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Journal of Agromedicine

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/wagr20

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To cite this article: Carly Hyland, Lisa Meierotto, Rebecca L. Som Castellano & Cynthia L. Curl (29 Jan 2024): Mixed-Methods Assessment of Farmworkers' Perceptions of Workplace Compliance with Worker Protection Standards and Implications for Risk Perceptions and Protective Behaviors, Journal of Agromedicine, DOI: 10.1080/1059924X.2024.2307483

To link to this article: https://doi.org/10.1080/1059924X.2024.2307483

JOURNAL OF AGROMEDICINE
https://doi.org/10.1080/1059924X.2024.2307483

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Mixed-Methods Assessment of Farmworkers' Perceptions of Workplace Compliance with Worker Protection Standards and Implications for Risk Perceptions and Protective Behaviors

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ABSTRACT

Introduction: The Environmental Protection Agency (EPA)'s Worker Protection Standards is the primary set of legislation aimed at protecting farmworkers from occupational pesticide exposure in the United States. Previous studies suggest that worker adoption of Pesticide Protective Behaviors (PPBs) promoted by WPS is associated with lower urinary pesticide concentrations. However, adoption of PPBs is often outside of the control of individual farmworkers and dependent on workplace factors such as employer provisioning of Personal Protective Equipment (PPE) and access to trainings/resources.

Methods: We conducted a mixed-method study including urinary pesticide biomonitoring, surveys, and interviews with 62 Latinx farmworkers in southwestern Idaho from April to July 2022. We integrated findings across the various data sources to identify emergent themes relating to farmworkers' perceptions of workplace compliance with WPS and potential implications for their pesticide risk perceptions, protective behaviors, and urinary pesticide concentrations.

Results: Participants reported some indications of poor workplace compliance with WPS regulations, notably inconsistent access to clean handwashing stations and notification of pesticide applications. Some farmworkers, particularly pesticide applicators, viewed herbicides to be categorically safer than other classes of pesticides such as insecticides; these perceptions appeared to influence protective behaviors, such as the relatively low use of PPE while applying herbicides. These findings are underscored by the higher concentrations of biomarkers of herbicides, but not insecticides, among pesticide applicators compared with non-applicators (e.g. median 2,4-D concentrations = 1.40 µg/L among applicators and 0.69 µg/L among non-applicators). Participants further reported concerns regarding the inadequacy of pesticide safety training, pesticide drift, and the lack of communication regarding pesticide applications on and near fields where they are working.

Discussion: Participants' perceptions that herbicides are categorically safer than other pesticide classes is in direct conflict with WPS training, raising concerns about discrepancies between WPS instruction and other on-the-job training, as well as the inadequate provisioning of PPE during the application of certain pesticides. Our findings also suggest that current WPS regulations may not sufficiently address farmworkers' concerns, particularly in regard to pesticide drift.

KEYWORDS
Pesticides; farmworker; risk perceptions; Worker protection standards; urinary biomonitoring

Introduction

Pesticides are substances designed to prevent, destroy, repel, or reduce the effects of pests and include substances such as insecticides, herbicides, fungicides, and rodenticides.[1] Occupational pesticide exposure has been associated with a range of adverse acute and chronic health effects, including cancer[2,3]; neurobehavioral deficits and diseases such as Parkinson's and Alzheimer's[2–4]; reproductive disorders[2,4]; genotoxicity, DNA damage, and oxidative stress[2,3]; respiratory symptoms such as coughing, wheezing, and asthma[2,3,5]; and impacts on thyroid function.[2]

The primary regulation aimed at protecting farmworkers from pesticides in the United States is the Environmental Protection Agency (EPA)'s Worker Protection Standard (WPS). Originally established in 1992 with revisions in 2015, the

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/1059924X.2024.2307483

WPS aims to reduce the risk of occupational pesticide exposure among agricultural workers (those who peform hand-labor tasks in pesticide-treated crops, such as harvesting, thinning, and pruning) and pesticide handlers (those who mix, load, or apply pesticides).[1,6] The primary responsibilities of employers mandated by the WPS pertain to 1) training and 2) notification of pesticide applications. Specifically, employers are required to ensure that all agricultural workers receive annual EPA-approved pesticide safety trainings, including pesticide handler training for those who apply or handle pesticides[6–8]; to provide decontamination supplies, including "ample" water, soap, and towels[8]; and to post warning signs or provide oral notification of any areas under a Restricted Entry Interval (REI) after pesticide application.[6–8] The primary goals of the annual training are to educate workers about how to prevent pesticide exposure before, during, and after work; to recognize and understand signs notifying workers to keep out of pesticide-treated areas under an REI; to identify sources of pesticide exposure during work (e.g., exposure to pesticide residues on plants, tractors, and application equipment or from pesticide drift); to adopt practices to minimize pesticide exposure (e.g., wearing Personal Protective Equipment (PPE), washing hands with soap and water while working, showering with soap and water after work, washing work clothes separately from non-work clothes); and to recognize the signs and symptoms of pesticide poisoning and know when to seek medical attention.[1,7]

Previous studies have provided consistent evidence that Pesticide Protective Behaviors (PPBs) promoted by WPS such as wearing PPE,[9–18] washing hands while working (particularly before eating or drinking), showering after work, and removing work boots and clothes before entering the home[15,18–20] are associated with lower urinary pesticide biomarker concentrations among farmworkers. However, there has been no systematic evaluation of WPS training and its impacts on farmworkers' risk perceptions, protective behaviors, and pesticide exposure. While factors such as perceived risk (i.e., an individual's subjective judgement of the potential for harm)[21] may influence the adoption of PPBs,[22] evidence suggests that structural factors that are often outside of farmworkers' control may be the most important determinants of protective behaviors.[9,22] For example, studies of workers in North Carolina and Washington have shown that workplace-level factors such as access to trainings, resources, and PPE support the adoption of PPBs[23–25] associated with lower urinary pesticide biomarker concentrations and adverse health outcomes.[14,26] Given that farmworkers often have limited control over their circumstances,[9,22] it is imperative to assess how factors such as workplace compliance with WPS influence risk perceptions, protective behaviors, and pesticide exposure, including whether there are any differences by pesticide class.

