Department of Pesticide Regulation
Environmental Monitoring Branch
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Study # 307: Measurement of airborne drift of the insecticide Imidacloprid as applied by an unmanned aerial vehicle

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1 Introduction

Unmanned Aerial Vehicles (UAVs) are remotely-piloted aircraft with no pilot on board. Section 333 of the Federal Aviation Administration's (FAA) Modernization and Reform Act of 2012 allows for UAV manufacturers to petition the agency for exemption from several elements of the Federal Aviation Regulations prior to the introduction of broader regulation governing the certification and operation of UAVs in national airspace. The Yamaha Corporation's R-MAX® II remotely-operated helicopter was approved under Section 333 in May 2015, making it the largest and heaviest UAV approved for civilian use so far, and the first with the ability to perform aerial applications of pesticide (U.S. FAA 2015). UAVs such as the R-MAX® II may eventually be used to perform aerial applications in situations where the use of traditional aircraft is infeasible, or where ground-based means of application are undesirable (e.g. due to soil compaction) or dangerous (e.g. due to steeply sloped land).

The Department of Pesticide Regulation (DPR) proposes to assess the airborne drift characteristics resulting from UAV aerial applications over a vineyard. Data collected in this study will support pesticide drift modeling efforts. Together with the results of similar drift studies in orchard and flat ground, the combined dataset will improve understanding of the differences in airborne drift that may occur with crop type and droplet size spectra and may inform the development of new regulatory standards for UAV pesticide applications.

2 Objectives

This study will focus on the measurement of primary spray drift of imidacloprid resulting from an aerial spray application delivered by the Yamaha R-MAX UAV over a vineyard, using both mass deposition sheets and air samples.

3 Personnel

The Environmental Monitoring Branch (EM), under the supervision of Edgar Vidrio, project supervisor, will conduct this study. The study will be carried out concurrently with a worker exposure study conducted by DPR's Worker Health and Safety division. Members of DPR's Enforcement and Human Health Assessment branches may also advise and review. Dr. Ken Giles of University of California at Davis will advise and assist in the logistics of the R-MAX® II aerial spray, including the use of the R-MAX® II and the services of a certified pilot and spotter.

- Project supervisor: Edgar Vidrio
- Project leader: Colin Brown
- Field Coordinator: Chris Collins
- Lab Liaison: Sue Peoples
- Staff: EM Staff
- Other: Dr. Ken Giles (UC Davis), DPR Worker Health and Safety Branch, DPR Enforcement Branch, DPR Human Health Assessment Branch

All questions concerning this project should be directed to Edgar Vidrio at (916) 323-2778 or Edgar.Vidrio@cdpr.ca.gov.

4 Study Plan and Sampling Methods

We will conduct air and mass deposition monitoring using methods developed by our partner laboratory at the California Department of Agriculture (CDFA) Center for Analytical Chemistry. Methods for air monitoring are similar to those used in previous DPR studies measuring aerial concentration of pesticides near fumigated fields. The methods for mass deposition have been widely employed in the broader scientific literature for measurement of drift from airplane, helicopter, and ground applications.

4.1 Site Description

The study will take place on land owned by the University of California at the Oakville Experimental Vineyard in Oakville, CA. The site is located in a valley with hills immediately (<1 mile) to the east and southwest. Wind at the site during September typically comes from the southeast (Figure 2). The layout of the vineyard will not allow for sampling from all edges, and instead samples will be collected in the expected downwind direction at the time of application. The application and monitoring areas are indicated in Figure 1. This site will allow for sampling of at least 150 feet downwind along the expected axis of wind movement and along bearings of ±30° from this axis.

The spray area will consist of an approximately 2-acre block of grapevines measuring 311 feet by 291 feet. The shorter side will form the upwind spray zone, or fetch. The vines in this area have been trellised and measure approximately 7 feet tall. The downwind monitoring location indicated in Figure 1 is a recently-planted block of grapevines measuring 240 feet by 300 feet. The plants and trellises in this area measure approximately 2.5 feet above ground level and will require elevated deposition platforms.

