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Summary of Chloropicrin Flux Studies Submitted to the California Department of Pesticide Regulation

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1. Overview

Chloropicrin (CP) is a fumigant used to control soil-borne diseases. CP is typically applied prior to planting, with common crops including strawberries, raspberries, and other high-value crops. It may be applied alone or in combination with other products including 1,3-dichlorpropene or methyl bromide. CP is sometimes included as a minor component in formulations with other fumigants to act as a warning agent due to volatilized CP causing eye and throat irritation at relatively low ambient concentrations.

Registrants of CP products and researchers carry out flux studies to evaluate different ways of mitigating off-site transport of CP. Staff from the Department of Pesticide Regulation (DPR) review these studies to ensure the data is of high quality before such studies are used in mitigation work, such as buffer zone development. Studies may include one or more experiments evaluating variables such as application depth, tarp type, or delivery method.

Much of the CP data available to DPR has been previously summarized as a component of work describing buffer zone development for CP (Barry 2014). However, the previous document does not include summaries of the flux over certain time periods relevant to activities within DPR's Environmental Monitoring Branch (EM). Therefore, for each experiment, we provide a summary of the experimental design and calculate the peak 8-hour, 24-hour rolling average fluxes and cumulative emissions as a fraction of the amount initially applied ("emission fraction" [EF]). Such values are of relevance to activities within EM because they pertain to worker exposure limits, acute bystander exposure, and long-term exposure, respectively.

2. Methods

We reviewed data volumes from DPR's Registration Branch relating to CP field flux studies. Where available, we additionally reviewed Evaluation Reports of each data volume performed by EM staff and provide a summary of their comments. Where no major issues with the flux data were indicated, and where the application methods described are permitted within California, the reported flux values were

then converted to machine-readable format using tabular data, or (if tabular data was not available) digitization of flux profile figures.

Field flux data is typically presented as a sequence of period-averaged flux values collected over varying durations—usually 3-to-12-hour intervals—which may not be suitable for direct extraction of 8- or 24-hour maximum values. Therefore, calculation of an 8-hour or 24-hour peak requires conversion of reported flux estimates into smaller increments. Flux results were converted into 6-minute (0.1 hour) increments by subdividing the duration of each reporting period into multiple 6-minute periods sharing the same period-average flux result. Once converted, 8- and 24-h peaks were extracted from each flux profile using a moving window (i.e., rolling average) approach in R (R Core Team 2022). Cumulative flux was calculated by summing the product of period-average flux and actual sampling duration and dividing by the broadcast-equivalent application rate. The broadcast-equivalent application rate was calculated as the actual pounds of CP applied, divided by the area of the treated field, minus the area of any non-crop areas such as access roads. In some cases, our calculated broadcast-equivalent application rate differed from the reported application rate due to a difference in the field area value, and these differences are noted where they occur.

3. Field Studies

We identified and reviewed 19 studies, comprising 47 experiments, evaluating whole-field flux of CP. Study locations included California, Washington, Georgia, Arizona, Florida, and Michigan. Chloropicrin products used in the various studies include Tri-Con 50/50, Tri-Clor, Midas 50:50, Chloropicrin 100, Pic Plus, Pic-Clor 60, Tri-Clor EC, Metapicrin, and four unknown product names. Whole-field flux estimation methods included the aerodynamic (AD) method, integrated horizontal flux (IHF) method, and back-calculation (BC) methods. Out of the 47 experiments, we identified 18 as suitable for representing current practices; the remaining studies either used application methods not approved for use in California, or were rejected in prior evaluations due to quality concerns.

3.1 Studies included in analysis

Ajwa and Sullivan, 2010a (123-0220)

This study was conducted in June 2009 near Wasco, CA and had 5 separate experiments.

Experiment #1: In this study, a 1-acre field was treated with 378.22 pounds of Tri-Con 50/50 applied via a noble shank broadcast application. The application rate was 187.98 lb/ac CP. The application depth was 12 inches, and a polyethylene (PE) tarp was used. The coordinates of the field are 35.60079, -119.2154. The flux estimation technique used was the BC method.

