RAYN GROWING SYSTEMS

an ETC Company

RAYN Vision System Analytics Software

User Manual

Version 1.4.0

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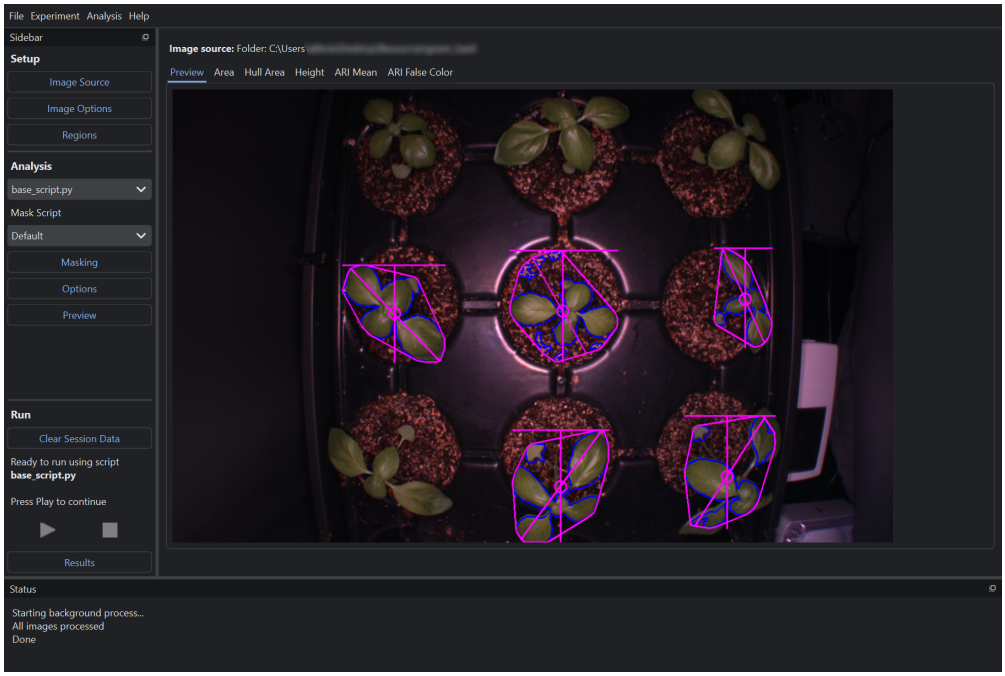
RAYN Vision System Analytics

Welcome to the RAYN Vision System v1.4.0 Analytics Software User Manual.
RAYN Vision System (RVS) Analytics is an open-source application for the processing and analysis of multispectral image cubes from multiple sources, including RVS Cameras in the same network.

Overview



The software user interface contains the following key areas:

- The horizontal bar of *Menus* in the top left.
- The vertical sidebar of *Setup* and *Analysis* options.
- The *Preview Tab* display.
- The *Status* information feed.

If a connected *RAYN Vision System Camera* is detected, its available storage will be indicated in the top right.

The pop-out buttons in the top right of the status feed and sidebar will separate them from the main application window, allowing them to be freely moved and positioned onscreen. **Status** can be docked to the software again by dragging it over the top, bottom, left, or right edge of the main window. The sidebar can be docked to the left or right. Both can be freely resized by dragging the divider icon.

The software color scheme will change to automatically match your computer's selected light or dark UI mode.

Compatibility

RAYN Vision System Analytics can be installed on computers running:

- Windows® 10 or 11.
- macOS® 11 (Big Sur) or later.

The software can also be used in conjunction with the *RAYN Vision System Camera* (RVS-C).

Installation Instructions

To install or update RVS Analytics on a compatible computer, you will need to acquire the software from our website, rayn.ag. Follow the instructions below to install or update the software.

1. If the installer has been provided as a zipped archive, unzip the file.
2. Double-click the installer. The RAYN Vision System Setup window will appear.
    a. macOS will block the installer when first opened. Permit the installation by opening **System Settings > Privacy & Security**, scrolling down to **Security**, and selecting **Open**. Select **Open Anyway** in the pop-up window and enter your password.
3. Follow the Setup prompts to begin software installation.
4. Click **Finish** when prompted. The software is now ready to use on your computer.

As installations of RAYN Vision System Analytics Software will not uninstall or overwrite older versions, it is possible to have multiple versions installed. You may uninstall versions as desired.

Resources

For more information about this RVS Analytics software release, see the *RAYN Vision System Analytics v1.4.0 Release Notes*. For more information about the *RAYN Vision System Camera*, see the *RAYN Vision System Camera Setup Guide* and *RAYN Vision System Camera Firmware Release Notes*.

User documentation and technical support are available via our website, rayn.ag, or by contacting your RAYN Growing Systems provider.

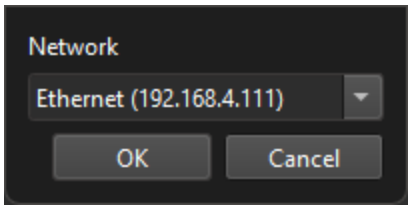
RVS Analytics is open-source software. Visit our Github page, github.com/rayngrowingsystems/rvs_analytics, to download the latest code and submit feature requests to the repository.

Menus

The drop-down menus in the top left provide options for managing key settings and files.

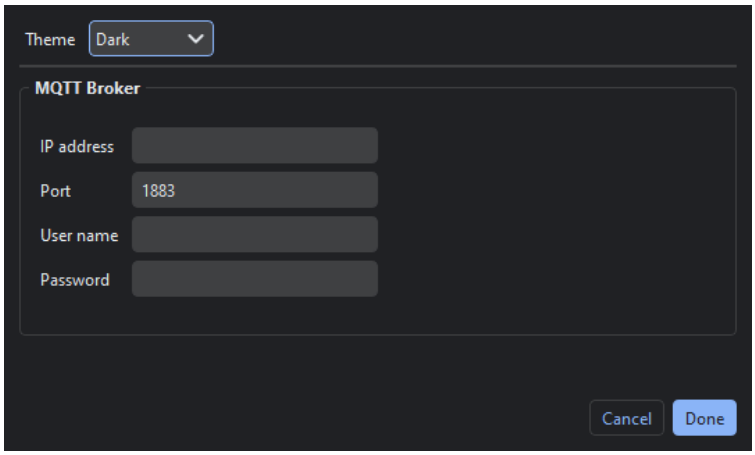
File

Select network...