This analysis is part of a larger mixed-methods study assessing gender differences in pesticide exposure and risk perceptions among Latinx farmworkers in Idaho. Here, we assess participants' experiences and perceptions of markers of workplace compliance with WPS from surveys and semi-structured interviews. We further examined potential implications for risk perceptions, protective behaviors, and urinary pesticide concentrations among agricultural workers and pesticide applicators.

Methods

Recruitment, enrollment, and consent

We conducted a mixed-methods study examining pesticide exposure and pesticide risk perceptions, perceived control (i.e., a participant's perception that they have the ability, resources, and opportunities to minimize pesticide exposure or their adverse health effects),[27] and self-reported protective behaviors among Latinx farmworkers in Idaho during the pesticide spray season in 2022. This study included urinary biological monitoring, surveys, and semi-structured interviews. We enrolled a convenience sample of 62 farmworkers in southwestern Idaho who 1) identified as Hispanic/Latina/Latino, 2) were 18 years or older, 3) spoke English or Spanish, and 4) reported currently working in agriculture with food crops. We recruited participants through collaborations with local health districts, housing authorities, healthcare providers, and community organizations serving farmworkers; mobile health clinics; food box distribution events; Head Start meetings; and snowball sampling. Participants were enrolled and all data were collected from April 24 through July 22, 2022. We intentionally recruited farmworkers outside of work and emphasized when explaining the study that we would not ask specifically where they worked or who employed them, to prioritize their confidentiality and anonymity and minimize potential concerns regarding the impact of participating in the study on the individual's employment.

After explaining the study and assessing potential participants' eligibly and interest, study staff read the informed consent to participants in their preferred language (English or Spanish). The urine sampling and survey were covered under one informed consent process. A subset of participants who also participated in a semi-structured interview completed a second consent process that described this additional component. The informed consent for the survey and urine sampling described the process for the collection of the urine samples, analysis of pesticide biomarkers, and indicated that we would administer a survey with questions regarding their history working as a farmworker, the types of crops they work with, the type of protective equipment they wear while working, and their perceptions of pesticides. The informed consent for the interview indicated that we were asking a subset of individuals from the larger study to participate in an open-ended interview so that we could learn more about their perspectives as a farmworker on issues related to pesticide use. This form also indicated we would ask participants questions such as their experiences as a farmworker, their thoughts about pesticides, and any challenges they face in their job related to pesticides.

All study procedures were approved by the Boise State University Institutional Review Board. Participants received a $25 gift card for each component of the study they completed (i.e., two separate study visits with the administration of a survey and collection of a urine sample and the open-ended interview, for a maximum of $75).

Data collection

All study visits were scheduled at a time and location that was convenient and comfortable for the participant; data collection occurred in either English or Spanish, depending on the participant's preference. All participants were asked to complete two study visits within a 7-day period that included the collection of a spot urine sample and the administration of a survey; a subset of 18 participants also completed a semi-structured interview. The first survey assessed factors including demographic information, occupational history, participants' experiences and perceptions of workplace compliance with specific components of WPS regulations (e.g., notification of pesticide applications, availability of handwash stations), current occupational activities (e.g., types of crops worked with, specific duties while working), protective behaviors during and after work, and perceptions regarding the risk of pesticides to themselves and others. The second survey briefly assessed a subset of questions from the first survey, including recent pesticide applications, PPE, and occupational activities during the previous 3 days. At each of these two study visits, participants were asked to provide at least 30 mL of urine in a 100 mL propylene cup to be analyzed for biomarkers of various pesticides, as described below.

Interviews

There were 18 participants (11 women, 7 men) who also completed semi-structured interviews that included open-ended questions to allow participants to describe in their own words their perceptions of the risks and benefits of pesticides, their perceived control to mitigate pesticide exposure and its potential health impacts, and their perceptions and experiences of workplace compliance with WPS regulations. We aimed to conduct these semi-structured interviews with 15–20 individuals. This range was selected given previous knowledge and experience with the population of interest, including the challenges that can be faced with recruitment and development of trust necessary for quality data collection. Further, we believed this number would be sufficient to develop the deeper understanding of experiences with and perceptions related to pesticides among farmworkers in our area of study.

Interviews lasted approximately 45–60 min and occurred at a time and location of the participant's choosing. If possible, interviews were scheduled in conjunction with the second study visit, which otherwise lasted about 10 min, to minimize participant burden. If the participant was not able to complete the interview at the second study visit, we identified another time and location that was convenient for them. As noted above, interview participants were given choice with regards to time and location of data collection. Additionally, the interviews were conducted in locations where participants' responses could not be overheard. Interviews were conducted primarily by the two faculty members on the study with expertise in qualitative methods. They were supported by other researchers on the project who they trained in qualitative data collection. Training included reading on qualitative data collection, interview shadowing and group practice. Interviews were conducted in the language of the participant's choosing, either with one bilingual (Spanish/English) study member or with two study members that included an interpreter. All interviews were audio-recorded, transcribed, and translated as needed. After each data collection event, we also recorded notes from anecdotal conversations with participants and observations, in line with norms in qualitative methodologies in the social sciences and humanities.

Urinary pesticide analysis

Urine storage and analysis procedures have been described previously.[28] Briefly, study staff created composite vials of each of the participants' two urine samples to more accurately reflect the participants' exposure over a one-week period while minimizing analysis costs. Urine samples were shipped on dry ice overnight to Centre de Toxicologie du Québec (CTQ), Institut national de santé publique du Québec (INSPQ) for analysis of 17 pesticide biomarkers in August 2022. These analytes were chosen because they represent exposure to commonly used agricultural pesticides and were available in the multi-pesticide residue and glyphosate panels.

Concentrations of 13 pesticide biomarkers representing exposure to OP and pyrethroid insecticides and the herbicides 2,4-D, 2,4,5-T, and dicamba were determined using Ultra Performance Liquid Chromatography (UPLC I-Class, Waters Acquity, Waters; Milford, MA, USA), as described previously.[29] Samples were also analyzed for glyphosate, glufosinate, and their respective metabolites (aminomethylphosphonic acid [AMPA]) and 3-(methylphosphinico)propionic acid (3-MPPA) using a second analytical method, as described previously.[30]

Data analysis

We measured the specific gravity of each individual sample within 24 h of collection and calculated the specific gravity of each participant's composite sample as the mean of the two samples from which the composite was comprised. We imputed values below the LOD as $\frac{LOD}{\sqrt{2}}$[31] and adjusted urinary concentrations for specific gravity using the following equation: $C_{SG} = C * \frac{1.023-1}{SG-1}$,[32] where C_{SG} is the adjusted result (μg/L), C is the original concentration (μg/L), 1.023 is the mean specific gravity measured within the study population, and SG is the mean specific gravity of the individual composite sample. All urinary concentrations henceforth refer to specific gravity-adjusted concentrations.

