The app to optimize and to perform quality control of pesticide spray applications in strawberry and other crops.

To access latest manual version – go to: http://chrnansen.wixsite.com/nansen2/Smart Spray

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“I think Smart Spray is a very helpful tool for growers and advisers as a guide to select spray tips, spray volumes, tractor speed, and other important factors to maximize sprayer coverage. Using spray cards is the best and simplest way to know, if you are penetrating everywhere in the canopy your pest target is a problem – placing cards where the specific pests attack the host gives the best information.”

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INTRODUCTION

The California Strawberry Commission and other stakeholder organizations recognize the importance and also challenges associated with obtaining high and consistent pesticide spray coverages. Many variables are known to affect the actual spray coverage in crop fields. These include: tractor speed, spray nozzles, spray volume, boom height, adjuvants, and weather conditions. But which ones are the most important ones? And are there possible interactions among some of these variables?

With better quantitative understanding of which variables affect the spray coverage, we can optimize spray applications and therefore: 1) obtain the best possible pest control and possibly use less pesticides, 2) reduce risks of target pests developing pesticide resistance, 3) reduce risks of spray drift, and 4) optimize spray application costs by introducing a quality control procedure (Nansen & Ridsdill-Smith, 2013).

Several studies have provided insight into variables affecting pesticide spray coverage (Nansen et al., 2015; Nansen et al., 2011), and Christian Nansen led a team that used this knowledge to develop an app entitled “SnapCard”, which by July 2019 has been downloaded more than 5000 times (https://play.google.com/store/apps/details?id=com.dafwa.snapcard&hl=en_US). The accuracy of SnapCard to quantify spray coverage based on water sensitive spray cards was confirmed as being as good or better than commercially available alternatives (Ferguson et al., 2016).

Smart Spray is similar to SnapCard, but the functionalities have been vastly improved, and Smart Spray can be used for operational spray settings that are relevant and meaningful to strawberry growers in California and elsewhere.

Smart Spray is freely available for both IOS and Android app stores, and its development was partially funded by the California Strawberry Commission and from funding from the Floriculture and Nursery Research Initiative (FNRI) under United States Department of Agriculture - Agricultural Research Service.

The Smart Spray team members are three very talented computer science students from UC Davis: Krishna Chennapragada, Gabriel Del Villar, and Alexander Recalde, and Associate Professor Christian Nansen (chrnansen@ucdavis.edu) from the Department of Entomology and Nematology, UC Davis.

We would very much welcome your feedback (chrnansen@ucdavis.edu), and you can always access the most version of this manual from Christian’s website: http://chrnansen.wix.com/nansen2

Smart Spray

Floriculture and Nursery Research Initiative (FNRI)

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BACKGROUND

The figure above to the left probably reflects what many would expect regarding the relationship between spray volume and spray coverage – that the more water being sprayed, the better spray coverage. The figure top the right shows actual data on that relationship for one particular nozzle (Albuz_ATR_80_Green) during experimental spray applications in commercial strawberry fields. The figure to the right shows that both with low and high spray volumes - you can obtain a high (or low!) spray coverage. In other words, spray volume by itself is a poor predictor of the spray coverage. This is because weather conditions, tractor speed, canopy characteristics and several other parameters also influence the spray coverage. Smart Spray allows you to input and examine to what extent a range of these variables affect spray coverage. In other words, we developed regression models for each nozzle type, in which we assumed that the obtained spray coverage was a function of 14 variables grouped into three categories:

- **Strawberry field**: width of beds, rows per bed, plant spacing, plant height, and plant width.
- **Spraying**: spray volume, nozzle spacing, nozzles per bed, tank pressure, tractor speed
- **Weather**: wind gust, average wind speed, relative humidity, ambient temperature

Thus, the predictions of spray coverage are based on the overall assumption that a combination of these model parameters from your field, your spray settings, and expected weather conditions, can generate an accurate prediction of spray coverage.

During three growing seasons (2016-2018), we have collected field spray data from 19 different dates. For each date, we deployed water sensitive spray cards and collected data on all the model parameters.
Weather data were collected on-site each time we collected field spray data. After collected all the field spray data, regression models based on linear and quadratic of model parameters were developed for each of nine spray nozzles. Field spray data were collected in collaboration with different strawberry growers, in different commercial strawberry fields, and with different spray rigs. So, the data collected is believed to encompass much of the variation among growers and fields. This field sampling effort was only possible due to outstanding collaboration with Mark Edsall from the California Strawberry Commission – thank you Mark!

