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Web Application for Managing Insecticide Resistance of Mango Pests in the Philippines

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Abstract

Insect pests in mango farms in the Philippines are commonly managed using commercial insecticides. However, insecticide overuse and lack of knowledge on proper insecticide usage by farmers results in increased insecticide resistance and limits the effectiveness of these chemicals. This study introduces an interactive, online tool that will provide custom advise on how to plan insecticide usage based on conditions specific to a farm. The tool visualizes and evaluates the insecticide usage in a farm's growing season, then suggests a future course of application with the goal of delaying, if not preventing the development of insecticide resistance in the farm's pest population. The application was tested by government agricultural officers who have experience in managing mango farms as well as training and working with mango farmers. It received a good usability score of 74.3, using the System Usability Survey.

Keywords: integrated pest management, chemical control of pests, pest management software, responsive web application

Introduction

Pest management is one of the biggest challenges faced by mango farmers in the Philippines [1]. The three main insect threats are cecid flies (*Procantarinia sp.)*, mango thrips (*Scirtothrips dorsalis* and *Thrips hawaiiensis)*, and mango leaf hoppers (*Idioscopus clypealis*). To control these threats, mango farmers rely heavily on the application of pesticides [2, 3]. Unfortunately, it has been noted that pesticides are often misused due to lack of knowledge on their proper application [3]. This has led, in turn, to increased resistance in the pest population, which is characterized by more insects surviving the same rate and frequency of application of the same chemical [2].

To promote proper insecticide use, the Agricultural Training Institute has been conducting training sessions to teach farmers how to manually track their insecticide usage and aid them in planning their farming seasons. Despite these efforts, high infestations of pests and insecticide misuse have still been reported in recent years [4, 5, 6, 7]. There is, thus, a need to explore additional or alternative mediums by which to inform and train more farmers on proper insecticide use. Awareness is particularly important, as most mango production in the country is small-scale [1, 3], and farmers might not have access to the knowledge and techniques employed in large-scale farming. The widespread dissemination of knowledge is also critical for the success of pest management in the whole mango industry. As noted in the case of insecticide resistance in thrips (though in onions instead of mangoes), the failure of other crop growers to implement effective insecticide resistance strategies may yet jeopardize the efforts of those who do [8].

The web can be utilized to increase mango farmers' access to valuable information on the proper use of insecticide. To this end, this study is designed to create and evaluate a web application that will provide a free and accessible resource for farmers to plan their insecticide usage, with an emphasis on managing insecticide resistance. The projected end-product is an online, interactive tool that will allow mango farmers to enter and visualize their insecticide usage practice throughout their farming season. The application will then generate an assessment of the insecticide management practices specific to a farm and a guideline on what to do in future farming seasons based on the principles of rotating different classes of insecticides and using the minimum necessary dosage.

The rest of the paper is organized as follows. Section 2 is a brief background on the insecticide classification scheme and how rotation is used to prevent the build-up of resistance. Section 3 describes the developed system and its features. User testing and results are discussed in section 4. Finally, section 5 concludes the study

Managing Insecticide Resistance

The basis of the insecticide resistance rules to be used by the application's evaluations and recommendations is the Mode of Action (MoA) of a given insecticide as classified by the Insecticide Resistance Action Committee (IRAC). IRAC is a technical group that promotes insecticide management knowledge and technologies, with a goal of addressing or delaying the onset of resistance in insect and mite pests [9].

IRAC's MoA classification scheme is based on available evidence for the target-sites of currently available insecticides. This classification has been reviewed and approved by internationally recognized academic and industrial experts in insecticide toxicology and resistance [10].

The MoA of an insecticide is the mechanism by which it acts on the insect. For example, some insecticides attack a pest's nervous system, some disrupt their growth cycle, some inhibit respiration, etc. IRAC's recommendation is to switch to a different insecticide every breeding window of the insect pests present in the farm. The new insecticide should not just be a different brand or have different active ingredient; its active ingredient should also have a different Mode of Action from the insecticide used previously. It should be noted that different insecticides may have similar MoA, even if they have different active ingredients.

The rationale for the switch in MoA is that the next generation will exhibit increased resistance to the previously used MoA, and thus a different one should be used for the new generation. The overall goal is to prevent compounded resistance build-up from repeated use of the same MoA. There are currently 32 groups of MoA classified by IRAC [11], but commercial mango insecticides collectively do not make use of this entire available range of choices.

Several other factors may also come into play. More than one type of pest may be present in a farm, each with different windows of time within the mango farming season in which they breed. Each pest may have different applicable insecticides, which may or may not have the same Mode of Action.