We examined participants' univariate responses to questions regarding markers of workplace compliance with requirements from WPS,[33,34] such having received pesticide safety training, the availability of handwash stations, and how participants are notified about pesticide applications at the fields where they work. Urinary pesticide biomarker data were non-normally distributed, and we examined differences in log-transformed concentrations between pesticide applicators and non-applicators using Wilcoxon rank-sum tests. We also examined differences in pesticide risk perceptions, perceived control, and protective behaviors between pesticide applicators and non-applicators using Chi square tests. We defined pesticide applicators as anyone who reported that they had mixed, loaded, or applied any pesticide, including insecticides, herbicides, fungicides, or any other chemical used to control weeds and pests within the last year. Analyses were conducted in STATA Version 14.2.

Qualitative data were analyzed by the two faculty researchers with relevant expertise in qualitative methods. The analysis of semi-structured interviews began with a pilot phase,[35] which involved the creation of a codebook. This initial codebook was developed from review of relevant literature and initial research questions. The codebook outlined these initial codes and documented associated meanings. From there the two faculty members involved in the qualitative data analysis each hand coded one interview. They subsequently met to review the results of this initial analysis, and the codebook was modified accordingly. Similar to the work of many other qualitative researchers,[36] this qualitative comparison between coders helped to maintain coder agreement and consistency.[37] Next, the two faculty members utilized this coding system and worked in MaxQDA, a qualitative data analysis software package, to completely code the entire set of interviews. Both faculty members coded all interview transcriptions. They met frequently to discuss additional, relevant codes that were emerging from the data, complementing the deductive approach with inductive codding. This process enabled "coordination through mutual adjustment".[38]

Mixed methods data integration

We integrated data from the surveys, urinary pesticide concentrations, and open-ended interviews to identify and examine trends that would not have been apparent from the quantitative data alone. First, we identified emergent themes from the semi-structured interviews and our notes from anecdotal conversations with participants during data collection events. Second, we used these emergent themes to identify relevant data from the surveys and urinary pesticide analysis and provide context to these findings. Third, we identified themes across these data sources that provide a broader understanding of participants' experiences. We focused on how findings from each of these data sources supported each other. We note that we report some findings from the surveys and urinary pesticide analysis that were statistically nonsignificant based on p-values but which, when viewed alongside our qualitative data, provide a broader and more holistic analysis of participants' experiences and potential impacts for protective behaviors and urinary pesticide concentrations.

Results

One of the primary themes from this project was the perception, particularly among pesticide applicators, that insecticides were the only "dangerous" pesticide class, and that other pesticide classes were not as harmful and required fewer safety precautions. These perceptions are inconsistent with WPS training and motivated us to examine potential differences in training and risk perceptions between applicators and non-applicators, and to assess participants' perceptions of workplace compliance with WPS regulations, across the various data sources. We define a pesticide applicator as anyone who had mixed, loaded, or applied pesticides in the last year. Non-pesticide applicators were individuals currently working in agriculture that completed other tasks (e.g., weeding, thinning, harvesting, moving water and irrigation pipes).

We examined differences in urinary pesticide concentrations, training, and risk perceptions between pesticide applicators ($n = 12$) and non-applicators ($n = 50$). We found that pesticide applicators were significantly more likely to be men but were otherwise similar socio-demographically compared with non-applicators (Table 1). Applicators and non-applicators reported similar pesticide risk perceptions, perceived control, and protective behaviors in the surveys. However, multiple participants made statements during interviews and informal conversations suggesting that they viewed "pesticides" to be synonymous with "insecticides" and thought that substances used to control other pests (e.g., herbicides, fungicides) were inherently less dangerous. Pesticide applicators, in particular, told us that they understood herbicides, as a class, to be categorically safer than other pesticides; these risk perceptions appeared to impact their safety behaviors when in contact with herbicides. For example, one participant reported that they do not have a pesticide applicator license and do not view themselves as a pesticide applicator because they only spray herbicides, and not insecticides. This participant also reported that they received training differentiating insecticides from other types of pesticides (e.g., herbicides, fungicides), and they were told that only those applying insecticides need to wear

Table 1. Participant demographic characteristics, stratified by pesticide applicator status[a] (*n* [%] or mean [SD]).

Characteristic	All Participants (*n* = 62)	Pesticide Applicators (*n* = 12)	Non-Applicators (*n* = 50)
Gender			
Man	30 (48.4)	10 (83.3)	20 (4.0)
Woman	32 (51.6)	2 (16.7)	30 (6.0)
Age (years)			
<30	5 (8.1)	1 (8.3)	4 (8.0)
30–39	18 (29.0)	3 (25.0)	15 (3.0)
40–49	16 (25.8)	3 (25.0)	13 (26.0)
50–59	19 (3.1)	4 (83.3)	15 (3.0)
≥60	4 (6.5)	1 (8.3)	3 (6.0)
Marital status			
Married/living as married	52 (83.9)	10 (83.3)	42 (84.0)
Divorced/separated	2 (3.2)	1 (8.3)	1 (2.0)
Single	8 (12.9)	1 (8.3)	7 (14.0)
Number of people living in house[b]	4.6 (1.6)	4.4 (1.7)	4.7 (1.6)
Number of agricultural workers living in house[b]	2.6 (1.7)	2.5 (2.1)	2.6 (1.6)
Ethnic identity			
Mexican	55 (88.7)	12 (1.0)	43 (86.0)
Mexican-American	3 (4.8)	0 (0.0)	3 (6.0)
Chicano/a	1 (1.6)	0 (0.0)	1 (2.0)
Other Hispanic	3 (4.8)	0 (0.0)	3 (6.0)
Country of birth			
United States	1 (1.6)	0 (0.0)	1 (2.0)
Mexico	59 (95.2)	12 (1.0)	47 (94.0)
Guatemala	2 (3.2)	0 (0.0)	2 (4.0)
Work status			
H2A worker	15 (24.1)	3 (25.0)	12 (24.0)
Non-H2A worker	47 (75.8)	9 (75.0)	38 (76.0)

[a]Pesticide applicator defined as an individual who had mixed, loaded, or applied pesticides in the last year.
[b]Values include participant responding to questionnaire.