We have collected large and comprehensive data sets for nine nozzles, which were identified as being widely used by strawberry growers: 1) Albuz_ATR_80_Green, 2) Albuz_ATR_80_Lilac, 3) Albuz_ATR_80_Orange, 4) TeeJet_AI_9502E, 5) TeeJet_D2, 6) TeeJet_D3, 7) TeeJet_TJ60-8004, 8) TeeJet_TP8002-VK, and 9) TeeJet_XR8003-VK. In total, data from more than 5300 water sensitive spray cards have been collected, and predictive models have been developed for all nine nozzles.
OTHER PESTICIDE-RELEVANT RESOURCES
Regarding safe use of pesticides during spray applications, avoiding spray drift, and proper calibration of spraying equipment, we strongly encourage you to access other available resources – these include:

Spray rig calibration

Pesticides – general information
http://npic.orst.edu/

Safe use of pesticides during spray applications
http://ipm.ucanr.edu/IPMPROJECT/pesttrain.html

How to avoid spray drift (VERY funny as well as highly educational):
https://play.streamshark.io/r/m/bnqfcvhxz/hQ0krcKp

Pesticide regulations
https://www.youtube.com/watch?v=B6wO6Fc2epc
http://ipm.ucanr.edu/GENERAL/pesticides.html

Experts on pesticide spraying technologies
https://ucanr.edu/sites/anrstaff/Divisionwide_Programs/Workgroups/Workgroup_Directory/?thiswg=419
This manual was developed for the iOS version of Smart Spray. The Android version is slightly different and the screens may look slightly different, but this manual should still be of use to Android users, as we have included details on most of the subtle differences between the two versions.

**HOW TO DOWNLOAD SMART SPRAY?**

Smart Spray available in the iOS app store! In the app store – search “Smart Spray” and look for the following logo:

![iOS App Store Logo](https://apps.apple.com/us/app/Smart%20Spray/id1472281763)

Or follow this link: [https://apps.apple.com/us/app/Smart Spray/id1472281763](https://apps.apple.com/us/app/Smart Spray/id1472281763)

From the Google app store (https://play.google.com/store/search?q=smart%20spray&c=apps)
Once installed on your device, make sure that the camera and data storage are both turned on. You do so by going to the Settings of your device, find Smart Spray and then turn on “Camera” and “Mobile Data”.

![Smart Spray Settings](image)

We are working on an Android version of Smart Spray, and it will be made available as soon as we have it ready.
**GETTING STARTED**

Whether using iOS or Android, Smart Spray works the same way. Once installed on your smart device, we recommend that you create an account, as this will give you additional benefits. The main advantage of having an account is that you can access your data on multiple devices, and in the future we will make your data available on a private database (only you will have access to your data), which you can use to analyze your own data. More about this later – let’s get started!

When creating an account, you will be asked to enter a valid email and a password.

Smart Spray will remember these credentials, so next time you can simply log in - you don't have to provide this information every time you use Smart Spray.
OVERALL DESCRIPTION OF SMART SPRAY
You are able to use Smart Spray as often as you want and completely free of charge. If you use Smart Spray at a location where you don't have internet connection and you have an account, then Smart Spray will not be able to store your data. In a future version, it will be possible to automatically sync your saved images of spray cards and your spray predictions when you get connected again.

Smart Spray has two main functionalities, and these are available from the main menu on the tab bar in the bottom portion of the screen (“Main”):

First functionality: Predict spray coverage. Smart Spray allows you to predict pesticide spray coverage under different operational (for instance, type of nozzles, spray volume, and tractor speed) and weather (temperature, relative humidity and wind) scenarios.

Second functionality: Get spray coverage of card. Quantify spray coverage based on water sensitive spray cards that were placed in fields prior to spray applications.
HOW TO PREDICT SPRAY COVERAGE?
This is the first functionality of Smart Spray. The overall purpose of this functionality is to optimize spray applications, as it is known that even quite small differences in operational settings (spray volume, tractor speed, and nozzle type, etc) can profoundly impact the obtained spray coverage. This means that you can use this functionality to, for instance, address questions like:

1. What differences in spray coverage should I expect, if I drive 1, 2, or 3 miles per hour?
2. What differences in spray coverage should I expect, if I use 100 compared to 150 gallons per acre?

On the tab bar at the bottom of your screen, you to go “Main”, and you click “Predict Spray Coverage”.

Smart Spray enables you to predict spray coverages using one of two unit selections, “Imperial” or “Metric”. Due to rounding of coefficients, the two units do not produce exactly the same prediction values, but they are VERY similar!
Model parameters are divided into three groups: 1) “Strawberry field” - characteristics related to the size and depth of the strawberry canopy 2) “Spraying” – parameters related to the operational settings and nozzles, and 3) “Weather” – the weather conditions.

For each model parameter, minimum and maximum values are given, and model predictions cannot be produced, if parameter values are used outside these ranges. Once values have been entered for all model parameters, the you click “Calculate” to obtain the spray coverage predictions.

After clicking, “Calculate”, the following screen shows the predicted spray coverages with the nine nozzles.

