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Managing Herbicide Drift for Vegetable Growers: Planning Management, Assessment and Lessons Learned from Extension Workshops

Abstract

Herbicide drift is part of risk management for vegetable operations, particularly when these border row crop operations. Knowing how to properly identify herbicide drift could help producers with managing risk, communicate with agents and inspectors, and file an herbicide drift report. This case study is a resource to Extension professionals seeking to offer workshops and resources to specialty crops growers related to herbicide drift and can be used as a reference to develop Extension programs in their area.

Keywords: adult education, demonstration, drift, pesticide, risk management strategies, workshop development

Introduction

Cooperative Extension Services (CES) are commonly used to obtain crop production information (Franke-Dvorak et al., 2010). Planned professional and Extension events including workshops, seminars and field days are some of the methods used to offer

targeted information to participants (Garst and McCawley, 2015). Programs are designed inherently for the community they serve; however, thoughtful program implementation, delivery and evaluation is key for successful programs (Gagnon et al., 2015).

Herbicide drift is a topic of concern for vegetable growers either from neighboring farms or one's own herbicide applications. In either case, drift could be devastating for production but can be partially mitigated with open communication between neighbors and use of best management practices on the farm. A team of Extension specialists, associates, and agents partnered to host workshops addressing growers' concerns with herbicide drift. Workshop topics included identification of herbicide symptoms on tomato and cucurbit crops; proper tank cleaning techniques to avoid accidental introduction of pesticides to off target crops; steps in making a drift claim; discussion points with neighboring farms to increase communication and decrease accidental sprays; and documentation of expenditures to better understand potential financial loss from drift related incidents.

While Extension professionals address drift concerns regularly, either via personal communication or through organized workshops and presentations, case studies and demonstrations are not documented in the literature. This article provides a resource to Extension agents in any state to replicate a drift management workshop, and help present herbicide drift information to growers throughout the United States. In this article, we present a map of our planning activities, our workshop agenda, and the field set up for the herbicide drift demonstration. We close by providing participant remarks and offering insights on planning management and workshop evaluations.

Methods

Collaborators and roles

When herbicide drift concerns arise, prior to filing a drift claim, several parties are involved in the process of identifying, reporting, and collecting information. These

parties may differ from state to state, but usually include Extension specialists, Extension agents, insurance agents, and regulatory agency (Department of Agriculture or equivalent) inspectors. To bring the best programming to participants, the University Extension specialists and Extension agents partnered with farm managers, industry representatives, Department of Agricultural and Farm Bureau Federation faculty. Each party provided expertise on the topic and resources to participants. Each party was involved in the pre- and post-assessment of the workshop.

Key insights for the demonstrations were offered from the state Extension weed specialist and state Extension vegetable specialists. Both serve as a person of contact for vegetable growers in the state. Each growing season, the state Extension weed specialist investigates drift complaints, often involving damaged vegetable crops to the point of complete yield loss from producers. The state Extension vegetable specialist often addresses herbicide damage complaints. Herbicide damage is often misdiagnosed as disease or insect damage, or as a nutrient deficiency. These specialists provided valuable information on herbicide drift symptoms, procedures to scout for herbicide symptoms vs symptoms from the aforementioned causes. Extension associates assisted with setting up, planting, maintaining, and simulating drift in the field plots at the workshop locations. These plots were key to participants walking through fields of simulated herbicide damage to better be able to diagnose drift symptoms.

Educational presentations were offered on record keeping and the use of financial tools in documenting production loss (ag finance specialist) and use of herbicides (state pesticide safety coordinator). External partners included Department of Agricultural Agents and Farm Bureau Federation employees. These agents conduct regular drift complaint assessments and are familiar with the process farmers need to register an official complaint with the legal entity. They could also describe sampling procedures and what happens after a complaint. Farm Bureau employees emphasized farm-worker risk and insurance.

Extension Agents throughout the state and University communications assisted with recruiting farmers, inspectors, crops consultants and Extension agents themselves to attend the two workshops. Included as an Appendix is a draft of our workshop agenda.

Program planning, workshop locations and field set up

Extension specialists should begin training farmers, Extension agents, and Department of Agriculture inspectors on herbicide symptomology to protect small scale vegetable producers. Drift damage can occur quickly and sporadically. For example, grapes can be damaged by 2,4-D at up to 100 times less than the labeled rate (Penn State Extension, 2022). Examples, such as these, are the reason why university employees are often called upon to identify symptomology of herbicide damage as compared to environmental damage.