4.2 Application Equipment and Methodology

The study will focus on the use of the active ingredient (AI) imidacloprid, a systemic neonicotinoid insecticide, applied with a fine droplet spectrum. Imidacloprid is moderately toxic to humans via ingestion and may result in acute symptoms including fatigue, cramps, and muscle weakness. Imidacloprid is very low volatility and inhalation of aerosols is not expected to be a major source of exposure, while exposure to contaminated dust may pose somewhat of a greater risk. Imidacloprid is extremely toxic to honeybees, beneficial insects, and aquatic invertebrates. The pesticide is not phytotoxic when used to specifications.

The product (Bayer Leverage® 360) is co-formulated with the insecticide β-cyfluthrin, a pyrethroid. Although it will be applied as part of the co-formulation, air concentrations and deposition of β-cylfluthrin will not be measured. β-clyfluthrin has low toxicity in humans, but exposure may cause skin and eye irritation. β-clyfluthrin is highly toxic to bees and other beneficial insects, and is highly toxic to fish and aquatic invertebrates.

Dr. Ken Giles and the UAV piloting team will be responsible for the operation of the UAV and related logistics. The UAV will first complete two initial passes ('pillow passes') perpendicular to the planned spray flight line, after which the passes will proceed along the planned path, oriented northwest-to-southeast and perpendicular to the vine rows and approximately perpendicular to wind direction. The estimated flight time for aerial spraying of a 2-acre plot is 1 hour. Details regarding the configuration of the R-MAX® II are described in Table 1.

