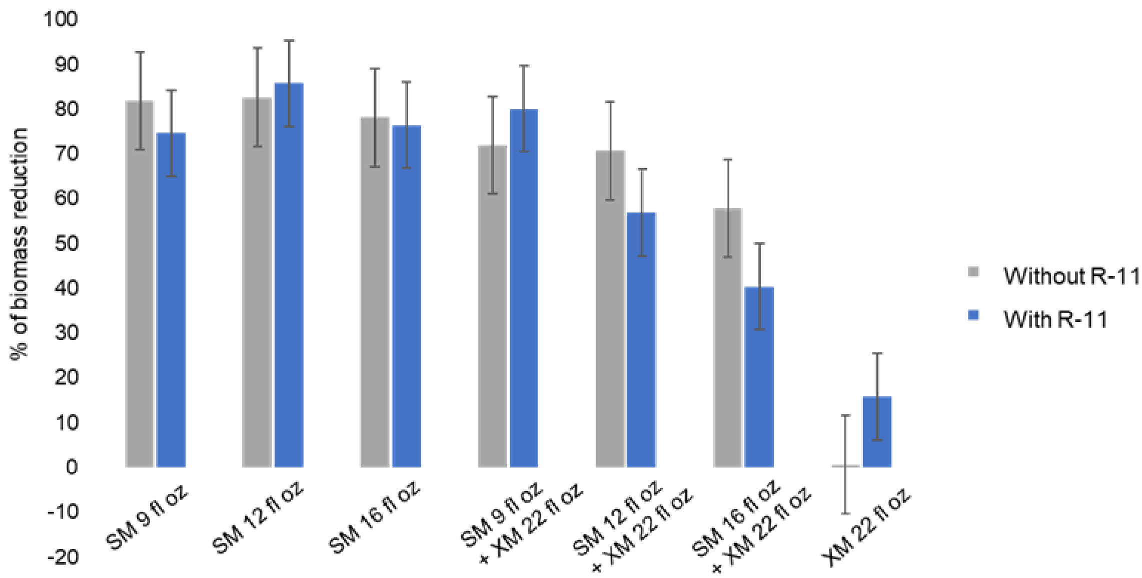


Figure 2: Biomass reduction from plants sprayed at 24 inches.

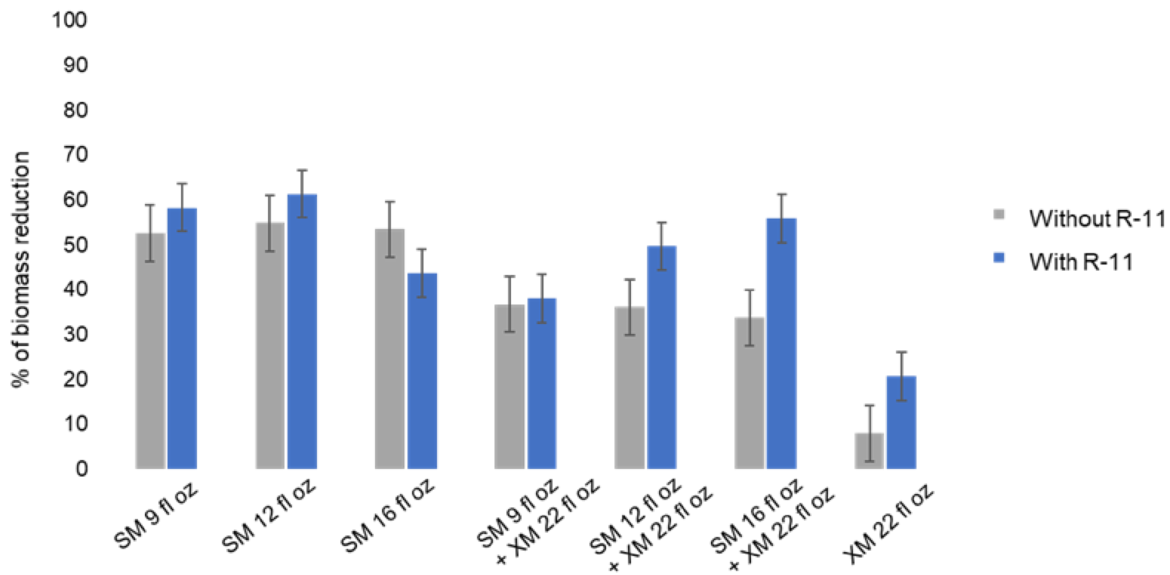


Figure 3: Biomass reduction from plants sprayed at 36 inches.