Experiment #2: In this study, a 1-acre field was treated with 360.60 pounds of Tri-Con 50/50 applied via a shank broadcast application. The application rate was 179.22 lb/ac. The application depth was 12 inches, and a PE tarp was used. The coordinates of the field are 35.59846, -119.2346. The flux estimation technique used was the BC method.

Experiment #3: In this study, a 1-acre field was treated with 355.80 pounds of Tri-Con 50/50 applied via a shank broadcast application. The application rate was 176.83 lb/ac. The application depth was 12 inches, and a PE tarp was used. The coordinates of the field are 35.59292, -119.2155. The flux estimation technique used was the BC method.

Experiment #4: In this study, a 1-acre field was treated with 202.60 pounds of Tri-Con 50/50 applied via a deep- strip application. The application rate was 100.69 lb/ac. The application depth was 18 inches, and a

PE tarp was used. The coordinates of the field are 35.59392, -119.2345. The flux estimation technique used was the BC method.

Experiment #5: In this study, a 1-acre field was treated with 362.20 pounds of Tri-Con 50/50 applied via a deep broadcast application. The application rate was 180.01 lb/ac. The application depth was 18 inches, and a PE tarp was used. The coordinates of the field are 35.59392, -119.2345. The flux estimation technique used was the BC method.

Note: Study found to be suitable for use in DPR's chloropicrin flux datasets. Evaluation Report recommends re-calculation of flux using standard DPR methodology. Re-calculation of flux later presented in Barry and Tao (2011) and these are the flux estimates used in this analysis.

Ajwa et al., 2010 (199-0143)

Two experiments were performed as part of this study, located in Fort Pierce, Florida on November 17,2009.

Experiment #1: The study was conducted in Fort Pierce, Florida on 11/17/2009. A 0.37-acre field was treated with 145.63 pounds of Pic-Clor 60 applied via a broadcast application. A 1-mil HDPE tarp was used. The application rate was 234.59 lb/ac. The application depth was 8- inches. The flux estimation technique used was the IHF method.

Experiment #2: The study was conducted in Fort Pierce, Florida on 11/17/2009. A 0.37-acre field was treated with 138.75 pounds of Pic-Clor 60 applied via a broadcast application. A 1-mil HDPE tarp was used. The application rate was 223.50 lb/ac. The application depth was 8- inches. The flux estimation technique used was the IHF method.

Notes: Minor problems with analytical recoveries noted in Evaluation Report but quality of study determined as sufficient for inclusion in chloropicrin flux database. Study is also available in the open literature as Chellemi et al. (2012).

Ajwa and Sullivan, 2012 (50046-0198)

Four experiments were submitted as part of this study conducted in Lost Hills, CA. The product Pic Clor-60 was used and TIF (VaporSafe) tarps were used in each experiment. Each experiment began on June 4, 2011.

Experiment #1: The study was conducted in Lost Hills, CA on 6/4/11. An 8.16-acre field was treated with 4,661.81 pounds of Pic-Clor 60 applied via a 12-inch-deep broadcast application. A TIF tarp was used, and the tarp duration was 16 days. The application rate was 340.49 lb/ac. The flux estimation technique used was the BC method.

Experiment #2: The study was conducted in Lost Hills, CA on 6/4/11. A 1.97-acre field was treated with 1,077.60 pounds of Pic-Clor 60 applied via a 12-inch-deep broadcast application. A TIF tarp was used, and the tarp duration was 10 days. The application rate was 326.02 lb/ac. The flux estimation technique used was the BC method.

Experiment #3: The study was conducted in Lost Hills, CA on 6/4/11. A 2.03-acre field was treated with 1,204.90 pounds of Pic-Clor 60 applied via a 12-inch-deep broadcast application. A TIF tarp was used, and the tarp duration was 5 days. The application rate was 353.75 lb/ac. The flux estimation technique used was the BC method.

