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SUBJECT: REVIEW OF FUMIGATION WORKER HOURS SURVEY: METHYL ISOTHIOCYANATE (MITC) (DATA VOLUME 50150-0170)

Overview

The California Department of Pesticide Regulation (DPR) is charged with regulating the safe use of pesticides in the State. One of the aspects of DPR's regulatory role is the development of risk assessments and, when necessary, mitigation measures, to ensure the safety of professional handlers when they are exposed to pesticides on the job. As part of its efforts to mitigate the occupational exposures to handlers of fumigants that form methyl isothiocyanate (MITC), DPR acknowledged that "there is a lack of data from field exposure studies for all the application methods currently in use" (McCarthy, 2017). The need for more information on soil fumigators' work practices, the actual tasks handlers carry out during applications, and the amount of time they spend on each task was identified. DPR developed a survey aimed at professional soil fumigation companies and individual growers in order to fill any data gaps in these areas. A consulting firm, Environmental Solutions Group, LLC (ESG), facilitated the communication between DPR and the Metam Task Force (MTF). ESG distributed the survey among the members of MTF and compiled a report ("ESG Report") summarizing the findings of the survey (ESG, 2018; ESG, 2019; ESG, 2020).

The active ingredient MITC is an organosulfur chemical used as a fumigant gas. It is formed from the breakdown of precursor chemicals: metam sodium, potassium N-methyldithiocarbamate (metam potassium), and dazomet. These chemicals are also known as MITC-generators or MITC-forming pesticides (hereafter collectively referred to as MITC). MITC is used as a preplant fumigant for weed, fungal, nematode and soil insect control on a variety of crops and sites, and as an antimicrobial and antifungal agent in industrial and commercial applications (wood protection, water treatment plants, sewage systems).

The largest use of MITC in California is for preplant soil fumigation in production agriculture—96% (11.62/12.1 million lbs) of the active ingredient (AI) was used in 2017—the time of the study (data from DPR Pesticide Use Report, PUR) (DPR, 2019a). As a soil fumigant, MITC is applied by embedding or injecting into soil, or by chemigation.

Thirty-five end-use MITC-generating products were registered in California in 2017: two metam potassium, nine metam sodium, and 24 dazomet products. As of December 2021, one more label of each chemical has received active registration to a total of 38 active end-use products (DPR, 2021a).

All metam potassium products (54% AI) and four metam sodium products (42% AI) are intended entirely for soil fumigation. They are in liquid or emulsifiable formulation, carry the signal word POISON/DANGER or DANGER, and have Federal and California restricted status. Dazomet is practically not used for soil applications. Metam potassium has a larger share of the soil fumigations compared to metam sodium—70% *versus* 30%, respectively, by pounds AI used in 2016-2020. Carrots, tomatoes, and potatoes are the most common crops for preplant MITC use with 34%, 16%, and 12%, respectively, of the pounds AI used in 2016-2020 for soil fumigations. Kern County has the highest use of MITC in California—32% of the pounds AI in 2016-2020 (DPR, 2019b; DPR, 2021b; DPR, 2021c).

The ESG Report provides information specific to the use of MITC in California and includes soil fumigations performed in 2017. The survey had a 62% response rate and covered 15% of the soil fumigation dates recorded in 2017 for MITC use as determined in the DPR's Pesticide Use Report (PUR) database (DPR, 2019a). The survey shows that MITC handlers can spend as much as 11 hours and as little as 0.5 hours on a soil fumigation. The average duration of a soil fumigation is 6.3 hours, and the workers wear a respirator for 4.0 hours of this duration. Fifty percent of the participating businesses perform one fumigation in a work day. Those who perform more than one fumigation per day also employ more than one crew. The respondents used five application methods: shank, drip, spray blade, sprinkler, and power mulcher/rotary tiller. The survey indicates that, due to the employment of multiple field crews, a fumigator crew and an individual worker may apply MITC 21 days out of the year.

Survey Design

The Work Hours Survey was developed by DPR's Worker Health and Safety (WHS) and Human Health Assessment Branches in 2016. The survey was distributed by ESG on behalf of MTF. The planned logistics were described in a letter from ESG to M. Zeiss, WHS, DPR, dated October 28, 2016, and included:

- Distribution of the survey by the member companies of the MTF to their customers—private applicators (growers) and Pest Control Operators (PCOs), referred to in the ESG Report as Pest Control Businesses. The recruited customers were intended to represent "the full spectrum of crops treated and methods used in California";

- Collection and review of the surveys for completeness and significant discrepancies between the individual responses. If discrepancies were due to the differences in work practices (as opposed to interpretations of the questions), then ESG would record them in the survey results; and
- Submission of the responses to DPR.

Fourteen PCOs and two growers, identified by Metam distributors, were invited to participate in the survey. The survey encompassed MITC soil fumigations conducted in 2017. The ESG summarized the results in a report, while keeping the identity of the respondents confidential. The first survey results were provided to DPR in February 2018 (ESG, 2018), and revised versions were submitted in July 2019 (ESG, 2019) and in October 2020 (ESG, 2020).

Initially the survey consisted of three questions about the typical use of MITC:

1. What is the number of fumigations the handler crews usually carry out in one day?
2. What is the typical number of work hours for fumigation, grouped by application method and handler category, and is a respirator used?
3. What is the number of application days in a month, grouped by application method?

Some answers to this question resulted in more than 30 application days/month because respondents were employing multiple crews. After consultation with DPR, ESG added a fourth question for those participants:

4. What is the number of application days in a month for a typical crew, grouped by application method?

Results of the Survey

Sixty-two percent (10/16) of the recipients participated in the survey. The respondents included 8 PCOs and 2 individual growers.

Question #1: "How many fumigations per day?"

Responses were received only for shank[1] and drip applications. Five of the participants (50%) conducted only one application per day and included the two individual growers. Two respondents (PCOs) reported doing more than one but less than two applications a day, and another pair of PCOs indicated performing two applications per day. One PCO did not respond to Question #1. Notably, all PCOs reported that they employed more than one crew (see further). The ESG Report listed the number of daily applications for shank and drip methods (Table 1). The sum of responses (12) is more than the number of survey participants because some businesses use both application methods.

[1] The terminology for fumigation methods and work activities used in this memorandum adheres to the terminology provided in the ESG report, and not necessarily that found on product labels or other sources.

Table 1. Frequency of applications per day for shank and drip applications.

Daily frequency of applications (number of respondents, n)	Applications/day by method[a]	
	Shank	Drip
One application/day (n=5)	5	2
More than one, less than two (n=2)	2	1
Two applications/day (n=2)	0	2

[a] Data from responses to Question #2

Question #2: Typical number of work hours per fumigation, grouped by application method and handler category, and if a respirator was used.

Responses were received for only five application methods: shank, drip, spray blade, sprinkler, and power mulcher/rotary tiller. The other four methods included in the survey (granular, drench, flood and rod bar) were not reported as used by the participants. Six respondents used only one application method in 2017; the rest used 2–4 application methods. The ESG Report also contained records of the hours spent by workers of each handler category for each fumigation method. This detailed information is presented below in multiple ways:

1. All data. The data was combined together and analyzed for all fumigators across the board regardless of job assignment or application method. This presents a global picture of how many hours per application the MITC fumigators work, and for what portion of the day they work in a respirator. This approach used the full data set and has the highest statistical power, but lacks resolution about the time the MITC handlers of various work categories spend when they fumigate using a variety of application methods. The aggregate data is presented graphically in Figure 1, and the statistical summaries are included in Table 1 in Appendix I.
2. Application methods. The hours per fumigation were broken down by application method, but aggregated by handler category. This gives an estimate of how long it takes for an MITC handler crew, regardless of the work assignments of the team members, to perform a soil fumigation by specific methods, e.g., shank, drip. The data are presented graphically in Figure 2 and the statistical summaries are included in Table 2, Appendix I.
3. Handler categories. The hours per fumigation were broken down by handler category, but aggregated by application method. This gives an estimate of how long the MITC handlers of each work category (e.g., an applicator or a supervisor) engage in a generic MITC soil fumigation, regardless of the fumigation method. The data is presented graphically in Figure 3, and the statistical summaries are included in Table 3 in Appendix I.
4. Fumigation method and handler category. The hours per fumigation were estimated for workers of each work category and for each application method. This approach achieves the highest resolution between handler categories **and** fumigation methods. However, caution should be exercised when interpreting the data, as the resulting subcategorized datasets are smaller overall compared to the other three methods, and as such have the

least statistical power. The data is presented graphically in Figures 4–8, and the statistical summaries are included in Tables 4–8 in Appendix I.

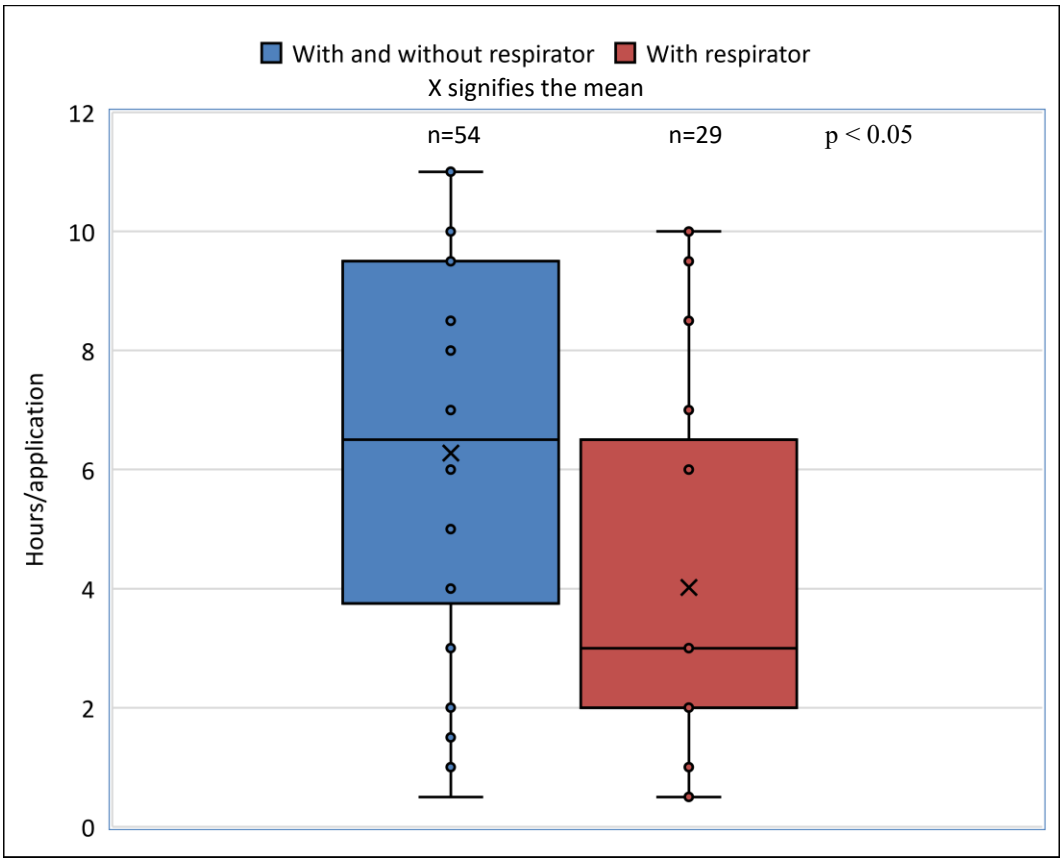
The results obtained for each of the methods are presented in detail below.