Choose from a drop-down list of available network interfaces. To download images from an RVS Camera directly, you must be connected to the same Wi-Fi network, or connected directly to a camera in Access Point mode.

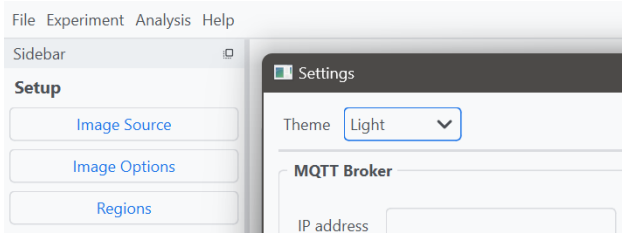
Settings...



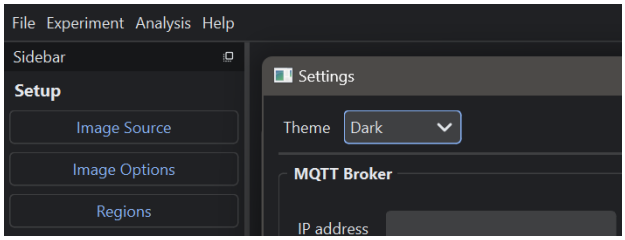
Use this dialog to adjust settings for the entire Analytics application.

The following options are available:

- Theme - choose an option from the dropdown menu to set the software color style.
  - Auto - matches the selected Windows or macOS light-dark system setting.
  - Light - a brighter, white-based color theme.



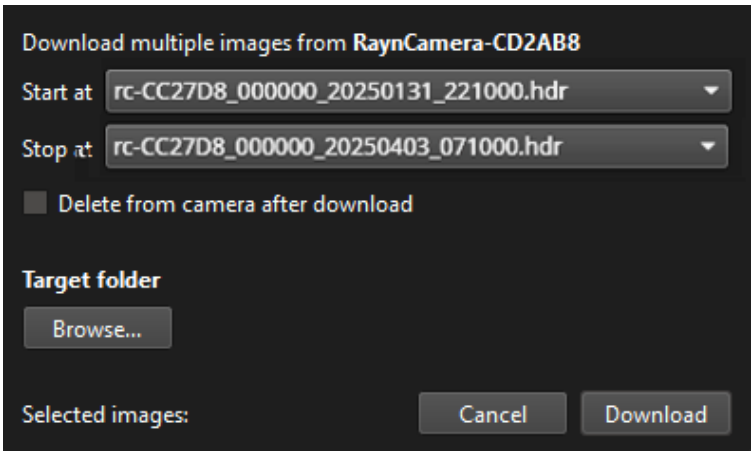
  - Dark - a darker, black-based color theme.



- MQTT Broker - enter the connection information for an MQTT broker in your network.

Analysis results can be exported as MQTT topics for external storage or plotting. When no broker information is entered, an MQTT: No broker defined message will display in the top right of the main software window.

Download images from camera...



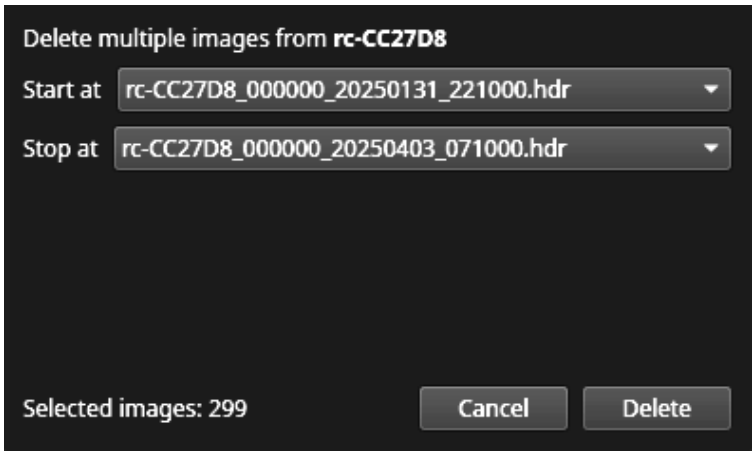
Use this dialog to download a selected image range to a folder on or accessible to the computer.

The following options are available:

- Start at - the first image in the range that will be downloaded from the camera.
- Stop at - the last image in the range.
- Delete from camera after download - removes the images from the camera after they are transferred to the target folder.

Use the Browse... button to choose a specific folder to store the images copied from the camera. The Download button in the bottom right will copy the images from the camera and close the window. The Cancel button will close the window without downloading images.

Delete images from camera...



Use this dialog to delete a selected image range from a connected camera.

Exit

Close the RAYN Vision System Analytics Software.

Experiment and Analysis

These menus provide options for managing the saving of configuration and analysis settings. Analysis files contain saved settings from the *Analysis* section of the sidebar. Experiment files contain saved settings from both the *Setup* and Analysis sections.

New Experiment or Analysis

Resets all experiment or analysis settings back to their defaults. You will be prompted to save any unsaved changes.

Open Experiment or Analysis

Locate a saved experiment (.xp) or analysis (.af) file of settings to load. You will be prompted to save any unsaved changes.

Save Experiment or Analysis

Save settings changes to an existing saved experiment or analysis file.

Save As Experiment or Analysis

Save settings changes to a new experiment or analysis file.

Help

The **Help...** menu option opens a window containing the software's user manual.

About

Opens a window displaying information about this installation of RAYN Vision System Analytics Software, and a copy of the End User License Agreement (EULA).