Experiment #4: The study was conducted in Lost Hills, CA on 6/4/11. A 1.98-acre field was treated with 1,181.10 pounds of Pic-Clor 60 applied via a 12-inch-deep broadcast application. Potassium thiosulfate (KTS) was applied as a soil surface treatment at the time of application. A TIF tarp was used, and the tarp duration was 5 days. The application rate was 355.52 lb/ac. The flux estimation technique used was the BC method.

Note: Experimental results detailed elsewhere in open literature (Ajwa et al. [2013]). Experiments #3 and #4 are not used due to the tarp duration falling under that of current 9-day requirement.

Ajwa and Sullivan, 2010b (199-0142)

Three 1-acre experiments were submitted as part of this study in Ventura County, California performed on September 10 and 11, 2009.

Experiment #1: The study was conducted in Ventura County, CA on 9/10/09. A 1-acre field was treated with 147.22 pounds of Tri-Clor applied via a 12-inch-deep broadcast application. A PE tarp was used, and the tarp duration was 6 days. The application rate was 145.75 lb/ac. The flux estimation technique used was the BC method.

Experiment #2: The study was conducted in Ventura County, CA on 9/10/09. A 1-acre field was treated with 136.57 pounds of Tri-Clor applied via a 12-inch-deep broadcast application. A TIF tarp was used, and the tarp duration was 6 days. The application rate was 135.20 lb/ac. The flux estimation technique used was the BC method.

Experiment #3: The study was conducted in Ventura County, CA on 9/11/09. A 1-acre field was treated with 179.49 pounds of Tri-Clor applied via a chemigation/drip application. A 1-mil TIF tarp was used. The application rate was 177.7 lb/ac. The flux estimation technique used was the BC method.

Note: Significant issues noted in Evaluation Report, including low analytical recovery on field spikes, low soil moisture and holes in tarp in Experiment #2, and cross-contamination from a commercial application in Field #3. Evaluation Report noted that results for Experiment #3 should be rejected from inclusion in the chloropicrin flux database due to the cross-contamination issue. Sealing duration for the TIF tarp in Experiment #2 is shorter than currently allowed. Therefore, only results from Experiment #1 are relevant to current practices.

Ajwa and Sullivan, 2008 (199-0130)

Four 1-acre experiments were submitted as part of this study conducted near Wasco, CA. The experiments were performed on May 28, 2008.

Experiment #1: The study was conducted near Wasco, CA on 5/28/08. A 1-acre field was treated with 357.60 pounds of product (unknown) applied via a 12-inch-deep broadcast application. A 1.0-mil PE tarp was used, and the tarp was cut on day 5. The application rate was 356.99 lb/ac. The flux estimation technique used was the IHF method.

Experiment #2: The study was conducted near Wasco, CA on 5/28/08. A 1-acre field was treated with 164.60 pounds of product (unknown) applied via a 12-inch-deep strip (flat-fume) application. A 1.0-mil PE tarp was used, and the tarp was cut on day 5. The application rate was 164.32 lb/ac. The flux estimation technique used was the IHF method.

Experiment #3: The study was conducted near Wasco, CA on 5/28/08. A 1-acre field was treated with 197 pounds of product (unknown) applied via a 12-inch-deep broadcast application. The application rate was 196.67 lb/ac. The flux estimation technique used was the IHF method.

Experiment #4: The study was conducted near Wasco, CA on 5/28/08. A 1-acre field was treated with 320.80 pounds of product (unknown) applied via 18-inch-deep broadcast application. The application rate was 320.25 lb/ac. The flux estimation technique used was the IHF method.

Notes: The Evaluation Report for this study notes several issues, including insufficient laboratory QA/QC data, missing meteorological data, and questions surrounding the use of central mast data for field #2 for all fields, despite significant differences in meteorology across fields and central mast data available from field #4. Incorrect fetch and field size values used in some calculations (Fields 1, 2, 4). Resolution of these problems is not known; however, the data was subsequently relied upon in CP buffer zone development (Barry 2014).

