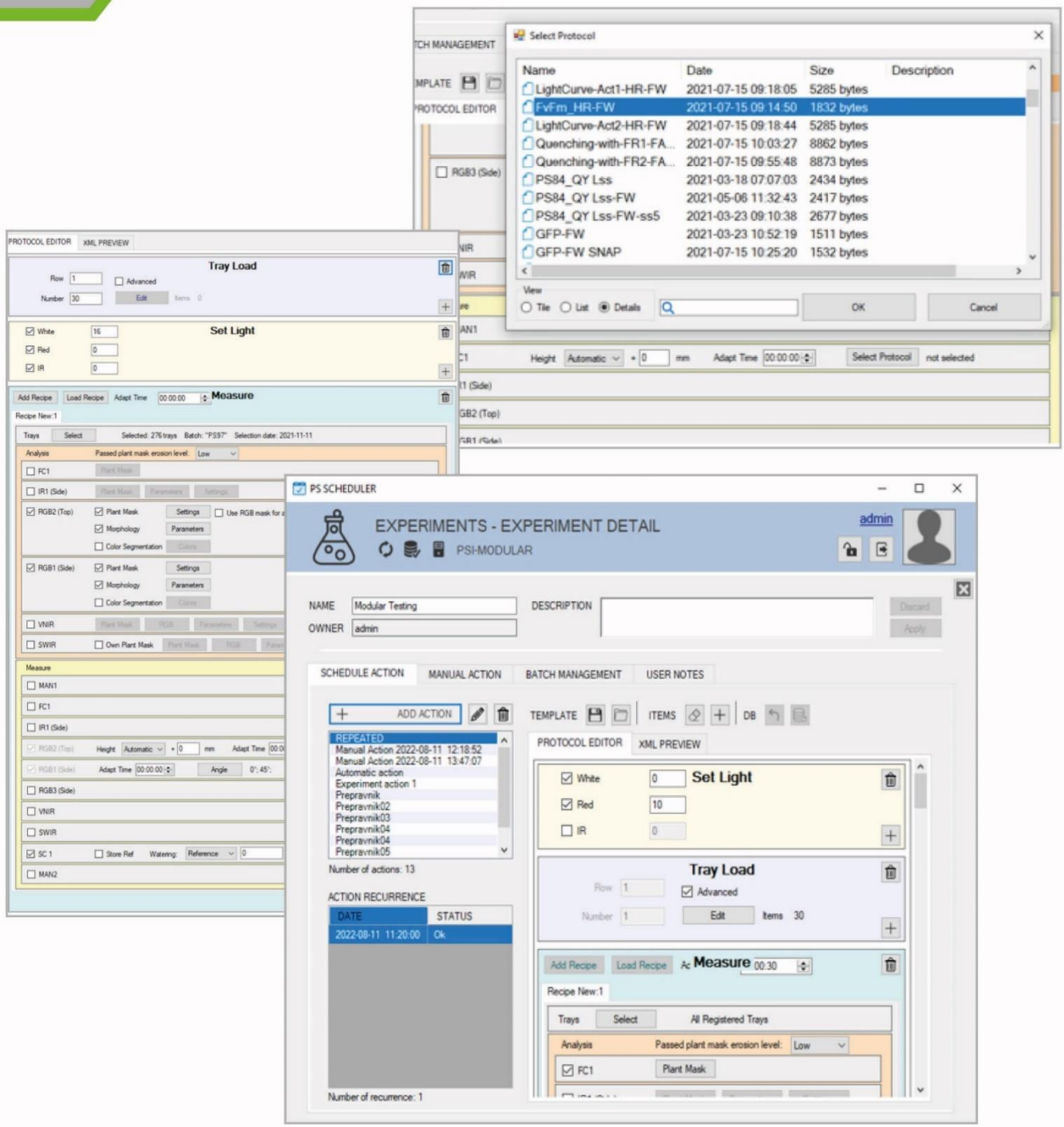
Instruction Guide

PHOTON SYSTEMS INSTRUMENTS

PlantScreen™ Scheduler Client

Please read the Guide before operating this product



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Date: 2024/03

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1 INTRODUCTION TO PLANTSCREEN SYSTEM

1.1 GENERAL INFORMATION

Read this manual carefully before operating the PlantScreen system. If you are not sure about something in the manual, contact the manufacturer for clarification.

By accepting the system, the customer agrees to follow the instructions in this guide. Always follow corresponding manuals while working with the PlantScreen system or doing the maintenance. It is forbidden to interfere with the hardware or software of the PlantScreen system in any way without previous agreement with the manufacturer. It is forbidden to perform any installation or re-installation of the software without PSI permission. Copying or other interference in the device software without PSI permission is forbidden. These activities can also lead to loss of warranty on the device and its accessories and/or may also cause damage to health and property.

This manual contains instructions to the PlantScreen Scheduler Client application. Its main purpose is to create and schedule experiments, manage trays and batches and setup extended watering modes. This manual describes full functionality of the PlantScreen Scheduler Client, version 2.7.8697.

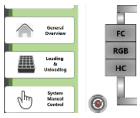
Symbol	Description
	Important information, read carefully.
	Complementary and additional information.

Tab. 1 Highlight symbols used in this manual

1.2 PLANTSCREEN COMPUTERS AND SOFTWARE

Two computers (main server PC and Database PC) and monitor (touch screen in some configurations) are supplied with the device. The computers are mounted in PC cabinet with server rack. In some systems second database PC is used for database mirroring. In smaller devices the main server and the database are runniong on a common single desktop or panel PC.

The computers come with a pre-installed operating system and PlantScreen software package necessary for running the PlantScreen™ system. Several applications are listed and briefly described in Tab. 4

	**PlantScreen™ Server** connects all system components, provides interface to the main database and executes experimental setups by client application. This service is running all the time the system is powered on. PlantScreen™ Server operates all system components and controls mode of system operation.
	**PlantScreen™ Scheduler** connects to the server, displays actual system state, provides GUI for experiment setup and control. The Scheduler Client is designed for visualization, planning and management of the individual experiments for multiple registered users. It is used to access and manage current and planned experiments and design experimental protocols. The Scheduler Client is also designed for tray and pot registration into the database and for water management. There can be multiple clients connected to the server, with different privileges assigned based on a built-in authentication mechanism.
	PlantScreen™ Data Analyzer provides tools for data browsing and analysis. Multiple clients can be connected to database, with different privileges assigned based on a built-in authentication mechanism.
	**PlantScreen™ HMI software** can initialize the system automation, select imaging loop mode and load or unload trays from the conveyor.
	**PlantScreen™ Database software** is used to create, edit, and maintain database files. PlantScreen™ Database does not require direct user interaction.
Other applications depending on configuration (e.g. Fluorcam10, MorphoAnalyzer, etc.)	

Tab. 2 PlantScreen™ software components

HMI panels used in PlantScreen Modular systems to faciliate system initialization, safety and tray manipulation tasks. Several tasks can be done with the panel: monitoring the status of the system, initializing the automation, selecting the conveyor loop mode and load or unload trays.

	Multiple copies of PlantScreen Scheduler and PlantScreen Data Analyzer can be used simultaneously. Changes made in one client are synchronized to all other connected clients immediately.
	Due to hardware limitations the Main Server Computer and Data Server Computer should not be used for other purposes then operating the PlantScreen system. During the measurement only applications that are directly utilized in measuring activities should be running. Other applications including Plant Data Analyzer should be closed.

1.3 PERMISSIONS AND ACCOUNT ROLES

PlantScreen™ System requires user authentication, which is common to the whole PlantScreen™ software package including Server application. User permissions are shared for all the three applications – user uses the same account to log in to all applications.

Managing other accounts, experiments of other users or advanced software functionality is enabled via accounts with specific roles assigned. For example, the Server application can be accessed only by users with Server User role, or new users can be created only by user with User Administrator role.

Multiple account roles can be assigned to one account by selecting multiple checkboxes. Full access to all system features and account roles requires all account roles. Rights to each of the account roles are summarized in Tab. 4.

Account role	Description
User Administrator	Complete administration of user accounts (new user creation, roles assignment)
Server user	Can login to Server app
Experiment Viewer	Can view experimental data of other accounts without access to perform any changes
Experiment Editor	Can start measurement for experiments of other accounts
Experiment Master	Can backup, restore and delete experiments of other accounts
Validator	Can validate system calibration
No account role (standard user)	Can view and manage only own experiments

Tab. 3 Description of account roles

System accounts can be changed only by a user authorized as User Administrator.

Only accounts which do not contain experiments can be deleted.

User accounts can be created and managed only with PS Scheduler. For detail information please refer to this manual, chapter 8.

1.4 LOGGING IN USING ADMIN ACCOUNT

After starting the computer it is necessary to log in to Windows operating system domain using the following username and password.

- User: *admin*
- password: *psi2013!?*

Start the PlantScreen Scheduler application with the *PSScheduler.exe* file located in C:\PSI\PSScheduler or use the Scheduler icon on the desktop. Filling three textboxes in the *Log-in* window (Fig. 1A) is required for the login procedure:

- **System** In the System drop-down list shows pre-selected option by default. The LOCAL option indicates that the Scheduler application runs on the Main Server computer and connects to the Server within the local PlantScreen system network. If configured for remote connection (from a computer in the network outside the system) several system connections can be configured in the System menu. The drop-down list-box is then used to select the system (Fig. 1B).
- **User:** *admin*
- **Password**: *admin*

Click the *Login* button and the application starts.

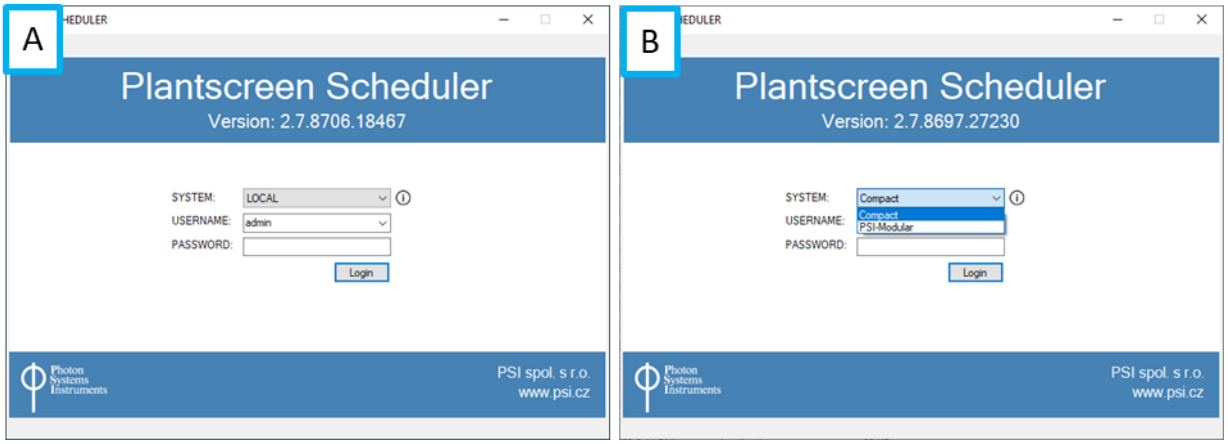


Fig. 1 Scheduler log-in window on local PC (A) and PC with remote access (B)

	Same user and password information is used to log in into Server, Scheduler and Data Analyzer application.