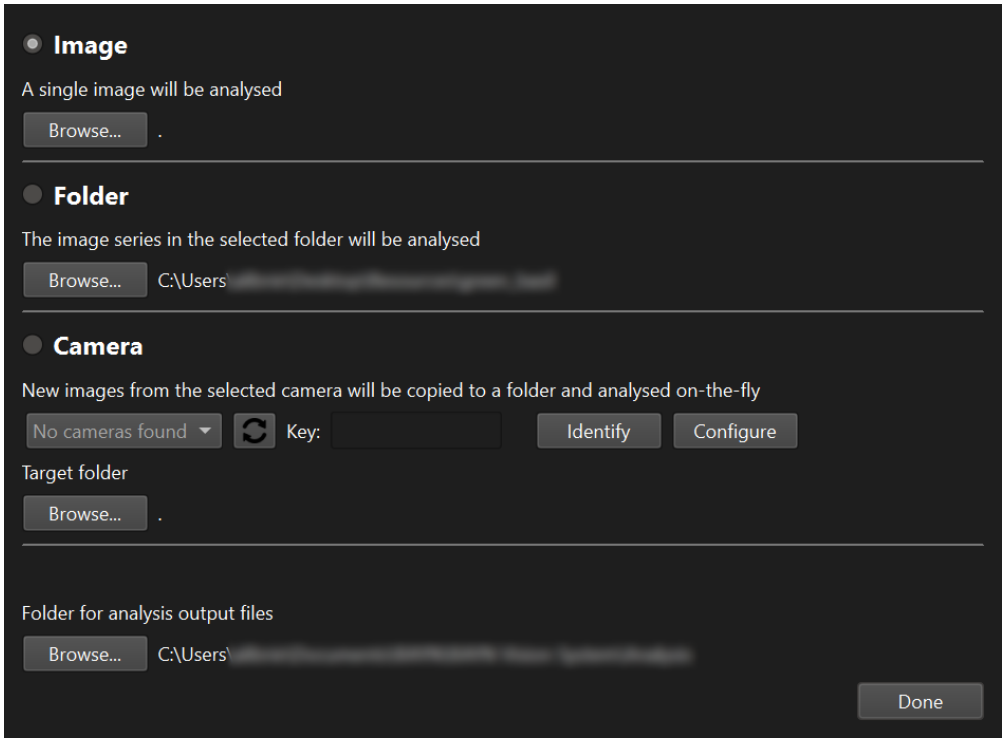
Setup

This section of the sidebar contains settings for importing and processing images, and defining which areas of those images should be analyzed.

Image Source

The **Image Source** button in the sidebar launches a window containing options for adding images to the software for analysis. A valid source of images must be selected before analysis can continue.

The **Done** button in the bottom right will apply any changes and close the window.



RVS Analytics supports the standard multispectral image ENVI (.hdr) format. There are three primary ways to add images for analysis.

Choose the **Image** option when analyzing a single image. Use the **Browse...** button to locate and select the image file.

Choose the **Folder** option when analyzing a saved set or series of multiple image files in a folder. Use the **Browse...** button to locate and select the folder containing the images. Changing the selected folder will reset all reference images used elsewhere in the software.

Camera

Choose this option when pulling images directly from an RVS Camera for analysis. Pick an available RVS Camera from the drop-down list. The following additional options are available:

- **Refresh** - refreshes the list of detected RVS Cameras.
- **Key** - enter the camera's API key, if one has been set up via the camera's web interface. If a key has not been set up, the API feature is inactive.
- **Identify** - the selected RVS Camera will blink white once.
- **Configure** - launches the web configuration page for the selected RVS Camera.

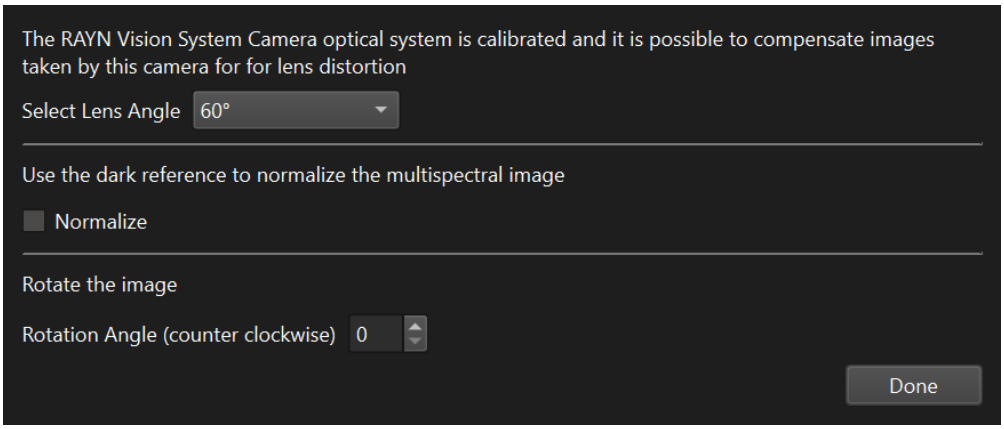
Use the **Browse...** button to choose a specific folder to store the images copied from the camera.

Folder for Analysis Output Files

At the bottom of the **Image Source** window, you can use the **Browse...** button to specify a folder where the software will save analysis output *Results*. The output location defaults to **...\Documents\RAYN\Rayn Vision System\Analysis**.

Image Options

The **Image Options** button in the sidebar launches a window with additional settings for processing the images added to the software.



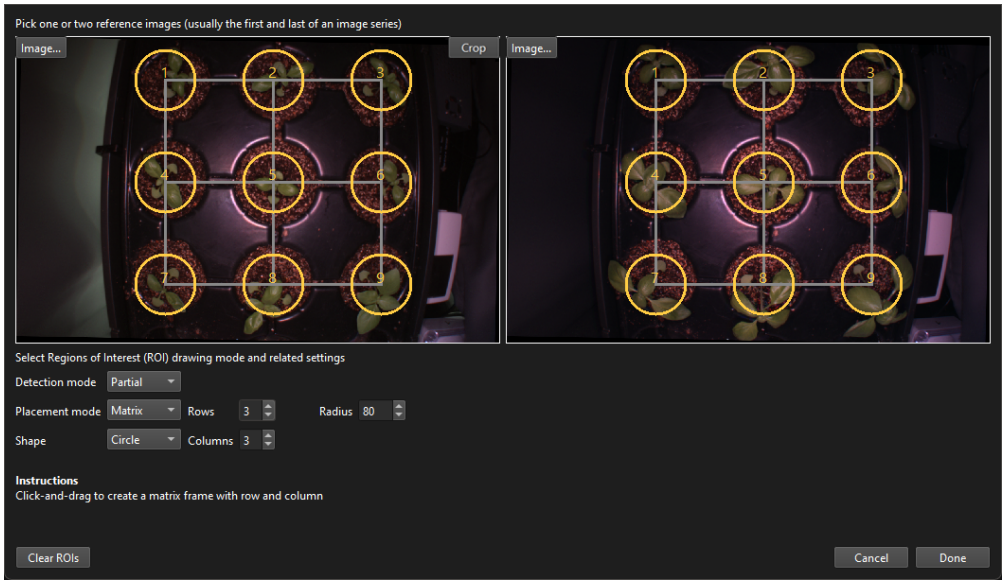
The following options are available:

- **Lens Angle** - distortion compensation allows the software to reduce the fish-eye camera effect when analyzing images from an RVS Camera. Choose from the following dropdown menu options:
  - **No compensation** - no compensation is applied to the analyzed images.
  - **60° lens** - compensation for a 60 degree camera lens.
  - **120° lens (legacy)** - compensation for a 120 degree camera lens.
- **Normalize** - when selected, the software will use a "dark" image (taken by the RVS Camera without lighting) to normalize images and compensate for stray light in the environment.
- **Image Rotation** - allows you to enter a degree value between 0° and 359° to rotate images counter-clockwise.