Ajwa et al, 2009b (52971-0112)

Three 1-acre experiments conducted in Tifton, Georgia were submitted in this study.

Experiment #1: The study was conducted in Tifton, GA on 2/7/09. A 0.963-acre field was treated with 295 pounds of Paladin (21% CP) applied via an 8-inch depth bedded application. A VIF tarp was used. The treated area rate for CP was 145.30 lb/acre and broadcast-equivalent rate of CP of 64.3 lb/ac. The coordinates of the field are: 31.50598, -83.56834. The flux estimation technique used was the IHF method.

Experiment #2: The study was conducted in Tifton, GA on 2/7/09. A 0.917-acre field was treated with 282 pounds of Paladin (21% CP) applied via an 8-inch depth bedded application. A LDPE tarp was used. The treated area application rate for CP was 143.20 lb/ac and broadcast-equivalent rate of CP of 64.6 lb/ac. The coordinates of the field are: 31.5122, -83.5527. The flux estimation technique used was the IHF method.

Experiment #3: The study was conducted in Tifton, GA on 2/7/09. A 0.989-acre field was treated with 295 pounds of Paladin (21% CP) applied via an 8-inch depth bedded application. A LDPE tarp was used. The treated area application rate for CP was 151.20 lb/ac and broadcast equivalent rate of CP of 62.6 lb/ac. The coordinates of the field are: 31.52341, -83.54807. The flux estimation technique used was the IHF method.

Note: Evaluation Report notes a lack of detailed QA/QC data included in report. Soil characterization data is limited. Certain electronic files necessary for reproducing flux calculations were not submitted. Data was subsequently relied upon in CP buffer zone development (Barry 2014). This data is also in the open literature as Chellemi et al. 2010. Experiment #1 excluded from further analysis due to use of VIF, not currently approved for use within California. Manual calculation of EF produced cumulative flux estimates higher than those reported in the original report, due to original calculations using calculations based on the treated area rate rather than the whole field rate.

Ajwa 2010 (199-0136)

Four fields near Salinas, CA were treated with a blend of chloropicrin, methyl bromide, and an emulsifier. All four applications were applied by drip irrigation with an effective broadcast rate of 200 lb/ac (treated area rate of 345 lb/ac). Fields were sealed with either LDPE, TIF, LDPE with post-

application water and potassium thiosulfate application, or LDPE with post-application water. The study used two flux estimation methods concurrently: IHF and back-calculation via ISCST3.

Experiment #1: This was a bedded surface drip chemigation study with LDPE tarp cover.

Experiment #2: This was a bedded surface drip chemigation study with TIF tarp cover.

Experiment #3: This was a bedded surface drip chemigation study with LDPE tarp cover and application potassium thiosulfate and post-application 8mm water seal.

Experiment #4: This was a bedded surface drip chemigation study with LDPE tarp cover and a post-application 8mm water seal.

Note: Evaluation Report found study not to have adequate documentation of analytical recovery. Flux estimates could not be verified by either BC or IHF methods because raw data and analysis files were not submitted. Tabular listing of BC fluxes was not provided. Experimental data was subsequently used in CP buffer zone development. However, experiments #3 and #4 are not relevant to CA regulation as KTS and post-application water seal for chemigation methods are not approved as distinct application methods.

Rotondaro 2004 (199-0112)

This volume is primarily a worker inhalation study, but flux was estimated for one instance of drip application at site #16.

Experiment #1: One 8.67-acre (bedded area = 4.50 acres) field near Salinas, CA was treated by surface drip chemigation at a broadcast equivalent rate of 148.7 lb/ac (treated bed rate of 300 lb/ac). Study occurred on August 27, 2003. Beds were covered with LDPE tarp. Flux was estimated with the AD method. Study reported mass loss of 15.2% of applied mass with highest flux rates occurring within the first 4-h of application, with minor emissions after 48 hours.

van Wesenbeeck and Phillips 2000 (50046-0152)

One experiment was conducted in December 1999 in Coffee County, Georgia.