The growth period of mango fruits is about 120 days after flowering is induced. If insecticides are to be used, their application starts ten days after induction. The fruits may be harvested at the end of this 120-day period or a few days before it ends. Prior to harvest, farmers make use of insecticides and/or bagging. The dilemmas faced by farmers are: Which insecticides to use, when and how to use them, how long to wait before switching to a different insecticide, and which insecticide to switch to.

IRAC has a mobile app for Android and iOS. The app explains the concepts of MoA and the importance of alternating between them. It also has a list of MoA classifications, but which otherwise functions only as a handy reference list.

System

The system was created using web technologies, namely, Node JS, React JS, and

Mongo DB. These were chosen for their speed and for being lightweight, which is important for the Philippine demographic where smartphones are ubiquitous, but high-speed Internet connection is not guaranteed. React JS was used to create the front-end interface, and Node JS was used for the back-end web server where all the analyses and recommendations are generated. The system was deployed in a Digital Ocean Server.

The application is accessible at https://mango-irm.com/ and can be viewed and used with either a desktop or mobile browser.

Worksheet

The worksheet is the interactive part of the web application. Here, the user is required to fill up the worksheet to receive feedback for their past practices and a recommendation for future farming seasons. The worksheet is divided into three parts: Pests, additional options, and insecticide usage.

Pests

The user is presented with a list of pests. Images and local/common names are provided. The user is required to select at least one pest present in the farm. There is no limit to the number of pests that can be selected.

Additional Options

In the additional options, the user must indicate if bagging was done during the farming season. Bagging is the practice of wrapping the fruits a certain number of days after flowering until harvest time.

Insecticide Usage

In the final part of the worksheet, the user is presented with a spreadsheet-like interface where insecticide usage within the growth period can be indicated. The cells range from 10-120 days after flower induction, in increments of two days (each cell representing two days). Usage information includes: The brand, which the user selects from a drop-down list; and the dosage in numerical terms and units. Units are pre-selected based on the insecticide chosen, and are limited to grams, milliliters, and sachets.

Users select a brand of insecticide, which is visualized in the cells as colors representing the MoA as seen in Figure 1. Multiple insecticide brands may share the same active ingredient and MoA, thus a period of using different insecticide brands may still be visualized as a single color. This design is intentional to emphasize the importance of using varying MoA. The application adopts the same color scheme used in live training sessions with farmers about IRAC MoA classifications so as to promote standardization.

Users can create new rows in the worksheet in case two or more insecticides are used on the same day.

The controls of the worksheet are responsive and made with both desktop and mobile users in mind. The controls transition to touch scrolling in small screens for ease of mobile use.

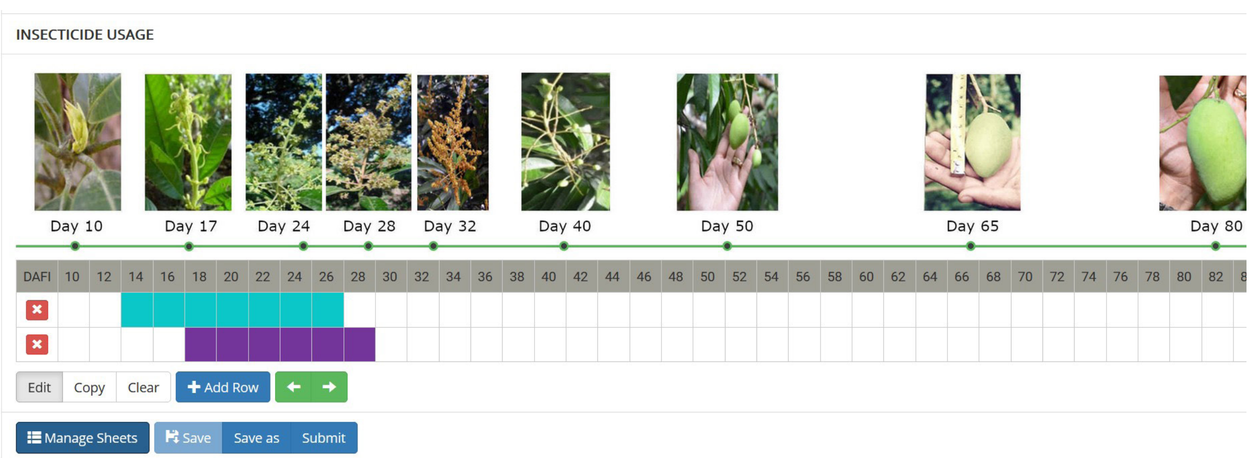


Figure 1. The spreadsheet interface indicates insecticide usage. Usage is represented by the MoA of the insecticide.