PPE. This participant subsequently reported "rarely" or "never" wearing PPE such as a respirator, Tyvek suit, or eye protection while applying pesticides. Further, this participant reported that warning signs are placed in the fields after insecticides are applied, but not after the application of herbicides.

These findings regarding pesticide applicators' perceptions of herbicide risk and subsequent safety behaviors are notable given trends in the urinary biomonitoring data (Table 2). While applicators and non-applicators had similar urinary concentrations of biomarkers of organophosphate (OP) and pyrethroid insecticides ($p = 0.39$–0.86, depending on the biomarker), we observed consistent trends in greater detection and higher urinary concentrations of herbicide biomarkers among applicators. For example, dicamba, glyphosate, and AMPA were detected more frequently among pesticide applicators (91–92%) compared with non-applicators (62–86%) (Table 2). Pesticide applicators also had higher median and maximum concentrations of all four herbicides/herbicide metabolites than non-applicators, though these differences were not statistically significant ($p = 0.14$–0.32; Table 2 Figure 1). The difference in urinary herbicide concentrations between applicators and non-applicators was most striking for 2,4-D (median = 1.40 µg/L vs. 0.69 µg/L and maximum = 8.72 µg/L and 3.50 µg/L, respectively; p value = 0.14). These findings were consistent when we restricted to participants who had applied pesticides in the three days prior to either of the study visits ($n = 9$).

We also examined participant-reported markers of WPS compliance and use of PPE among pesticide applicators (Table 3). Notably, fewer than half of pesticide applicators (41.7%) reported typically wearing a respirator while applying pesticides, and none reported having had their respirator fit tested. Participants who reported ever (i.e., rarely, sometimes, often, or always) wearing eye protection or a respirator while applying pesticides accessed the equipment almost exclusively from their boss or supervisor, with only one participant reporting they provided their own respirator and two participants reporting they provided their own eye protection. When asked why they did not wear

Table 2. Specific-gravity adjusted urinary concentrations of herbicide and herbicide metabolites (μg/L)[a] among all participants and stratified by pesticide applicator status.

	% > LOD	n	Percentiles 10th	25th	50th	75th	90th	Max	Geometric mean (95% CI)	p value[b]
Herbicides										
2,4D										
All	100%	62	0.21	0.38	0.75	1.41	2.52	8.72	0.75 (0.59, 0.96)	
Applicator	100%	12	0.20	0.41	1.40	2.38	4.43	8.72	1.14 (0.52, 2.47)	0.14
Non-applicator	100%	50	0.23	0.38	0.69	1.26	2.33	3.50	0.68 (0.53, 0.87)	
Dicamba[c]										
All	69%	58	0.10	0.14	0.25	0.49	1.09	5.95	0.29 (0.23, 0.38)	
Applicator	91%	11	0.14	0.17	0.29	0.70	2.10	5.95	0.41 (0.17, 0.96)	0.32
Non-applicator	62%	47	0.10	0.12	0.24	0.45	1.03	2.20	0.27 (0.21, 0.35)	
Glyphosate[d]										
All	82%	59	0.08	0.10	0.15	0.34	0.45	3.63	0.18 (0.15, 0.23)	
Applicator	92%	12	0.09	0.10	0.30	0.66	0.91	3.63	0.28 (0.12, 0.61)	0.26
Non-applicator	79%	47	0.08	0.10	0.14	0.30	0.41	0.82	0.16 (0.14, 0.20)	
AMPA										
All	87%	62	0.09	0.17	0.24	0.38	0.63	0.91	0.24 (0.20, 0.29)	
Applicator	92%	12	0.15	0.21	0.27	0.56	0.79	0.91	0.29 (0.18, 0.48)	0.24
Non-applicator	86%	50	0.09	0.15	0.23	0.38	0.58	0.73	0.23 (0.20, 0.28)	

Abbreviations.
[a]Machine-read values used for concentrations <LOD.
[b]*p*-value for difference in urinary concentrations between applicators and non-applicators from Wilcoxon rank sum test.
[c]No result due to interference for four participants.
[d]No result due to interference for three participants.

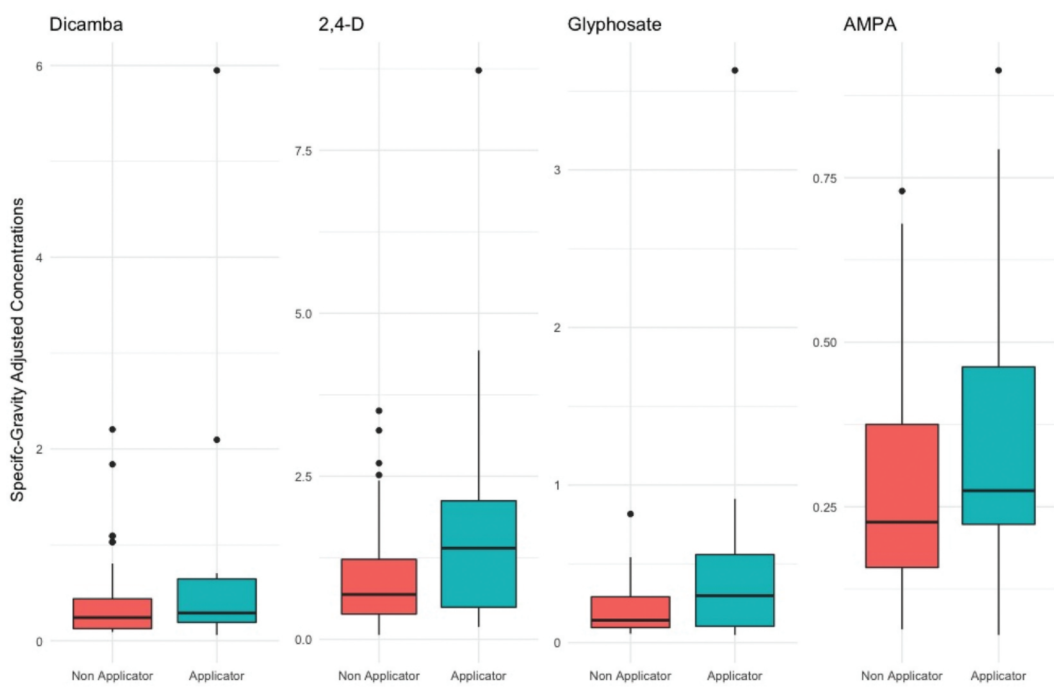

Figure 1. Boxplots of urinary herbicide concentrations among pesticide applicators (blue boxplots) and non-applicators (red boxplots).