While Extension agents are not legally responsible for determining the causation of off-target drift impacts, they are often called upon for their expertise in this area. Therefore, we want to better educate farmers, Extension agents, and Department of Agriculture inspectors on how to identify herbicide symptomology, so that, as a team, they are better prepared in those situations. In Louisiana, for example, where the workshops took place, final determination of the causing agent is made by the Department of Agriculture and Forestry using visual symptomology and testing of plant material.

During program planning, the project coordinators determined that the program would consist of two in-person workshops, video capture of demonstrations, fact sheets and a series of Extension publications developed by the end of the project. Two locations were selected for the workshops based on 1) accessibility to interested participants and travel time ensuring maximum participation, 2) access to facilities and space to set up field demonstration plots and monitor them throughout the duration of the project.

Demonstration plots were established at both workshop locations. The crop selection was based on 1) key crops raised in the state, 2) similarity of symptoms in plant family, and 3) frequency of inquiries for pesticide drift determination. Tomatoes and squash were planted in both locations. We increased the number of vegetable crops in the north

location, adding okra, beans, and cotton to simulate herbicide drift based on participant interest.

Tomatoes and squash were planted on plastic mulch lined raised beds with drip irrigation. Plots were 48 inches wide and 25 feet long. Each tomato plot had at least 15 plants per row planted single drill on 18-inch centers. Squash plots had at least 10 plants per row planted single drill on 24-inch centers. Herbicide treatments were applied over each row. Approximately 8 feet of space was left unplanted between plots to minimize cross contamination of herbicides.

The four herbicides used were glyphosate, dicamba, paraquat and 2,4 -D. Off target drift from pesticides such as 2,4 – D and dicamba are becoming more of a widespread problem with off target crops (Sharkey et al., 2021). In addition to the two vegetable crops, specialists also incorporated a time factor to the field plots. Plots were sprayed 3 days, 7 days and 14 days prior to each workshop to demonstrate the change in symptoms of herbicides over time. The set up was replicated to create a field walkthrough activity. Three plots of each herbicide by crop time treatment were labeled and three were unlabeled. The unlabeled plots were used to quiz participants' ability to correctly identify drift symptoms after learning with specialist in the labeled portion of the field. The original setup was replicated in the north location.

At the south location, the herbicide rates were applied at 50% of the recommended rate to observe symptoms resembling a direct or near direct hit. Severe herbicide injury was observed at the 50% rate in the south location. This information led to the adjustment of herbicide rates to 10% of the recommended rate at the north location to simulate drift from a neighboring field more accurately. Depending on what symptoms you would like to showcase, different rates may be more applicable. Table 1 displays the rates at a near direct hit and drift rate needed to show symptoms on tomato and squash crops.

Table 1. Actual drift and direct application rates used at the north and south herbicide drift workshops

Herbicide	Recommended Rate/ Acre	South Simulating Drift at a 50% Recommended Rate	North Simulating Drift at a 10% Recommended Rate
Glyphosate (4lb./Gallon)	32 oz.	16 oz.	3.2 oz.
Paraquat (2lbs./Gallon)	32 oz.	16 oz.	3.2 oz.
2, 4 -D (4 lbs./Gallon)	32 oz.	16 oz.	3.2 oz.
Dicamba (4 lbs./Gallon)	16 oz.	8 oz.	1.6 oz.

Note the pounds of active ingredient in your herbicide formulation and adjust the rates accordingly.

During the workshops, participants walked through the field explaining symptomatology from the four selected herbicides on all crops. The first set of plots were labeled with both the herbicide and date it was sprayed in the field. The second set of plots remained unlabeled. Participants worked in teams to go through the second set of plots to determine if they themselves after the training were able to correctly identify herbicide damage and when it was sprayed. Correct answers were provided in the field after participants filled out a paper with their educated guesses.

Timeline of tasks

Table 2 provides an approximate timeline to coordinate all activities needed before hosting an herbicide drift workshop. Tomato and squash crops are used as reference but can be replaced with other vegetable crops.