The *admin* account should be later used to manage and create new user accounts and also to change the default admin account password.

PS Server, Scheduler or Plant Data Analyzer application predefined administrator account:

- **User:** admin
- **Password:** admin

1.5 Main menu

The Main screen with following items is displayed after logging in (Fig. 2):

1. Logged user identity
2. Experiments - Generate and schedule a measuring protocol.
3. Trays - Register groups of trays and plants to the system.
4. Watering - Register trays and plants for watering.
5. User profile - Display and change current user details.
6. User account management (visible to accounts with *User Administrator* role only)
7. Monthly calendar
8. Weekly calendar with planned actions
9. Status bar

Controls listed above are further described in the following chapters.

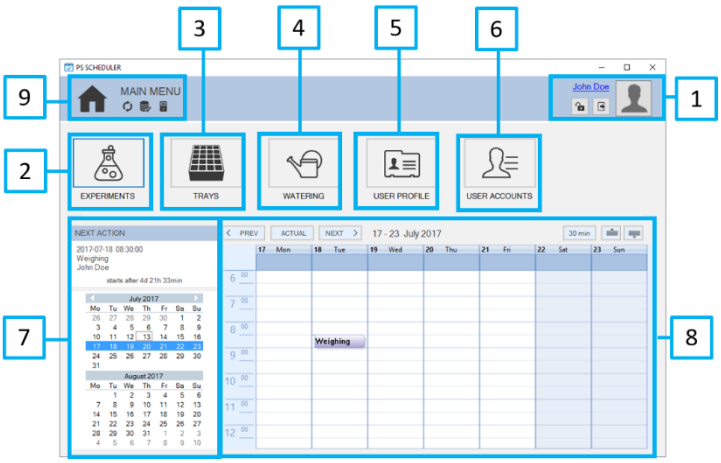


Fig. 2 Main Screen

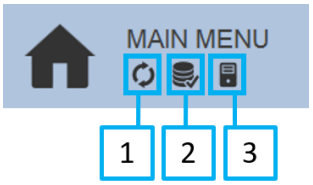


Fig. 3 Status Icons

Status icons are located in the top left corner of the application (Fig. 3). There is an icon of the synchronization server (Fig. 3-1), the database server (Fig. 3-2) and the icon of the management server (Fig. 3-3). The red coloring of the icons indicates a problem in the communication with the corresponding server. In such case, check if all system computers are on and connected to the network, and if the Server application is running.

Following symbols appear on multiple screens in the application:

+	**Add or create new object, add protocol item**
	Edit the object
	Delete the object
	Close currently opened window or dialog
	Save protocol template
	Open protocol template
	Erase protocol item
	Search button is used for filtering trays
<	Move button - assign
>	Move button - unassign
	Hides unchecked measure items

2 CURRENT USER PROFILE

Basic information and controls associated with the logged in user are displayed in the top right corner of the Main screen (Fig. 4):

1. User's name
2. Lock workspace button
3. Logout button

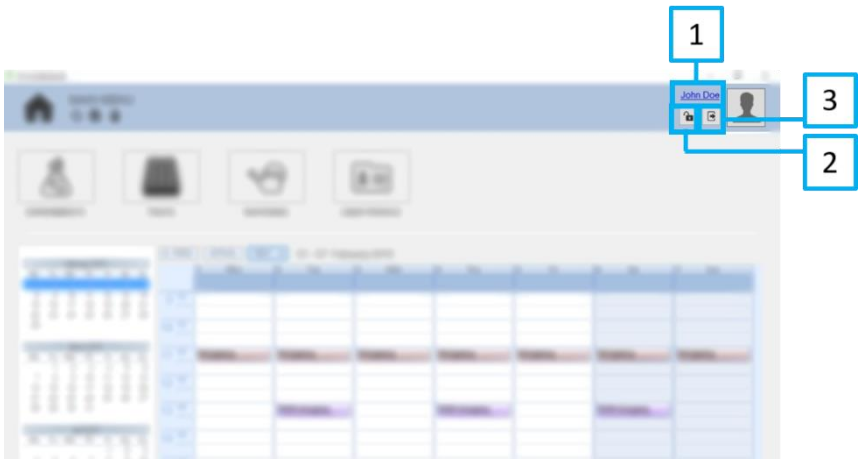


Fig. 4 Basic information and controls associated with the logged in user

Window with detailed information about the current user displayed after clicking the user's name (Fig. 4-1).

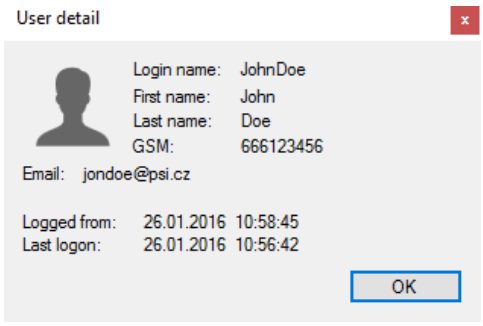


Fig. 5 Detailed user information

Application can be switched to the locked mode (Fig. 6) by clicking *Lock workspace* button (Fig. 4-2). In this mode, user remains logged in, but only basic status information, the logged-in user identity, and lock and login controls are displayed.

Fig. 6 Locked workspace

The workspace is unlocked by clicking the *Lock workspace* button again and filling inthe password in the authentication dialog (Fig. 7). Click the *Logout* button (Fig. 4-3) to sign out. Clicking the cross symbol ✕ in the top right corner of the *Main* screen closes the application.

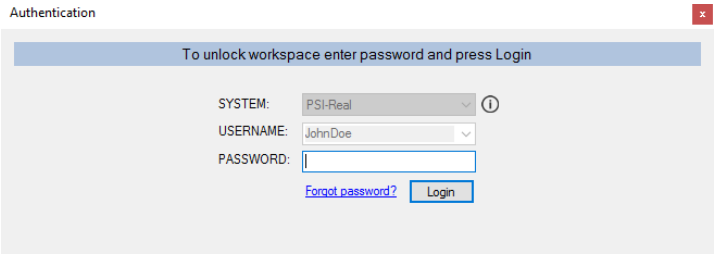


Fig. 7 Authentication window for workspace unlock

3 CALENDAR

Calendar displays all planned experiment actions directly in the main menu window (Fig. 2-7). Navigation through the calendar is done at the month level in the left part of the calendar. After selecting a week in the navigation tab, the corresponding row of seven days of the week is displayed in the calendar tab (Fig. 2-8).

All scheduled actions are shown as notes in the calendar. Each note represents a start of scheduled action (Fig. 2-8). Double click the action note to show the protocol details in a separate action window.

Monthly calendar is shown on the left tab of the Main screen (Fig. 2-7) and the weekly calendar in the right tab (Fig. 2-8). The week highlighted on the left tab is shown on the right as the actual item of the weekly calendar.

Start time points of scheduled actions are displayed in the weekly calendar as textboxes containing experiment name (Fig. 8-1). Double-clicking the scheduled action item opens the *Experiment Detail* window (Fig. 12).

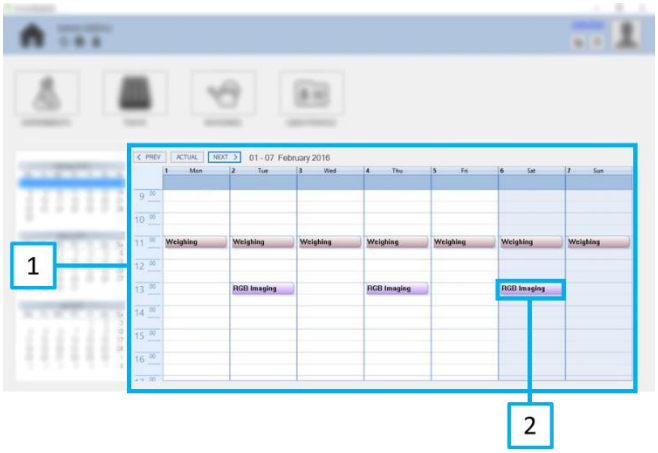


Fig. 8 Weekly calendar

4 EXPERIMENTS

4.1 EXPERIMENTS WINDOW

Experiments window is opened by clicking the *Experiments* button located on the on the Main screen (Fig. 9).

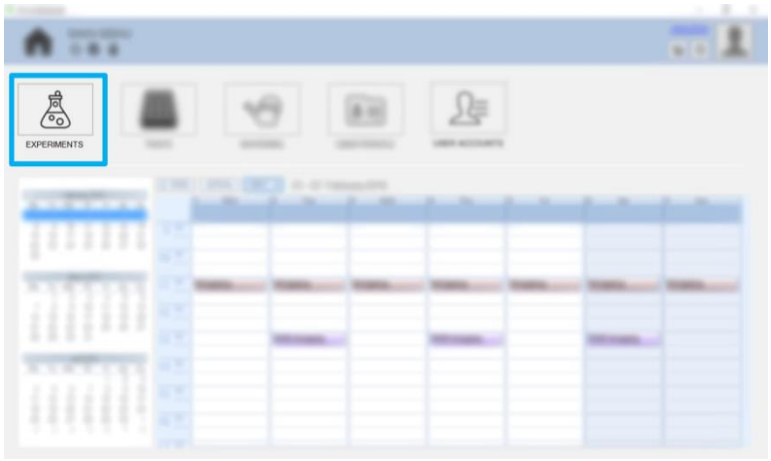


Fig. 9 Experiments picture button on the Main screen

The *Experiments* window (Fig. 10) contains controls for setting up, editing and scheduling experiments. In each experiment item (Fig. 10-1) controls to rename or delete each experiment (Fig. 10-2) are included. Clicking the individual experiment item opens *Experiment detail window* (described in paragraph 4.20).

The list of experiment can be filtered out by several filtering tools (Fig. 10-4). Filtering is done by experiment name, experiment state and creation date. The checkboxes *Active – Backed Up – Finalized – Delete* allow to change the filter based on experiment status.

Users with *Experiment Manager* role can access all experiments (see chapter 8 User accounts for more details). *My experiments only* checkbox (Fig. 10-5) toggles between the option of displaying all experiments or displaying experiments owned by the user.