Usage Analysis and Recommendation

Once the user submits their completed worksheet, the system will generate an analysis and recommendation. The analyses and recommendations generated take into account the rules which are held by the system (which can be customized), and the practices unique to the user.

Users feed the system with information about their previous farming season: The pests encountered, bagging practices, insecticides used, in what amounts, and on which days. The system has a list of registered insecticides and pests. The two sets of data are cross-referenced to produce analyses on the following areas:

- Dosage. Farmers may be using too little or too much of an insecticide. This is presented in the spreadsheet as either an overdose or underdose (Figure 2). It is also presented in text form in the analysis list (Figure 3)
- Usage Range. Insecticides have a day of earliest allowable usage, which is a minimum number of days after flower

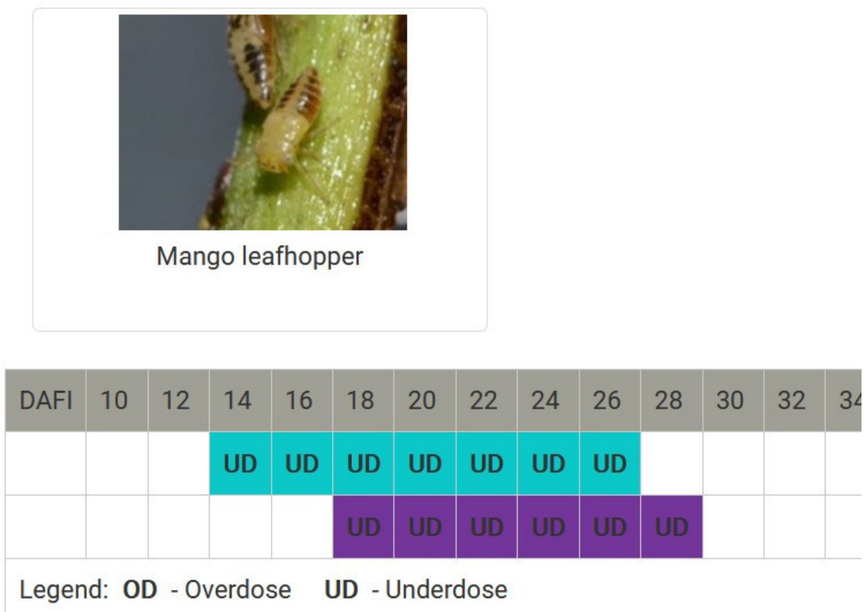
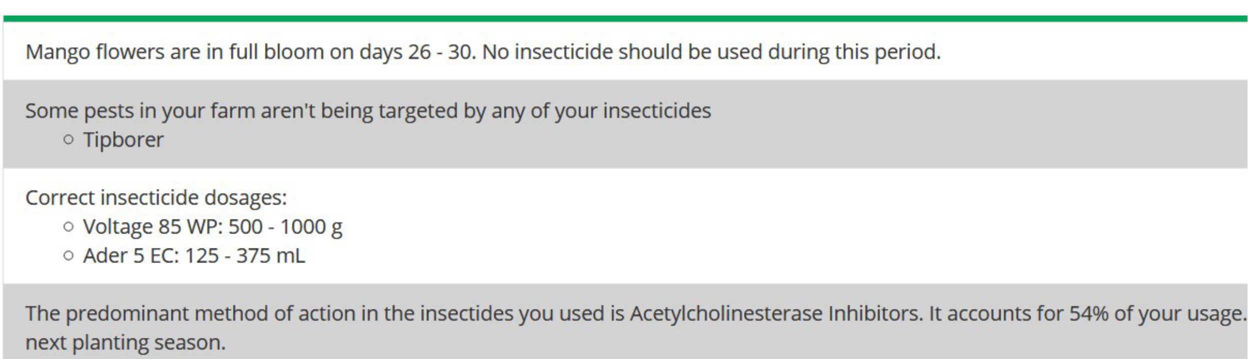


Figure 2. The usage chart indicates if the dosages used are above or below the recommended values.


Mango flowers are in full bloom on days 26 - 30. No insecticide should be used during this period.

Some pests in your farm aren't being targeted by any of your insecticides
- Tipborer

Correct insecticide dosages:
- Voltage 85 WP: 500 - 1000 g
- Ader 5 EC: 125 - 375 mL

The predominant method of action in the insectides you used is Acetylcholinesterase Inhibitors. It accounts for 54% of your usage. next planting season.