The **Done** button in the bottom right will apply any changes and close the window.

Regions of Interest

The **Regions** button in the sidebar launches a window of settings for defining regions of interest (ROIs). These regions determine the areas and objects in your images that will be analyzed. If no regions are defined, you will be prompted when applying changes, and the entire image will be analyzed.



The **Done** button in the bottom right will apply any changes and close the window. The **Cancel** button will close the window without applying changes.

Reference Images

Use the **Image...** buttons in the top left of either preview window to choose one or two images to reference while defining regions. It is often best for this to be the first and last image of a series, to ensure the regions contain the full range of growth captured by your images.

The following options are available:

- **Pick existing image** - opens Windows Explorer or macOS Finder to allow you to select an image on your computer.
- **Fetch image from camera** - opens a pop-up to allow you to import an image from a *RAYN Vision System Camera*. The camera must already be detected in the *Image Source* window. Use the dropdown to select an existing image, or **Take new image** to capture a new one. A pop-up window will warn that this process will take a minute or two. You must close this pop-up with the **OK** button or the **X** in the top-right for the image capture process to start. When complete, the image will appear in the reference window.

Choosing a source in the *Image Source* window can bypass these options.

- If a folder source has been chosen, the **Image...** buttons will open directly to that folder in Windows Explorer or macOS Finder.
- If a camera source has been chosen, **Image...** will automatically open the **Fetch image from camera** pop-up.

The **Cancel** button will close the window without choosing an image.

Defining Regions

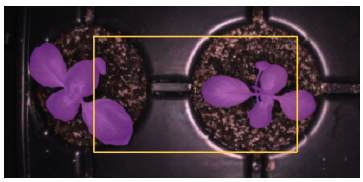
Once reference images have been chosen, regions can be created according to the settings below. Enlarging the **Regions** window will also scale the chosen images, which can assist in defining regions accurately.

Regions are highlighted in green once created, and yellow when selected. The **Clear ROIs** button in the bottom left will clear all defined regions.

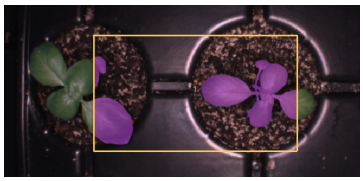
The **Crop** button in the top right can be used to assist with more accurate region definition. Draw a rectangle around the desired portion of the reference image and use **Accept** to crop the image or **Cancel** to abandon cropping. Once cropped, the **Reset** button can be used to return the image to its original dimensions. Cropping an image or resetting a crop will clear all defined regions.

Object Detection

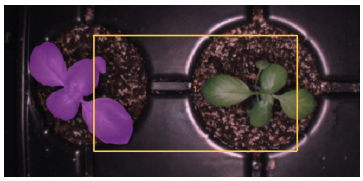
The following options define how objects within regions will be detected for analysis:



- **Partial** - all objects detected within defined regions will be analyzed, including any parts of the object that extend past the region boundaries.



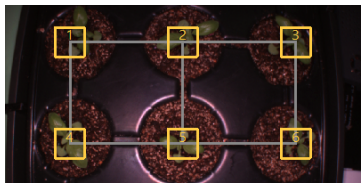
- **Cut to** - nothing outside the defined region boundaries will be analyzed.



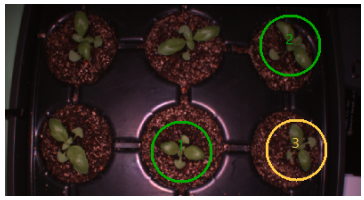
- **Largest** - the largest of any objects detected within defined regions will be analyzed, including any parts of the object that extend past the region boundaries.

Layout

Regions can be created together or separately. The following options are available:



- **Matrix** - clicking and dragging within a reference image creates a matrix of connected regions spaced at fixed relative distances apart. The **Rows** and **Columns** settings allow you to adjust vertical and horizontal region layout. Click again to clear the matrix.



- **Individual** - clicking within a reference image creates a single region which can be freely moved and positioned individually. Click again to create additional regions, or to select specific regions for editing. Right-click on a region to clear it.

You can use **Matrix** to lay out multiple regions and then change to **Individual** to make specific edits. Changing from **Individual** to **Matrix** will clear your regions.

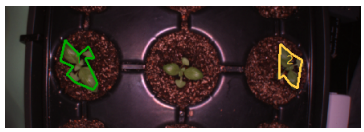
Shape

Regions can be created in a variety of shapes. Shape size can be used to both edit existing regions and set the size for new regions. The following options are available:

- **Circle** - creates circular regions. The **Radius** setting allows you to adjust circle size.

- **Rectangle** - creates rectangular regions. The **Width** and **Height** settings allow you to adjust rectangle size in pixels, starting at 5 px. While there is no upper limit, an error will appear when a region extends outside of an image.

- **Ellipse** - creates elliptical regions. The **Width** and **Height** settings allow you to adjust ellipse size in pixels, starting at 5 px. While there is no upper limit, an error will appear when a region extends outside of an image.



- **Polygon** - creates regions with custom shapes. Click to define the points of the region, connected by straight lines. Double-click to finalize regions. This option is only available when using **Individual** layout.

Analysis

This section of the sidebar contains the list of available analysis scripts, along with access to masking and options for the selected script.

Scripts

RVS Analytics uses two separate Python (.py) scripts to determine the processing and filtering parameters used when analyzing images: an analysis script and a mask script.

Available scripts are chosen via the drop-down menus in the sidebar. Once scripts are chosen, the analysis can be configured via *Options*, and unwanted data filtered out via *Masking*.