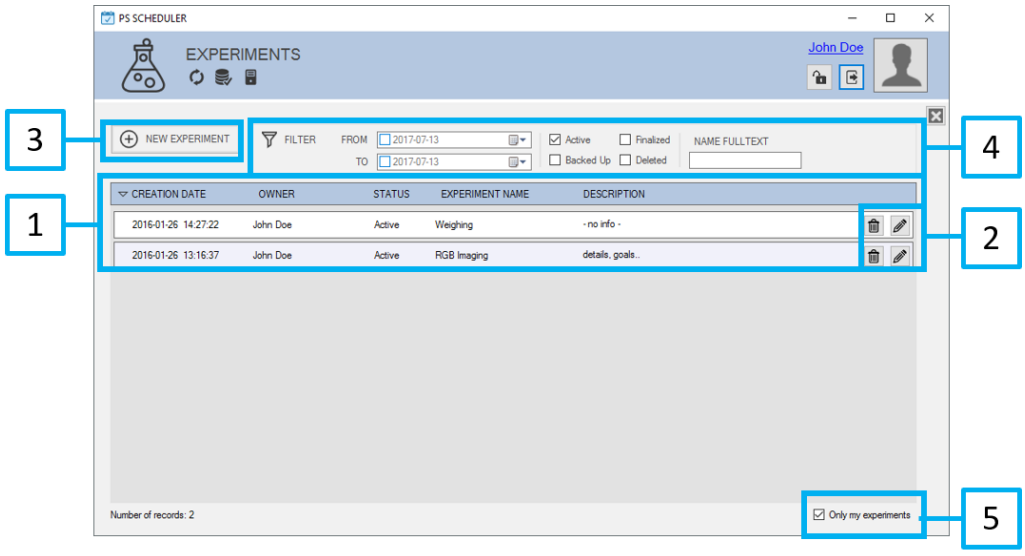


Fig. 10 Experiments window

New experiment is created by opening *New Experiment* (Fig. 10-3). The window contains the *Name* (Fig. 11-1) and *Description* textboxes. The text in *Description* textbox is optional (Fig. 11-2). The text in *Description* textbox (Fig. 11-2) to further describe the experiment goals or settings. Confirm the entry with the *OK* button (Fig. 11-4). Then the *Experiment detail window* opens (Fig. 11).

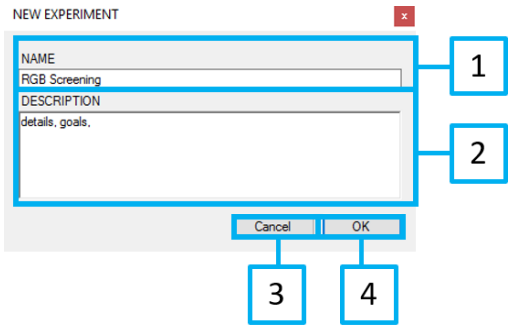


Fig. 11 New experiment window

4.2 EXPERIMENT DETAIL

The *Experiment Detail* window (Fig. 12- 1) contains experiment and user information which can be further modified. Each modification has to be confirmed by the *Apply* button.

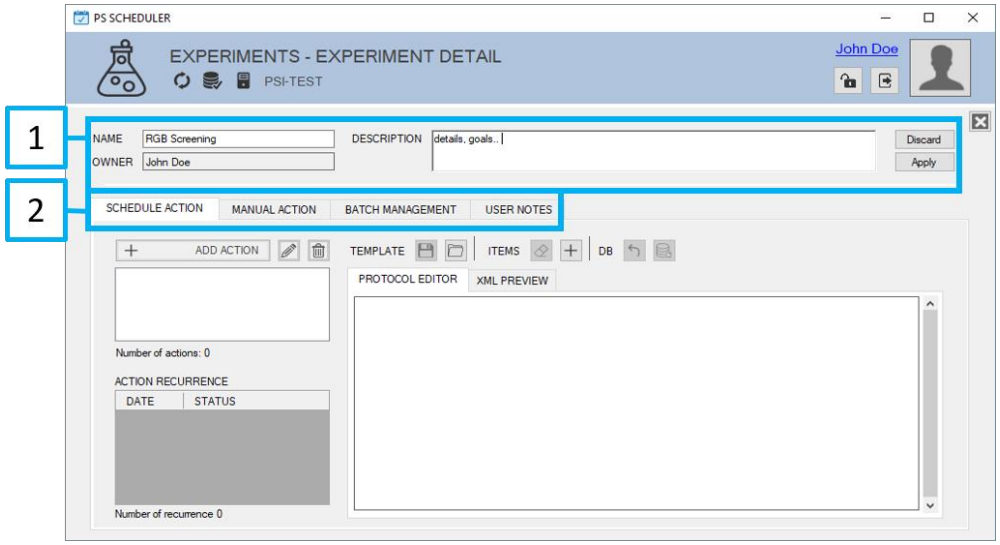


Fig. 12 Experiment detail window

The second part of the window contains four tabs: *Schedule Action*, *Manual Action*, *Batch Management* and *User notes* (Fig. 12-2). The basic element of each experiment is an action specified by the measurement protocol. Each action can be either scheduled or executed immediately.

The *Schedule action* window (Fig. 13-1) is used for action scheduling. The window contains controls for protocol setup and time scheduling tools. The *Manual action* window (Fig. 13-2) is used for starting the action with the start button.

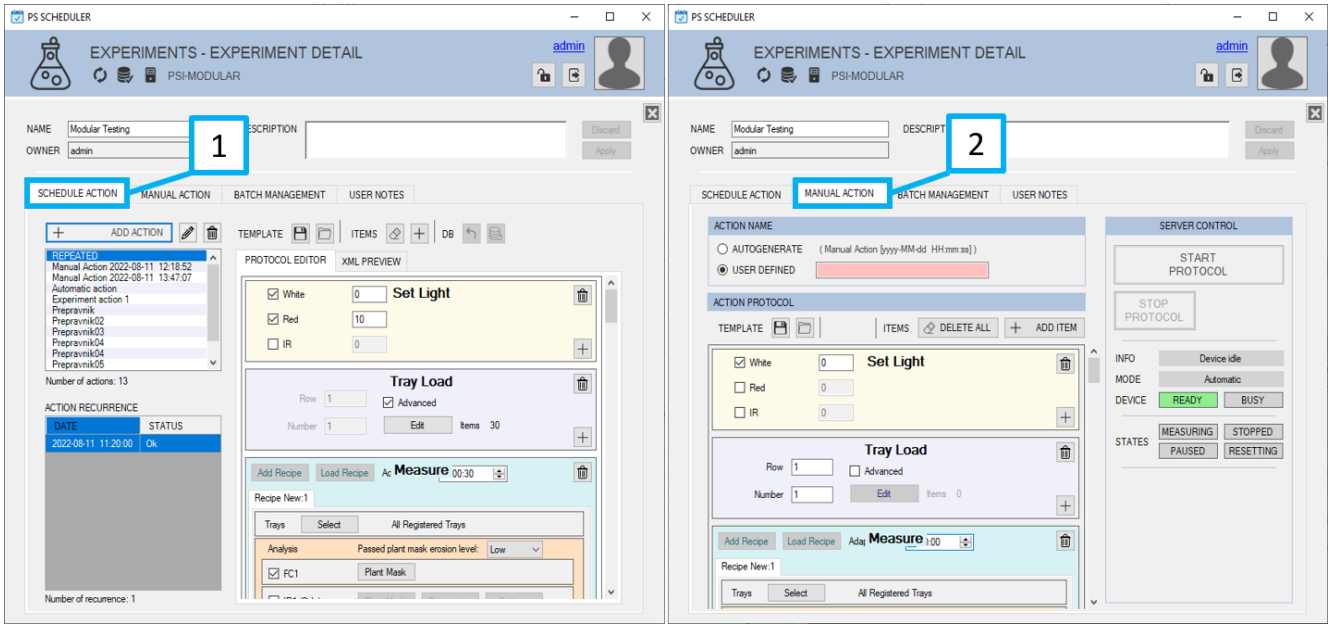


Fig. 13 Schedule action window and Manual action window

4.3 MANUAL ACTION

The *Action* is a scheduled measurement defined by the protocol. *Manual Action* mode is used when immediate execution of the action is required. The *Manual action* window (Fig. 14) contains controls for editing and executing the single measurement action. User interface of the manual mode differs from the automatic mode in that the measuring action can be started immediately by clicking the *Start* button.

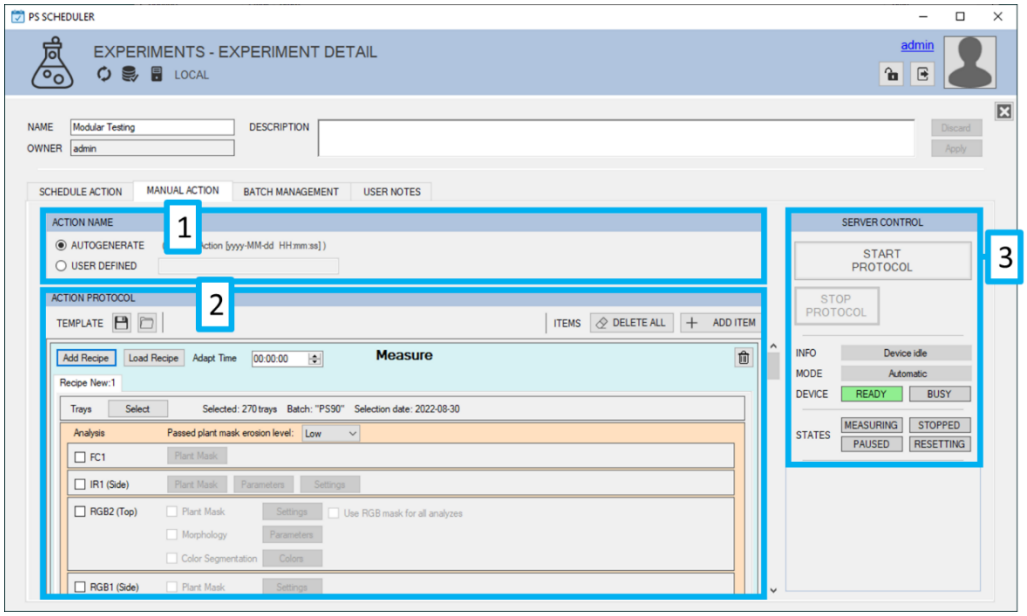


Fig. 14 Manual action window

In the *Manual Action* window two options of naming the action are available (Fig. 14-1).

AUTOGENERATE: the action name is created automatically with the "*Manual action"* prefix followed by action date and time.

USER DEFINED: user edits the action name.

The measured data will be saved in database with the specified name. Start creating protocol by adding first step using the + ADD ITEM button in the *ACTION PROTOCOL* tab (Fig. 14-2). Continue with protocol creation as is described in chapter 4.7

The Server Control tab (Fig. 14-3) contains several controls for action execution. When the protocol is prepared, press button *START PROTOCOL* for immediate measurement (Fig. 14-3). To start an experiment the system must be in ready mode. The device status is indicated by the green Ready control in the Server control tab. You can also stop protocol by buttons *STOP PROTOCOL*. *Info*, *Mode*, *Device*, *States* defines detailed system status information.