Experiment #1: 1,3-D and chloropicrin were applied through a surface drip application to a 10.7-acre field (bedded area = 4.3 acres) at a treated-area rate of 24.6 GPA In-Line (60.2% 1,3-D, 33% CP [90.9 lb/ac CP]) and a broadcast-equivalent rate of 36.8 lb/ac CP. The beds were covered with PE tarp. Flux was evaluated using the AD method. The study found mass loss of 12.3% of applied CP.

Note: Results are also reported in the open literature as part of Wesenbeeck et al. (2007). Study also evaluated flux using dynamic flux chambers in addition to the AD method.

3.2 Studies excluded from analysis

We identified several studies which were not suitable for further analysis as part of this report. While select experiments were excluded out of data quality concerns noted in DPR Evaluation Reports, the following studies were excluded only due to their not being representative of methods currently approved for use within California.

Ajwa et al. 2009a (199-0138)

Three 1-acre experiments were performed in Duette, Florida using the product Metapicrin. The experiments took place on January 14, 2009.

Experiment #1: The study was conducted in Duette, Florida on 1/14/09. A 1.2-acre field was treated with 61.30 pounds of Metapicrin applied via an 8-inch depth broadcast application. A 1.25 mil Canslit Metal tarp was used. The application rate was 51.08 lb/ac. The flux estimation technique used was the IHF method.

Experiment #2: The study was conducted in Duette, Florida on 1/14/09. A 1.1-acre field was treated with 63.0 pounds of Metapicrin applied via an 8-inch depth broadcast application. A 1.2 mil VIF tarp was used. The application rate was 57.27 lb/ac. The flux estimation technique used was the IHF method.

Experiment #3: The study was conducted in Duette, Florida on 1/14/09. A 1.1-acre field was treated with 58.80 pounds of Metapicrin applied via an 8-inch depth broadcast application. A 1.25 mil Canslit Metal tarp was used. The application rate was 53.45 lb/ac. The flux estimation technique used was the IHF method.

Note: VIF and metallized tarps not currently approved in California; flux estimates not applicable at present. No Evaluation Report located for this study.

Ajwa and Sullivan 2010c (0199-0140)

Two experiments were evaluated as part of this Florida-based study, one evaluating application to a tarped bedded field, and one using a novel "hot gas" application method. A third planned broadcast experiment was not completed due to problems during application.

Experiment #1: Chloropicrin was applied at a rate of 134.5 lb/ac to a 1.07-acre bedded field sealed with TIF. Flux was estimated with the IHF method.

Experiment #2: Chloropicrin was applied at a rate of 8.7 lb/ac to a 0.39-acre field using a "hot gas" method. Flux was estimated with the IHF method.

Note: The study was found by the Evaluation Report to be conducted in an acceptable manner. However, flux estimates could not be verified because raw data and analysis files were not submitted with the volume. Furthermore, the "hot gas" method and 8-inch bedded TIF methods are not currently used within California.

Baker and Arndt 2007 (52875-0128)

This field study evaluated emissions in Bainbridge, GA and two in Hart, MI. The experiments were performed on 2.5-acre field. The product, Midas 50:50 was used in all experiment and the application depth was 8 inches.

Experiment #1: The study was conducted in Dover, Florida on 1/31/2007. The coordinates of the field are: 27.970256, -82.242426A. 2.5-acre field was treated with 181.00 pounds of Midas 50:50 applied via a broadcast application. A 0.0013-inch metalized white plastic tarp was used. The application rate was 36.20 lb/ac. The application depth was 8 inches. Both BC and AD methods were used concurrently.

Baker and Ardnt 2007 (52875-0129)

This study includes one experiment performed in Bainbridge, GA.

Experiment #1: The study was conducted in Bainbridge, Georgia on 3/21/2007. The coordinates of the field are: 30.794993, -84.590386A. 2.5-acre field was treated with 178.00 pounds of Midas 50:50 applied via application into raised beds. A 0.00125-inch VIF tarp was used. The application rate was 35.60 lb/ac. The application depth was 8 inches. Both BC and AD methods were used concurrently.