Method 1 (aggregate of all data):
The survey responses showed wide variability of the number of work hours for MITC soil fumigations. The data is presented graphically in Figure 1, and the statistical summaries are included in Table 1 in Appendix I.

Overall, fumigators of all work categories and across all application methods (n=54) spent between 0.5 hours (minimum) and 11.0 hours (maximum) per MITC application. The mean was 6.3 hours (standard deviation, SD = 3.2), and the 95% upper confidence limit for the mean ($UCL_{95\%}$) was 7.2 hours (see Figure 1 below and Table 1 in Appendix I).

Respondents also reported how long during a fumigation the handlers wore a respirator. This smaller subset of data (n=29) showed durations working in a respirator ranging from 0.5 hours to 10.0 hours, with a mean of 4.0 (3.1) hours, and $UCL_{95\%}$ = 5.2 hours. The respirator types used, as indicated by survey respondents, are full face, organic vapor cartridge, or "specified on label". As pointed out in the survey, the respirator use is voluntary: product labels do not require routine respirator use unless certain sensory triggers are met (burning in the eyes or nose, or lacrimation). There is a statistically significant difference ($p < 0.05$) between the full duration of the application and the time MITC handlers wore a respirator.

Figure 1. Hours per fumigation combined for all handler categories and all application methods regardless of respirator use ("with and without respirator") and when a respirator is used ("with respirator").



Method 2 (application methods):

Fumigators of all handler categories combined using particular application methods (n=4–19) spent between 0.5 hours (drip applications) and 11.0 hours (drip applications) per MITC application. The means ranged between 5.0 (3.6) hours (rototiller/power mulcher) and 8.5 (3.1) hours (spray blade), with $UCL_{95\%}$s spanning between 6.8 (drip) and 11.1 hours (spray blade) (Figure 2A below and Table 2 in Appendix I).

The hours per day the handlers wore a respirator (n=4–11), except rototiller, ranged from 0.5 hours (drip and sprinkler methods) to 10.0 hours (shank and sprinkler methods). The mean durations were between 3.1 (3.0) hours (drip) and 5.5 (4.1) hours (spray blade), $UCL_{95\%}$s between 5.4 hours (drip) and 12.1 hours (spray blade) (Figure 2B and Table 2 in Appendix I). Only one company (n=1) reported a handler of rototiller/power mulcher equipment using a respirator for 3 hours during the fumigation.

Figure 2A. Hours per fumigation by application method combined for all handler categories, with and without respirator.

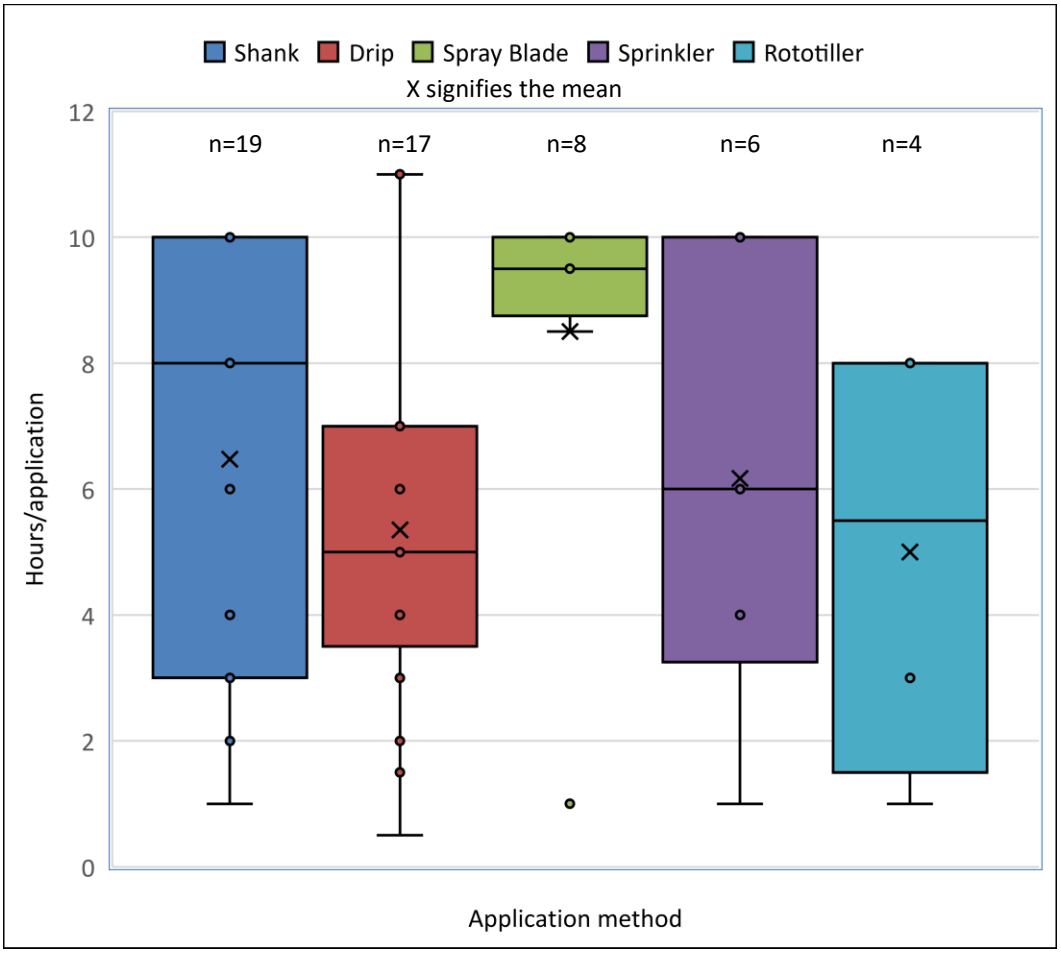
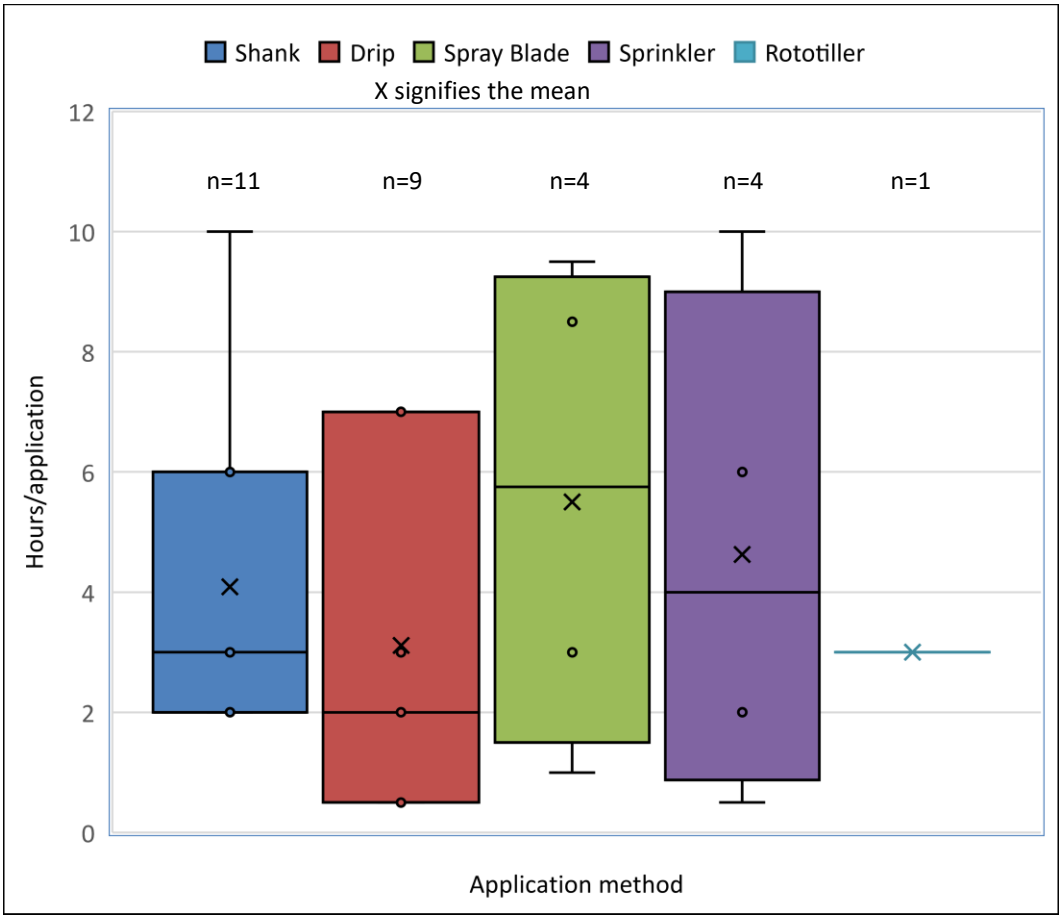


Figure 2B. Hours per fumigation by application method combined for all handler categories, with respirator.



Method 3 (handler categories):

Fumigators of all application methods in separate handler categories (n=2–15), except tractor driver, spent between 0.5 hours (loader) and 11.0 hours (applicator and monitor) per MITC application. The mean fumigation durations were between 3.3 (2.7) hours (loader) and 8.2 (1.8) hours (applicator), with $UCL_{95\%}$s ranging from 5.6 hours (loader) to 17.7 hours (irrigator) (Figure 3A below and Table 3 in Appendix I). Only one company (n=1) reported employing a soil-cap tractor driver, who worked 9.5 hours on a fumigation.