4.4 SCHEDULE ACTION

Unlimited number of actions can be assigned to one experiment. *Schedule action* tab contains controls for defining start times of the action(s) and for designing the action protocol.

List of scheduled actions (Fig. 15-2) is displayed in the left part of the window. Above the list three buttons: + ADD ACTION, *Edit* and *Delete* can be used (Fig. 15-1).

For creating a measurement protocol save or load protocol buttons (Fig. 15-3) save or load the protocol files to the local storage. Items buttons (Fig. 15-4) enable to add a protocol item at the beginning of the protocol + or erase all items. DB button (Fig. 15-5) saves the action protocol to database.

	Protocols are saved as XML files. XML files can be edited in a text editor.

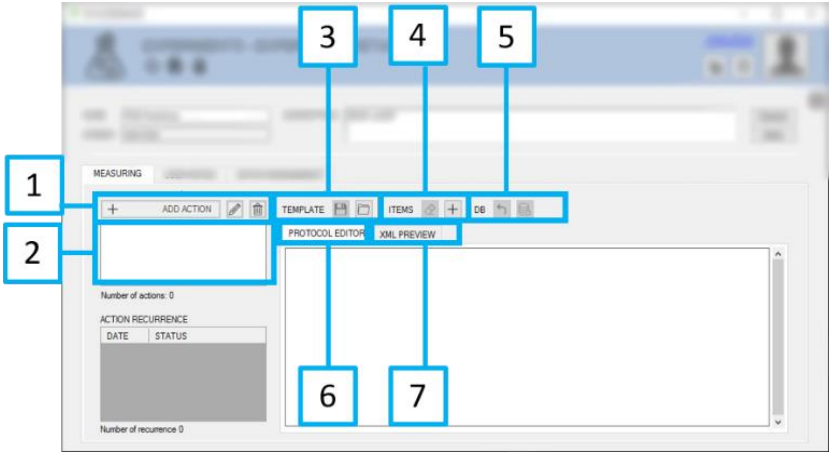


Fig. 15 Experiment, Measuring tab

	Protocols are NOT saved to database automatically. When editing is complete, pending changes need to be saved to the database with the *DB* icon button.

The *Protocol editor* tab (Fig. 15-6) displays the current protocol for the action selected from the list (Fig. 15-2) and enables editing the using graphical tools. The *XML Preview* tab (Fig. 15-7) displays the protocol in the text representation (Fig. 16). This tab cannot be used for editing, which is limited only to the graphical tools of the *Protocol editor* tab.

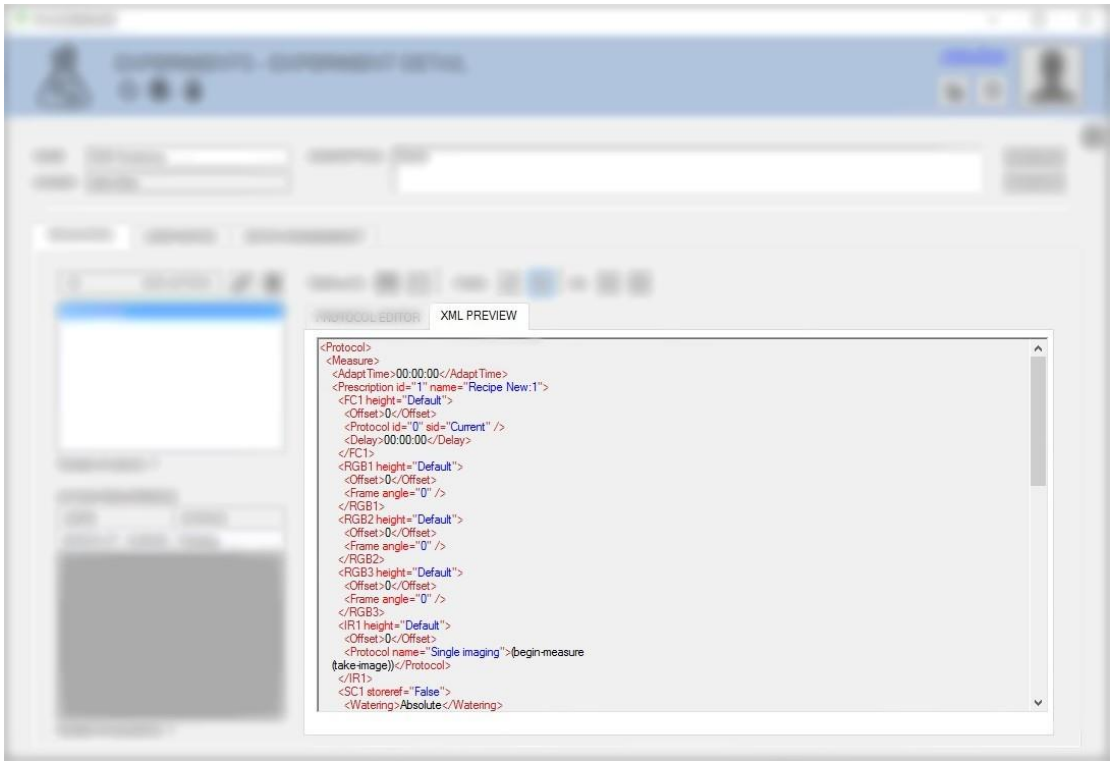


Fig. 16 XML preview

	Timing of the action must be defined prior to the protocol design.

New action is created using the *Add Action* button (Fig. 15-1). The *Action Scheduling* window is used to fill the *Action Name* (Fig. 17-1) and prepare the timing with one of the three options (Fig. 17-2):

Once– the action is scheduled to start only once at a given date and time (Fig. 17-3). Click *OK* button to confirm the time point.

Recurrent action (Fig. 17-2,Fig. 18) – recurrence is set for repeated starts of the same action and can range from minutes to months. Type a time value in the *Time* textbox (Fig. 18-2) and add the time point to the *Time per Day* list of time points with the *move (>)* button. Remove the selected points with the *minus (-)* button. Clear the list with the *trash bin* button.

Multiple time points can be also generated automatically with *Generate List* button (Fig. 19). In *Generate day times* window fill the following textboxes:

Recurrence action time interval (Fig. 19-1) is edited either by selecting time from textbox menu or typing time value directly to the textbox.

Start time and *stop time* must be both specified in the other two textboxes (Fig. 19-2). Click the *Generate* button to display the resulting list in the separate box (Fig. 19-3) and confirm with *OK* to add the list to the *Schedule action* window.

The Day recurrence tab allows to choose whether the action will be performed daily or only on certain days of the week.

The *Range of Reccurence* tab (Fig. 18-3) is used to select start day from drop down calendar. End date can be selected in the *End by* textbox similarly or, experiment time period can be defined directly in the textbox.

Specific dates (Fig. 20) – action does not have period, or there are just few repeats. Specific dates method is based on manually editing the dates and times for each action execution. Click OK button to add the list of time points to the Schedule action window.

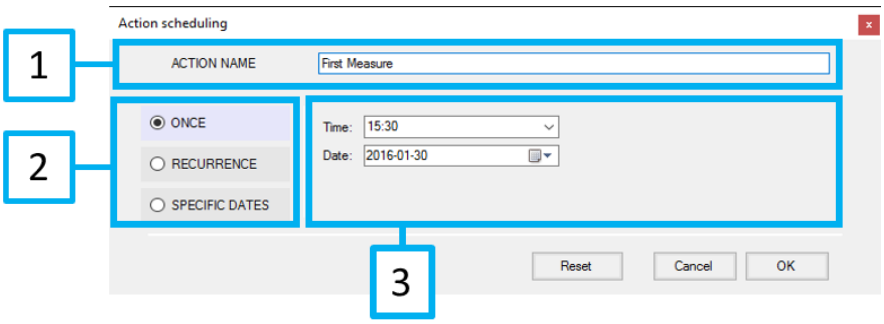


Fig. 17 Option Once in Action Scheduling window

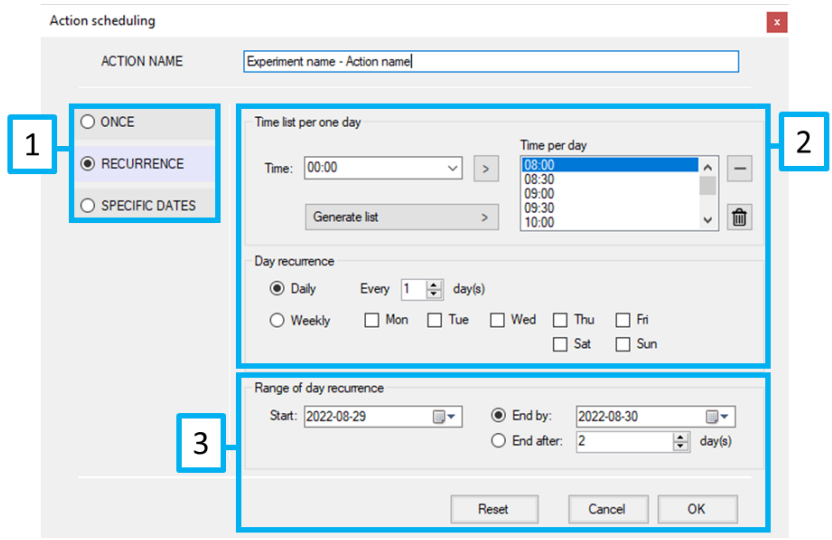


Fig. 18 Option Recurrence in Action Scheduling window

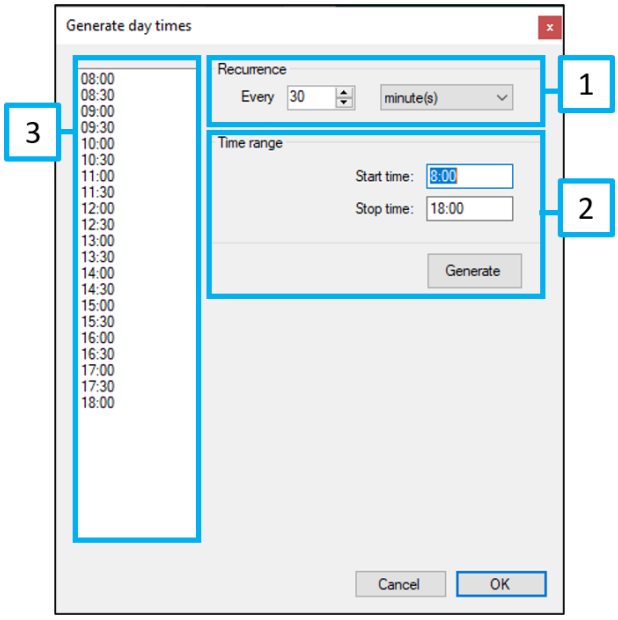


Fig. 19 Generator of repeated actions.