Table 2. Timeline and list of essential activities when hosting an herbicide drift workshop to ensure maximum participation and success of participants,

Action Item	Approximate Date to Be Completed
Agents discuss and vet speakers for the workshop.	Four months prior to the selected workshop date
Start seeds for the tomato transplants.	Eight to ten weeks prior to the first frost free planting date in your area. Or contact a nursery to grow them for your workshop date at least 14 weeks in advance.
Start seeds for the squash transplants.	Start seed three to four weeks before the planting date. Planting date is the first frost free day in your area. Or contact a nursery to grow these for your workshop at least 6 weeks in advance.
Agents and speakers review all curriculum for the workshop and create an assessment tool. Develop an assessment tool that aligns with the workshop materials to gauge change in participant knowledge from workshop participation.	Two months prior to the workshop date. Please note that some agencies require IRB approval so you will need to time-budget this process as well.
Prepare the field for tomato and squash planting.	One month prior to the first frost-free planting date in your area. This is to manage for rainy days/ weeks, so the ground is ready to plant when the transplants are of correct size.
Plant and stake tomato plants in the field. Plant squash plants in the field.	First historical frost-free date in your area or sometime after.
Develop and distribute marketing materials for the workshop.	Two months before the workshop date
Resubmit marketing materials through social media outlets, news outlets to obtain the maximum number of participants you can accommodate.	One month before the workshop date and again two weeks before the workshop date until your target audience number is recruited.

Spray the first round of herbicide treatments on squash and tomato plants. Tomato plants do not need to have fruit on them. Squash plants develop and produce quickly. It is ok if they have fruit.	Two weeks prior to your workshop date
Spray second round of herbicide treatments to squash and tomato plants	One week prior to your workshop date.
Spray third round of herbicide treatments to squash and tomato plants	Three days prior to your workshop date.
Host the herbicide drift workshop Assess the workshop after end of business.	Day of the workshop.
Thank your presenters	Within a day or two of the workshops. Ask if they would like to receive a summary of their evaluations.
Self-assess your workshop	Shortly after completion of the workshop, convene as a planning committee and discuss lessons and improvements.
Reach out to workshop participants with a follow up assessment regarding behavioral changes regarding pesticide usage.	Six months after the workshop occurred.
If phone responses were low, send out email links to an online questionnaire.	One month after initial follow up phone calls were made.

Assessment

Assessments are helpful to determine if the workshop content was well received and if the speakers and presenters impacted participant knowledge and behavior. Table 3 presents the survey approved for use through the IRB board approval number IRB-AG-23-0069-01. This survey can easily be modified to work with agents in any state wanting to host a similar program.

Table 3. Survey questions used in the herbicide drift workshops,

Question	Potential Answers	Pre or Post Test or Both
Section: Getting to Know You		
My profession is	Producer, Extension agent, Ag inspector, Crop Consultant, Other	Both
I have ____ years of experience in my profession	0-3; 4-9; 10-20; 21 +	Pre-only (Both is advised)
Gender	Male, Female, Prefer not to say	Pre-only (Both is advised)
How would you best describe your racial background	American Indian or Alaska Native, Asia, Black or African American, Multiple ethnicity/ Other, Native Hawaiian or Pacific Islander, Hispanic, White Caucasian, prefer not to answer	Pre-only (Both is advised)
Have you ever made a formal pesticide drift complaint?	Yes or No	Pre-only (Both is advised)
Have you ever had pesticide injury to your crops that occurred from pesticides you did not apply yourself?	Yes or No	Pre-only (Both is advised)
Have you ever accidentally damaged your own crops with pesticides?	Yes or No	Pre-only (Both is advised)
Section: Cleaning Equipment		
Is it important to wash the outside of your spray equipment?	Yes or No	Both
Is water and dish soap an adequate solution for cleaning pesticide tanks?	Yes or No	Both
Are handheld and backpack sprayers cleaned the same as Agricultural spray rigs?	Yes or No	Both

Does the pesticide label provide any information on cleaning spray rig equipment?	Yes or No	Both
Section: Handling Pesticides		
Which resource provides the most accurate information for the handling, safe transport, and application of pesticides?	Options offered: 1) Pesticide label for the product; 2) handbook on pesticides; 3) social media comments on pesticide; 4) EPA website	Both
How can you know when the gloves you are wearing are breaking down from pesticide chemicals spilled on them?	Options offered: 1) The gloves feel wet on the inside; 2) If you remove the gloves and inflate them by blowing inside they will not hold air; 3) There is evidence of discoloration or thinning in the area contaminated by the chemical; 4) there is no way of knowing.	Both
The level of Personal Protection Equipment (PPE) that you should wear when working with a pesticide is determined by	Options offered: 1) The pesticide's toxicity; 2) The activity you are performing with the pesticide (mixing, loading, applying, etc.); 3) Both 1 and 2; 4) You only need PPE when spraying, not mixing pesticides.	Both
Do certified private and commercial applicators have different recordkeeping requirements?	Yes or No	Both
Section: Reporting		
If a pesticide drift occurs, who is the responsible party?	Options offered: 1) Farmer; 2) flying service; 3) agricultural consultant; 4) Certified pesticide applicator who applied the pesticide	Both
Who do you first call if you suspect drift of a pesticide on your vegetables?	Options offered: 1) Extension agent; 2) State Department of Agriculture; 3) state Farm Bureau Federation; 4) the local sheriff's office.	Both
If a pesticide drift occurs, what are common steps after contacting the appropriate agency? Select all that apply.	Options offered: 1) Document the damage; 2) document weather conditions; 3) Check with neighbors to see if they witnessed anyone spraying in the area; 4) Contact a lawyer	Both
Who is required to have a pesticide applicators license?	Options offered: 1) Any person applying pesticides on the farm; 2) The farm owner; 3) Any workers on the farm despite of they apply pesticides or not; 4) No one unless you are spraying a pesticide that requires a license.	Both