Further work on the project: Looking forward to adjuvants that neither decrease Dicamba broadleaves control nor Clethodim grasses control but help to overcome antagonism in this tank-mixture and therefore improve Glyphosate-resistant volunteer corn control on Dicamba-tolerant soybean fields.

Title: Use of pulse width modulation to compare carrier volume and dose response on soybean.

Authors: Raquel B. Moreira; Bruno C.Vieira; Dan Reynolds; Jeffrey A. Golus; Ulisses R. Antuniassi J., Greg R. Kruger

Objectives: A major concern associated with the introduction of herbicide-resistant crops is the potential for herbicide drift. Drift simulation studies are usually performed with low herbicide rates applied at constant carrier volumes. However, these simulations differ from real herbicide drift events in terms of droplet concentration. Furthermore, it has been reported in the literature that carrier volume and consequently herbicide concentration within droplets can influence herbicide activity. The objective of this study was to compare soybean (non-dicamba-tolerant) injury and height reduction following applications of growth regulator herbicides at variable and constant carrier volumes.

Results: Herbicide solution concentration influenced plant height reduction for dicamba ($p = 0.0002$), 2,4-D ($p = 0.0603$), and florpyrauxifen ($p < 0.0001$). Generally, diluted herbicide solutions resulted in more plant growth reduction compared to concentrated solutions. For visual estimations of injury, applications with diluted and concentrated solutions had similar injury for 2,4-D ($p = 0.8077$) and dicamba ($p = 0.7882$).

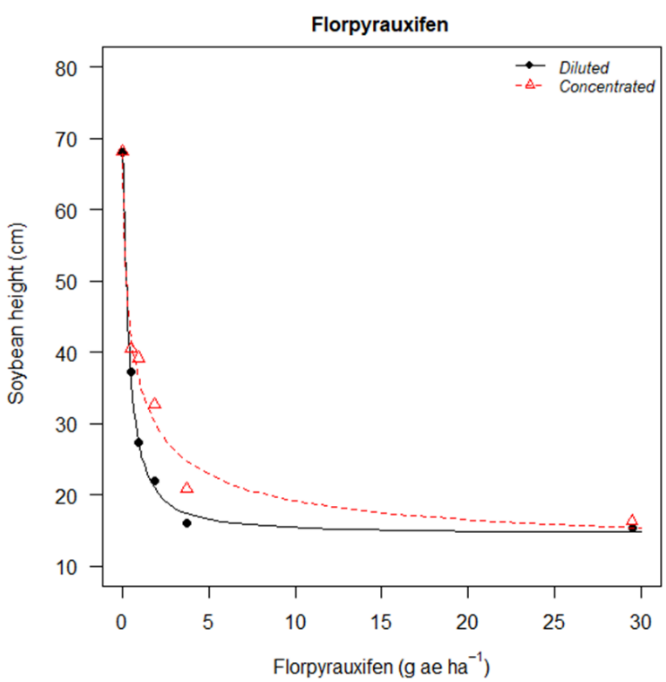


Figure 1. Soybean height reduction as influenced by concentrated and diluted rates of florpyrauxifen.

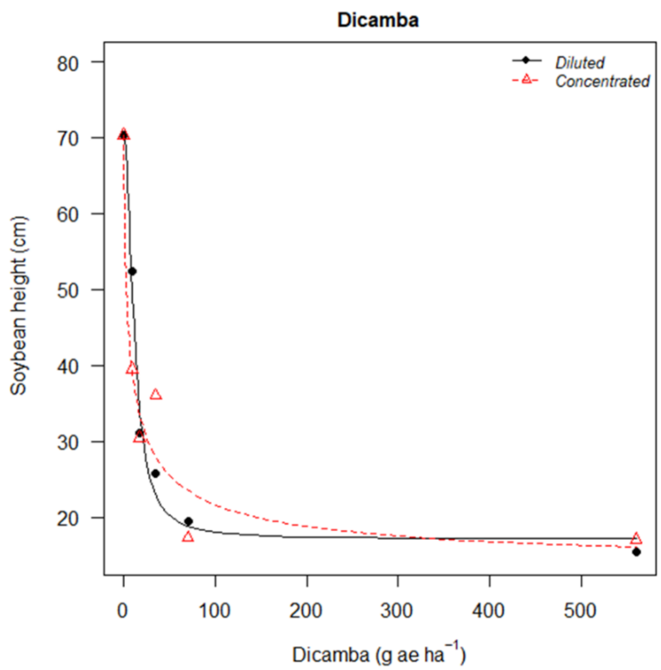


Figure 2. Soybean height reduction as influenced by concentrated and diluted rates of dicamba.