Figure 3. Overdosage or underdosage are also presented in text form, along with other notes on the insecticide usage.

induction that must pass before it can be used. There is also a pre-harvest interval (PHI), which is the number of days before harvest time that the insecticide should not be used anymore. This corresponds to the number of days it takes for the insecticide on the plant to reach innocuous levels, making the fruit safe for consumption.

- Superfluous insecticides. Farmers might be using insecticides that are not applicable to any of the pests they indicated in the worksheet.
- Untreated pests. Farmers may be failing to use insecticides to target a pest that they selected in the worksheet.

In addition to analyzing the previous practices, the system will suggest a course of action for a future farming season. The assumption is that the inputted data is from the previous farming season, so the system will avoid recommending similar Modes of Action.

As seen in Figure 4, the recommended course of insecticide usage is presented in the same spreadsheet format used in the worksheet, so that users will be able to cross-reference the two more easily. The system will recommend a MoA for a particular period instead of a specific brand to avoid unfair endorsement. Insecticide manufacturers are required to put their Mode of Action on their packaging. The system's recommendations will only help users make more informed purchases.

There are two versions of the generated recommendations. The insecticide usage for the first is cut short by a bagging period that lasts until the harvest date. Bagging is recommended for economic reasons. A second recommendation without bagging is also provided. This alternative continues the insecticide usage schedule according to the parameters of present pests and previously used MoA.

The recommendations include MoA that are applicable to the pests present in the farm as indicated by the user. All insect pests will be targeted, and application is recommended only on the days in the farming season when the pests are typically active. The recommended start and end dates, in accordance with pre-harvest intervals of the MoA, are observed by the system's recommendation. In addition, some parts of the calendar are blocked out to remind the farmer of the critical non-spraying days when the trees are flowering.

The site includes a reference table for the available brands of each MoA, so that the users can easily check which brands of insecticide they should acquire.

Figure 4. A sample recommendation has two versions: one with bagging and one without.

Users

The site contains informational sections with lessons about insecticide management, pest life cycles, and registered insecticides. Those sections are publicly available. However, an account, which anyone may sign up for, is needed to use the worksheet. Users who are logged in can view the worksheet tutorial, and the worksheet itself. They can also save worksheets for future use. Additionally, there is a built-in administrator account that has permission to modify the data of the system.

Content Management System

The system is dependent on its data set, which contains the rules used for cross-referencing with user inputs. Database entries on pests include their breeding windows and spraying intervals. Entries on insecticides include applicable pests, minimum and maximum dosage, units, earliest allowable usage data, PHI, etc.

The system was designed with a content management system to allow a built-in administrator account to modify certain data sets within the app. These data sets are the Insecticides, Active ingredients, Modes of Action, and Pests. This removes the need for a programmer to keep the site data updated. This is particularly important for insecticide brands. New ones may be released anytime, or existing ones may be removed from the shelves depending on government regulations.

Results of User Testing

The system was tested by 30 participants who were mostly agricultural officers (25 out of 30; 5 were businessmen who run their own farms). Agricultural officers are government employees who provide technical assistance and support to the farmers in their respective areas. One of their responsibilities is to train farmers to use, or aid them in using, tools such as the system developed in this study.

A two-hour hands-on training was conducted to introduce the system's objectives and features to the participants. They were shown the steps on how to input insecticide usage and how to interpret the results. They created accounts where they inputted insecticide usage scenarios similar to the ones they encounter in their line of work. Given the inputs, the system provided them with insecticide usage recommendations for the next planting season.

After the activity, the participants were asked to answer a survey in order to gauge the usability of the system as well as to gather feedback on this. The System Usability Scale (SUS) [12] was used for the survey. This consists of ten Likert Scale questions as follows:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

The survey alternately asks about opinions on positive and negative qualities, so ideal answers would also alternate between 'strongly agree,' and 'strongly disagree.' The score calculation takes this into account by normalizing the score from each item so that higher values are better regardless of the question. The resulting score, taking into account all the questions, is a number between 0-100. A score between 51 and 68 is considered 'Poor,' between 68-80.3 is 'Good,' and greater than 80.3 is 'Excellent.'

Based on the collected data from the participants, the average usability score was 74.3, which is classified by the SUS as 'Good.' The SUS results in a single usability score from each participant who filled out the survey, but the average score per item can also be looked at for more insight into which usability aspects of the system are excellent or needs improvement.