Section: Financial		
What is best way to document yield loss?	Options offered: 1) Visual estimates of yield loss; 2) Yield from damaged area vs yield from undamaged area from the same field; 3) Yield from damaged area vs yield from undamaged area from another field; 4) Yield from damaged area field from previous years	Both
Which financial tool is best used to calculate loss from drift?	Options offered: 1) Balance sheet; 2) Enterprise budget; 3) Income statement; 4) Partial Budget	Both
What do you expect to get out of today's workshop?	Fill in the blank	Pre
How would you rate the quality of the materials and the presentations?	Rating options were Not Good, Somewhat Good, Good, or Very Good for each presentation: 1) Symptomology of herbicides; 2) Tank cleaning demonstration; 3) Monitoring financial risk; 4) Rules and regulations; 5) Pesticide licensing requirements; 6) Claims and worker safety, and overall workshop evaluation	Post
Check all that you intend to do as a result of this workshop	Options offered: 1) Monitor more frequently for drift; 2) Buy an additional pesticide tank; 3) Improve record keeping; 4) Keep sales records for each crop; 5) Clean tanks using instructions provided in this workshop; 6) Obtain a pesticide handlers license; 7) Keep better track of input costs	Post
How can we make this workshop better?	Fill in the blank	Post

Additional questions were asked to each participant to gauge their potential knowledge gain in ability to identify pesticide symptoms from herbicides. These questions were given on both the pre and post-test. Instructions were provided for this specific section of the pre and post survey. Those instructions were: The following question has description of damage shown on plants. Review each statement and select the pesticide responsible for the specific damage. Only one answer is correct per symptom.

Table 4. Survey questions used in the drift herbicide workshops to gauge if participants gained knowledge specifically related to identification of herbicide symptoms on vegetable crops.

Symptoms	Roundup	Paraquat	Dicamba	2, 4-D
	Place a mark in the column that matches the description to the left.			
The newest leaves in the uppermost part of my tomato are turning bright yellow and it seems like my plant just quit growing. Blooms were delayed and the fruit made was distorted.				
The tips of all my tomato branches are severely curled and very distorted and malformed. The stems look twisted.				
My tomato leaves are curled upwards and very small. If I fold out the leaves, they appear crinkled.				
If the pesticide drifted on the plants on a hot day, the foliage on my tomatoes and squash turn brown within hours... If it was a cool day, I noticed browning of my squash and tomatoes leaves in about 3 days.				
The leaves of my squash appear extremely serrated around the edges and almost look slightly curved downward from the edges inward. There are some leaves that appear to have upward cupping.				
The newest or youngest leaves on my squash plants are distorted and starting to yellow.				
The leaves of my squash are stunted, distorted and may appear speckled with small brown to white spots.				

Results

Workshop feedback

The workshops were well attended. Workshop I (south region) was attended by thirty people and Workshop II (northern region) was attended by thirty-four people. Most attendees were Department of Agriculture agents who serve as first responders to herbicide drift incidents. Most participants rated all sections of the workshops as good or very good. Many participants walked away stating how well they enjoyed the hands-on portion of the workshop (tank cleaning and herbicide symptomology fields). Many of the participants took detailed photos in the fields so they could make presentations and recordings of the symptoms for later use in investigations and for future Extension presentations. Several agricultural inspectors requested the hosts repeat the workshop with additional vegetable and ornamental crops in the future.

After six months, participants were contacted to understand more about their experiences after participating in the workshops. An online survey instrument was developed using Qualtrics and distributed. Many attendees responded with positive feedback.

Table 5. Survey questions used in the herbicide drift workshops to gauge if participants retained the information and skill approximately six months later.