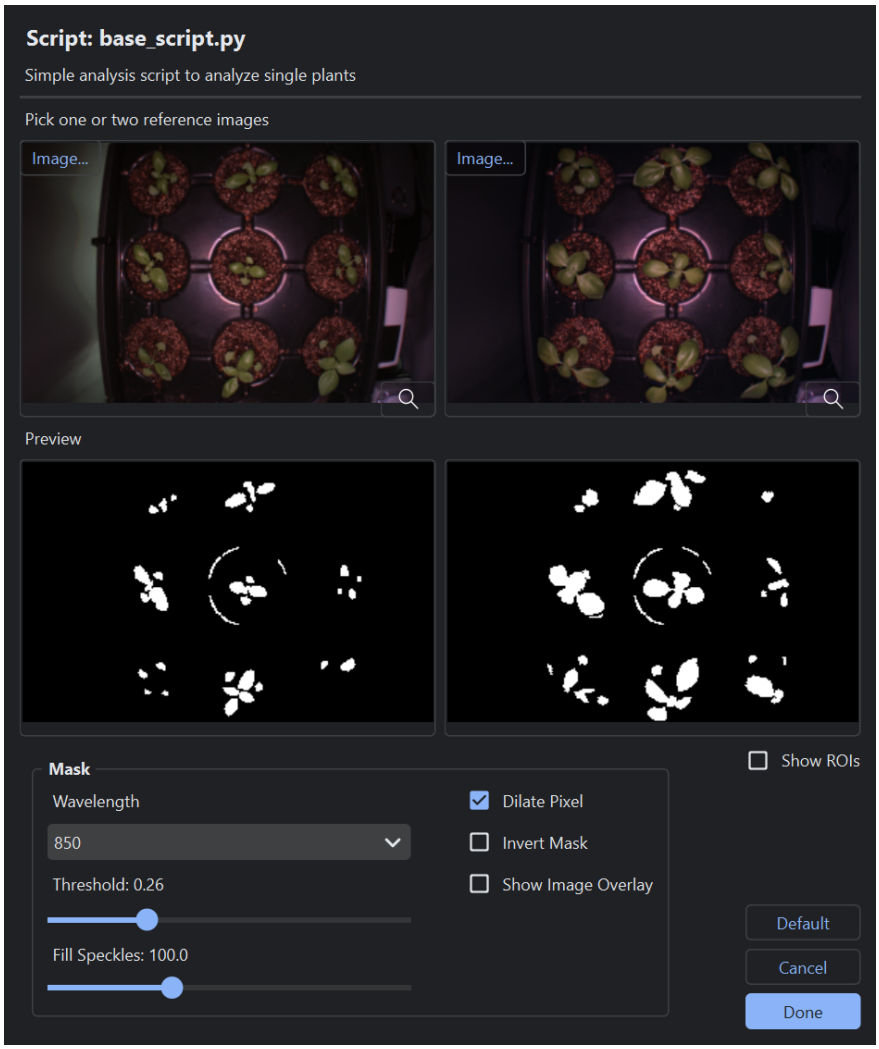
Analysis Scripts

A default analysis script, *base_script.py*, is provided, allowing analysis of a single reflection index using a variety of masking options.

Additional scripts are available via the Analytics Github page, github.com/rayngrowingsystems/rvs_analytics, allowing you to track seedling emergence, check *Regions of Interest* for new plant material and intrusions from neighboring plants, export timestamped analysis *Results* to CSV, and more. For more information, see the script feature overview videos provided on Github.

Masking

The **Masking** button in the sidebar launches a configuration window of masking options used to filter out unwanted background image data during analysis.



The **Default** button in the bottom right will restore all values to their original defaults. **Cancel** will close the window without applying any changes. **Done** will apply any changes and close the window.

Reference Images

Use the **Image...** buttons in the top left of either preview window to choose one or two images to reference while defining regions. It is often best for this to be the first and last image of a series, to ensure the regions contain the full range of growth captured by your images.

The following options are available:

- **Pick existing image** - opens Windows Explorer or macOS Finder to allow you to select an image on your computer.
- **Fetch image from camera** - opens a pop-up to allow you to import an image from a *RAYN Vision System Camera*. The camera must already be detected in the *Image Source* window. Use the dropdown to select an existing image, or **Take new image** to capture a new one. A pop-up window will warn that this process will take a minute or two. You must close this pop-up with the **OK** button or the **X** in the top-right for the image capture process to start. When complete, the image will appear in the reference window.

Choosing a source in the *Image Source* window can bypass these options.

- If a folder source has been chosen, the **Image...** buttons will open directly to that folder in Windows Explorer or macOS Finder.
- If a camera source has been chosen, **Image...** will automatically open the **Fetch image from camera** pop-up.

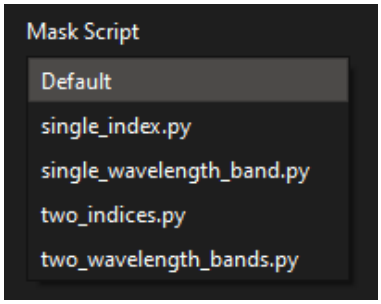
The **Cancel** button will close the window without choosing an image.

Once an image is chosen, if the magnifying glass button is selected (orange), clicking on the image will display an enlarged segment.

Click and hold to drag the magnification window around the image.

Mask Script

Each mask script provides different options for segmenting plants from background data you may wish to exclude from your analyses. While a default mask script is applied when an analysis script is chosen, other available mask scripts can be chosen from the drop-down menu.

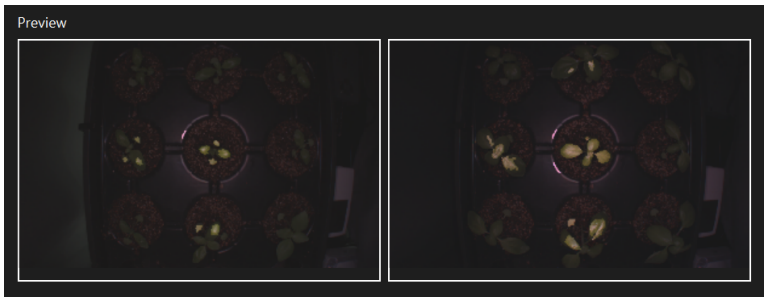


The included mask scripts allow you to filter on a single wavelength or reflection index, or simultaneously filter for two.