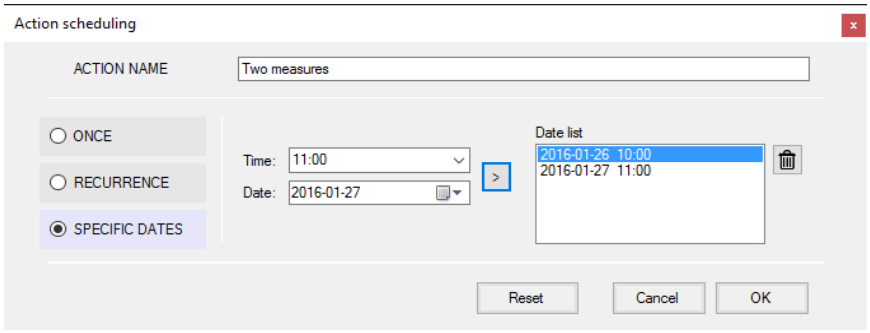


Fig. 20 Specific Dates option in Action scheduling window

	Action times can be specified either by writing directly into the corresponding field, or by using time combo box for times of the day and calendar for dates.

The newly created action is saved to database and appears in the list of actions (Fig. 21-1), where all actions of experiment are listed. After selecting an action with left mouse click in the list of actions all action recurrences are displayed separately in the *Action recurrence* window (Fig. 21-2).

The *Status* column in the *Action recurrence* list displays one of the following statuses:

- ***Ok*** status appears when action ends successfully
- ***ActionConflict*** status appears when action did not run, because the device was in busy state at the scheduled time. Typically, this occurs when previous action was still running, or when there are more actions scheduled at the same time.
- ***Error*** status appears when an action ended with an error, the detailed information can be displayed in Plant Data Analyzer application.
- ***Running*** status means that an action is running at the moment.
- ***Pending*** means that a scheduled action is waiting for its execution.

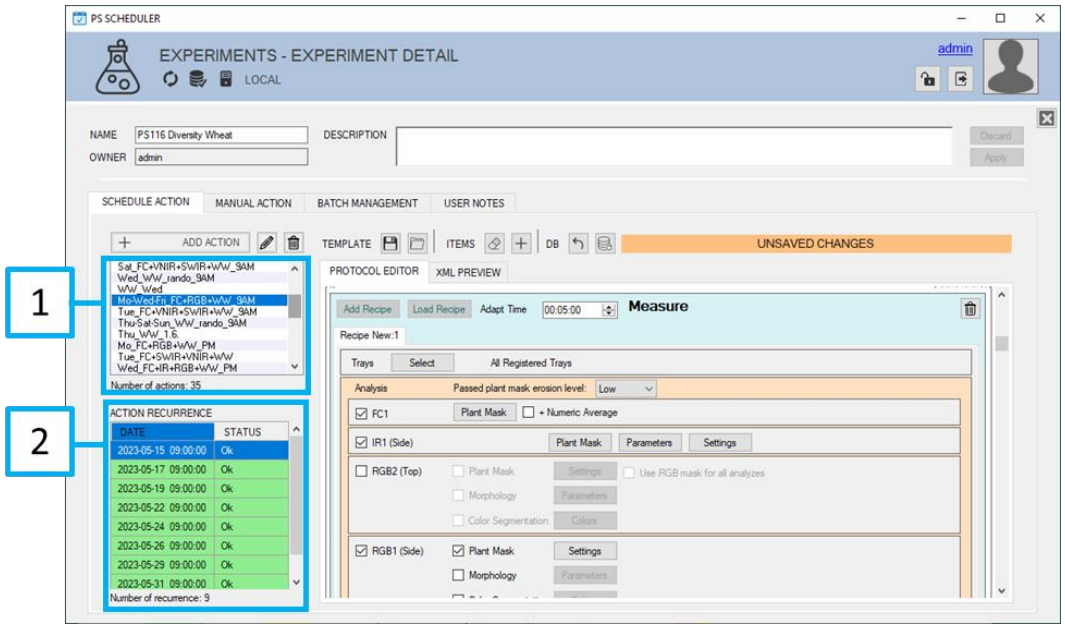


Fig. 21 List of actions and Action Recurrence window

4.5 BATCH MANAGEMENT

Batch management tab contains controls for creating, editing and deleting groups of trays (Fig. 22). Batch refers to a set of trays to be measured with a pre-defined protocol and must contain at least one tray. The batch is then selected in the *Measure Item* of the measurement protocol using *Add Recipe* button (see chapter 4.7.6.) Multiple recipes with different protocols and batches can be used in a same action.

To create a new batch first click the *New Batch* button (Fig. 22-1) and then name the batch in the *Batch Name* pop out window. Use *Trays of selected batch* (Fig. 22-3) and *Available Trays* (Fig. 22-4) tabs to select trays. In *Available Trays* tab click the (<) button to add the trays to selected batch. Conversely, select trays in *Trays of selected batch* tab and click remove (>) button. The *Search* button can be used to filter the trays by name, move arrow buttons (</>) to add/remove trays to/from selected batch.

	Two *Batch Management* windows exist in Scheduler app. One window is included in the *Experiments* section and the other window is included in the *Trays* section. Synchronization with database occurs regardless of which window was used for batch editing. All changes are saved to database immediately.

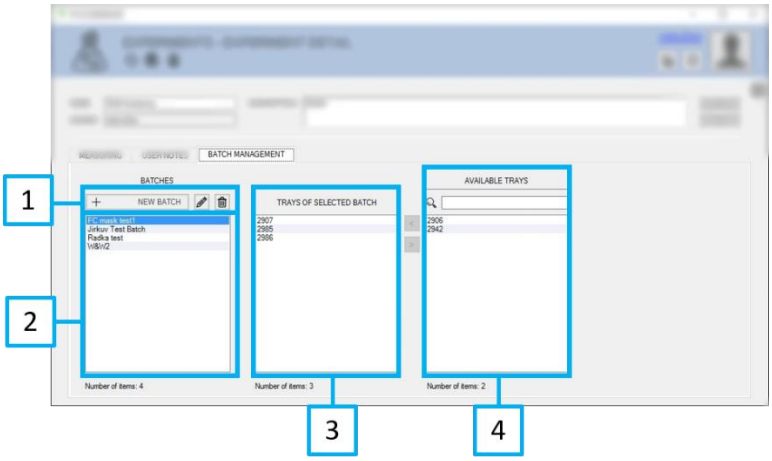


Fig. 22 Batch management window

4.6 USER NOTES

User notes with time labels can be optionally added to the Experiment window. *User Notes* tab contains chronologically ordered list of notes (Fig. 23-2) and allows to add new one and to edit or remove existing note (Fig. 23 -1).

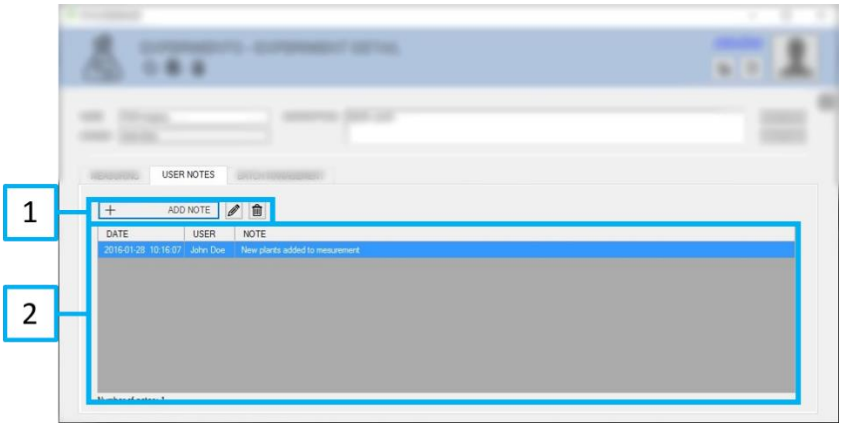


Fig. 23 List of experiment notes

When *Add Note* button is clicked, *Experiment note* window (Fig. 24) is displayed. It is necessary to select whether the current (Fig. 24-1) or custom (Fig. 24-2) date is used, and fill in the note text (Fig. 24-3). Note is saved to the database by the *OK* button. The thrash bin picture button deletes the selected note. The list of notes is ordered chronologically based on date and time defined in the *Experiment Note* tab.

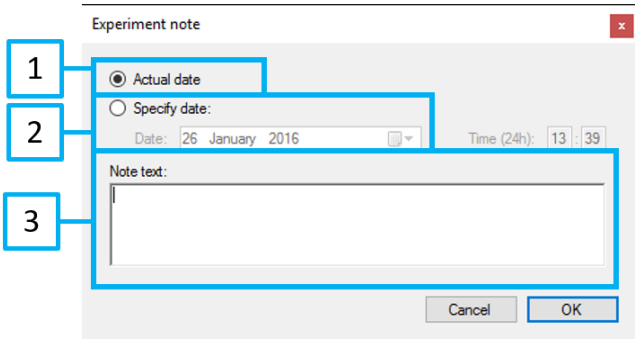


Fig. 24 Experiment note window

4.7 Protocol Editor

Protocol editor displays protocol corresponding to action selected in action window. The editor uses common picture buttons and items menu to define measuring protocol body (Tab. 4, Fig. 25). The measuring protocol can be edited in the *Schedule Action* window (Fig. 25-1) or in the *Manual Action* window (Fig. 25-2).

New protocol for the measuring action is created using add item button **+** for Schedule Action option and with *Add Item* button for Manual Action option. (Fig. 25-3).