The hours per application the handlers wore a respirator (n=2–12), except tractor driver, ranged between 0.5 hours (applicator, loader, and supervisor) and 10.0 hours (applicator). The mean durations were between 1.0 (0.9) hour (supervisor) and 5.1 (3.4) hours (applicator). $UCL_{95\%}$s were between 3.2 hours (supervisor) and 9.3 hours (monitor) (Figure 3B and Table 3 in Appendix I). Only one response (n=1) was received for soil cap tractor driver using a respirator, which was for 9.5 hours—the entire duration of the fumigation (see above).

Figure 3A. Hours per fumigation by handler category combined for all methods, with and without respirator.

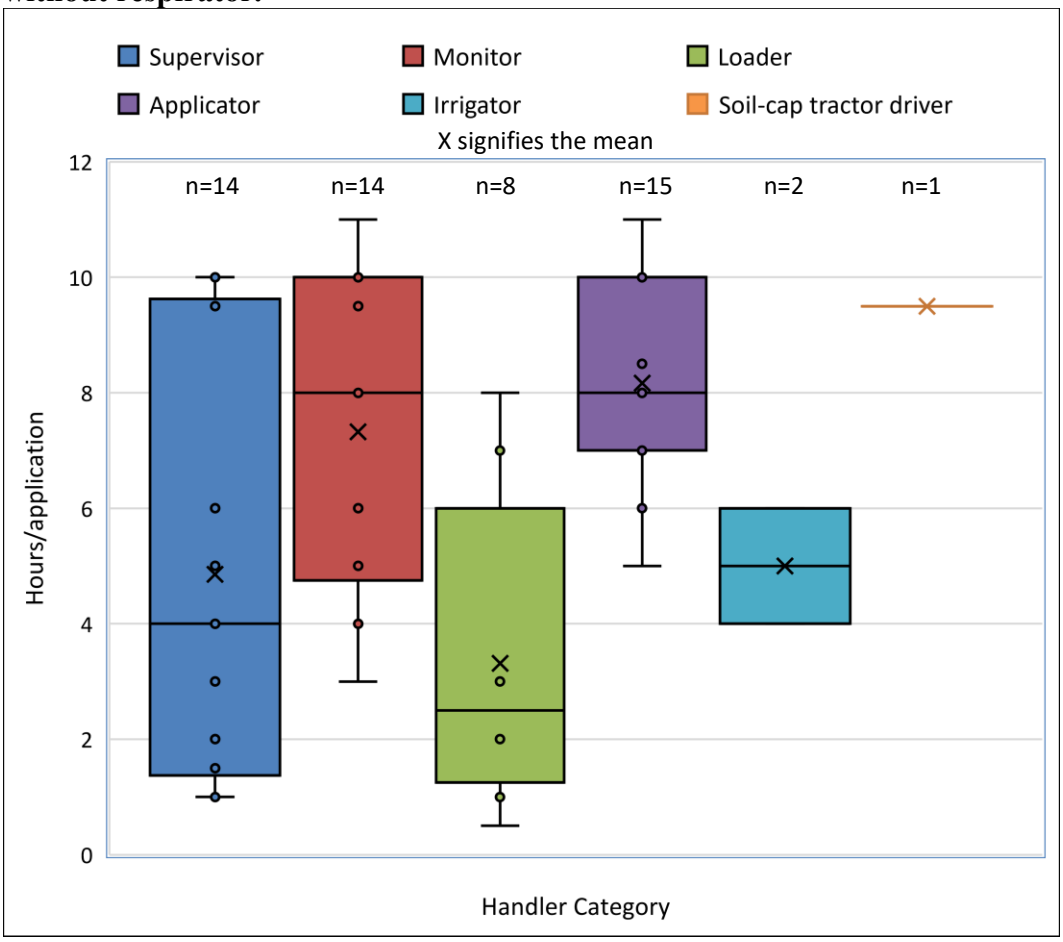
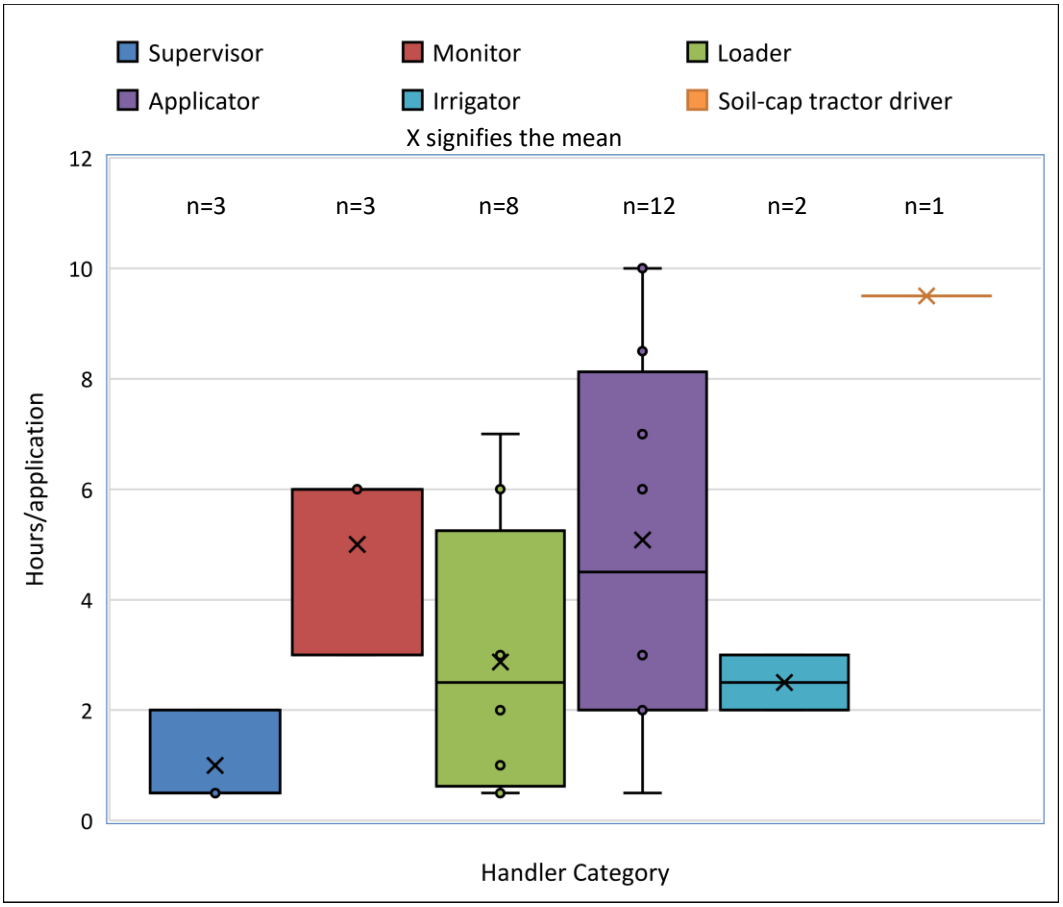


Figure 3B. Hours per fumigation by handler category combined for all methods, with respirator.



Method 4 (fumigation method and handler category):

Shank applications

Fumigators of specific work categories engaged in shank applications (n=2–5) spent between 1.0 hour (supervisor) and 10.0 hours (applicator, monitor, and supervisor) on an MITC application. The average time handlers spent on a shank fumigation was between 4.3 (3.2) hours (loader) and 8.8 (1.1) hours (applicator) (Figure 4A below and Table 4 in Appendix I). As discussed above, the smaller overall sample sizes of the subcategorized datasets stratifying individual work assignments **and** types of fumigations, and in many cases the large data variability, bring uncertainty to the estimates. Only the range and mean statistics are discussed here. The summary statistics are included in the tables in Appendix I.

Single records (n=1) for a supervisor and a monitor showed that they used a respirator for 2 and 6 hours, respectively. For the other three work assignments (n=2–4), these hours ranged between 2.0 hours (applicator, loader, and irrigator) and 10.0 hours (applicator). The mean durations were between 2.5 (0.7) hours (irrigator) and 5.3 (3.6) hours (applicator) (Figure 4B and Table 4 in Appendix I).

Figure 4A. Hours per fumigation spent on shank applications by handler category, with and without respirator.