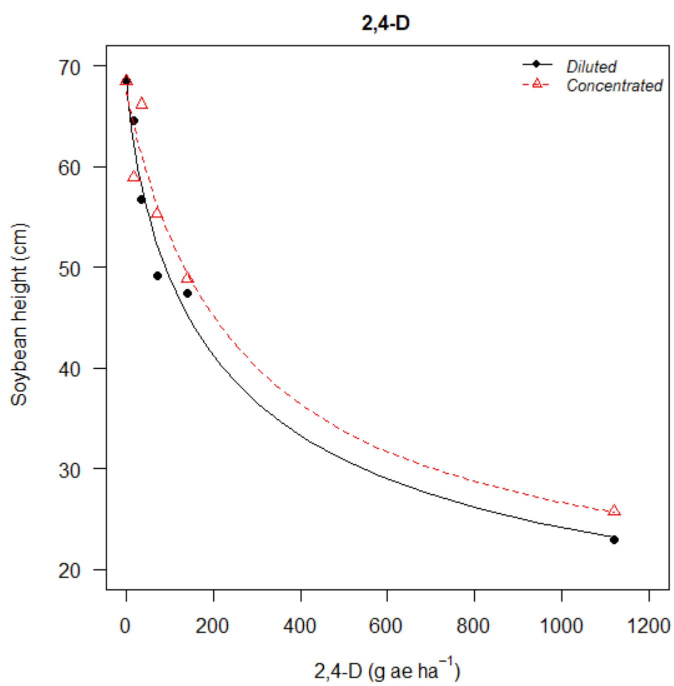


Figure 3. Soybean height reduction as influenced by concentrated and diluted rates of 2,4-D.

Title: Physical Properties of Various Glyphosate Formulations as Critical Components for Common Lambsquarters (*Chenopodium album* L.) Control

Authors: Milos Zaric, Greg Kruger

Study outline: This study was conducted to evaluate the efficacy of different glyphosate formulations on common lambsquarters control. The study also investigated whether different concentrations of nonionic surfactant (NIS) associated with a glyphosate formulation that does not contain surfactants influenced common lambsquarters control. The study also investigated potential relationships between physical properties and weed efficacy for various glyphosate formulations.

Results: The addition of NIS to unloaded glyphosate formulations such as Touchdown HI TECH is necessary optimize efficacy on common lambsquarters. As the amount of NIS increase density and viscosity values increase. Furthermore, this caused reduction in surface tension and contact angle which led to higher efficacy. In general, loaded glyphosate formulations had 85% or greater control. However, there was a difference among loaded formulations used. Original glyphosate formulations such us Roundup PowerMax and WeatherMax performed similarly through both studies. However, efficacy related with loaded isopropylamine salt formulation only can be partially explained by looking at physical properties. Herbicide formulations, amount of surfactants used, and leaf surface represent critical components for successful common lambsquarters control. Additional research such as droplet evaporation time will be necessary to understand the effect of different glyphosate formulations on common lambsquarters control.