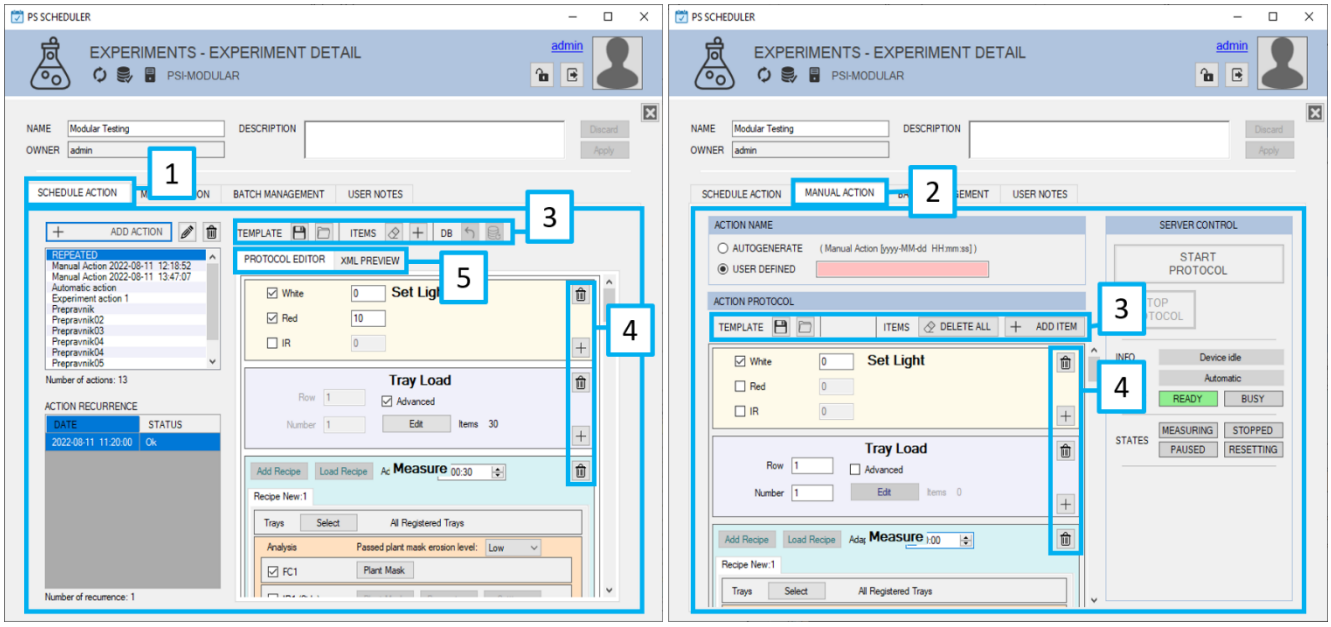


Fig. 25 Controls for editing protocol in the Schedule action window (1) and in the Manual action window (2).

+	**Add or create new object, add protocol item**
	Edit the object
	Delete the object
	Close currently opened window or dialog
	Save protocol template
	Open protocol template
	Erase protocol item
	Search button is used for filtering trays
<	Move button - assign
>	Move button - unassign
	Hides unchecked measure items

Tab. 4 Buttons and items menu to define measuring protocol body

Each protocol item can be deleted by delete button, or new protocol item can be added right after the current one by add button + (Fig. 25-4). Click the *Add* button and select a protocol item from the dropdown menu (Fig. 26).

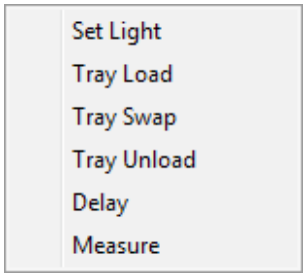


Fig. 26 Protocol items drop-down menu

The items for the protocol are dependent on actual system configuration. Several types exist

1. Tray manipulation items (Fig. 27-1)
2. System controls or light setting item (Fig. 27-2)
3. Measure items (Fig. 27-3) consist of Analysis tab (Fig. 27-4) and Measure tab (Fig. 27-5)

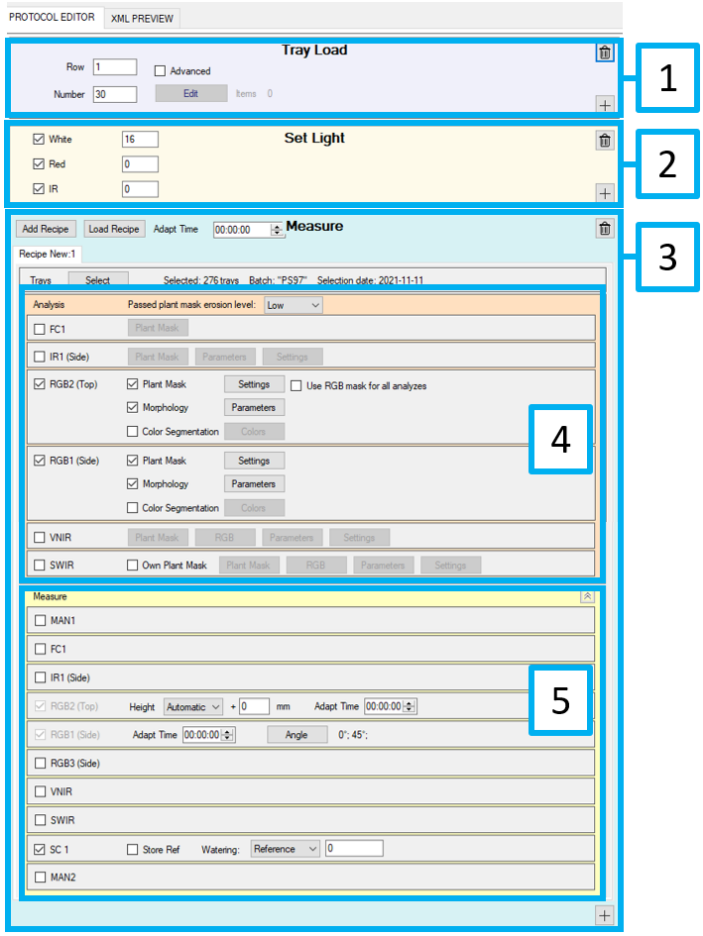


Fig. 27 Protocol Editor items

4.7.1 SET LIGHT

Item type *SetLight* enables light control of the available light sources (Fig. 28) (e.g. the acclimation chamber of the device, the LED panel of the FluorCam imaging unit). Number and colors of the light channels depend on the device configuration. Values are in range from 0 to 100 and refer to the percent of the maximal light intensity. To change intensity of a light source first Set the light channel by checking the checkbox to activate the selected light source textbox (Fig. 28-1) and then define Value by typing an intensity of selected light (Fig. 28-2). If the checkbox Set is unchecked, the light setting remains unchanged.

Fig. 28 *Set Light* protocol item

4.7.2 SYSTEM CONTROLS

System Controls item can be used to apply *Lights Disable* control (Fig. 29). This function is used to switch ON/OFF cultivation lights. The Fytoscope control of the cultivation lights is optionally and temporarily interrupted with the PlantScreen measurement protocol.

When *Lights Options -> Lights Disable* checkbox is flagged all cultivation lights can be turned ON or OFF. When switched OFF the Fytoscope protocol is still running but the cultivation lights are OFF. This status can be restored with another System Controls item in the protocol containing *Lights Disable* OFF.

When *Lights Options -> HC – use LEDs* checkbox is flagged the cultivation lights can be used for hyperspectral measurement (status: *ON*) or not (status: *OFF*).

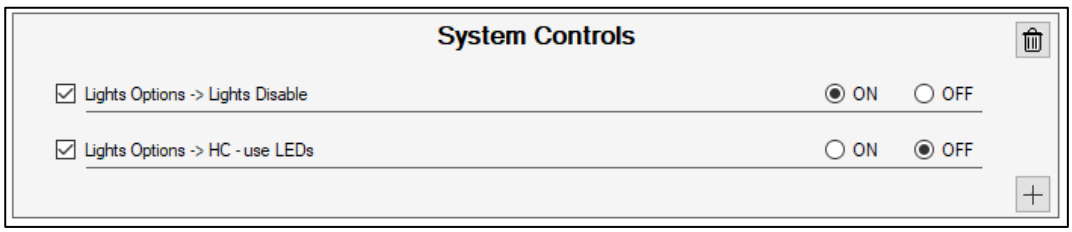


Fig. 29 System Controls protocol item

Typical example for use of *Lights Disable* function is shown below reflecting the follow up measurement steps:

1. *Set Light – Lights Disable 100* Sets the control of the cultivation lights to PlantScreen Server
2. *Delay 10 min* - wait for 10 min
3. *Measure* - execute measurement

Set Light – Lights Disable 0 Sets the control of the cultivation lights back to Fytoscope Client Server

4.7.3 TRAY LOAD/UNLOAD

Item types *Tray Load* and *Tray Unload* enable to load or unload trays from the tray buffer to the area of rating stations. To load or unload the trays it is necessary to specify buffer line number (*Row*) and the number of trays (*Number*) zone to the measuring units. Note that the item is available only for certain device configurations. *TrayLoad* has two parameters (Fig. 30-1), row and number of trays which are loaded. *TrayUnload* returns the trays to the original position. Alternatively, when specific trays need to be transferred between specific buffer lines the *Advanced* mode (Fig. 30-2) is used.

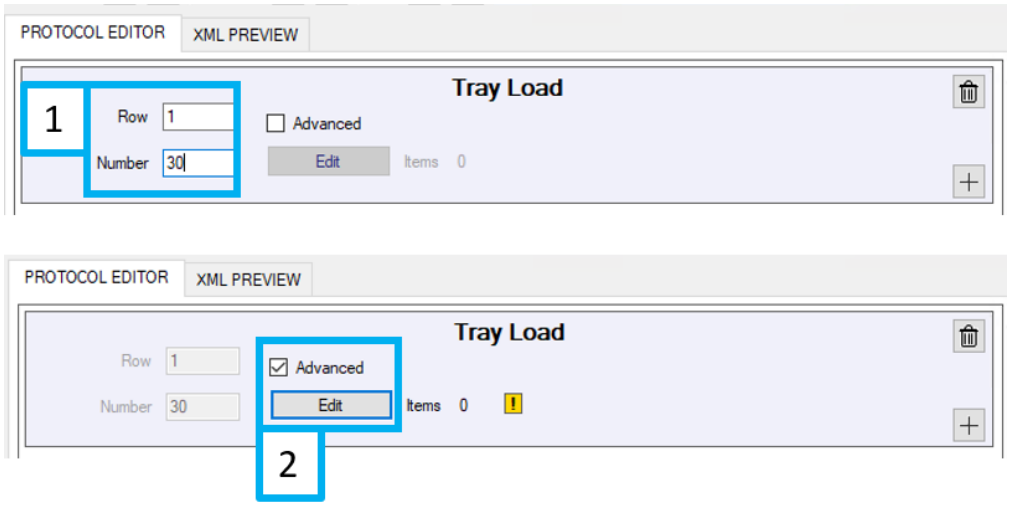


Fig. 30 Tray Load protocol item

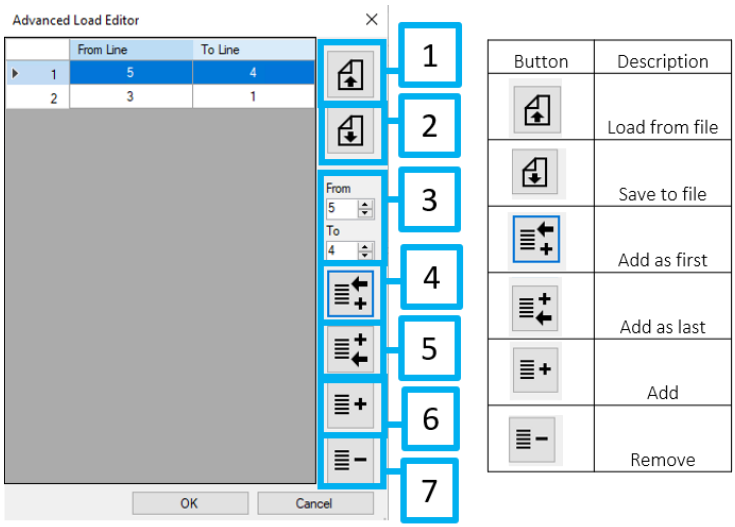


Fig. 31 Advanced Load Editor

Switch to advanced mode by flagging the corresponding *Advanced* checkbox and click the *Edit* button. The *Advanced Load Editor* window opens (Fig. 31). Multiple controls are used to create multiple single tray transfers between two buffer lines. To add a single tray transfer define from which line to which line the tray should be moved (Fig. 31-3). The transferred tray is always in the first position of the line. Then click the *add* button (Fig. 31-6) and the new item appears in the list (Fig. 31-left). Other items can be added above the list with *Add as first (*Fig. 31-4) and/or below the list with Add as last (Fig. 31-5) buttons. Use *Remove* (Fig. 31-7) button to remove a selected item. The *Save to file* (Fig. 31-2) button saves the list locally in xml format. The xml file can be edited using external tools and imported back with *Load from file* (Fig. 31-1) button.