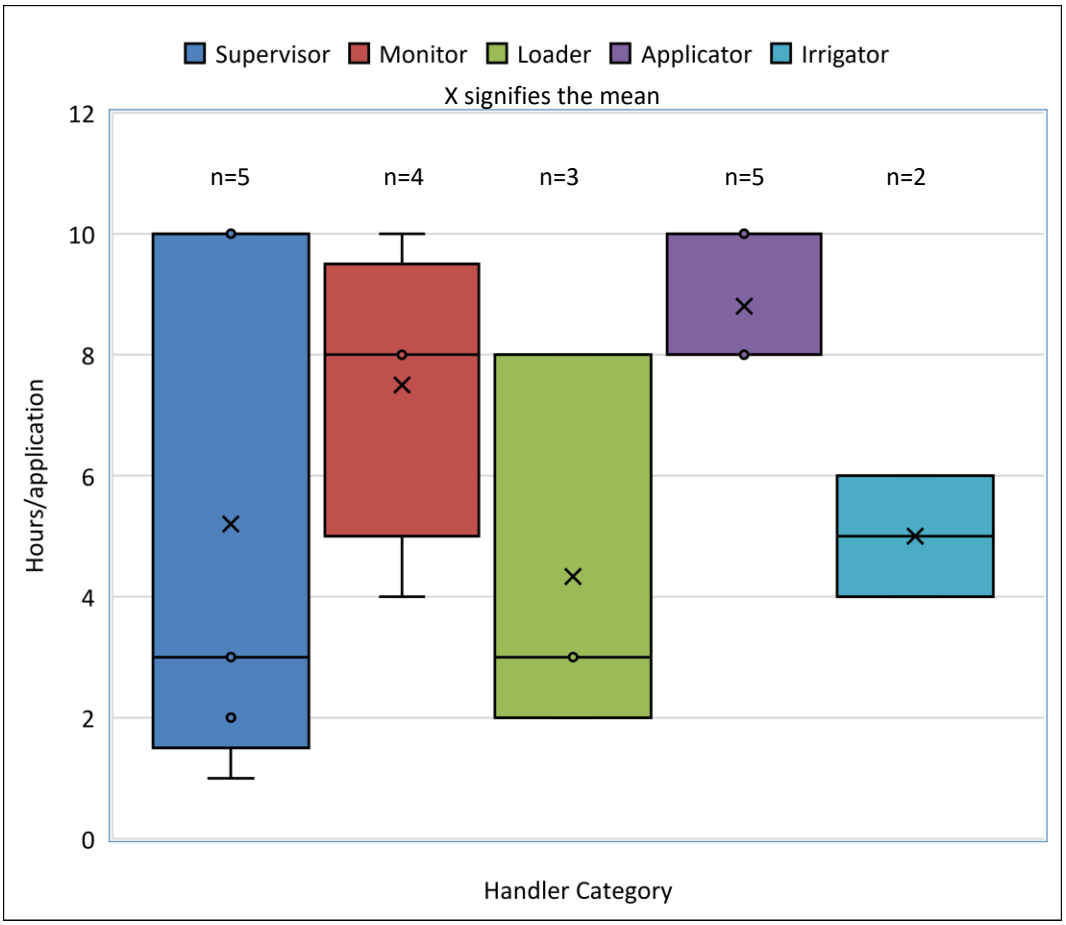
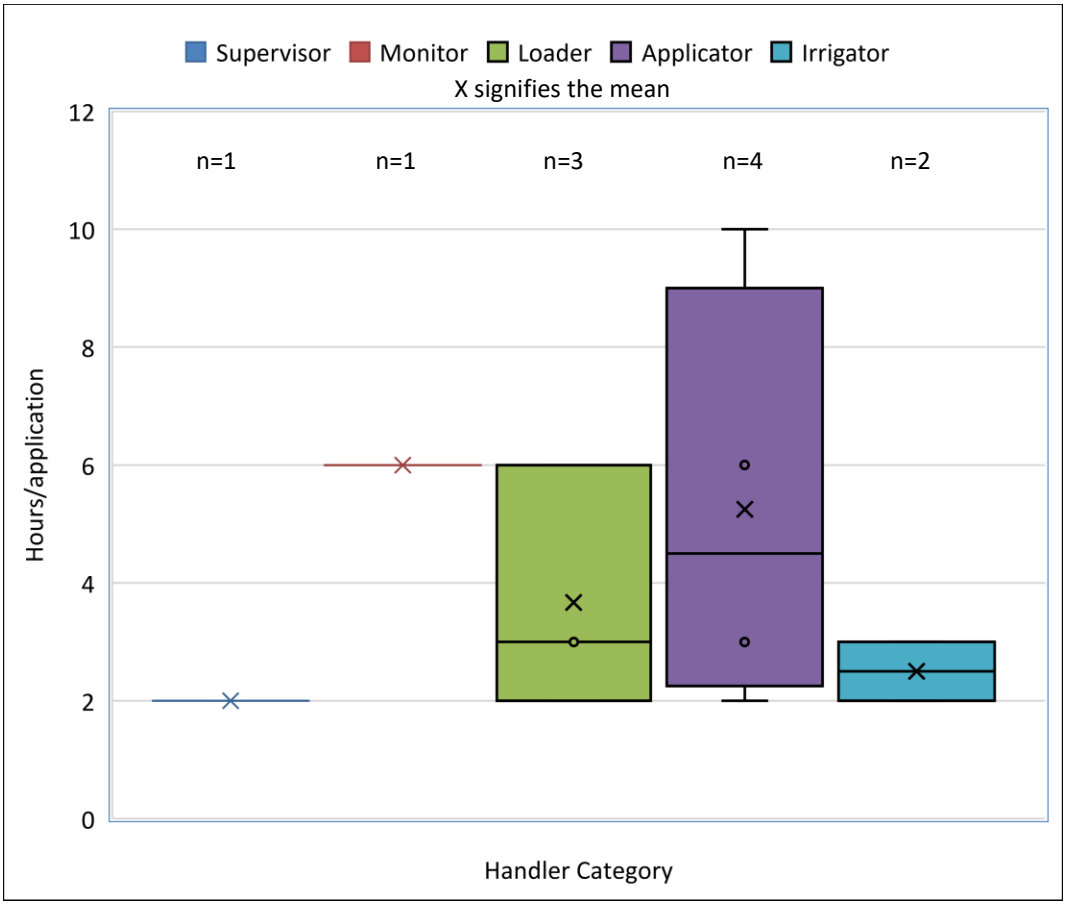


Figure 4B. Hours per fumigation spent on shank applications by handler category, with respirator.



Drip applications

Fumigators engaged in drip applications (n=3–5) spent between 0.5 hours (loader) and 11.0 hours (applicator and monitor) on an MITC application. The mean duration was between 3.2 (3.4) hours (loader) and 7.2 (2.3) hours (applicator) (Figure 5A below and Table 5 in Appendix I).

The hours per drip application when the applicators (n=4) and loaders (n=3) wore a respirator ranged between 0.5 and 7.0 hours. The mean durations were 2.7 (3.8) hours (loader) and 4.1 (3.4) hours (applicator). Single responses (n=1) for a supervisor and a monitor showed that they used a respirator for 0.5 and 3.0 hours, respectively (Figure 5B and Table 5 in Appendix I).

Figure 5A. Hours per fumigation spent on drip applications by handler category, with and without respirator.

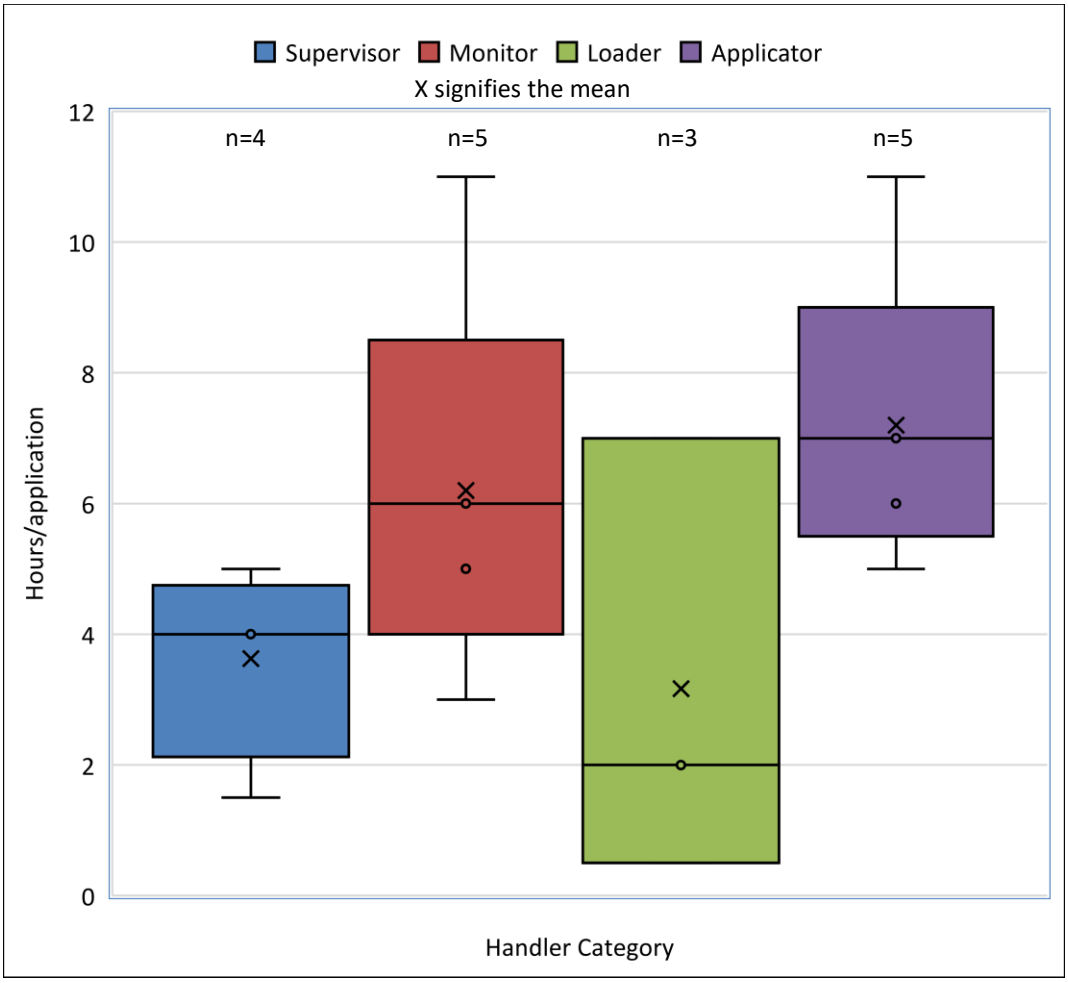
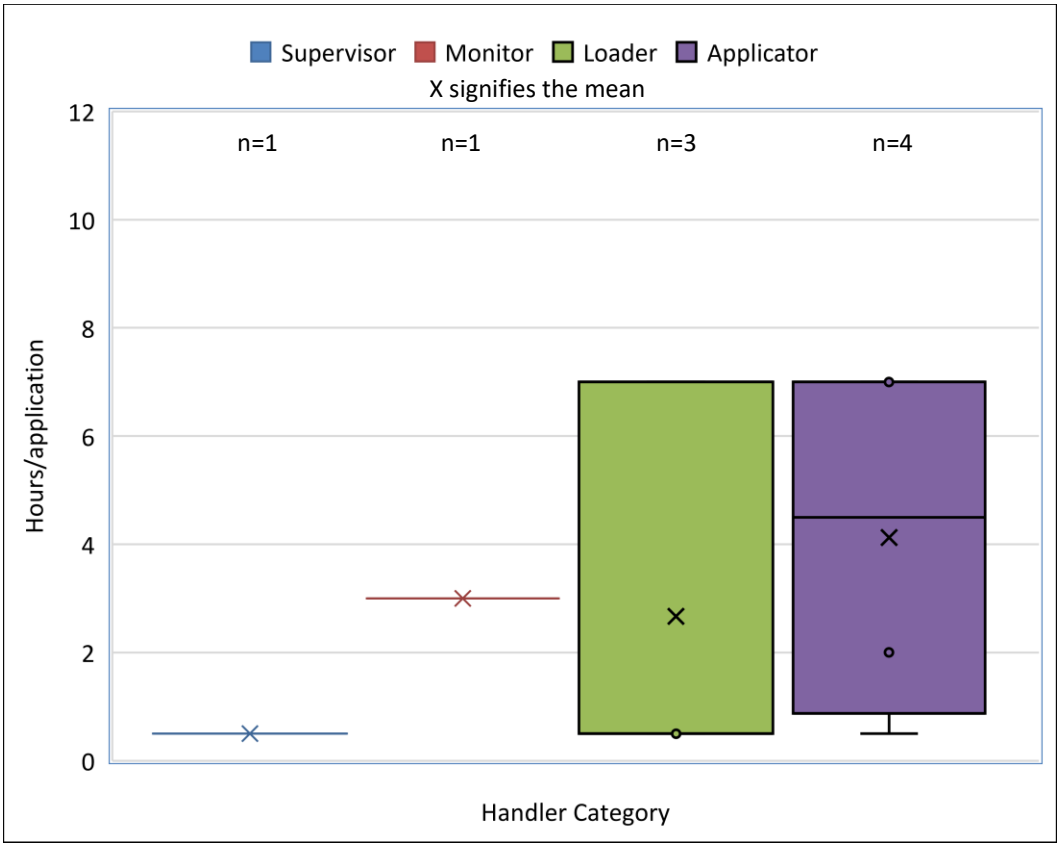


Figure 5B. Hours per fumigation spent on drip applications by handler category, with respirator.