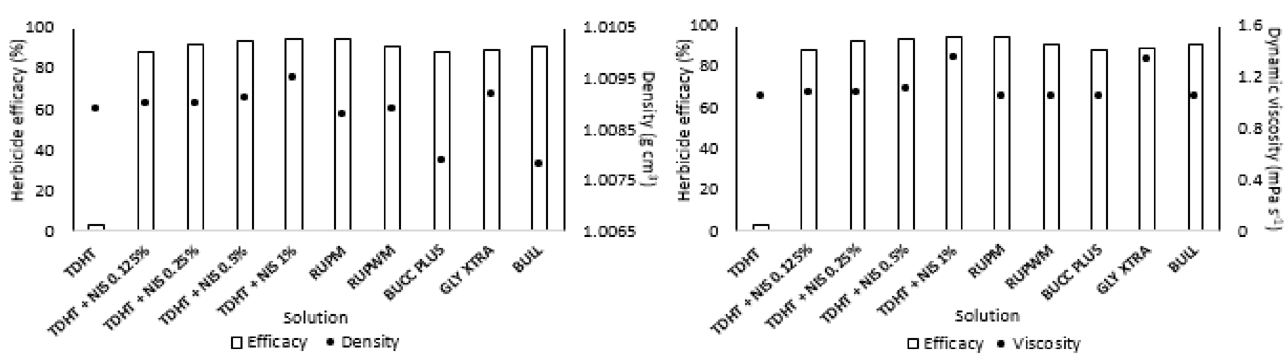


Figure 1. Glyphosate solutions density (left) and viscosity (right) plotted over visual estimations of injury for common lambsquarters.

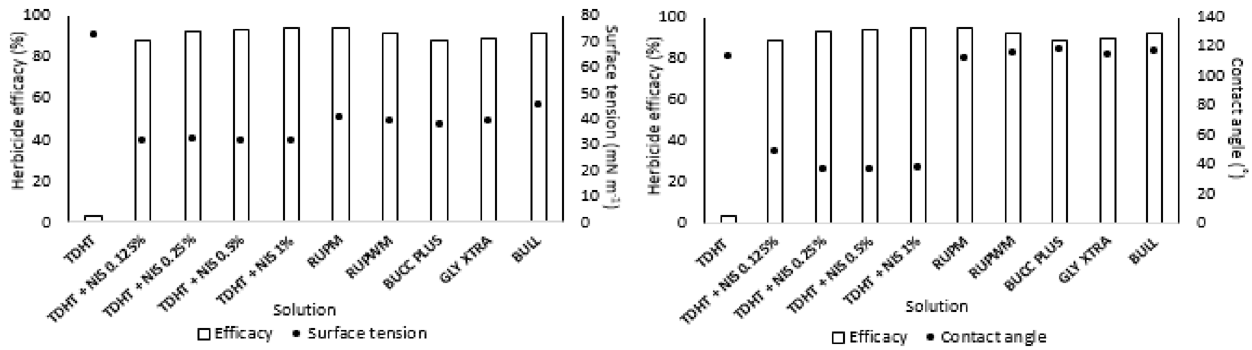


Figure 2. Glyphosate solutions surface tension (left) and contact angle (right) plotted over visual estimations of injury for common lambsquarters.

2017-2018 Interaction of Lactofen with Glyphosate or Glufosinate for Weed Control as Affected by Adjuvants and Droplet Size

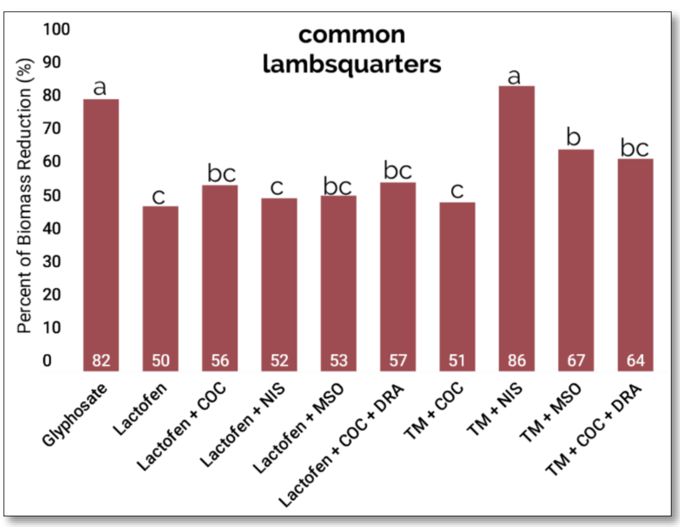
Author: Jesaelen G. Moraes, PhD student in Weed Science