Note: Study not relevant to current practices within CA as no methods use VIF tarp. Application uses proprietary "Symmetry" application system.

Baker and Ardnt 2007 (52875-0130)

This study includes one experiment performed in Hart, MI.

Experiment #1: The study was conducted in Hart, Michigan on 5/16/2007. A 2.5-acre field was treated with 206.00 pounds of Midas 50:50 applied via application into raised beds. A 0.00125-inch VIF tarp was used. The application rate was 41.20 lb/ac. The application depth was 8 inches. Both BC and AD methods were used concurrently.

Note: Study not relevant to current practices within CA as no methods use VIF tarp. Application uses proprietary "Symmetry" application system.

Beard et al. 1996 (199-0072, 199-0073)

This study contained 6 experiments in three locations, 4 experiments near Phoenix, AZ, one in Yakima, WA and one in Bradenton, FL. All experiments used Tri-Clor.

Experiment #1: The study was conducted near Phoenix, AZ on 4/13/1995. An 8.01-acre field was treated with 1375.25 pounds of Tri-Clor applied via a broadcast application. The application rate was 170.66 lb/ac. The application depth was 12.5 to 13 inches. The flux estimation technique used was the AD method.

Experiment #2: The study was conducted near Phoenix, AZ on 4/14/1995. An 8.46-acre field was treated with 728.37 pounds of Tri-clor applied via a bedded application. The application rate was 85.58 lb/ac. The application depth was 11 to 12.5 inches. The flux estimation technique used was the AD method.

Experiment #3: The study was conducted near Phoenix, AZ on 5/2/1995. A 5.92-acre field was treated with 1,123.74 pounds of Tri-Clor applied via a bedded application. A 1.5 mil polyethylene tarp was cut at 7-days. The application rate was 188.682 lb/ac. The application depth was 11 inches. The flux estimation technique used was the AD method.

Experiment #4: The study was conducted near Phoenix, AZ on 5/8/1995. A 7.97-acre field was treated with 2,662.98 pounds of Tri-Clor applied via a broadcast application. A 1 mil polyethylene tarp was cut at 7-days. The application rate was 332.121 lb/ac. The application depth was 10.5 inches. The flux estimation technique used was the AD method.

Experiment #5: The study was conducted in Yakima, Washington on 10/17/1995. An 8.35-acre field was treated with 2,857.43 pounds of Tri-Clor applied via a broadcast application. A 1 mil polyethylene high barrier tarp was cut at 7-days. The application rate was 340.84 lb/ac. The application depth was 9 inches. The flux estimation technique used was the AD method.

Experiment #6: The study was conducted in Bradenton, Florida on 1/23/1996. An 8.18-acre field was treated with 2,860.47 pounds of Tri-Clor applied via a broadcast application. A 1 mil polyethylene tarp was cut at 7-days. The application rate was 345.84 lb/ac. The application depth was 10 inches. The flux estimation technique used was the AD method.

Note: Evaluation Report indicates that the experiments met acceptance criteria, but experiments performed in AZ (Experiments #1-4) were removed from past analyses under direction of DPR management due to applications not meeting Good Agricultural Practices (GAPs) required for compliance

with the federal label (Barry 2014). Experiment #5 is not relevant to current CA practices due to the use of high-barrier tarps. Experiment #6 is valid but uses an intermediate application depth of 25 cm, which falls between 20 cm and 30 cm depth minimums used to classify application depth. While such an application would be classified as FFM 1103 (broadcast/PE tarp/20 cm depth), the application depth of 25 cm does not provide a conservative representation of this method due to the mitigating effect of increased application depth on fumigant emissions.

Gillis and Smith 2002 (199-0093)

This study was performed in Somerton, Arizona beginning on September 3, 1997. Two 8-acre experiments were submitted as part of this study.