Spray blade applications

The ESG Report contained only one or two detailed records for specific handler categories for spray blade applications. Single records (n=1) for a loader and a soil-cap tractor driver showed that they applied MITC for 1.0 and 9.5 hours, respectively. The responses for supervisors, monitors and applicators (n=2) showed that these fumigators spent between 8.5 hours (applicator) and 10.0 hours (applicator, monitor, and supervisor) on MITC application. The mean duration was between 9.3 (1.1) hours (applicator) and 9.8 (0.4) hours (monitors and supervisors) (Figure 6A below and Table 6 in Appendix I).

The hours per spray blade application when the handlers wore a respirator were recorded only for applicators, loaders, and soil-cap tractor drivers. Single responses (n=1) for a loader and a soil-cap tractor driver showed that they used a respirator for 1.0 and 9.5 hours, respectively, and this is the entire duration of the application (see above). Two records (n=2) showed that the applicators wore a respirator between 3.0 and 8.5 hours of the spray blade application with a mean of 5.8 (3.9) hours (Figure 6B and Table 6 in Appendix I).

Figure 6A. Hours per fumigation spent on spray blade applications by handler category, with and without respirator.

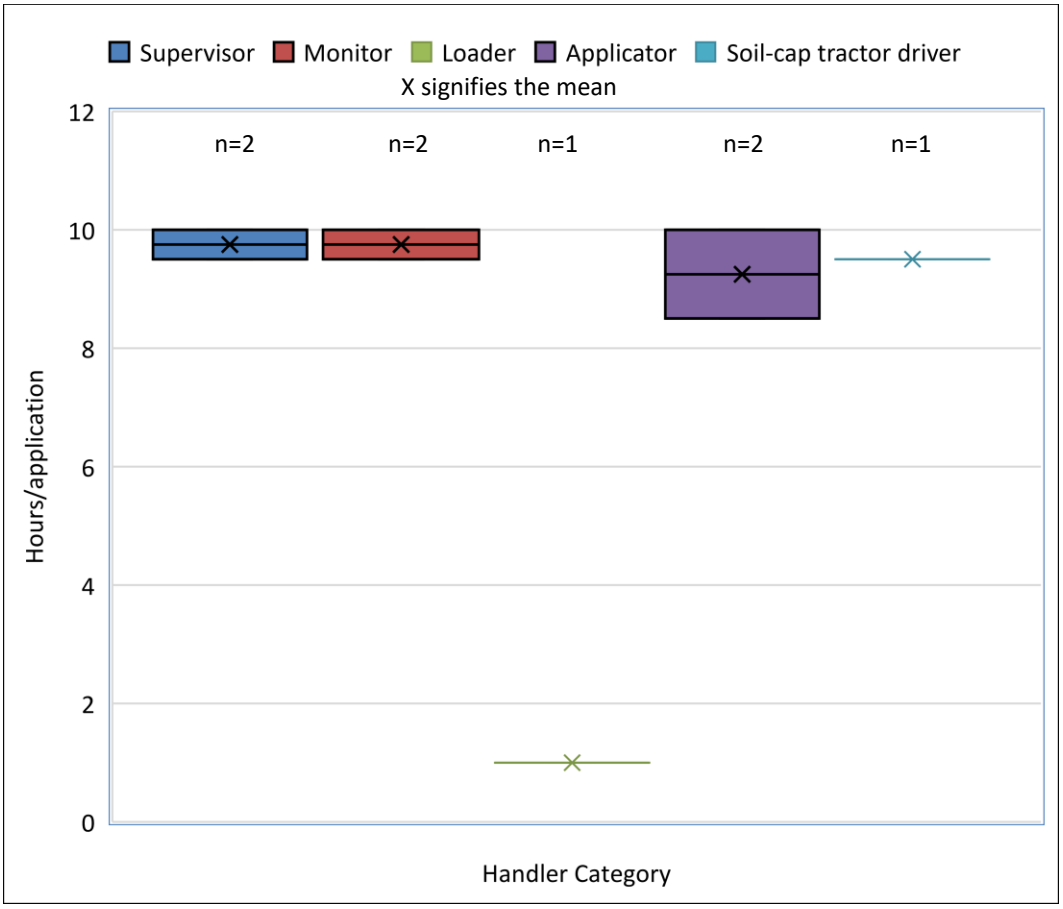


Figure 6B. Hours per fumigation spent on spray blade applications by handler category, with respirator.

Sprinkler applications

The respondents recorded employing only applicators, monitors, and supervisors in sprinkler applications. The responses (n=2) showed that the handlers of these work categories spent between 1.0 hour (supervisor) and 10.0 hours (applicator and monitor) on MITC application. On average, the handlers worked on sprinkler fumigations between 3.5 (3.5) hours (supervisor) and 8.0 (2.8) hours (applicator) (Figure 7A below and Table 7 in Appendix I).

Single responses (n=1) were received for supervisor and monitor showing respirator use for 0.5 and 6.0 hours, respectively. There were two records (n=2) showing that the applicators wore a respirator between 2.0 and 10.0 hours of the sprinkler fumigation with a mean of 6.0 (5.7) hours (Figure 7B and Table 7 in Appendix I).

Figure 7A. Hours per fumigation spent on sprinkler applications by handler category, with and without respirator.

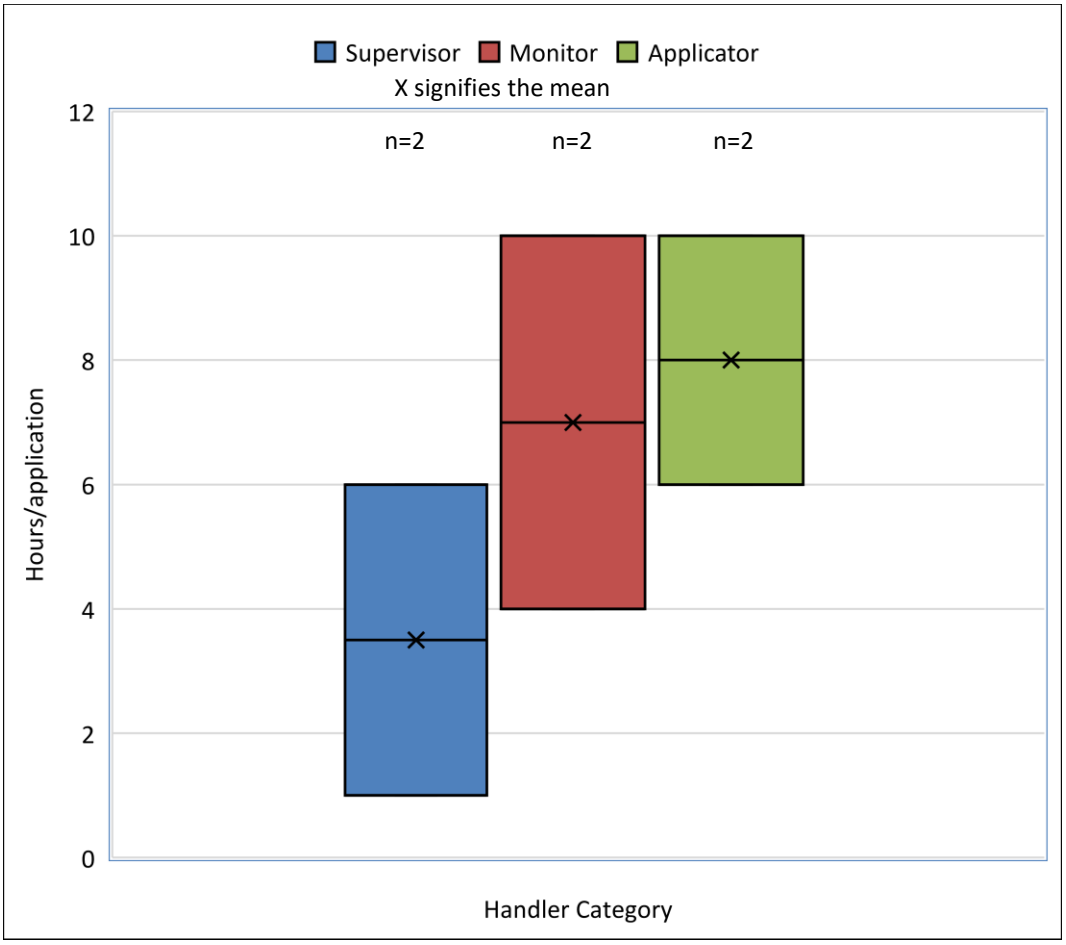
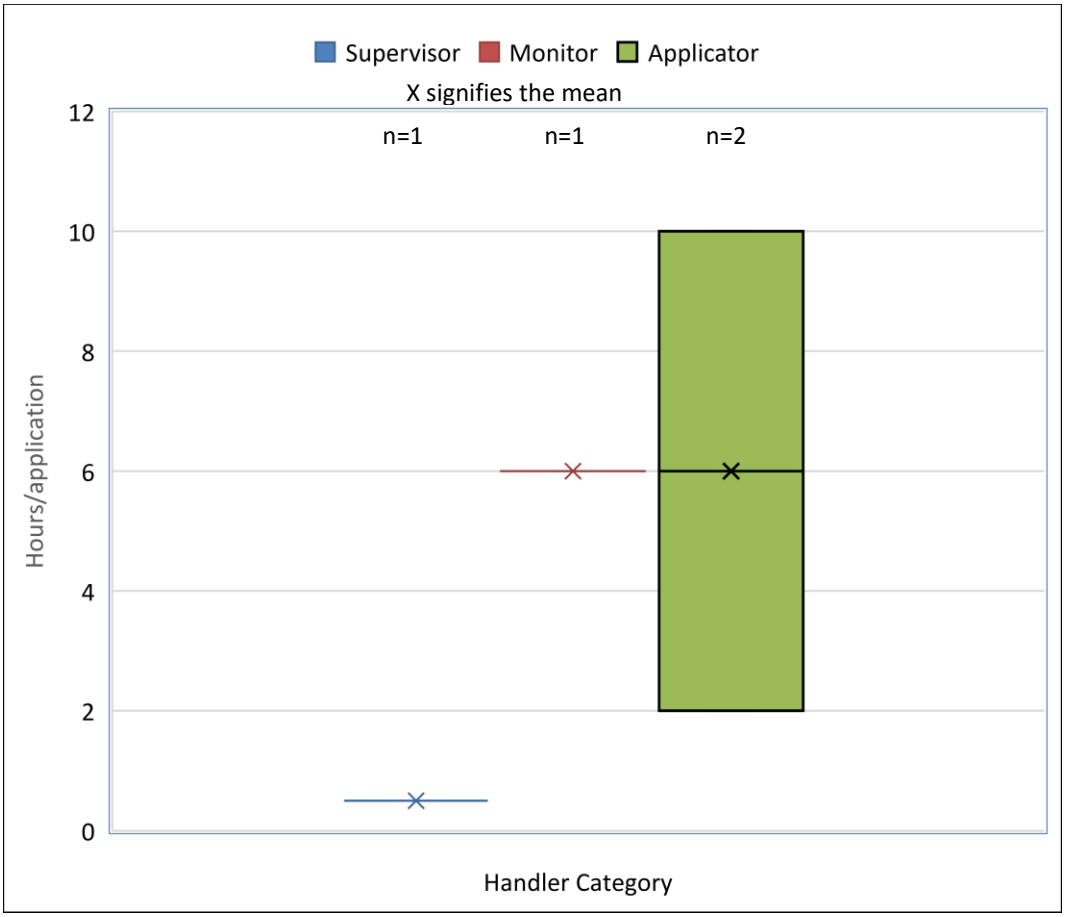