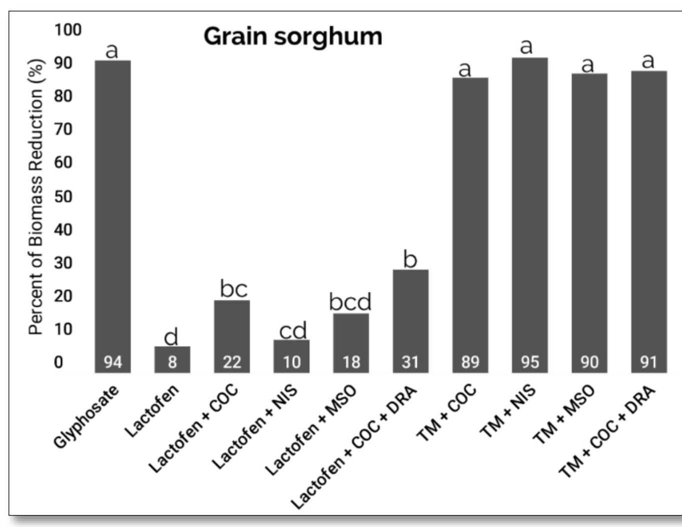
Funding:

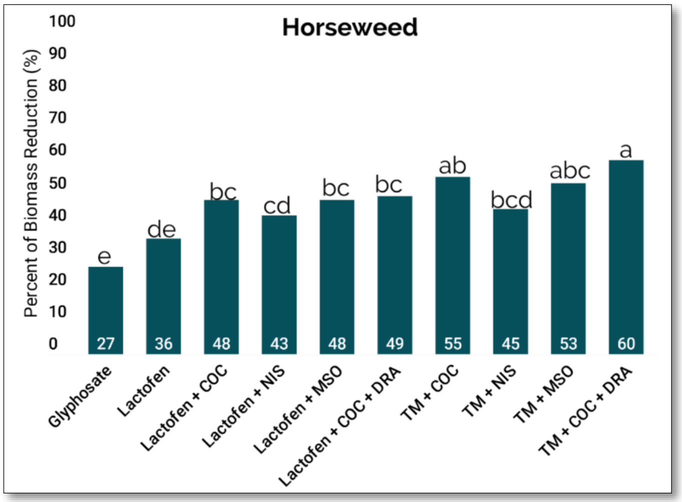
Study Outline: Greenhouse studies were conducted at the Pesticide Application Technology Laboratory - West Central Research and Extension Center, in North Platte, NE, using four plant species: kochia (*Kochia scoparia (L.)* Schrad.), horseweed (*Conyza canadensis (L.)* Cronq.), common lambsquarters (*Chenopodium album L.*), and grain sorghum (*Sorghum bicolor (L.)* Moench ssp. *Bicolor*). Treatments were arranged in a 10 x 2 factorial consisting of ten spray solutions and two nozzle types (XR11004 and TTI11004). Spray treatments consisted of postemergence applications of glyphosate at 16 fl oz/ac, glufosinate at 14.5 fl oz/ac, lactofen at 6.25 fl oz/ac, or lactofen with crop oil concentrate (COC) at 1% v v^{-1}, non-ionic surfactant (NIS) at 0.25% v v^{-1}, methylated seed oil (MSO) at 1% v v^{-1}, or a drift reducing agent (DRA) at 0.5% v v^{-1}, and either glyphosate or glufosinate with lactofen in combination with each of the adjuvants aforementioned. All applications were performed at 40 psi and 6 mph to deliver 20 gpa using a three-nozzle laboratory track sprayer. Droplet size spectra were also recorded using a laser diffraction system. The objective of this study was to determine the interaction of lactofen with glyphosate or glufosinate for weed control as affected by adjuvants and nozzle selection

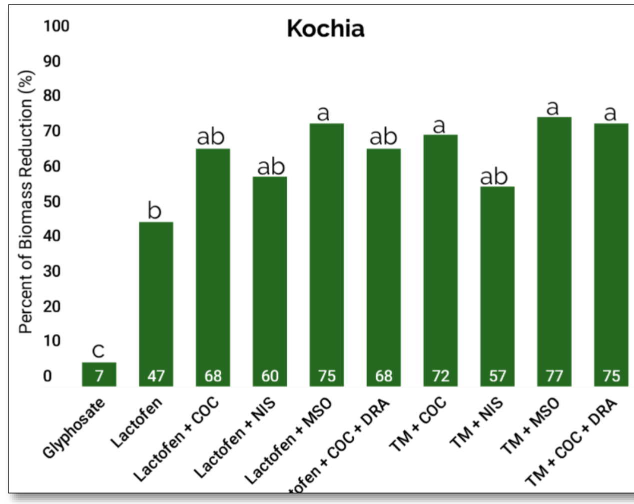
Results:

A) Study 1 - Glyphosate

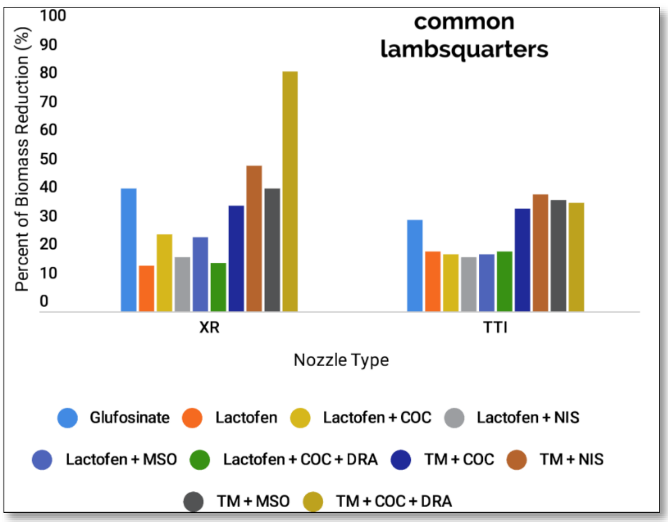


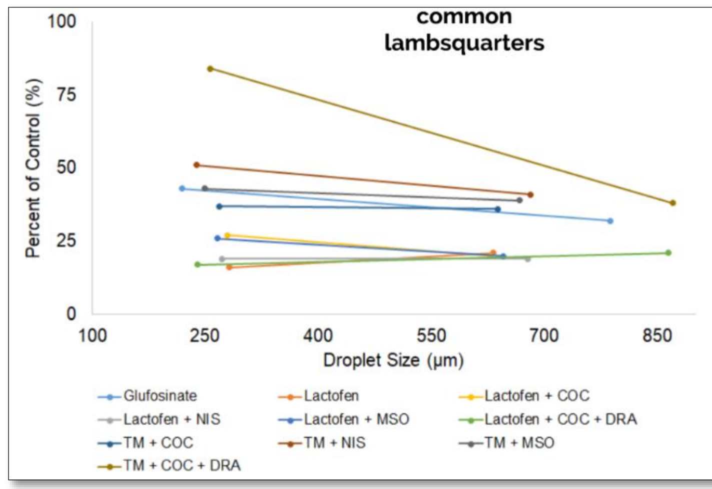


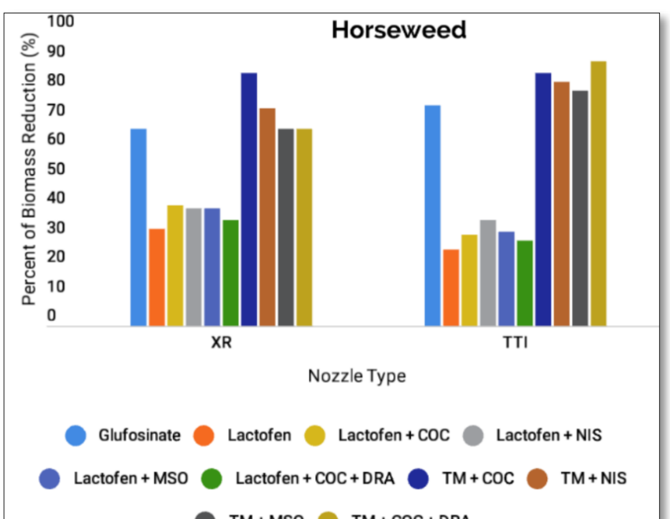


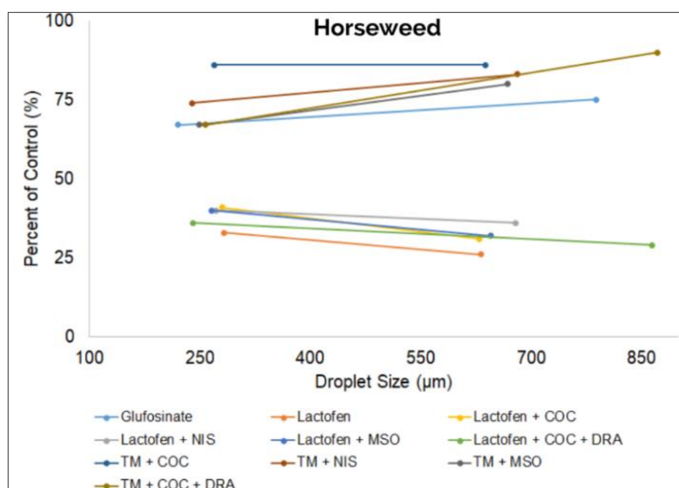


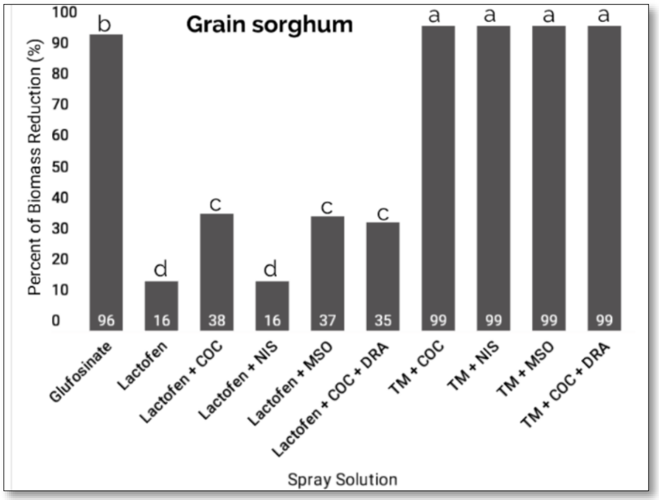
B) Study 2 – Glufosinate

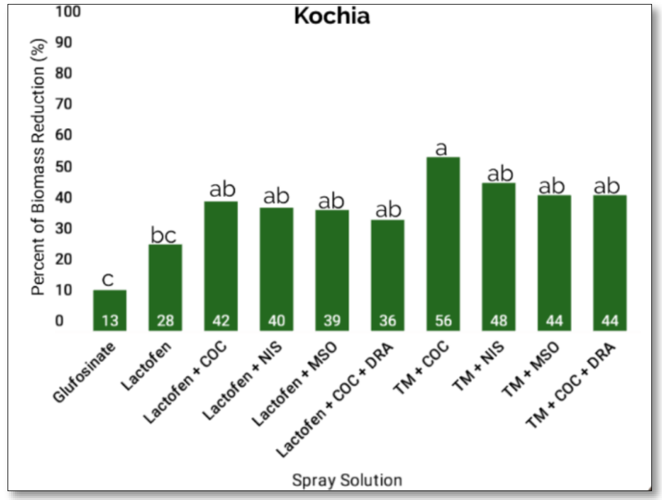












Results: Nozzle selection was not the major contributing factor on herbicide efficacy when using glyphosate whereas XR nozzle improved weed control when glufosinate was applied. Herbicides, adjuvants, and plant species must be taken into consideration in selection of the nozzle type. Larger droplets could be used to minimize drift when applying glyphosate. It may reduce time and increase penetration depending on the foliar structure. Reduced activity of glyphosate is weed-species specific whereas glufosinate is species and nozzles specific. A greater impact on droplet size and on herbicide efficacy was observed when using the adjuvants NIS and the drift reducing agent.

2018 Effect of Adjuvants on Physical Properties of Glyphosate and PPO-Inhibiting Herbicide Spray Mixtures

Author: Jesaelen G. Moraes, PhD student in Weed Science

Abstract: Adjuvants are known to enhance spray droplet retention on leaf surfaces and penetration of herbicide active ingredients through cuticles due to changes in physical properties such as density, viscosity, surface tension (SFT), and contact angle (CA) increasing leaf wettability. However, previous research has shown that the performance of an adjuvant is dependent on the herbicide with which it is applied, the plant species, and environmental conditions. The objectives of this study were to determine the effect of adjuvants on these physical properties when glyphosate and lactofen are applied alone and in combination and to determine if these changes can be correlated to herbicide efficacy. The impact of the addition of the adjuvants into the treatment solutions was greater on viscosity than on density values. Overall, adjuvants significantly decreased the SFT of treatment solutions when compared to either water or herbicides alone. In addition, reduced CA was observed due to the reduction in surface tension. However, results were adjuvant- and species-dependent. Herbicide efficacy was only partially explained by the changes in these physical properties. Observations from this study highlighted the importance of adjuvants on reducing SFT and CA properties of spray solutions; however, further investigation is needed to better understand the factors influencing herbicide uptake and how they are correlated in order to maximize herbicide efficacy.