PPE more often while applying pesticides, the most common answers were that it is too hot outside (58.3%), that the PPE is uncomfortable (33.3%), that they do not have access to specific types of PPE (e.g., a respirator) (33.3%), and that they forget (33.3%). Two participants reported that they do not always wear PPE while applying pesticides because the pesticides that they use are not dangerous, or that they do not wear PPE depending on the danger of the pesticides being applied.

Table 3. Occupational characteristics among participants who had mixed, loaded, or applied pesticides within last year ($n = 12$).

Characteristic	*n* (%) or Mean (SD)
Typical PPE use while applying pesticides	
Rubber gloves	10 (83.3)
Other type of glove	5 (41.7)
Tyvek suit	2 (16.7)
Other type of suit	1 (8.3)
Face shield	4 (33.3)
Eye protection	9 (75.0)
Respirator	5 (41.7)
Frequency of use of Tyvek suit while applying pesticides	
Never	0 (0.0)
Rarely	7 (58.3)
Sometimes	1 (8.3)
Often	1 (8.3)
Always	2 (16.7)
Don't know	1 (8.3)
Frequency of use of eye protection while applying pesticides	
Never	0 (0.0)
Rarely	2 (16.7)
Sometimes	1 (8.3)
Often	1 (8.3)
Always	2 (16.7)
Don't know	6 (50.0)
Frequency of use of respirator while applying pesticides	
Never	0 (0.0)
Rarely	5 (41.7)
Sometimes	1 (8.3)
Often	3 (25.0)
Always	0 (0.0)
Don't know	3 (25.0)
Reasons for not wearing PPE while applying pesticides	
Don't have access	4 (33.3)
Not important	2 (16.7)
Too expensive	3 (25.0)
It is too hot outside	7 (58.3)
PPE doesn't fit properly	1 (8.3)
PPE is uncomfortable	6 (50.0)
Forget to wear PPE	4 (33.3)
Other – the pesticides they use are not dangerous/will not wear PPE depending on danger of pesticides	2 (16.7)
Has had respirator fit tested	0 (0.0)

The emergent theme regarding pesticide applicators' herbicide risk perceptions, which are inconsistent with WPS training, also motivated the analysis of participants' perceptions of workplace compliance with WPS regulations. In the survey, nearly 73% of participants reported they had received pesticide safety training (Table 4). Of the pesticide handlers, 8 of the 12 (66.7%) reported they had received specific pesticide handler safety training, however only 4 (33.3%) reported they had received the training in the last year, as required by WPS. Participants were asked about the way in which they were notified about pesticide applications at their workplace; most commonly, they reported being notified by a supervisor (80.7%) and signs being posted at the field in English only (19.4%), Spanish only (4.8%), or both English and Spanish (45.2%). Six participants (9.7%) reported that they are not notified by their supervisor or posted signs, as required by WPS, and are notified in another manner, such as by the person applying pesticides, seeing the pesticide application equipment, or being able to smell the pesticides. Three participants (4.8%) reported they are not normally notified in any manner when pesticides are applied at the field where they work.

During the interviews, participants shared concerns regarding the quality of pesticide safety training and the lack of notification regarding pesticide applications (representative quotes shown in Table 5). Specifically, in addition to some interview respondents reporting never having been to a pesticide safety training, respondents shared concerns about the content and quality of the training they had received, particularly for video trainings. Participants further reported a lack of notification about pesticide applications while they are working in the fields, especially in large fields where signs could be missed, and some respondents reported they have previously been working in a field during aerial pesticide application. Participants additionally voiced concerns regarding the lack of communication of pesticide use on nearby farms, and stated that they are often exposed to pesticides through drift from these nearby applications. Some suggestions that participants offered to address these issues included greater communication between neighboring farm owners and then between farm owners and farmworkers, daily briefings for workers, and using radio to relay health and safety messages.

We also assessed access to bathrooms and hand wash stations with water, soap, and towels in the surveys and interviews. While 77% of participants reported that they are able to wash their hands at work as often as they need during the survey, most participants (69.4%) identified at least one barrier when prompted with specific options. We provided participants with six potential barriers, and they could select multiple options. We found that 13 (21.0%) participants selected one barrier; 11

Table 4. Participant-reported indicators of workplace compliance with worker protection standards (WPS) regulations.

Characteristic	n (%)
Has attended pesticide safety training[a]	45 (72.6)
Pesticide handler safety training[b]	
Has previously attended pesticide handler safety training (ever)	8 (66.7)
Has attended pesticide handler safety training within last year	4 (33.3)
Method of notification when pesticides are sprayed at the field where participant works[c]	
Notification from boss/supervisor	50 (80.7)
Notification from person who applies pesticides	20 (32.3)
Sign in English posted in field	40 (64.5)
Sign in Spanish posted in field	31 (50.0)
Not usually notified	3 (4.8)
Frequency of handwashing while working and barriers to washing hands while working[c]	
Able to wash hands at work as often as needed	47 (77.1)
Handwash stations are too far from where they work	25 (40.3)
Handwash stations run out of water	19 (30.1)
Handwash stations run out of soap	21 (33.9)
Handwash stations run out of towels	20 (32.3)
Not given enough breaks to wash hands	13 (21.0)

[a]For all workers ($n = 62$).
[b]For pesticide handlers ($n = 12$).
[c]Participant could select multiple options.

(17.7%) selected two; and 19 (30.6%) selected three or more. The most commonly reported barriers were that the handwash stations were too far from where they typically work (40.3%), and that they run out of soap (33.9%), water (30.1%), or towels (32.3%). Seven participants (11.3%) reported that they do not have handwash stations available where they are working. Additional barriers to washing hands as frequently as needed included that the bathrooms and handwash stations were very dirty, there were not enough handwash stations for the number of employees, and that there was "pressure to only use [the handwash stations] if necessary to deter laziness". These results are consistent with findings from the interviews, in which participants reported inconsistent access to bathrooms and hand washing stations with water, soap, and towels (Table 5). Participants reported addressing these barriers by bringing their own water or hand sanitizers, and using the bathroom in the field.