4.7.4 TRAY SWAP

Tray swap protocol item loads defined number of tray pairs from two different lines from the buffer and then swaps the two trays when unloading (i.e. when returning the trays back to buffer). To swap the trays use the *TraySwap* protocol item (Fig. 32). Fill in the following textboxes: *Original row* from where the first tray should be loaded and *Target Row* from where the other tray of the pair should be loaded. The *Number* defines the number of tray pairs loaded for the tray swap.

Fig. 32 Tray Swap protocol item

4.7.5 DELAY

The *Delay* protocol item (Fig. 33) allows to define waiting time interval prior the next action item is executed. For example, *Delay* could be used to define waiting time of the system with trays in the growing area or adaptation area under specific conditions (i.e. light or dark adaptation time).

Fig. 33 Delay protocol item

4.7.6 MEASURE ITEM

Recipe

The *Measure item* (Fig. 34) contains *Add Recipe* and *Load Recipe* buttons. The *Measure item* can not be edited until a tray batch is selected.

To select a batch click the *Add recipe* button (Fig. 34-1). In the pop out *Batch Picker* window (Fig. 35) search for the required batch using the search box (Fig. 35-1), which can filter all prepared batches by matching symbols in the name. After selecting a batch, the list of trays assigned to the batch appears.

Each *Measure* item contains one or more *Recipes*. Checkbox *All Registered Trays* can be used to find all actual tray registrations (Fig. 35-2) and apply them to the measured tray IDs. This option is not available in XYZ systems.

Adapt time parameter (Fig. 34-3) is used to define duration of the light/dark adaptation of the plants inside the acclimation chamber prior to the measurement. If set to 00:00:00, trays just pass the acclimation chamber.

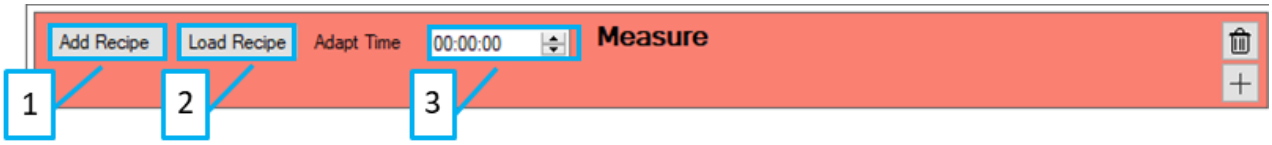


Fig. 34 Measurement protocol item

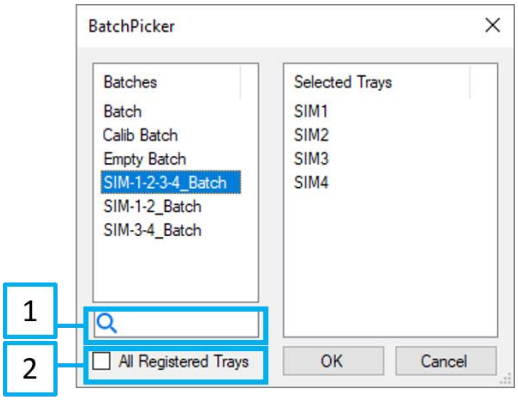


Fig. 35 Batch Picker

In the next step *Analysis* and *Measure* tabs open inside the *Measure* item, where measurement type, parameters and settings for the measured data analysis are specified. When the batch is added, batch name, number of trays and current date (date of the selection) are displayed (Fig. 37-3). Trays selected for the action can be modified or selected again by clicking the *Select* button. Trays from the batch are written directly into the protocol. If the protocol is saved and subsequently loaded, it contains exactly the same trays, no matter if the batch has been changed in the meantime.

Click the *Add Recipe* or *Load Recipe* button (Fig. 34-1,2) to add more recipes into the measuring protocol (Fig. 36-1). Multiple recipes can be used to set different measuring protocols for different sets of trays (i.e. different batches).

After creating a new *Recipe* further management of the individual recipe is possible. Select the recipe by moving the mouse over the name of the recipe (Fig. 36-1). Right click the mouse and select one of the tasks in the list (Fig. 36-2). Several options appear in the list (*Load*, *Delete*, *Delete All*, *Save* and *Rename*).

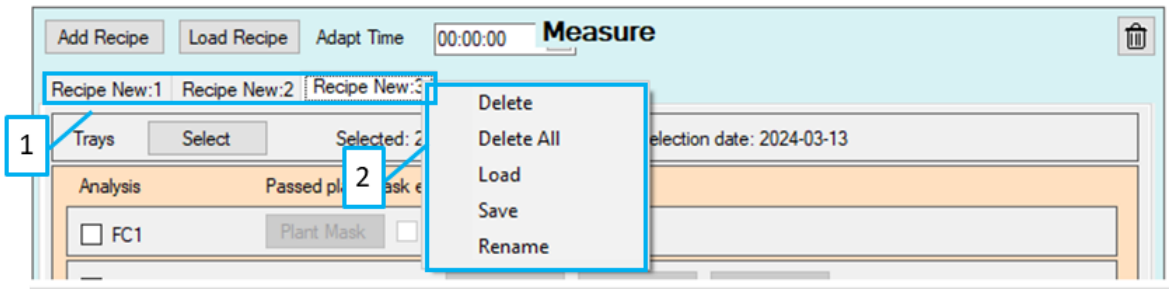


Fig. 36 New measurement block

	Measure items are colored red when the batch for measure step is not defined (Fig. 34). After adding a batch the full size item opens (Fig. 36).

Tray Order

In PlantScreen XY or PlantScreen XYZ systems *Tray order* and *Tray-Position Registration* must be specified (Fig. 37). The *Tray Order* option defines the order of the trays measured during one measurement round (Fig. 37-1) and the *Tray-Position Registration* (Fig. 37-2) is used to select a predefined assignment of measured trays to the available positions in the XYZ/XY system.

Two *Tray order* options are available:

- *Shortest path* mode uses algorithm for finding the shortest path between last system position and the next measured position.
- *Custom* option allows the user to set its own tray measurement order.

After selecting the *Custom* option and clicking on *Edit Order* button (Fig. 37-1) an editor (Fig. 38) is opened with trays from all recipes of the given measure item. The editor contains tools for alphabetical ordering and manual selected trays moving. *Save to file* (Fig. 38-1) saves the current list of trays to a local storage in csv format, *Load from file* (Fig. 38-2) loads the locally stored csv file to the editor, *Ascending Alphabetic Order* and *Descending Alphabetic Order* aligns the trays in the list in alphabetical order (Fig. 38-3,4), *Move Selection Up* and *Move Selection Down* moves selected trays up or down in the list (Fig. 38-5,6).

The *Save* and *Load* from file controls can be used to re-edit (e.g. randomize) the tray order file in a spreadsheet software (Fig. 38-7) using i.e. R-script. The first column in the spreadsheet contains unique Database ID number. The second column is a list of tray IDs corresponding to the Database IDs. The row order determines the tray order during the measurement (i.e. row 1 in the file defines the first tray to be measured in the given round).

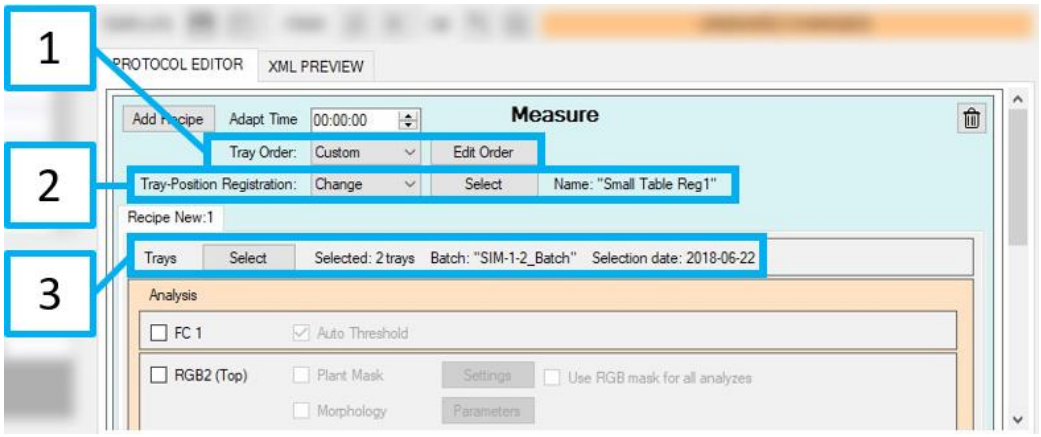


Fig. 37 Tray order and Tray-Position Registration

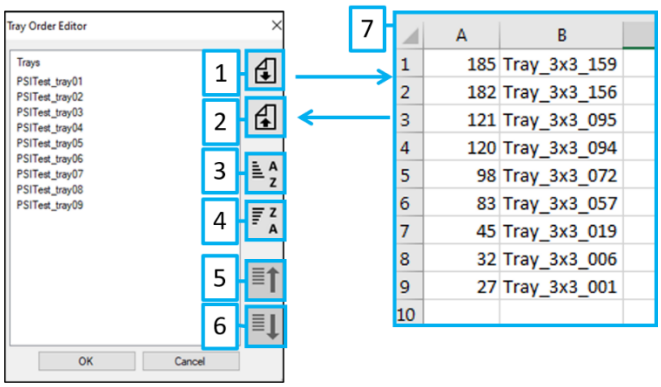


Fig. 38 Tray Order Editor

Tray-Position Registration is used to link a given XYZ position in the grid to a given Tray ID. *Tray-Position Registration* defines whether the Tray-Position Registration last loaded in the Server application, window XYZ, will be used for the measurement = option *Current*, or whether the registration stored in the database will be selected for the measurement by the user = *Change* option. After changing to option *Change* or clicking *Select* button the selection editor (Fig. 39) is opened. The editor shows all stored registrations and allows selection one of them.