Figure 7B. Hours per fumigation spent on sprinkler applications by handler category, with respirator.



Power mulcher and rotary tiller applications

Only one respondent reported using power mulcher and rotary tiller method (n=1). The handlers on this crew worked between 1.0 hour (supervisor) and 8.0 hours (applicator and monitor) on a fumigation. The loader worked 3.0 hours and wore a respirator for the whole time (Figure 8A and 8B and Table 8 in Appendix I).

Figure 8A. Hours per fumigation spent on power mulcher and rotary tiller applications by handler category, with and without respirator.

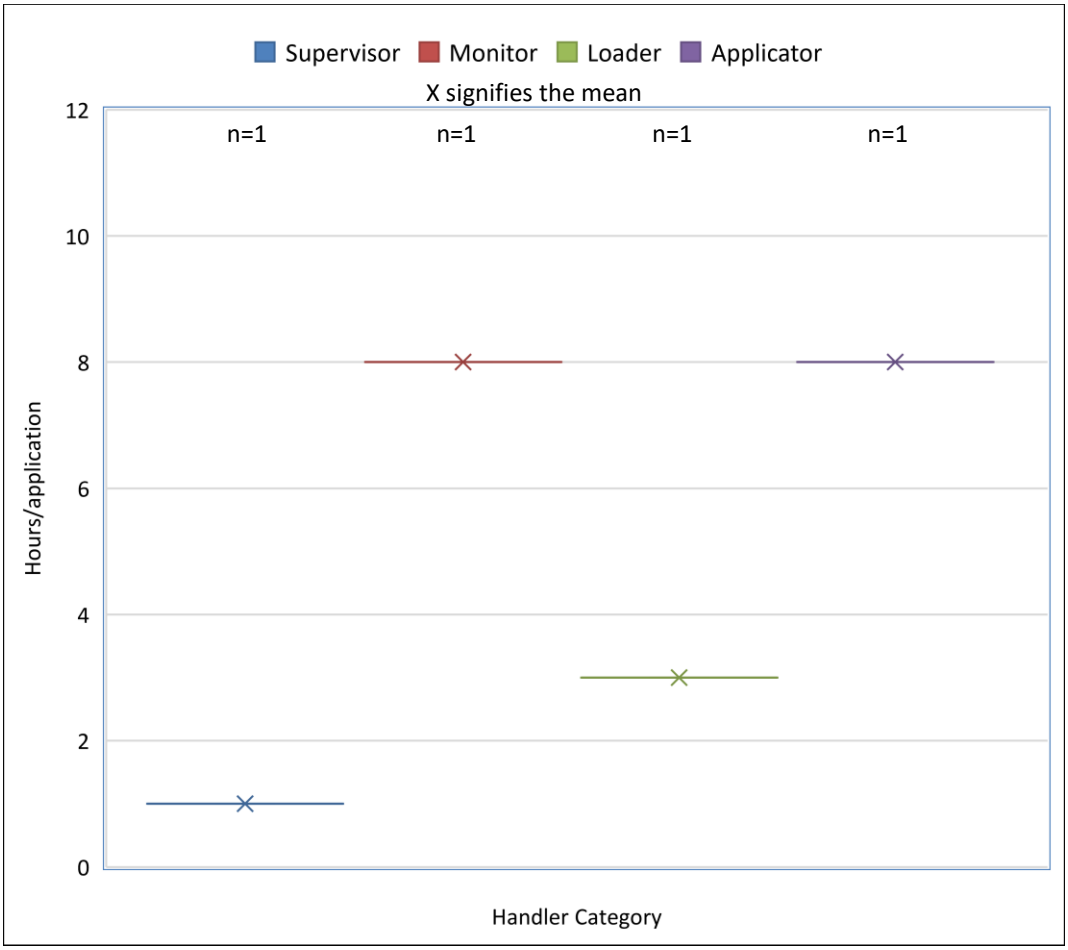


Figure 8B. Hours per fumigation spent on power mulcher and rotary tiller applications by handler category, with respirator.

Questions #3 and 4: "Number of fumigation days per month", grouped by application method.
When ESG collected information on Question #3, some participants tallied more than 30 fumigation days in a month. This indicated that some respondents may employ more than one applicator crew. Question #3 was revised to ask about the number of days in a month a typical crew works and how many crews were employed. The question was returned to the respondents as Question #4. The ESG Report provides details on the number of fumigation days per month entered by each of the study participants for the particular application methods. The number of crews employed throughout the year is listed in the ESG Report as a summary per respondent per method, but not per month. In order to align the number of crews with the number of days worked in a year, the monthly fumigation days for each application method were summarized into an annual pool in Table 2 below. Some respondents entered the number of crews they hired in 2017 as a range (e.g., 1–4 or "up to 6"). In those cases, the mean statistic was used to generate the values in Table 2. When the response was "n/a", only one crew was assumed to be employed.

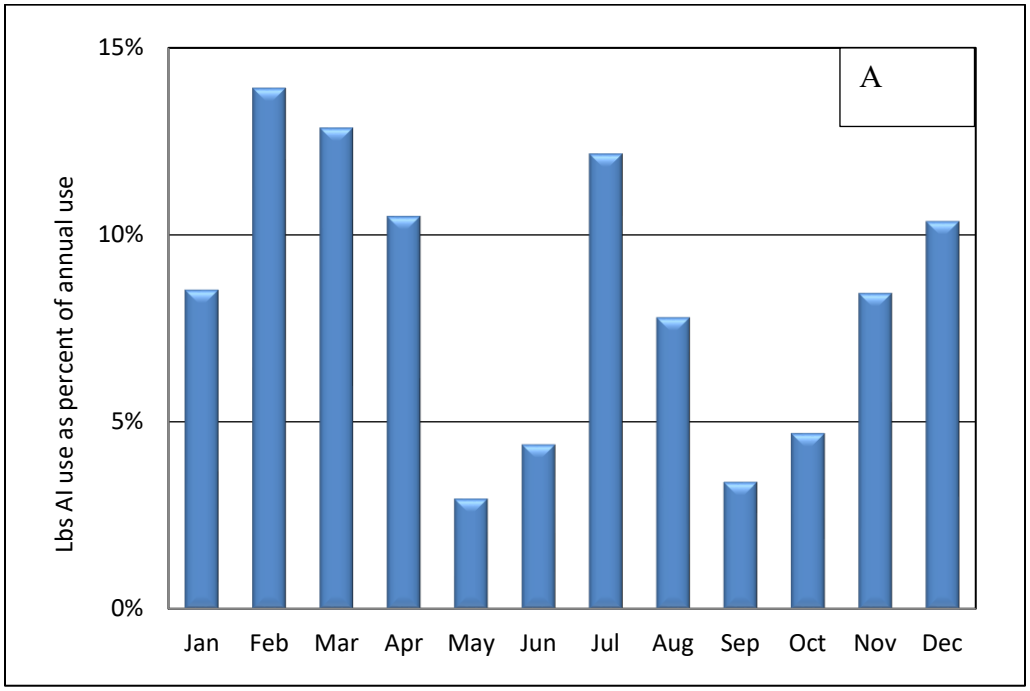
Table 2. MITC soil fumigation days and crews utilized in a year.

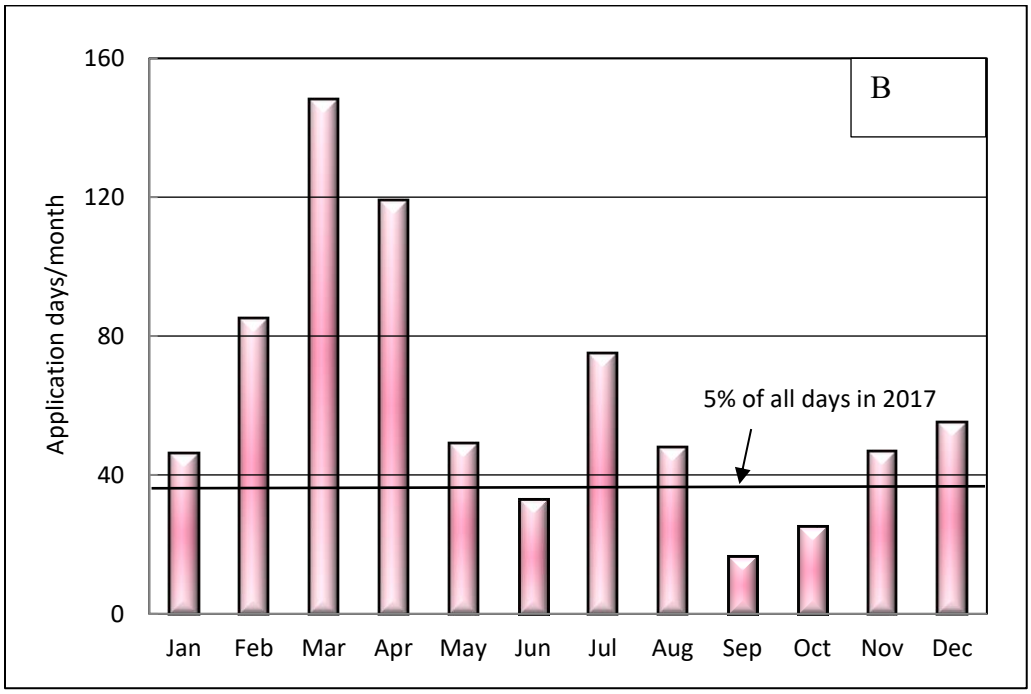
	Fumigation Method					
	Drip	Shank	Spray Blade	Sprinkler	Rotary Tiller	All Methods
Application days/year	200.3	436.0	50.0	41.0	19.0	746.3
Number of crews employed in a year [a]	10.5	12.0	5.5	6.0	2.0	36.0
Mean number of application days/crew/year	19.1	36.3	9.1	6.8	9.5	20.7
Number of respondents (n)	4	7	2	2	4	16 [b]

[a] Many participants reported a range of crews (e.g., 1–4 or "up to 6") they employed throughout the year. In this case, the sum of the mean values was listed in the table. When the response was "n/a", the assumption was that there was only one crew.
[b] Some of the ten study participants use more than one application method.