Discussion

Participants reported indications of inconsistent workplace compliance with WPS regulations and training that may have influenced protective behaviors and pesticide exposure in this mixed-methods study of Latinx farmworkers in Idaho. While participants generally indicated high markers of WPS compliance in the questionnaire, information from open-ended interviews and observations made by participants revealed gaps in workplace training and practices, including multiple barriers to accessing clean handwashing stations with soap, water, and towels; insufficient systems to notify workers of pesticide applications; and incomplete or incorrect information regarding the precautions required when working with pesticides. Interview data also suggest that existing regulations not sufficiently address participants' concerns, particularly regarding pesticide drift from nearby farms, where notification may not be required. Previous studies have highlighted the limited control many farmworkers have over their circumstances at the workplace,[9,22] underscoring the need for upstream development and enforcement of health protective regulations.

The WPS is a federal regulation issued by the EPA under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) that aims to reduce the risks of occupational pesticide exposure among agricultural workers and pesticide handlers.[1] Under the 2015 revision, employers are mandated to ensure all agricultural workers and pesticide handlers receive annual EPA-approved pesticide safety training, with some exceptions for immediate family members of the farm owner.[1] In addition, employers are required

Table 5. Emerging themes and representative quotes from open-ended interviews highlighting participants' concerns regarding pesticide safety training, information about pesticide applications, and handwashing stations at the workplace.

Emerging Theme	Representative Quote(s)
Quality of training	"Well, I think that they should give more guidance. Like their side effects. In the video, it explains that you have to use pants, gloves, and everything else. But I think that they should have more signs about spraying pesticides, specifically what day if it's been more than 72 hours. For us to be cautious because of the residue. Wash your hands thoroughly. To protect ourselves."
Lack of notification of pesticide applications	"And then one year ... when we were working on the beets ... and we were in the fields and we saw the plane go by like that and he just passed and sprayed over us and we dropped in the field, and I had my little boy, he was three years old, and he saw it and he fell on the row of the beets and he was crawling and everyone got sprayed on the back with white stuff on them. We all got sprayed. But I guess – at that time, nobody reported anything. So, we just changed our clothes and keep on going." "They don't let us know like that. I remember we were harvesting and a little plane passed by very close by fumigating another field next to us. So, I don't know if it's something that won't hurt us or if they don't care. I don't know. And they say that when they put chemicals on a field, they put a sign up or something like that. When they put that sign up, they don't have us go in there, but the sprayers, the tractors pass close by and that doesn't – that's what happens, they don't let us know that much. They don't care that much about letting us know."
Pesticide drift	[When asked about experiences with direct contact with pesticides while working in the fields] "Yes, when they fumigate the neighboring fields. We do have direct contact with it." [Interviewer]: "because the wind brings it over?" [Participant]: "Yes."
Communication about pesticide applications between neighboring farms, and between farm owners and farmworkers	"They could communicate a bit more between themselves and communicate with us as workers. If they see that – the workers of the other farmer should let the others know and say, "Hey your people are there, so get out." Because sometimes you get there and you smell it. Sometimes it has happened that – I think more communication between themselves and with us ... "sometimes [the fields are] long. We don't know where they put them, if it's at the entry, or if it's – there are 70 acres of onion ... sometimes you don't know where their entrance is ... I'll to that edge, but at the other edge, they're fumigating from the other farm. That's the only bad thing is that they don't communicate. I think that they should communicate among themselves because sometimes you're in the field, but the neighbor is spraying. They aren't spraying in your work site, but someone else is spraying and it makes it to you."
Access to bathrooms and handwash stations with soap, water, and towels	"The bathroom is nearby, but sometimes there's no water. Sometimes I have water with me, but I also forget to bring it. I have a case of bottled water inside my car. Just in case I need it." "Yes, they don't bring you any water. You are the one who has to bring your water to wash your hands or your hand sanitizer." "I always bring my sanitizer with me, always, because sometimes you are not near the car and you feel like it, or the bathroom is on the other side of the field; well, I'm not ashamed to say it, outside the car, you open the door and there we go to the bathroom. Most of the time we do that because it is close to us; the bathroom is very far away, and when you really feel like going, sometimes we don't wait to go to the bathroom, you just turn around and say, 'Everybody looks over there because I have an emergency.' We do that, but we cover it with dirt." "Actually, the water is very restricted for us, but we use the same water from the little bottles of water we drink from to wash our hands."

to provide access to information about the pesticides with which workers and handlers may have contact,[8] notify workers within a quarter mile of any area that is being treated with pesticides or that may be under an REI verbally or by posting warning signs,[7] and provide decontamination supplies, including an "ample" supply of water, soap, and towels (at least 1 gallon of water for each worker and 3 gallons for each handler or early entry worker).[8] Further, the Occupational Safety and Health Administration (OSHA) requires toilet facilities for 11 or more workers.[8]

The WPS has additional requirements for employers of pesticide handlers, broadly defined as a person who works at an agricultural establishment who mixes, loads or applies agricultural pesticides; assists with pesticide application; cleans, handles, or disposes of opened pesticide containers; cleans, handles, or repairs pesticide application equipment; works as a flagger; or enters an area after pesticide application under certain conditions.[1] In addition to providing or verifying that each such worker receives annual pesticide handler safety training, employers are required to provide a respirator and fit-testing, training, and a medical evaluation conforming to OSHA standards if the product labeling of any of the pesticides requires the use of a respirator; provide, clean, maintain, store, and ensure the use of all required PPE; provide decontamination supplies; and provide specific information about pesticide use and labeling information.[1,39] Finally, the WPS mandates that pesticide handlers follow the pesticide label, which contains information specific to each pesticide product such as PPE requirements, safety precautions and directions for use, and the re-entry interval after application.[1] If the handler is not able to understand the pesticide label, it is the employer's responsibility to ensure that there is someone available to explain the health, safety, and directions for use information.[40]