Mask Parameters

Depending on the chosen mask script, the following mask parameters may be available:

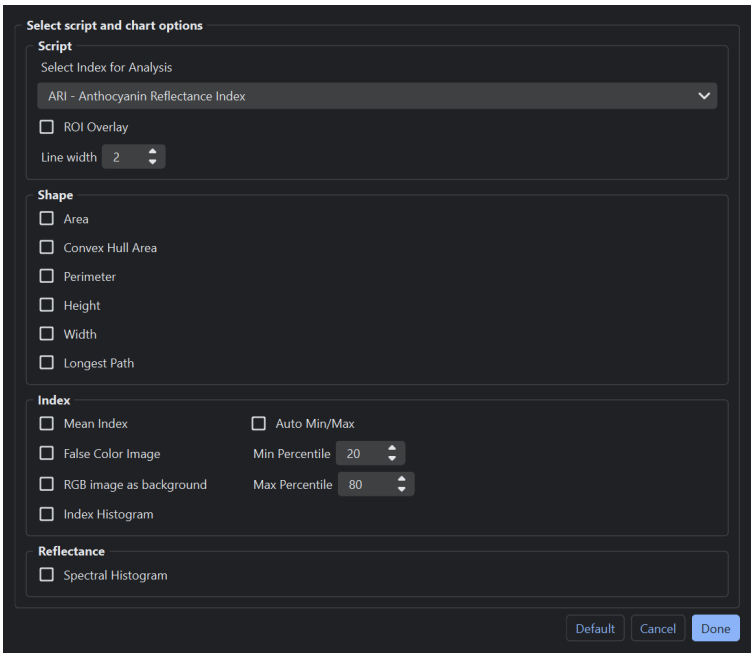
- **Wavelength** - choose from a list of available wavelength bands to use for thresholding.
- **Threshold** - set up to two wavelength thresholds.
- **Select Index** - choose from a list of available reflection indices to use for thresholding.
- **Index Threshold** - set up to two index thresholds.
- **Logical Operation** - perform a logical operation with two or more threshold masks using (and, or, xor).
- **Fill Speckles** - fills holes in the binary mask up to the maximum given pixel size.
- **Dilate Pixel** - enlarges pixels, which may help smooth the boundaries of individual objects.
- **Invert Mask** - reverses selection areas of the applied mask.
- **Show Image Overlay** - replaces the preview of the mask with an image preview that uses the mask.



Select the **Show ROIs** box to display any reference image *Regions of Interest*, which can assist with masking accuracy.

Options

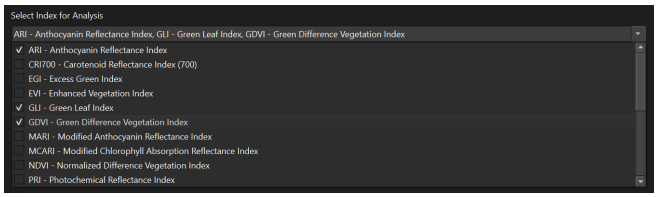
The **Options** button in the sidebar launches a new window containing any additional options associated with the selected analysis script.



The **Default** button in the bottom right will restore all values to their original defaults. **Cancel** will close the window without applying any changes. **Done** will apply any changes and close the window.

Script Options

- **Analyze Index** - when selected, the included default base script allows for analysis of a single reflection index. Choose one or more available index using the boxes in the drop-down menu.



- **ROI Overlay** - when selected, defined regions of interest will be outlined in the results.
- **Line width** - sets the width of the shape analysis and ROI outlines between 1 and 5.

The chosen index is used when generating any selected **Index and Reflectance** options.

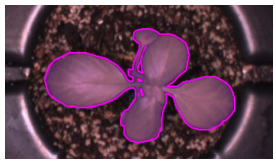
Chart Options

The checkboxes in this section allow you to choose various metrics to be analyzed and plotted on charts. After analysis, charts of the selected options are saved to the *Results* folder, and can be viewed in the *Chart Tabs* to the right of the *Preview Tab*.

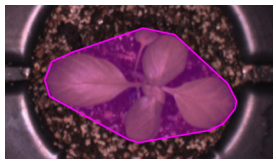
One or more of the metrics can be chosen by selecting the associated box.

Shape

The following options are available to chart analyzed shape data:



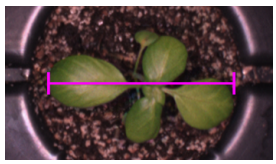
- **Area** - the size of the plant canopy.



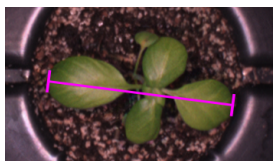
- **Convex Hull Area** - the size of the shape that encloses the outer edges of the plant.

- **Perimeter** - the distance around the outside edges of the plant.

- **Height** - plant height measured across the Y axis of the 2D image.



- **Width** - plant width measured across the X axis of the 2D image.



- **Longest Path** - the furthest distance between the outer edges of the plant.

Index and Reflectance

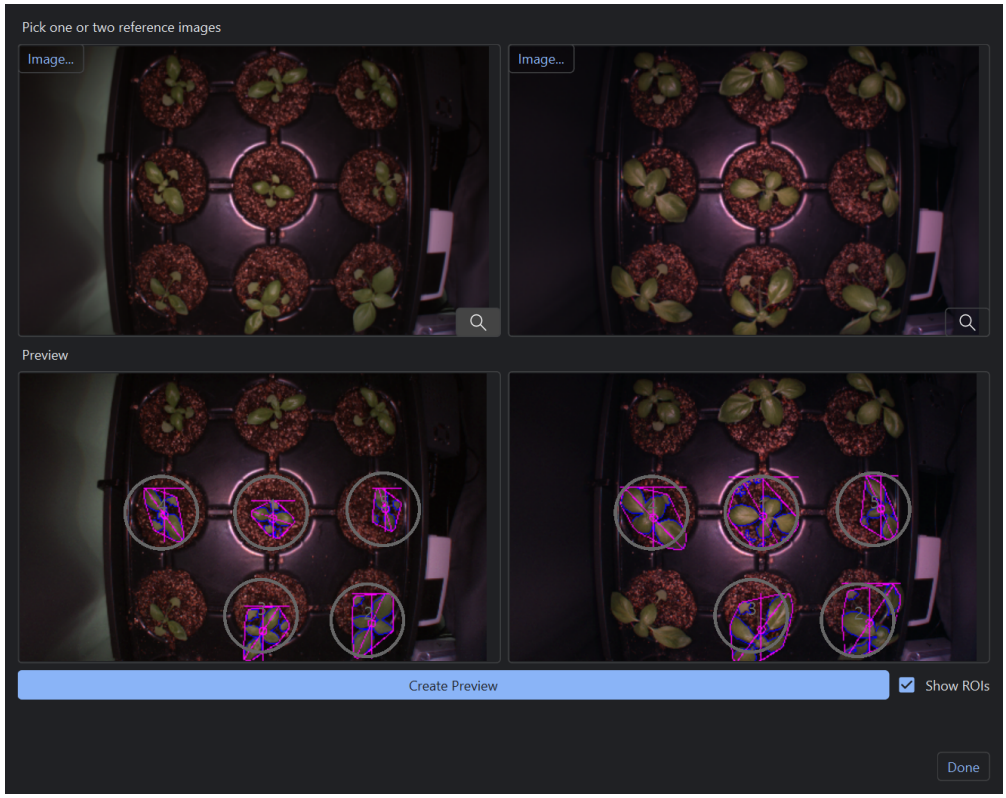
The following options are available to chart analyzed index and reflectance data:

- **Mean Index** - takes an average of the selected reflectance index, returning mean, median, and standard deviation values for the plant.
- **False Color Image** - generates a false color image showing the values of the selected index. One false color image is created for each hyperspectral image analyzed; only the last false color image is displayed in the results tab.
  - **RGB image as background** - generates the false color image with an RGB background.
- **Index Histogram** - generates distribution charts of index values.
- **Auto Min/Max** - set custom **Min Percentile** and **Max Percentile** levels to adjust the range used when generating false color images.
- **Spectral Histogram** - generates distribution charts of reflectance values.

The histogram options generate a chart for each of the configured *Regions of Interest*. The index chosen in **Script Options** is used to analyze detected objects within each ROI and the results are averaged together in the chart for that region. The last histogram created is displayed in the results tab.

Preview

The **Preview** button in the sidebar launches a window containing options to choose which analysis results will be plotted on the chart. After analysis, the chart is available in the *Chart Tabs* display and saved to a file in the *Results* folder.



The **Create Preview** button will generate a preview of the analysis results based on the options chosen.

Select the **Show ROIs** box to display any reference image *Regions of Interest*, which can assist with masking accuracy.

Reference Images

Use the **Image...** buttons in the top left of either preview window to choose one or two images to reference while defining regions. It is often best for this to be the first and last image of a series, to ensure the regions contain the full range of growth captured by your images.

The following options are available:

- **Pick existing image** - opens Windows Explorer or macOS Finder to allow you to select an image on your computer.
- **Fetch image from camera** - opens a pop-up to allow you to import an image from a *RAYN Vision System Camera*. The camera must already be detected in the *Image Source* window. Use the dropdown to select an existing image, or **Take new image** to capture a new one. A pop-up window will warn that this process will take a minute or two. You must close this pop-up with the **OK** button or the **X** in the top-right for the image capture process to start. When complete, the image will appear in the reference window.

Choosing a source in the *Image Source* window can bypass these options.

- If a folder source has been chosen, the **Image...** buttons will open directly to that folder in Windows Explorer or macOS Finder.
- If a camera source has been chosen, **Image...** will automatically open the **Fetch image from camera** pop-up.

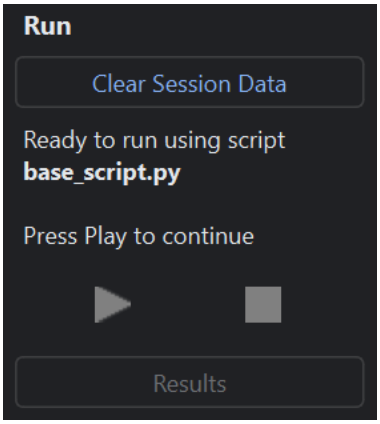
The **Cancel** button will close the window without choosing an image.

Once an image is chosen, if the magnifying glass button is selected (orange), clicking on the image will display an enlarged segment.

Click and hold to drag the magnification window around the image.

Running Analyses

Analyses can be started and stopped from this area at the bottom of the sidebar.



The software will prompt if any required setup or configuration steps need to be completed before the analysis can be run. When setup is complete, the prompt will indicate the analysis is ready to run.

Use the **Play** and **Stop** buttons to start and stop an analysis. A progress bar will appear under the *Preview Tab* window, and updates will appear in the *Status* display.

Session Data

Session data, which can include color and object information, is stored after each analysis and saved with the experiment file. Session data is unique to each analysis and analysis script. Session data can be cleared before running new analyses with the **Clear Session Data** button.

Results

Once completed, each analysis creates a new date- and time-stamped folder of results. The folder save location can be configured in the *Image Source* window.

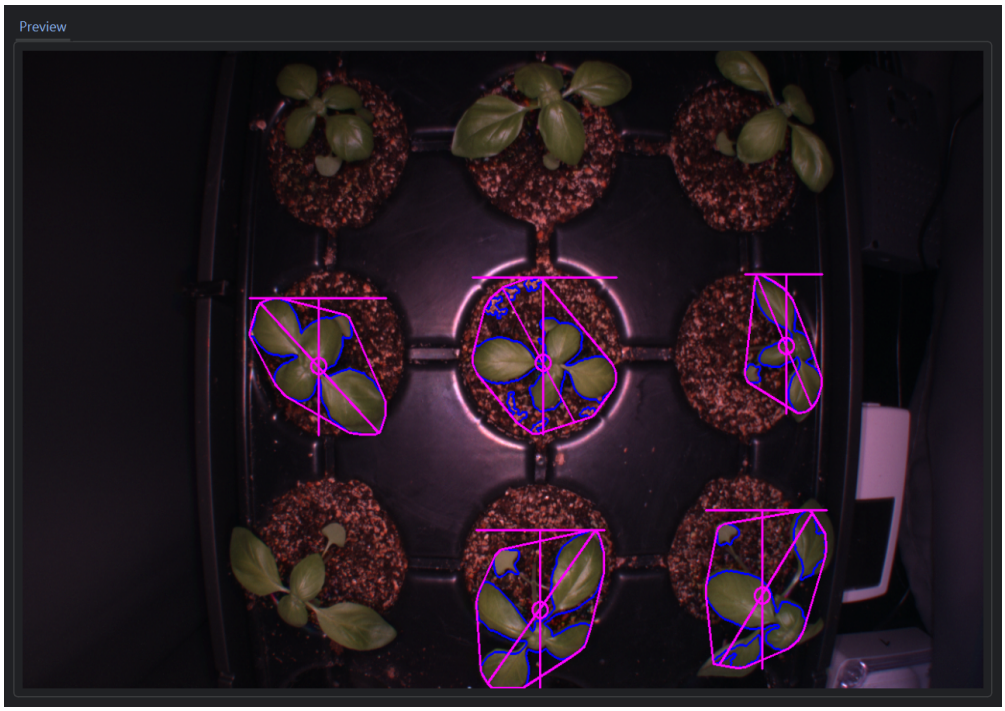
Use the **Results** button at the bottom of the sidebar to open the folder, which contains the following:

- An **images** folder of the processed RGB image outputs in PNG format. These images can also be viewed in the software via *Preview Tab*.
- A **rawData** folder of the analysis results for each image in JSON format.
- A **visuals** folder of plotted results in HTML and PNG formats. Plotted results are determined in *Options* and can also be viewed in the software via the *Chart Tabs*.
- A spreadsheet of single value results in CSV format. This spreadsheet contains analysis data that returns a single value per ROI (for example, **Shape > Area**).
- A spreadsheet of multiple value results in CSV format. This spreadsheet contains analysis data that returns more than one value per ROI (for example, **Reflectance > Spectral histogram**, which returns values for each spectrum).
- Session parameters used during the analysis in JSON format.
- A copy of the experiment file.

If an MQTT broker has been defined in the *File* menu, ROI values will be sent as MQTT topics for display by other systems.

Preview Tab

During analysis, image outputs will appear in the **Preview** tab as they are processed.



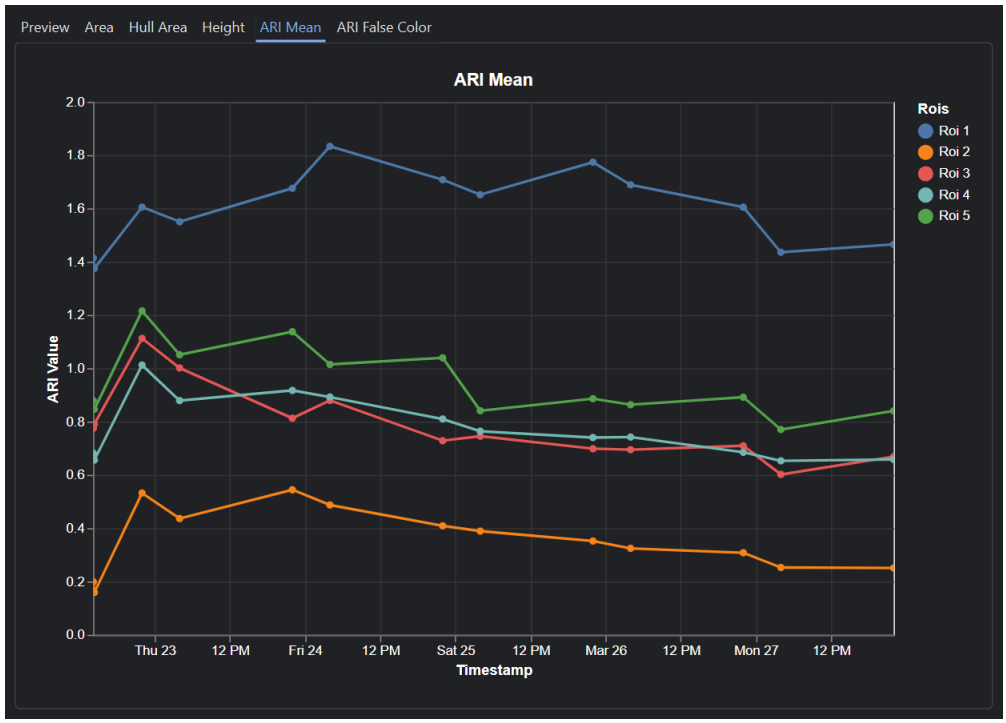
Shape and size changes within defined *Regions of Interest* are outlined in magenta.

Once an analysis has been completed, previewed images are available as files in the *Results* folder.

Chart Tabs

The checkboxes in *Options* allow you to choose various metrics to be analyzed and plotted on charts. After analysis, charts of the selected options are saved to the *Results* folder, and can be viewed in the chart tabs to the right of the *Preview Tab*.

Results for individual ROIs are color-coded. Refer to the *Regions of Interest* window to check ROI numbers.

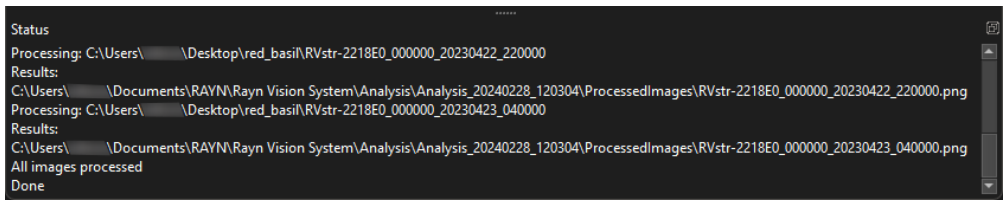


A non-interactive preview of each chart is displayed during the analysis, which can help identify trends or issues without having to run an entire image set.

Once an analysis has been completed, the charts become interactive. Hover over data points for more information. Hover in the top right for access to additional chart selection and zoom tools.

Status

The status display provides a real-time report of the software's analysis functions. Images are listed as they are processed, and analysis status messages are provided.



The pop-out buttons in the top right of the status feed and sidebar will separate them from the main application window, allowing them to be freely moved and positioned onscreen. **Status** can be docked to the software again by dragging it over the top, bottom, left, or right edge of the main window. The sidebar can be docked to the left or right. Both can be freely resized by dragging the divider icon.

RAYN Vision System Camera

The RAYN Vision System (RVS) Camera is a compact research tool for observing and recording across multiple light wavebands, and includes a variety of connectivity options for remote and automated image capture, processing, and analysis.

For more information, see the *RAYN Vision System Camera Setup Guide* and *RAYN Vision System Camera Firmware Release Notes*.

User documentation and technical support are available via our website, rayn.ag, or by contacting your RAYN Growing Systems provider.

RVS Analytics is open-source software. Visit our Github page, github.com/rayngrowingsystems/rvs_analytics, to download the latest code and submit feature requests to the repository.

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