When the toxicity endpoints warrant intermediate- and long-term exposure estimates and risk assessment, exposure assessors need to determine the duration of these exposures to the pesticide. Usually, DPR estimates the length of the pesticide use season by the number of consecutive months in a five-year period with AI use at or above 5% of the total annual pesticide use (Beauvais, 2014, Thongsinthusak, 2004). PUR data from 2016–2020 (DPR, 2019b; DPR, 2021b; DPR, 2021c) show that the duration for the MITC soil application season is 6 months, November through April (Figure 9A). Based on PUR data, Thongsinthusak (2004) concluded that the metam sodium (the main MITC-generating soil fumigant at the time) season is 8 months. Using a similar approach, but based on 746 application days reported in 2017 in the ESG report (Table 2), the duration for the MITC soil application season is 7 months, November through May (Figure 9B).

Figure 9. MITC monthly use in soil fumigations: A. Pounds AI applied, PUR data from 2016–2020 (DPR, 2019b; DPR, 2021b; DPR, 2021c); B. Days/month applied in 2017, ESG Report**.**





This health-protective approach assumes that all handlers participate in every pesticide application carried out in the State and is justifiable when chemical- or scenario-specific knowledge is lacking.

The ESG Report provides information tailored for the MITC fumigations. It shows that PCOs and growers employ multiple fumigator crews in their business practice, and on average, one crew, and therefore an individual worker, applies MITC 21 days out of the year (Table 2). The data in the ESG Report supports the observation of Haskell (1994) that the yearly metam sodium handler exposure may be up to fifteen days (a work day may be up to 12 hours). Similarly, Thongsinthusak (2004) pointed out a particular exposure scenario (treatment for oak root fungus) where the handler exposure is 15 days per year. DPR defines seasonal exposure as that which lasts between one week and one year (Kwok, 2017). The data in the ESG Report suggests that the seasonal MITC handlers' exposure varies depending on the fumigation method, and averages about 21 days out of the year.

Typically, DPR uses eight hours as a default value for a work day duration in exposure estimates when there is no job- or chemical-specific information. The ESG Report provides information specific for the MITC fumigations showing that the average work day of MITC fumigators is 6.3 hours (n=54), with $UCL_{95\%}$ = 7.2 hours, a value quite similar to the default. For part of this time—4.0 hours (n=29, $p < 0.05$)—the handlers don a respirator.

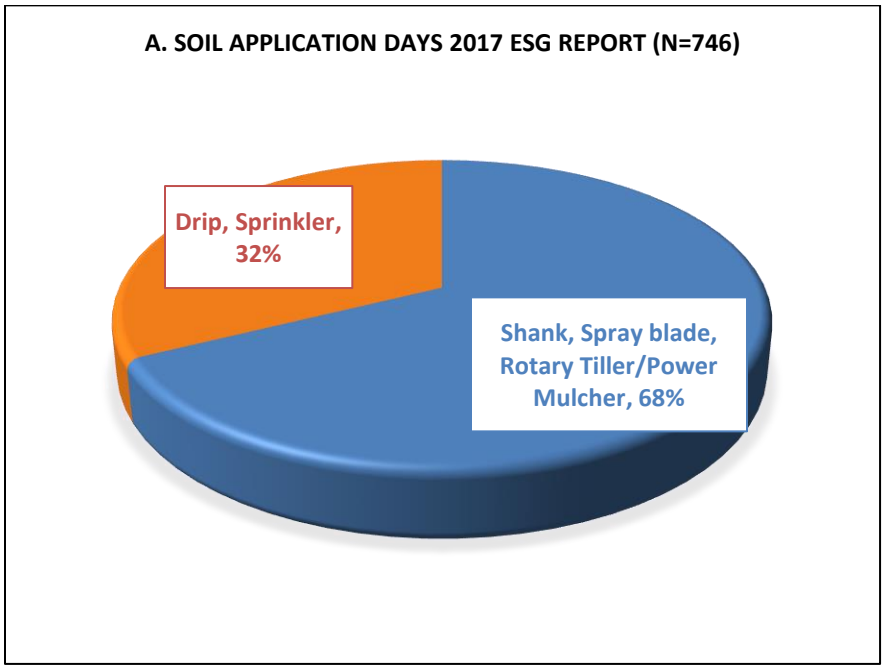
In some instances, the work day extends up to 11 hours. Some of the participating pest control businesses conduct more than one fumigation per day, and as stated in the ESG Report, this is due to the fact that multiple crews are employed. For this reason, the length of a fumigation can be equated to a work shift duration. The high end of the work day duration is in agreement with the previously discussed report by Haskell (1994) that metam sodium handlers work 12-hour shifts.

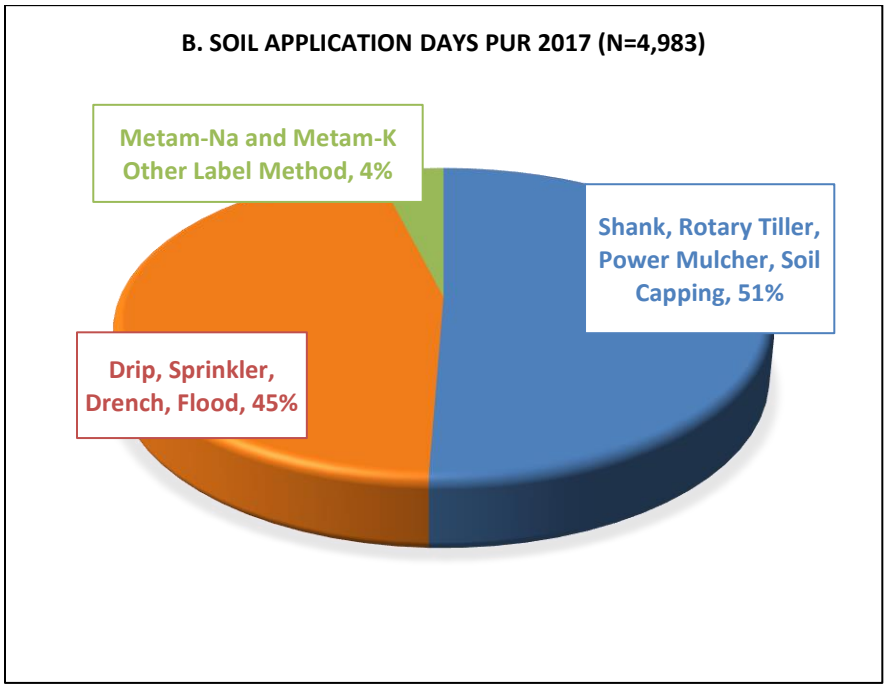
In an effort to understand how well the MITC Worker Hour Survey (ESG Report) captured the soil fumigation practices in California, the Report was compared to the data obtained from the DPR PUR database for 2017. Four different approaches were used to do the comparison:

1. **By the number of application dates:** The ESG Report recorded 746 soil fumigant application dates for 2017 compared to the 4,983 soil fumigation dates found in the PUR—15.0% coverage of all MITC field applications for the year. Only soil fumigation method codes (PUR database field FUME_CD (DPR, 2019c)) were included in the PUR count because the ESG Report reflects only soil fumigations. Thus, PUR entries without these codes (e.g., rights-of-way (RoW), landscape maintenance) were excluded from the PUR count. Overall, with 15% representation of the PUR soil fumigation dates, the ESG Report captured the number of soil fumigations recorded by DPR in 2017 very well.

2. **By the monthly application pattern:** The data from the ESG Report showed a monthly use trend very similar to that obtained from the PUR database, albeit using different metrics (Figure 9, A and B).
3. **By the representation of the PCOs and individual growers:** Twenty percent (2/10) of the survey respondents were individual growers and 80% (8/10) were PCOs. The makeup of the PUR data pool of 327 entities applying MITC in 2017 could not provide fair comparison to the survey configuration because only 6% (21/327) were PCOs (PUR database field LICENSE_NO) and they applied almost exclusively on RoW. On the other side, all agricultural soil fumigations in the PUR database were recorded by 306 individual growers (PUR field GROWER_ID). Soil fumigation methods require specialized and expensive equipment, and California growers often hire PCOs to apply MITC-generating fumigants for them. It is a common practice for the hired PCOs to report soil fumigations in the PUR database under the grower ID rather than under their own license number. A comparison between the survey respondents' configuration and PUR records is not justified in this case, because the share of PCOs conducting soil fumigations is not accurately represented in the PUR database.
4. **By the variety of application methods:** Another way to look at the data is by examining the prevalence and use of the various application methods in the ESG Report compared to the PUR database. The graph below represents the number of soil application days in 2017 distributed by fumigation method in the ESG Report (Figure 10A), *versus* the PUR database (n=4,983) (Figure 10B). The methods were divided into two groups. The first group included shank, spray blade, rotary tiller, power mulcher, and soil capping fumigations, as they involve injection of the product into the soil, followed by compaction of the surface to delay the loss of active ingredient. The second group included drip, flood, drench, and sprinkler applications. This was done because there appears to be a difference in the way licensed professional fumigators classify application methods compared to the fumigation method codes in the PUR database (DPR, 2019c). For example, spray blade applications were recorded on 7% (50/746) of the days in the ESG report (Table 2), while there is no fumigation code (and hence no entries) for this method in the PUR database. It is possible that when fumigators entered the fumigation method codes in the PUR database or responded to the survey, they did not distinguish clearly between the various injection methods. Overall, both graphs show the smaller share of drip, sprinkler, and similar methods compared to the shank-related methods, suggesting that the ESG Report captured the trends in MITC fumigation practices in California.