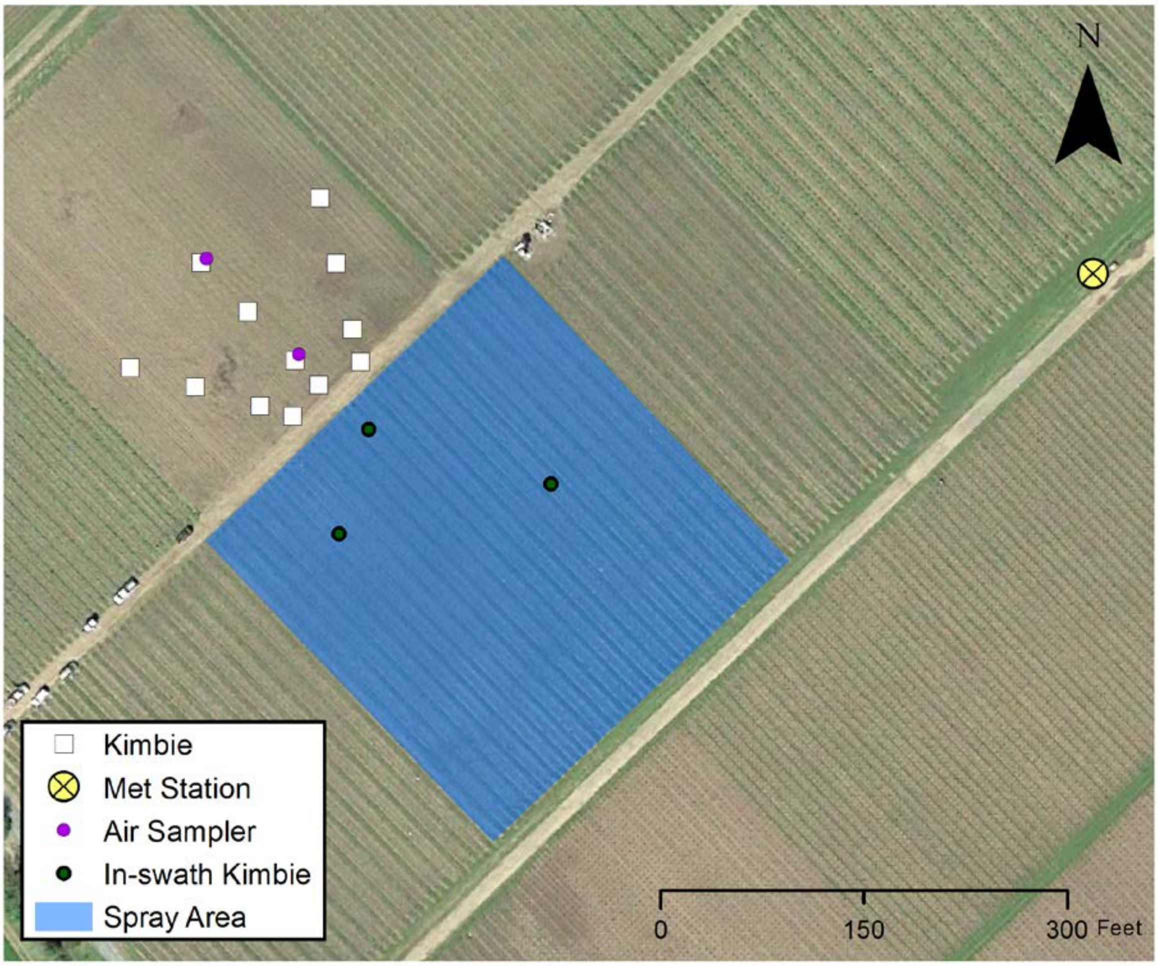

Figure 1: Layout of the proposed study. The spray block consists of 2 acres of mature grapevines trellised to a height of 7 feet. Monitoring will occur downwind of the spray zone in a recently planted field to the northwest of the spray block.