As seen in Figure 5, Item 1 received the highest average score, normalized at 89.5 out of 100. Item 4 received the lowest average score at 51.6. These findings agree with the remarks made by the participants: First, that there is a great need for such an application in the country; and, second, that the technical aspects of insecticide management presented in the application give the impression that one needs technical support in using this. For the latter, the agricultural officers reported that many farmers may not be able to navigate the site on their own due to lack of access to an internet connection or lack of experience in using computers. Nonetheless, they still considered the system as a useful tool to aid government training activities.

Conclusion

The study aimed to create an online interactive tool that can generate insecticide usage advice specific to a mango farm. An application was developed using up-to-date web technologies and made publicly accessible online. The system is able to display a graphic of insecticide usage in a farm, assess them according to expert recommendations and guidelines, and generate custom plans for future farming seasons that rotate active ingredients, prescribe the minimum necessary dosage, and target the specific attack window of pests.

The application received favorable responses from the user-participants, and a good usability rating according to the System Usability Scale. However, the system could still benefit from further simplification of the interface and presentation of ideas via tooltips or a more detailed online guide. The current interface streamlines the process of entering and visualizing data related to insecticide usage, but the concepts behind the analysis and the interpretation made some users feel like they would need a person to guide them in using this. There is a guide included in the site, but hands-on training may be a necessity for some users.

For future work, the system can be converted into a progressive web application (PWA) for offline use, which would greatly benefit areas

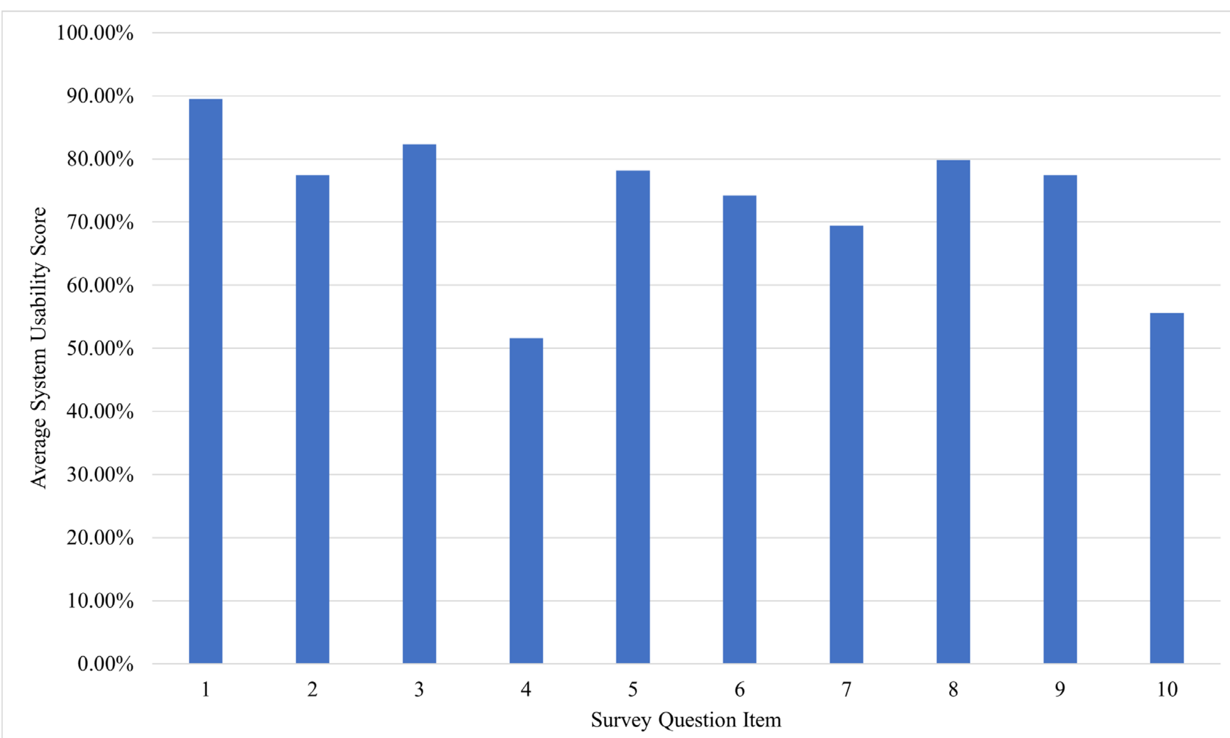


Figure 5. Average normalized scores of each survey question.

with poor Internet access. The chosen front-end framework, React JS, has support for PWAs so this would not be a complete overhaul of the system.

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