In this particular case, some nozzles were associated with a 0% spray coverage, while TeeJet TJ60-8004 was associated with a predicted spray coverage of over 70%. Thus, in this particular case, it would be recommended that the spray application was performed with TeeJet TJ60-8004.
We are very much aware that the nine nozzles are not used for the same pressures, spray volumes etc – so some of the predictions will be unrealistic. But we decided to make predictions for all nozzles each time you examine a scenario (a set of model parameters) for you to compare them directly. After viewing the predictions of a given set of model parameters, you can always go back and change the model parameters to generate a new set of predictions.

It is VERY important to remember the limitations of water sensitive spray cards – that they tend to underestimate when spray coverages are either very high and/or very low. Thus, the “exact” prediction of spray coverage is not really that important, it is more a way to compare nozzles and/or the importance of model parameters. For instance, if the prediction with nozzle “A” is twice as high as that with nozzle “B”, and you have nozzle “A’s” on your spray rig, then Smart Spray results could be used to justify switching to “B” nozzles before performing the spray application. Another example, if the spray coverage prediction is twice as high at one speed or spray volume as with different speeds or spray volume – well, then you might decide to use the operational settings that give you the highest spray coverage.

SAVE A PREDICTION

After examining different scenarios of predicted spray coverages, you can save a given prediction. This allows you later on to associate spray card data from a sprayed field with a prediction. In other words, the prediction would be your “expected spray coverage result”, and the second functionality of Smart Spray (How to get spray coverage of card?) is used to examine, as a quality control, to what extent the actual spray coverage aligned with the expected.

To save a prediction, you need to provide a name of the prediction, and you have three separate fields for you to include information of your choice, such as: 1) what field(s) the prediction will be used for, 2) who will be the spray applicator, 3) what was grown in the field and in what development stage. All these fields are optional, but in the future, we intend to add database features, so that you can use this information to study
trends in your spray applications. For instance, you will be able to examine spray coverages (predicted and actual) from different fields, by among spray applicators, during the growing season – in other words, you will be able to use your own data to identify trends and possibly improve your pesticide spray application coverages.

Once you have entered the information you want to use to describe this prediction, click “Save” and the prediction becomes available on your list of predictions.

LIST OF PREDICTIONS
You can view a prediction by selecting it from “Predictions” on the tab bar, and all information about the prediction is displayed. You delete a prediction from the list of predictions by swiping the arrow to the left, and the “delete” option appears, which you then click.
Furthermore, you can view the spray cards associated with that prediction. If the GPS was used to georeference the spray cards, then all cards associated with the prediction are visualized on a Google map. This feature allows you to visualize where in fields the spray cards were placed and potentially identify trends in spray coverages. For instance, maybe several spray cards in a portion of a field were all showing low or high spray coverage, and you can use this information to learn more about the operational practices that affect the performance of pesticide applications. This information will be of particular value, when we add database functionalities to Smart Spray.
HOW TO GET SPRAY COVERAGE OF CARD?
This is the second functionality of Smart Spray, in which the camera on your device is activated and used to take a photo of a water sensitive spray card.

On the tab bar at the bottom of your screen, you go “Main”, and you click “Take Card Photo”.

This will activate the camera on your smart device, and you need to place the card at a distance and position so that a focused photo can be taken of the spray card. The screen shots below are from the IOS version of Smart Spray.

You hold the spray card in front of your smart device, and when in the right position and distance from your smart device distance, you click the white circle to the right on the screen.
To exclude background (what is not spray card) from the image field, you use two fingers to move and enlarge the photo of the spray card, so that it fills the entire image field. Subsequently, you click “Use Photo”, and the you will obtain an estimate of the spray coverage on the water sensitive spray card.

In the Android version, the imaging of a water sensitive spray card is a little different.

First, you are asked to “OK” or “Cancel” a given photo of a water sensitive spray card. Secondly, you move the corners of the white rectangle to crop out any background and then “Accept crop”. Afterwards, Smart Spray will calculate the spray coverage.

**VERY IMPORTANT AND FOR BOTH VERSIONS:** The algorithm used to calculate spray coverage is somewhat sensitive to how the water sensitive spray cards are being imaged. Therefore, water sensitive spray cards must be imaged under similar conditions in order to get comparable results. That is, we recommend ALWAYS to image water sensitive spray cards WITHOUT direct sunlight and ALWAYS when held in a flat/horizontal position (no bending of cards and no tilting of cards).
You can save the spray card and the spray coverage estimate by clicking “Save”. A window appears, in which you can associate the spray card with an existing prediction. You would want to do that, if you wanted to compare your actual spray coverage with what you had predicted (First functionality).

You add name and descriptions to the card. You also have the option of invoking the gps on your smart device and associate the card with a geographical location. If you include the geographical location, then the spray card position will appear on a Google map.

If you have already created a prediction of spray coverage (first functionality), then you can associate the spray card with a prediction. Thus, you can directly compare your actual spray coverage with what Smart Spray had predicted based on the model parameter settings you provided.

REFERENCES