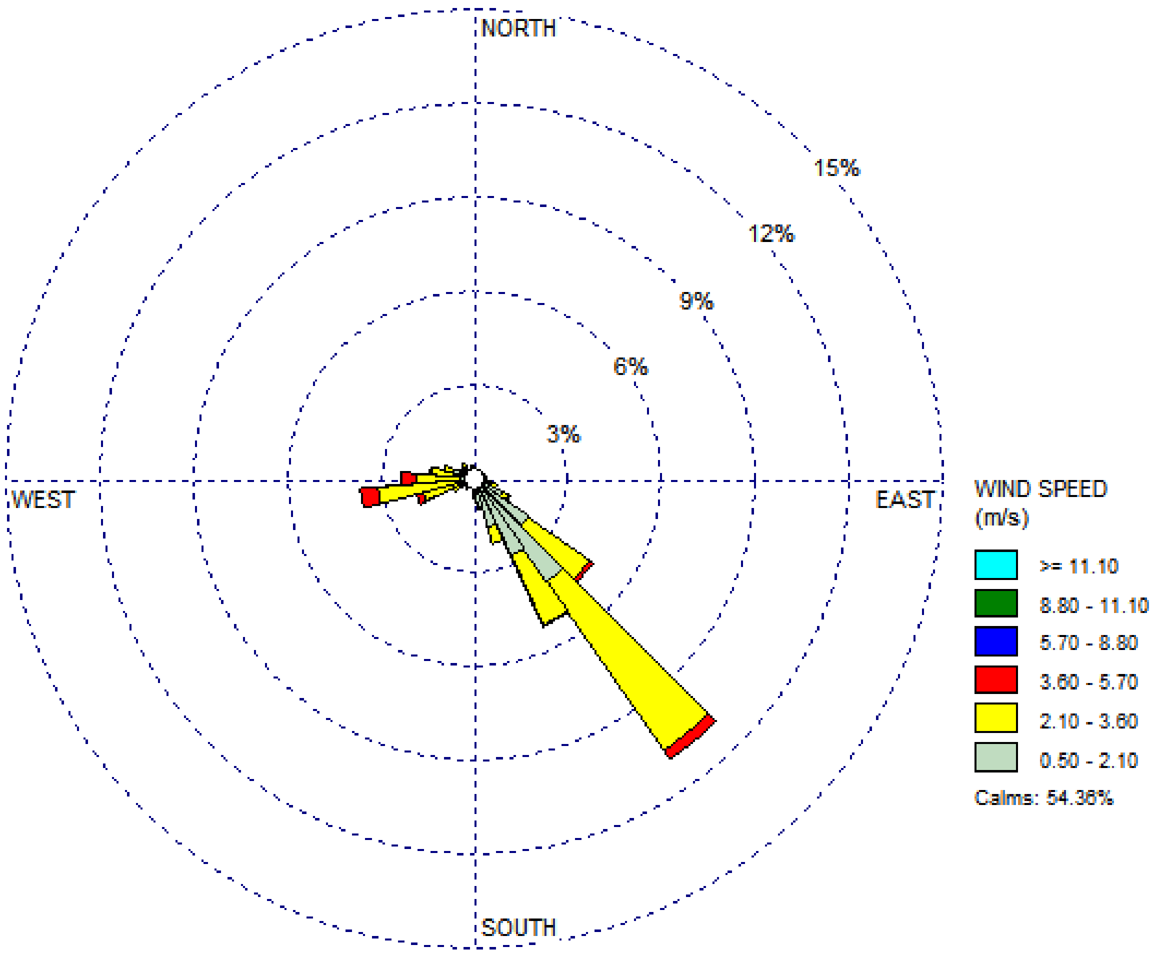

Figure 2: Wind roses for September wind patterns at CIMIS weather station #77, located in Oakville. The weather station is located on the Oakville Experimental Vineyard property approximately 0.75 mile northwest of the intended spray location.

Table 1: Summary of UAV and application characteristics for use in the proposed study.

Characteristic	Specification
UAV Model Type	Yamaha R-MAX II
Nozzle Flow Rate	1 ga/min
Application Height	8 feet above canopy
Application A.I.	imidacloprid, β-cyfluthrin
Application Product	Bayer Leverage® 360 (21% imidacloprid, 10.5% β-cyfluthrin)
Application Rate	6.4 oz/acre (0.10 lbs/acre imidacloprid, 0.05 lbs/acre β-cyfluthrin)

4.3 Sampling Methods

4.3.1 Air Sampling

Each air sampling station will consist of an SKC AirChek HV30 sample pump (SKC # 228-030), automotive battery, attachment hardware, plastic tubing, a pre-packed XAD-4 resin sample tube, and a stake to secure the assembly to the ground. Stakes for each air assembly will be placed on the day prior to the study to minimize setup time on the morning of the aerial spray. Air sampling assemblies will collect air from 5 feet above ground level.

Air samples will be collected in two intervals: a 24-hour background sampling phase, and an application sampling phase. A total of 3 air samples will be collected: one sample to measure background levels of imidacloprid prior to the application, and two for the treatment period. Two spiked samples (trip spikes) and one trip blank will be added for quality assurance and quality control (QA/QC) purposes.

Operation and calibration of the sampling equipment will follow those procedures outlined in Standard Operating Procedure (SOP) EQAI001.00 (Wofford 2001). Pumps will be calibrated to a flow of 2L/min and the exact flow rate recorded at the beginning of sampling. Time of activation and deactivation of each pump will be recorded. The sampling period for the aerial spray will begin approximately 30 minutes prior to the application to allow adequate time for flow measurement and calibration flight of the UAV. Sampling pumps will be manually deactivated following a 30-minute waiting period following completion of the aerial spray. Total runtime will be approximately 90-minutes per sample.

Air samples will follow chain of custody (COC) procedures as described in DPR's SOP FSAI001.01 (Ganapathy 2003). COCs will additionally include information on study number, pump flow rate, sample start time, sample end time, sample identification number, and sample location. Sorbent tubes will be capped upon sample collection and stored on dry ice in an insulated container. Additional details regarding the packing and transport of field samples are detailed in SOP QAQC004.01 (Jones 1999). Samples will follow COC procedures described in SOP ADMN006.01 (Ganapathy 1997) and receipt log-in and verification procedures described in SOP QAQC003.02 (Ganapathy 2005).

4.3.2 Mass Deposition Sampling

We will perform deposition sampling using a 1000 cm^2 mass deposition sheets (MDS) cut to a size of 40 cm by 25 cm. MDS construction consists of plastic-backed paper towels attached to a corrugated cardboard mount using clips or thumbtacks, which is then secured to a fixed object with the absorbent material facing upwards. Each MDS will be labeled with a unique identifier that will allow tracking of its location relative to the field and its relation to any co-located air samples. We will also submit one trip blank and two trip spikes for QA/QC purposes. Additional details regarding the construction, use, and transport of MDS are described in DPR's SOP FSOT005.00 (Walters 2003), and COCs will be completed following the directions specified in SOP ADMN006.01 (Ganapathy 1997).