Experiment #1: The study was conducted in Somerton, Arizona on 9/3/97. An 8.54-acre field was treated with 1,888 pounds of Tri-Clor EC applied via a 10-inch depth bedded- drip application. The application rate was 233.64 lb/ac. The flux estimation technique used was the AD method.

Experiment #2: The study was conducted in Somerton, Arizona on 9/7/97. An 8.37-acre field was treated with 1,886 pounds of Tri-Clor EC applied via a 10-inch bedded drip application. A black embossed mulch tarp was used in this experiment. The application rate was 233.39 lb/ac. The flux estimation technique used was the AD method.

Note: Report Evaluation found data package insufficient for inclusion in flux database. In addition, untarped and deep buried drip applications are at present not allowable methods within California.

Knuteson and Dolder 2000 (50046-0153)

One 9.4-acre field near Salinas, CA was treated by drip chemigation at a rate of 75 lb/ac. Beds were covered with VIF tarp.

Note: The study was generally found to be acceptable for use in developing chloropicrin mitigation measures. However, VIF tarps are not used in California and therefore the data is not applicable to current practices.

Rotondaro 2009 (199-0131)

This study includes one experiment performed near Yuma, AZ.

Experiment #1: This study evaluated buried drip chemigation of CP into untarped raised beds at an application rate of 70.8 lb/ac.

Note: Study not relevant to current practices within CA as buried drip is not an approved method distinct from surface drip application.

Rotondaro and Rotondaro 2010 (199-0137)

Two 10-inch depth broadcast experiments were performed in Elkton, Florida on December 3, 2009.

Experiment #1: The study was conducted in Elkton, Florida on 12/3/2009. Coordinates of the field are: 29.757895, -81.482915. A 2.98-acre field was treated with 426.20 pounds of Chloropicrin 100 applied via a broadcast application. The application rate was 142.16 lb/ac. The application depth was 10 inches below the top of beds. The flux estimation technique used was the AD method.

Experiment #2: The study was conducted in Elkton, Florida on 12/3/2009. Coordinates of the field are: 29.757895, -81.482915. A 2.98-acre field was treated with 493.80 pounds of Pic Plus applied via a

broadcast application. The application rate was 154.77 lb/ac. The application depth was 10 inches below the top of beds. The flux estimation technique used was the AD method.

Note: Evaluation Report supports the study, but untarped methods of less than 30 cm depth are not permitted in California. No soil moisture data was collected prior to application.

Table 1. Summary of experiments representative of current chloropicrin application methods in California

Reference	Study	Study ID	Exp. No.	Application Date	Location	Fumigation Method	Depth (in)	Broadcast Rate (lb ac^{-1})	Tarp	Tarp Cut (day)	Monitoring Days
1	Ajwa and Sullivan 2010a	123-0220	1	6/8/2009	Wasco, CA	Shank (Noble Plow), Shallow, Broadcast	12	189.1	PE	7	13
2	Ajwa and Sullivan 2010a	123-0220	2	6/8/2009	Wasco, CA	Broadcast	12	180.3	TIF	7	13
3	Ajwa and Sullivan 2010a	123-0220	4	6/8/2009	Wasco, CA	Deep, Strip	18	101.3	TIF	7	13
4	Ajwa and Sullivan 2010a	123-0220	5	6/8/2009	Wasco, CA	Broadcast	18	181.1	TIF	7	13
5	Ajwa, et al. 2010	199-0143	1	11/17/2009	Fort Pierce, FL	Broadcast	8	254.8	HDPE	No Cut	10
6	Ajwa, et al. 2010	199-0143	2	11/17/2009	Fort Pierce, FL	Broadcast	8	230.4	HDPE	No Cut	10
7	Ajwa, et al. 2012	50046-0198	1	6/4/2011	Lost Hills, CA	Broadcast	12	342.6	TIF	16	18
8	Ajwa, et al. 2012	50046-0198	2	6/4/2011	Lost Hills, CA	Broadcast	12	328.3	TIF	10	12
9	Ajwa and Sullivan 2010b	199-0142	1	9/10/2009	Ventura County, CA	Broadcast	12	145.4	PE	6	13
10	Ajwa and Sullivan 2008	199-0130	1	5/28/2008	Wasco, CA	Broadcast	12	356.9	PE	5	14
11	Ajwa and Sullivan 2008	199-0130	3	5/28/2008	Wasco, CA	Broadcast	12	197.0	N/A		14
12	Ajwa and Sullivan 2008	199-0130	4	5/28/2008	Wasco, CA	Broadcast	18	320.3	N/A		14