In press: J. G. Moraes, J. D. Luck, U. R. Antuniassi, W. C. Hoffmann, and G. R. Kruger, "Effect of Adjuvants on Physical Properties of Glyphosate and PPO-Inhibiting Herbicide Spray Mixtures," in Pesticide Formulation and Delivery Systems: 39th Volume, Innovative Formulation, Application, and Adjuvant Technologies for Agriculture, ed. D. J. Linscott (West Conshohocken, PA: ASTM International, 2019), 64–74. http://doi.org/10.1520/STP161920180130

2019 Management of Troublesome Weeds in XtendFlex® Soybeans

Author: Jesaelen G. Moraes, PhD student in Weed Science

Funding:

Study Outline: The study was conducted in two XtendFlex® Soybean fields located in North Platte and Brule, NE. Spray treatments consisted of postemergence applications of glyphosate (32 fl oz/ac) and dicamba (22 fl oz/ac) both alone and in combination and both herbicides in tank-mixture with glufosinate (32 fl oz/ac), or clethodim (16 fl oz/ac), or clethodim plus glufosinate, or clethodim plus acetochlor (48 fl oz/ac), or clethodim plus s-metolachlor (16 fl oz/ac). Tank-mixtures containing two or more herbicides were tested with two different drift reducing agents at 0.5 % v/v. A control plot (no herbicide) was included for a total of 16 treatments. Each treatment was sprayed with a backpack sprayer calibrated to deliver 15 gpa at 40 psi and at 4 mph using the TTI11002 nozzle on a 20 inches nozzle spacing. Two rectangles (30.5 x 12.5 in) were placed in each plot allowing visual estimations of herbicide injury in-row and between-row in addition to the entire plot. The objective of this research was to observe the response of troublesome weeds to tank-mixtures containing two or more herbicide sites-of-action as affected by drift reducing agents.

Results yet to be reported: Data were collected at 7, 14, 21, and 28 days after application (DAA). At 35 DAA, the number of weeds in each rectangle was counted and harvested. Plants were placed in a dryer until reached constant mass and dry biomass was recorded. Results from are being analyzed and will help to predict and recommend the most appropriate tank-mixtures to be used with this new soybean trait.

2019-2020 Soybean Symptomatology and Yield Response to Sub-Labeled Doses of Dicamba and 2,4-D

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Funding:

Study Outline: The experiment was conducted at the West Central Research and Extension Center, in North Platte, NE, during the summer of 2019. Main plots consisted of eight soybean cultivars (Hoegemeyer 2511NRR, Hoegemeyer 2811NR, Asgrow 2636, Pionner P27T59R, Pioneer P22T41R2, Syngenta S26-F4L, Syngenta S28-6L, Bayer CZ2312LL), and sub-plot consisted of five doses (1/10, 1/100, 1/1000, 1/10000, and 1/100000) of dicamba (22 fl oz/ac) and 2,4-D (32 fl oz/ac) applied as late POST (~R1). Herbicide applications (15 gpa) were made using a commercial sprayer equipped with 15 independently spray booms using the TTT11003 nozzle at 40 psi and a travel speed of 6 mph. A control plot (no herbicide) was included for a total of 88 treatments. Plots were kept weed free from planting to harvest. The objective of this study was to investigate the herbicide injury and consequent impact on yield caused by exposition of plants to sub-labeled doses of two auxin herbicides (dicamba and 2,4-D) on the most commonly used soybean cultivars in Nebraska.

Results yet to be reported: Visual estimation of injury was collected at 7, 14, 21, and 28 d after application (DAA). Plant heights were collected at 14, 28 DAA, and before harvesting. Number of pods per plant, number of seeds per pod, 100 seed weight, and total seed mass were recorded for six plants from each plot at harvest, as well as soybean grain yield. Results from 2019 are being analyzed and same study will be conducted in two more locations next year (2020).