Downwind deposition sampling will take place in a newly-planted vineyard. There are various low-lying obstacles in the vineyard (grape trellises and vines) that will necessitate raising the deposition samplers to the level of the surrounding obstacles in order to minimize sampling interference. Four stacked cinder blocks measuring 6”x8”x16” will be used to raise samplers to 24” above ground level, approximately level with the height of surrounding obstacles. The cinder blocks that serve as the foundation of each MDS assembly will be placed on the day prior to the aerial spray. Mass deposition sheets will be placed on cinder blocks on the morning prior to application and collected alongside the cinder blocks following completion of the application.

Three in-swath samples will be retrieved from the one-acre treatment area. In-swath samples will be set to the height of the surrounding canopy, approximately 6 feet above ground level and placed in-between rows. In-swath samplers will consist of a kimbie clipped or pinned to a cardboard sheet interlaced with two lengths of wire and suspended at tension between grape trellis wires. Two small turnbuckles will be used to adjust tension of the suspension wires in order to minimize movement of the assembly when subject to powerful downwash forces.

Each collected MDS will be wrapped in aluminum foil and placed into a labeled envelope prior to storage in an ice chest with dry ice. Samples will be held in cold storage until delivery to the CDFA laboratory for analysis.

4.4 Meteorological Data

We will assemble a MetOne® meteorological station adjacent to the study plot at least one day prior to the beginning of the aerial spraying, with the main instrument assembly at a height of 30 feet. This mobile weather station collects data on wind direction, wind speed, temperature, solar radiation, and relative humidity. We will pair each weather station instrument to a Campbell Scientific CR 21X data logger, which will record data as a 1-minute average of 1-second instantaneous readings for all instruments excluding wind direction, which will instead use instantaneous measurements once every minute. The approximate location of this meteorological station is indicated in Figure 1.

CIMIS station #77 is located approximately 0.75 mile to the northwest of the proposed spray area on a different property of the Oakville Experimental Vineyard. The CIMIS station can provide hourly summaries of several meteorological parameters including solar radiation, wind speed, and wind direction and data from this station has informed our understanding of seasonal wind patterns in the area (Figure 2). However, the 30-minute spray duration will limit the usefulness of CIMIS data for the purposes of modeling spray drift in the analysis phase of the project.

4.5 Chemical Analysis

Air and mass deposition samples will be analyzed by the CDFA Center for Analytical Chemistry (CAC). Quality assurance and quality control for laboratory methods will follow the standards outlined in SOP QAQC001.00 (Segawa 1995). CDFA CAC will validate methods to analyze air and mass deposition for imidacloprid. CDFA CAC is also developing methods to analyze cloth samples, which is relevant for the completion of a worker exposure study conducted concurrently with the present study.

5 Data Analysis

5.1 Air Concentration and Mass Deposition Calculations

Chemical analysis of field samples provides a result of weight of pesticide analyte per sample (sorbent tube or kimbie). We will determine the air concentration of AI resulting from downwind primary drift by multiplying the weight of analyte per sample by the volume of air pulled through the sample medium over the duration of the sampling period.

Air concentrations will be reported in nanograms per cubic meter (ng/m^3). Deposition results will be reported in $mg/1000cm^2$ (the area of each kimbie), as well as a percentage of the measured in-swath deposition for imidacloprid applied at 0.1 lb/acre.

5.2 Drift Transport Modeling

Data collected in this study will be evaluated using the AGDISP aerial application model. AGDISP is a physics-based model designed purposely for the prediction of spray drift from aerial applications. The model will be evaluated based on the level of over- or under-prediction as compared to the deposition results. Graphical methods including quantile-quantile plots may be used to compare the predicted and actual distributions of deposition over distance.

6 Timetable

Up to nine months will be required to take the study from the end of the field sampling phase to the end of the report preparation phase.

References

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