13	Ajwa, et al.,2009	52971-0112	2	2/7/2009	Tifton, GA	Bedded	8	64.6[a]	LDPE	No Cut	10
14	Ajwa, et al. 2009	52971-0112	3	2/7/2009	Tifton, GA	Bedded	8	67.4[a]	LDPE	No Cut	10
15	Ajwa 2010	199-0136	1	9/7/2007	Salinas, CA	Chemigation/Drip	0	200	LDPE	No Cut	5
16	Ajwa 2010	199-0136	2	9/7/2007	Salinas, CA	Chemigation/Drip	0	200	TIF	No Cut	5
17	Rotondaro 2004	199-0112	1	8/27/2003	Salinas, CA	Chemigation/Drip	0	148.7	LDPE	10	12
18	Wesenbeeck and Phillips 2000	50046-0152	1	12/5/1999	Coffee County, GA	Chemigation/Drip	0	48.18[b]	PE	No Cut	14

a. Rate calculated from total mass CP applied (field 2 = 59.22 lb, field 3 = 67.41) and total field area (bed + furrow, field 2 = 0.917 acres, field 3=1.00 acres) based on reported bed width, number, and length. This contrasts with the study report which describes application rate based on treated area only (based on combined area of bed tops).
b. Rate calculated based on total mass CP applied (394.3 lb) over total field area (bed + furrow) subtracting access roads (total bed + furrow area = 8.12 acres).

Table 2. Emission fraction (EF), 8-hr peak flux, and 24-hr peak flux for each of the studies included in Table 1.

Reference No.	Study	FFM Code	Emission Fraction	8-hr Peak Flux (ug m^{-2} s^{-1})	24-hr Peak Flux (ug m^{-2} s^{-1})
1	Ajwa and Sullivan 2010a	1202	0.16	27.63	17.28
2	Ajwa and Sullivan 2010a	1242	0.08[a]	11.75	4.57
3	Ajwa and Sullivan 2010a	1249	0.12[a]	2.29	4.09
4	Ajwa and Sullivan 2010a	1247	0.06[a]	5.90	3.26
5	Ajwa, et al., 2010	1103	0.35	45.64	30.97
6	Ajwa, et al., 2010	1103	0.44	41.28	32.43
7	Ajwa, et al., 2012	1242	0.05	6.46	3.59
8	Ajwa, et al., 2012	1242	0.04	5.12	3.61

9	Ajwa and Sullivan 2010b	1202	0.12	8.31	5.14
10	Ajwa and Sullivan 2008	1202	0.48	70.73	44.05
11	Ajwa and Sullivan 2008	1201	0.47	54.30	40.70
12	Ajwa and Sullivan 2008	1206	0.46	69.00	53.40
13	Ajwa, et al., 2009	1106	0.20[b]	11.65	8.98
14	Ajwa, et al., 2009	1106	0.18[b]	12.24	10.53
15	Ajwa 2010	1209	0.44[c]	75.95	45.16
16	Ajwa 2010	1259	0.03[c]	5.27	3.5
17	Rotondaro 2004	1209	0.16	48.6	22.33
18	Wesenbeeck and Phillips 2000	1209	0.11	7.33	5.15

a. Tarpcut for TIF earlier than required by current regulation; EF not representative of current conditions. However, period of peak flux does not coincide with tarp cut period and peak 24-h flux values may be considered representative.

b. EF calculated from total emissions, reported application rate, and total field acreage differs from reported in original study report; see text.

c. Length of study 5 days; EF likely not representative or comparable to other studies.

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