Data from surveys and interviews revealed potential gaps in workers' experiences of their workplace's compliance with these WPS regulations, with the interviews providing more nuanced details. For example, while most participants indicated they were able to wash their hands as often as needed while working, when prompted with specific exemplars, the majority identified multiple barriers to accessible hand washing. Further, most participants indicated they are notified in some manner about pesticide applications in the field where they work during the questionnaire; however, data from interviews revealed multiple issues regarding communication of pesticide applications. Namely, participants voiced concerns about the use of signs alone, as many fields where they work are extremely large and it can be easy to miss the postings in certain areas of the field. Participants also reported in the interviews and anecdotally during conversations that they had been working in or near fields during aerial pesticide application, with some participants reporting they subsequently experienced an Acute Pesticide Poisoning (APP). These inconsistencies regarding workers' experiences of their workplace's adoption of WPS regulations between survey and open-ended interview responses are largely consistent with previous studies that have reported discrepancies in WPS-endorsed PPBs between participant report and observations from investigators. For example, in a study of 71 Latino farmworkers in North Carolina, researchers found that participants significantly over-reported hand-washing before eating or drinking compared to field observations ($p < .01$ for each); investigators further reported that handwash stations were not even available over one-third of the time.[9] Future research studies should consider including open-ended interviews and/or field observations in conjunction with any survey questions to more thoroughly understand potential barriers.

One of the largest gaps in WPS compliance participants reported was regarding the perception of the relative safety of herbicides compared with other pesticide classes. Multiple participants, particularly pesticide applicators, reported receiving information in direct conflict with WPS training that herbicides as a class are categorically less dangerous than other pesticides. These perceptions of herbicide safety appeared to result in the adoption of fewer protective behaviors, such as not wearing PPE while working with herbicides, and may have in turn impacted urinary herbicide biomarker concentrations. We reviewed manuals and videos approved for WPS worker/handler pesticide safety training, and confirmed these trainings consistently refer to a pesticide as "any substance used to prevent, destroy, repel, or reduce the effects of pests", which may include "insects, rodents, nematodes (microscopic worms), fungi (fungus), and weeds".[1,40,41] None of these training materials distinguished pesticide classes (e.g., herbicides vs. insecticides) in regards to the level of risk posed to workers/handlers or the type of PPE that should be worn when handling that type of pesticide. Rather, all of the reviewed materials indicate that the pesticide label, which is unique to each product, contains information about that product's toxicity, and that handlers should read the pesticide label and wear the PPE required for that product.

Supplementary Figure 1 provides examples of pesticide label for products containing glyphosate, 2,4-D, and Dicamba. These example labels highlight both the PPE requirements and the different re-entry intervals for specific products, raising concerns over participants' comments that signs are not typically placed in the fields after the application of herbicides. Our review of these training materials and pesticide labels suggests that participants' perceptions of the lower risk of herbicides and subsequent behaviors, including not wearing PPE while handling herbicides, likely did not originate from EPA-approved WPS training. This is also particularly concerning due to "herbicide stacking". Weeds are increasingly becoming resistant to multiple herbicides with different modes of action, requiring the use herbicides mixtures (e.g., simultaneous use of glyphosate and dicamba), when previously one of these herbicides in isolation could have effectively controlled weeds at the same application rates.[42,43] While a particular pesticide product may have minimal PPE requirements, the growth of multi-herbicide resistant weeds suggests that farmworkers are increasingly handling multiple types of herbicides, underscoring concerns that they may not be receiving proper safety instruction and using the correct PPE.

Future studies should evaluate sources of information guiding these herbicide risk perceptions to address potential misconceptions. One potential explanation is that participants may perceive insecticides to present a greater acute health risk (e.g., through pesticide poisoning). However, exposure to herbicides has also been associated with adverse health outcomes, underscoring the importance of following proper safety behaviors. Notably, the International Agency for Research on Cancer (IARC) has listed glyphosate as a probable human carcinogen,[44] and higher prenatal glyphosate exposure has been associated with an increased risk of adverse birth outcomes, including preterm birth,[45] shortened gestational length,[46] and reduced fetal growth[46] in non-occupational populations. Occupational exposure to herbicides like 2,4-D has been associated with outcomes such as Parkinson's Disease,[47,48] and *in vitro* and toxicological evidence suggest that glyphosate, 2,4-D, and dicamba, alone or in combination, may have carcinogenic properties such as DNA damage and oxidative stress.[49,50]

Notably, while WPS requirements were updated in 2015,[1] there has been no systematic evaluation of the training and its impacts on farmworkers' pesticide exposure, risk perceptions, adoption of protective behaviors, or perceived control to mitigate pesticide exposure. Findings from this study highlight some potential gaps in WPS regulation and suggest a widespread evaluation is warranted. In addition to reported gaps in adherence with WPS, participants voiced concerns suggesting that current regulations may not be sufficiently protective even at farms with high levels of compliance, particularly in regards to pesticide safety training. The EPA does not require employers to provide the training to workers themselves and has approved a variety of formats for administering WPS training, including presentations by qualified WPS trainers or showing an EPA-approved video. The majority of participants anecdotally reported receiving training from the videos; in line with findings from previous studies,[9,22] we found participants typically did not view this as an engaging or useful format to learn and retain important safety information, and a number expressed a preference for in-person trainings. Concerns regarding video trainings raised in previous studies include workers not being able to ask questions, the ability for participants to not pay attention, and not meeting the needs of non-Spanish speakers.[9,51]

In addition to improved trainings, the findings from our study and others highlight that the upstream provision of resources, including some not currently required under WPS, are ultimately necessary to protect farmworkers,[25] as individual behavioral changes alone are insufficient,[52] and circumstances affecting pesticide exposure are often outside of farmworkers' control.[52,53] For example, previously reported barriers to the adoption of WPS-recommended PPBs including not having access to PPE[54] or laundry facilities[22,55]; not being able to read warning signs after pesticide application[13,51]; and not being able to read the pesticide safety label or simply not being provided information on which pesticide product they are handling.[51,56,57] Further, previous studies have shown that some of the primary determinants for engaging in PPBs such as using PPE or washing hands while working are employer provisioning of protective equipment[11,23] and the availability of handwash stations at the workplace.[24] Thus, while trainings and education are important to inform pesticide risk perceptions and encourage the adoption of PPBs,[22] systematic changes inside and outside of the workplace are ultimately needed to provide farmworkers the autonomy and control to engage in safety behaviors.