Question	Potential Answers
How would you describe yourself?	Farmer; Inspector; Extension Agent
Did this workshop increase your confidence in managing herbicide drift?	Yes; No
What specifically increased your confidence?	Fill in the blank
What information do you need to become more confident?	Fill in the blank

Among the survey respondents were farmers, Extension agents and state government inspectors who all stated they learned a lot of information at these workshops. However, they felt the impact of the new information and skills did not become visible until later

when it was applied in the field. For example, one Extension agent said she was already very confident in identifying herbicide drift damage but that this was limited to herbicides commonly applied in the area where she works. Less commonly applied herbicides such as Dicamba or Gramoxone (Paraquat) would be unlikely to be identified by her or potentially even go undetected until much later when the herbicide's effects have severely impacted agricultural production. The agent stated she is now much more likely to be able to correctly identify a broader range of herbicides and thus being able to help her clients more efficiently and effectively.

A second Extension agent stated that after attending the workshop, his understanding of early herbicide drift symptomology has significantly improved. In the agent's area, off-target applications and drift occur frequently, and while the Extension agent gained considerable hands-on experience recognizing later-stage symptoms, early identification has often been a challenge. The herbicide drift workshop provided valuable insight into recognizing these issues earlier and with greater accuracy, which he hopes will enhance his ability to address drift complaints in the future.

A third Extension agent said any herbicide drift incidences he experienced before the workshop were typically involving row crops. He has only on rare occasions witnessed herbicide drift effects on fruit and vegetable production in his area. Should drift occur to home gardeners in his area, he will now be able to recognize the early warning signs. The agent said he was especially glad to have seen the effects of herbicide drift on vegetable crops in the early and late stages.

Workshop assessment

Beyond participant's growth, workshop organizers also learned several lessons.

Lesson 1: Plan for your primary and secondary target audience. Though the workshops were targeting vegetable growers, most attendees were agricultural Extension agents and state government inspectors. It is believed that the small number of attendees that identify as farmers is due to timing, as many of state's farmers plant and harvest every month of the year without break. Furthermore, one of the many incentives to attend this

workshop was the fulfillment of requirements to renew a pesticide application certification license, however, this did not grab the attention of farmers as much as the organizers had hoped. Considering that our topics would be of interest to both growers and inspectors, the workshop evaluation tool was designed to apply to both primary and secondary target audience.

Lesson 2: Identify several ways to market your workshop. The workshops were advertised by local Extension personnel to farmers via various e-mail lists and University Facebook and collaborator social media. We believe though that additional ways need to be found to advertise the workshops and market their benefits.

Lesson 3: Prepare alternative plans. Alternative plans must be in place to mitigate weather related events that may impact these workshops. The workshop in the north location was delayed by a month because of excessive rainfall that rendered the field inaccessible and prevented the organizers from planting. Additionally, this negatively impacted the organizers financially as additional plants needed to be purchased to replace the initial seedlings that had become too old to transplant. When replicating this workshop, organizers must pay attention to having access to extra plants for adverse weather events.

Conclusion

Workshops and field demonstrations offer participants the opportunity to receive targeted information, connect with professionals and network with peers. As such, these activities are integral for the success of Extension programs. Considering the amount of effort and resources invested in hosting the educational activities, we hope this case study offers a guideline to Extension and county agents as they prepare their events. Though our templates evaluate a horticulture-focused workshop on pesticide drift, the templates and assessment tools can be adapted to other disciplines.

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Appendix I

Table A1. Sample “Mitigating Herbicide Drift” workshop agenda

Time	Topic
8:00 – 8:30	Welcome sign in
8:30- 9:00	Workshop Expectations, Introductions, Pre-Survey
9:00 – 10:30	Symptomology of Herbicides. Walk through the fields with specialists.
10:30 – 11:30	Tank Cleaning Demonstration and Team Tank Cleans
11:30 - 11:45	Restroom / Refreshment Break
11:45 – 12:45	Risk Management, Crop Loss, Marketing Windows, Budget Presentation and Lunch
12:45 – 2:00	Pesticide Rules and Regulations, Record Keeping, LDAF Complaint and Sampling Procedures
2:00 - 2:15	Restroom / Refreshment Break
2:15 – 3:15	General Pesticide Safety and Pesticide Certification Requirements
3:15 – 4:15	Worker Safety / Crop Damage Claims
4:15 – 4:30	Post Survey, Questions from the Audience, Paperwork to Renew Pesticide Licenses. *This course was sufficient for fulfilling the requirements to renew one’s personal or commercial pesticide applicators license.