Figure 10. MITC soil fumigation dates grouped by application methods in 2017.





The ESG Report shows that each fumigation crew has members performing three to five different functions during the application (ESG, 2020, page 8). Depending on the type of MITC fumigation, these work assignments include applicators, monitors, loaders, supervisors, irrigators, and soil-cap tractor drivers. However, the ESG Report does not provide details on the nature of the duties associated with each of these work assignments. It is possible that different survey respondents have different definitions of the "titles" of their crew members. Heavy machinery, such as tractors, is an essential part of every soil fumigation, and many MITC soil fumigation methods include watering of the fumigated field either during (sprinkler, drip) or post-application for soil sealing (some shank injections), or to accelerate the hydrolysis of MITC from its precursor chemicals. Notably, the handler categories of irrigator and soil-cap tractor driver were included in the ESG Report only for shank and spray blade applications, respectively.

Survey Limitations

Notable limitations of the survey include the following:

- The survey is based on self-reporting rather than on independent observations, which has potential for reporting and recollection bias.
- Some answers were reported as ranges, e.g., number of crews employed in a year, which introduces uncertainty into the calculated estimates.
- The hours-by-activity table for drip applications (page 7 of the ESG Report) includes entries dated prior to 2017. These were submitted by one of the participants, because the "respondent has not conducted drip applications in the past couple of years". The accuracy of such recollection and its effect on the overall survey data quality are not clear.
- Some data sets are very small in size and/or have high sample variability. In those cases the data uncertainty increases, as evidenced by some wide confidence intervals, resulting in unrealistic upper-bound estimates (e.g., $UCL_{95\%}$=18 hours and up, Appendix I).
- DPR bases short-term exposures on the upper-bound or highest parameter estimates, while the intermediate- and long-term exposures, representing typical or average trends, use central tendency estimates. The survey inquired about the "usual" and "typical" use patterns. The upper-bound estimates presented in this analysis can be used for short-term exposures only with this caveat in mind.

Conclusions

The survey on MITC handler work practices had a high response rate (62%) and represented 15% of the soil fumigation dates in California for 2017. The survey shows that the average duration of the work day for an MITC handler is 6.3 hours. Some MITC handlers worked as many as 11 hours and as few as 0.5 hours per day. Handlers can choose whether or not to wear a respirator, unless certain conditions listed on the label occur that mandate its use. The ESG Report showed that on average, MITC handlers don a respirator only for part of the fumigation

day—4.0 hours, or 63% of the work shift. However, in a few instances, handlers don a respirator throughout the entire application process. Among all MITC handler job assignments, the average applicator has the longest work day, 8.2 hours. Spray blade is the soil fumigation method of longest duration, with the average spray blade fumigation crew working 8.5 hours per day. The stratification of the aggregate MITC work day data by fumigation methods **and** handler categories provides high resolution details about the various job assignments, but also results in some very small data sets with low statistical power. The survey data suggests that the average duration of seasonal exposure for MITC handlers is approximately 21 days out of the year.

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Appendix I: Statistical summaries for work hours spent on a fumigation

Table 1. Hours per fumigation combined for all handler categories and all application methods with and without respirator, and with respirator.

Statistic	All handler categories and all application methods combined, with and without respirator	All handler categories and all application methods combined, with respirator
Mean	6.3	4.0
Standard deviation	3.2	3.1
Minimum	0.5	0.5
Maximum	11.0	10.0
95th percentile	10.0	9.8
$UCL_{95\%}$	7.2	5.2
Sample size (n)	54	29

Table 2. Hours per fumigation combined for all handler categories by application method.

Statistic	All job assignments by method, with and without respirator					All job assignments by method, with respirator[a]				
	Shank	Drip	Spray blade	Sprinkler	Rototiller	Shank	Drip	Spray blade	Sprinkler	Rototiller
Mean	6.5	5.4	8.5	6.2	5.0	4.1	3.1	5.5	4.6	3.0
Standard deviation	3.2	2.9	3.1	3.5	3.6	2.6	3.0	4.1	4.3	N/A[a]
Minimum	1.0	0.5	1.0	1.0	1.0	2.0	0.5	1.0	0.5	3.0
Maximum	10.0	11.0	10.0	10.0	8.0	10.0	7.0	9.5	10.0	3.0
95th percentile	10.0	11.0	10.0	10.0	8.0	8.0	7.0	9.4	9.4	N/A
$UCL_{95\%}$	8.0	6.8	11.1	9.8	10.7	5.8	5.4	12.1	11.4	N/A
Sample size (n)	19	17	8	6	4	11	9	4	4	1

[a] N/A = not applicable.

Table 3. Hours per fumigation combined for all methods by handler category.

Statistic	All methods by job assignment, with and without respirator[a]						All methods by job assignment, with respirator					
	Supervisor	Monitor	Loader	Applicator	Irrigator	Soil-cap tractor driver	Supervisor	Monitor	Loader	Applicator	Irrigator	Soil-cap tractor driver
Mean	4.9	7.3	3.3	8.2	5.0	9.5	1.0	5.0	2.9	5.1	2.5	9.5
Standard deviation	3.6	2.6	2.7	1.8	1.4	N/A	0.9	1.7	2.5	3.4	0.7	N/A
Minimum	1.0	3.0	0.5	5.0	4.0	9.5	0.5	3.0	0.5	0.5	2.0	9.5
Maximum	10.0	11.0	8.0	11.0	6.0	9.5	2.0	6.0	7.0	10.0	3.0	9.5
95th percentile	10.0	10.4	7.7	10.3	5.9	N/A	1.9	6.0	6.7	10.0	3.0	N/A
$UCL_{95\%}$	7.0	8.8	5.6	9.1	17.7	N/A	3.2	9.3	4.9	7.2	8.9	N/A
Sample size (n)	14	14	8	15	2	1	3	3	8	12	2	1

[a] N/A = not applicable.

Table 4. Hours per fumigation spent on shank applications by handler category.

Statistic	Shank, with and without respirator					Shank, with respirator[a]				
	Supervisor	Monitor	Loader	Applicator	Irrigator	Supervisor	Monitor	Loader	Applicator	Irrigator
Mean	5.2	7.5	4.3	8.8	5.0	2.0	6.0	3.7	5.3	2.5
Standard deviation	4.4	2.5	3.2	1.1	1.4	N/A	N/A	2.1	3.6	0.7
Minimum	1.0	4.0	2.0	8.0	4.0	2.0	6.0	2.0	2.0	2.0
Maximum	10.0	10.0	8.0	10.0	6.0	2.0	6.0	6.0	10.0	3.0
95th percentile	10.0	9.7	7.5	10.0	5.9	N/A	N/A	5.7	9.4	3.0
$UCL_{95\%}$	10.7	11.5	12.3	10.2	17.7	N/A	N/A	8.8	11.0	8.9
Sample size (n)	5	4	3	5	2	1	1	3	4	2

[a] N/A = not applicable.

Table 5. Hours per fumigation spent on drip applications by handler category.

Statistic	Drip, with and without respirator				Drip, with respirator[a]			
	Supervisor	Monitor	Loader	Applicator	Supervisor	Monitor	Loader	Applicator
Mean	3.6	6.2	3.2	7.2	0.5	3.0	2.7	4.1
Standard deviation	1.5	2.9	3.4	2.3	N/A	N/A	3.8	3.4
Minimum	1.5	3.0	0.5	5.0	0.5	3.0	0.5	0.5
Maximum	5.0	11.0	7.0	11.0	0.5	3.0	7.0	7.0
95th percentile	4.9	10.0	6.5	10.2	N/A	N/A	6.4	7.0
$UCL_{95\%}$	6.0	9.9	11.6	10.0	N/A	N/A	12.0	9.5
Sample size (n)	4	5	3	5	1	1	3	4

[a] N/A = not applicable.

Table 6. Hours per fumigation spent on spray blade applications by handler category.

Statistic	Spray blade, with and without respirator[a]					Spray blade, with respirator[b]				
	Supervisor	Monitor	Loader	Applicator	Soil-cap tractor driver	Supervisor	Monitor	Loader	Applicator	Soil-cap tractor driver
Mean	9.8	9.8	1.0	9.3	9.5			1.0	5.8	9.5
Standard deviation	0.4	0.4	N/A	1.1	N/A			N/A	3.9	N/A
Minimum	9.5	9.5	1.0	8.5	9.5			1.0	3.0	9.5
Maximum	10.0	10.0	1.0	10.0	9.5			1.0	8.5	9.5
95th percentile	10.0	10.0	N/A	9.9	N/A			N/A	8.2	N/A
$UCL_{95\%}$	12.9	12.9	N/A	18.8	N/A			N/A	40.7	N/A
Sample size (n)	2	2	1	2	1			1	2	1

[a] N/A = not applicable.
[b] Blank cells denote no data available.

Table 7. Hours per fumigation spent on sprinkler applications by handler category.

Statistic	Sprinkler, with and without respirator			Sprinkler, with respirator[a]		
	Supervisor	Monitor	Applicator	Supervisor	Monitor	Applicator
Mean	3.5	7.0	8.0	0.5	6.0	6.0
Standard deviation	3.5	4.2	2.8	N/A	N/A	5.7
Minimum	1.0	4.0	6.0	0.5	6.0	2.0
Maximum	6.0	10.0	10.0	0.5	6.0	10.0
95th percentile	5.8	9.7	9.8	N/A	N/A	9.6
$UCL_{95\%}$	35.3	45.1	33.4	N/A	N/A	56.8
Sample size (n)	2	2	2	1	1	2

[a] N/A = not applicable.

Table 8. Hours per fumigation spent on power mulcher and rotary tiller applications by handler category.

Statistic	Power mulcher and rototiller, with and without respirator[a]				Power mulcher and rototiller, with respirator[b]			
	Supervisor	Monitor	Loader	Applicator	Supervisor	Monitor	Loader	Applicator
Mean	1	8	3	8			3	
Standard Deviation	N/A	N/A	N/A	N/A			N/A	
Minimum	1	8	3	8			3	
Maximum	1	8	3	8			3	
95th percentile	N/A	N/A	N/A	N/A			N/A	
$UCL_{95\%}$	N/A	N/A	N/A	N/A			N/A	
Sample size (n)	1	1	1	1			1	

[a] N/A = not applicable.
[b] Blank cells denote no data available.