Findings from this study should be interpreted in light of various strengths and limitations. This was a relatively small cross-sectional pilot study conducted in a limited geographic setting. Further, the primary goal of this study was to assess pesticide exposure and risk perceptions among farmworkers. Thus, some observations regarding participants' perceptions are based on informal observations and conversations with participants; however, our findings are supported by open-ended interviews, survey responses, and biomonitoring data. Additionally, we intentionally did not ask participants about the farm where they worked or who they were employed by to protect their confidentiality and anonymity, and it is likely some participants worked for the same employer/labor contractor. Some of the items we evaluated in this analysis are largely farm characteristics (e.g., availability of hand wash stations), and we are not able to disentangle how many participants were reporting on characteristics at the same farm. We suggest future studies explore potential ways to assess or control for the number of participants from a particular farm while also prioritizing confidentiality.

This study also has a number of strengths. Notably, this is one of the only mixed-methods studies examining both urinary pesticide biomarker concentrations and participants' perceptions and experiences of pesticide risk and WPS compliance. The semi-structured interviews from this study provide vital context to the findings from the surveys and urinary pesticide biomarker analysis and also provide more nuanced information regarding participants' perceptions of potential gaps in workplace compliance with WPS regulations. We further examined these questions in one of the few studies enrolling a cohort of farmworkers balanced on gender. Women are increasing in the workforce in the US, and worldwide and gender has been shown to influence risk perceptions and protective behaviors,[58] underscoring the importance of examining the experiences of both men and women. Our study provides novel data regarding potential differences in the perceptions of herbicide risk that should be explored in larger studies with more geographical diversity.

We have a number of recommendations to increase farmworker protection from pesticides based on the findings from this and previous studies:

(1) Improved pesticide safety training. Taken with previous studies, our findings suggest that WPS-approved pesticide safety videos, a common format through which this required training is provided, may not be very effective at providing farmworkers with necessary safety information. We encourage the implementation of more engaging trainings, such as in-person instruction or WPS-approved "train the trainer" sessions that allows participants to ask questions and interact with other farmworkers and the instructor in the language most comfortable to the workers.
(2) Enhanced communication regarding the specific pesticide products farmworkers are handling, including all relevant safety requirements. Pesticide handlers are expected to read and understand complex pesticide safety labels to follow the proper safety precautions and wear the required PPE. There are multiple potential barriers to this, including safety labels having inconsistent formatting, being printed in English, whereas the majority of farmworkers speak Spanish or another language, and handlers not being provided with the required PPE. Further, anecdotal evidence from this and our previous work suggests farmworkers are rarely informed of the specific products they are handling, preventing the adoption of proper safety precautions. This is particularly important with the increasing use of mixtures of pesticide products with different PPE and safety requirements to address multi-pesticide resistance.

(3) Improved communication about pesticide applications on and near fields where people are working. While the WPS does not require notification of pesticide use outside of the Application Exclusion Zone (AEZ) (which is typically 25 or 100 feet, depending on the application type),[59] our findings suggest farmworkers would like to be notified of the timing, location, and type of pesticide used in fields near where they are working. These concerns are underscored by multiple participants reporting being in a field during aerial pesticide application, suggesting there are sometimes breakdowns in communication resulting in people working inside the AEZ. Some suggestions provided by participants included improved communication between the owners of neighboring farms, which is then transmitted clearly to farmworker's; daily briefings; and radio messages with health and safety information.

(4) Improved regulations regarding handwash stations and bathrooms at the workplace. WPS encourages behaviors such as washing hands before eating or drinking while at work, and these behaviors have consistently been associated with decreased urinary concentrations of pesticide biomarkers. However, the official WPS regulations are ambiguous, and indicate there must be "ample" access to water, soap, and towels. There are also no specific guidelines regarding sanitation requirements for bathrooms, and many participants shared concerns regarding the cleanliness of the toilets, with some reporting solutions such as going to the bathroom in the field. Further, some participants reported using hand sanitizer because water is not available at work, which may not effectively reduce pesticide residues. We also encourage improved access to clean housing with bathrooms and laundry facilities to increase farmworkers' ability to adhere to WPS-recommended PPBs outside of the workplace.

Conclusion

Our study provides novel data suggesting that some farmworkers receive workplace training that herbicides are categorically safer than other pesticide classes, and that this may in turn impact protective behaviors, and ultimately, urinary herbicide concentrations. These findings are particularly concerning given the increased use of herbicide mixtures with greater PPE requirements to combat multiple-herbicide resistant weeds. Our findings also suggest that current WPS regulations may not sufficiently address farmworkers' concerns regarding notification of pesticide applications on and near the farm where they are working. Systems-level regulations and provision of resources inside and outside of the workplace (e.g., provision of PPE; access to safe and clean housing with laundry facilities; engaging pesticide safety training; and improved communication regarding pesticide applications) are needed to provide farmworkers the control to engage in behaviors to protect themselves from pesticides.

Abbreviations

EPA	Environmental Protection Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
OP	Organophosphate
PPB	Pesticide Protective Behavior
REI	Restricted Entry Interval
WPS	Worker Protection Standard

Acknowledgments

We gratefully acknowledge the study participants and our numerous community partners who helped us recruit participants, including (but not limited to) the Idaho Organization for Resource Councils, the Northwest Center for Alternatives to Pesticides, Latinx Farmworkers of Southern Idaho, the Boise State University College Assistance Migrant Program, Community Council of Idaho, St. Luke's Ventana de Salúd, the St. Alphonsus mobile health clinics, the Centro de Comunidad y Justicia, the Mexican Consulate in Boise, and various school districts and Head Start programs. We thank Lorely Lira, Yasmín Estrella, and Laura Villegas-Ortiz for assisting with fieldwork and data collection. We thank Drs. Éric Gaudrea, Jessica Larose, and Jean-François Bienvenu at the Centre de Toxicologie du Québec (CTQ), Institut national de santé publique du Québec for conducting the urinary pesticide analysis. This work was supported by the Pacific Northwest Occupational Safety and Health Center (NIOSH/CDC Cooperative

Agreement #5 U54 OH007544), the Northwest Center for Occupational Health and Safety (NWCOHS) Professional Training Opportunity Program grant (NIOSH Federal Training Grant T42OH008433), and the St. Luke's Health System.

Disclosure statement

The authors declare they have no actual or potential conflicts of interest.

Funding

The work was supported by the National Institute for Occupational Safety and Health [T42OH008433] and [U54 OH007544].

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