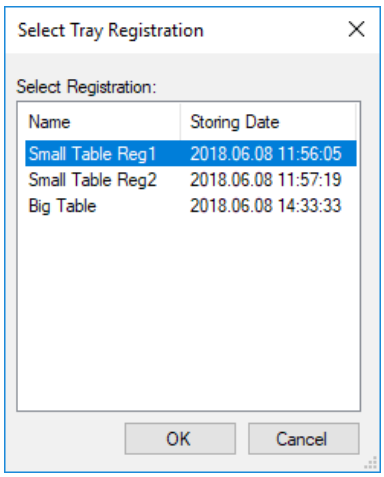


Fig. 39 Tray Registration Selection

	Tray-position registration carries information about positions calibration and registration of trays into the position. The *Tray – Position registration* is created in XY/XYZ window in the PlantScreen Server application. The instructions how to create a grid of positions and how to assign trays to grid positions are part of the PlantScreen Server manual.

Analysis and Measure tabs

The measure item contains *Analysis* and *Measure* tabs. Both tabs use checkboxes on the left side of the item to select sensors used for imaging and analysis. After selecting the sensor by flagging the corresponding checkbox, various setting controls for conveyor, camera or analysis are shown. The complete setting options are displayed only after selecting the sensor. Content of the measurement block is generated automatically based on the sensors installed in the system.

The *Analysis* tab is used to define settings of the automatic analysis procedure performed automatically during the measurement. Data analysis proceeds immediately after storing measured data to database. Detailed description of analysis setting is described in the technical documentation of individual imaging sensors.

The *Measure* tab is placed bellow the *Analysis* tab and is used to define the measurement settings of the individual sensors, i.e. number of angles used for the side view imaging. Selecting the sensors in *Analysis* tab selects the corresponding sensors in *Measure* tab automatically.

	Analysis block is shown always above the Measurement block. Measurements can be either selected manually directly in the Measurement block, or automatically by checking a checkbox of the given sensor in the analysis section. When analysis for given sensors is selected in the Analysis block, the sensor is automatically selected in the Measurement block.
	Note that types of items will differ depending on the HW configuration of the given phenotyping system and some of the items might not be available for specific HW configurations.

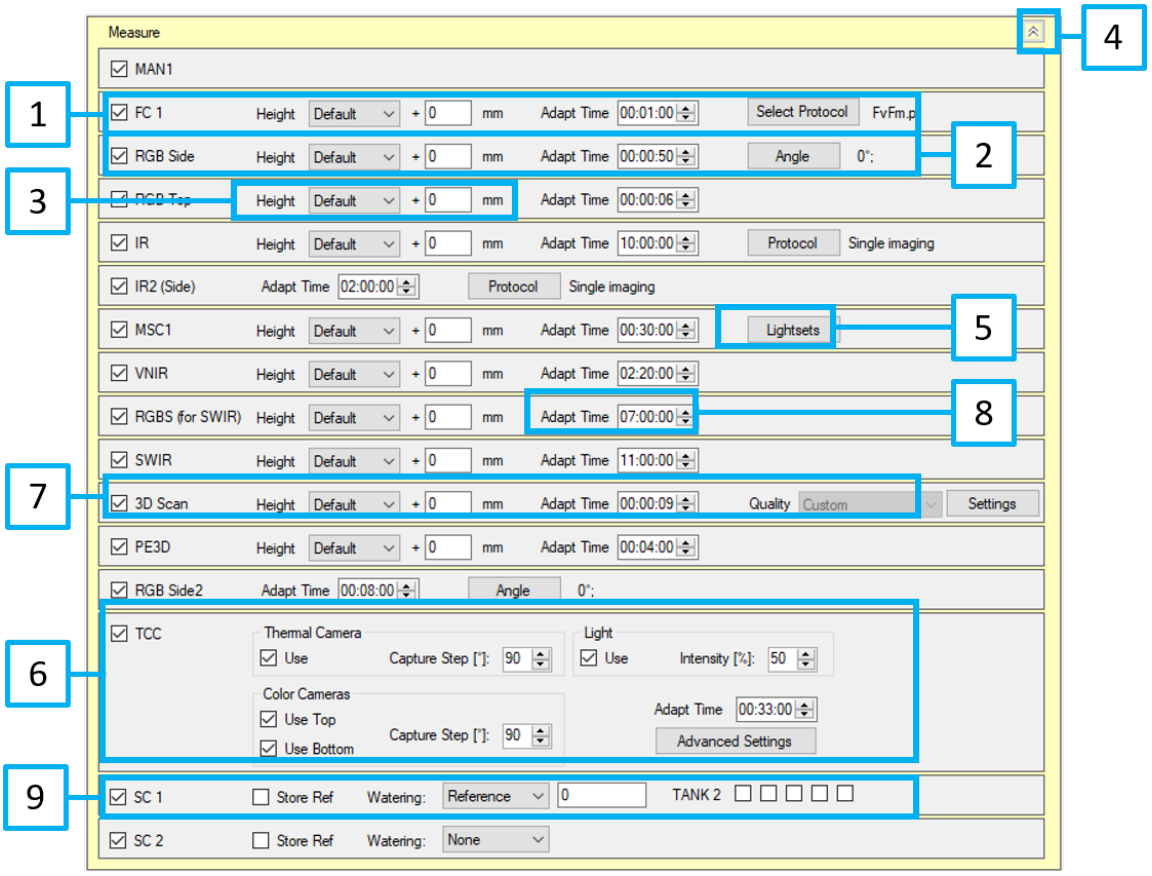


Fig. 40 Measurement tab

The arrow button (Fig. 40-4) shows and hides unchecked measurements. If checkbox with the sensor name is checked, measurement with that sensor is invoked in the current action, and if measurement has any parameters to be specified, the parameters are displayed (Fig. 40-1). If the checkbox is not checked, parameters are hidden and trays just pass through the measurement station (Fig. 40-2).

Adaptation time is defines time that elapses from the moment tray arrives at the station before the measurement starts. This could be used to provide time to cease all plant movements or to adapt plant to certain light condition. The adaptation time can be defined separately for each imaging unit (Fig. 40-8). Warning appears when the time is set shorter than the default time value.

Height position of the sensor is another required parameter in the measurement tab (Fig. 40-3). Three options for adjusting height of the imaging sensors to the height of measured plants are available (Fig. 41):

- ***Default*** – position is set based on the optimal calibration height of each of the sensors (i.e. optimal working distance) (Fig. 42). Value in mm can be added to this height either positive or negative. This field is usually used to specify plant height - height of the plant above the PlantScreen tray lid. The offset textbox is used to readjust the default height settings to the top of the plant.
- ***Fix*** – position is set to the parameter value. It does not represent actual height above the tray, but the physical position of the sensor on Z axis.
- ***Automatic*** – position is set to the optimal calibration height + parameter + measured height of the plant. This mode is available only for device configurations with automatic height measurement laser gate.

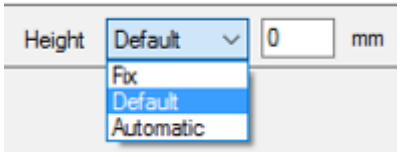


Fig. 41 Camera height setting

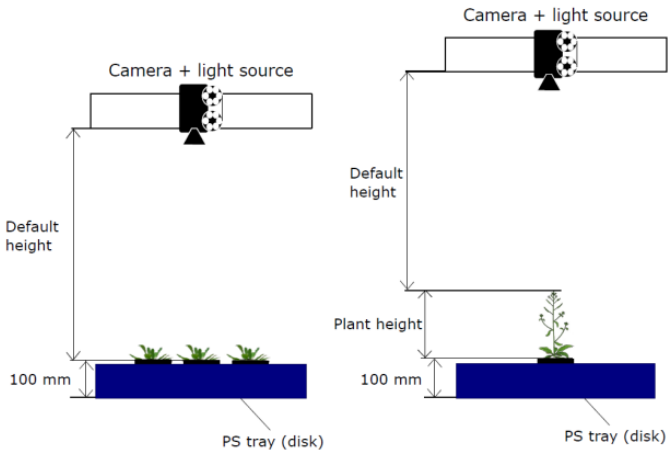


Fig. 42 Default camera height setting

The fixed value for a given sensor corresponding to the top of the standard 5x4 tray (i.e. Default value set to 0) can be displayed in the protocol measure item when switching the height list box to *Fix* ***mode*** (Fig. 43-1). Another option to display the default position of the sensor is to use *Default* mode and place the cursor of the mouse on the *Default* window (Fig. 43-2). This feature and information about the physical value of the sensor is mainly used for system calibration and/or when new mask is created in ***Service Mode***.

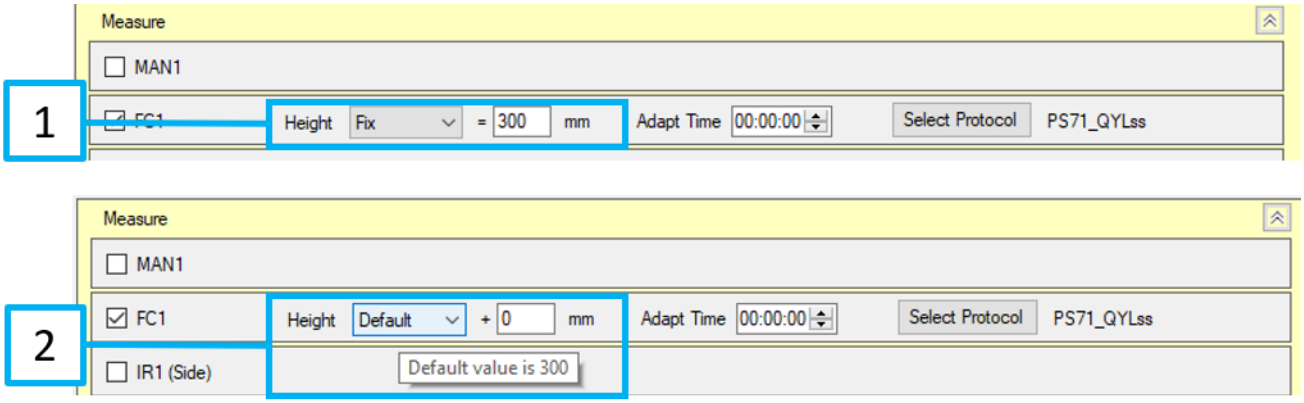


Fig. 43 Camera height setting – fix and default options

Select Protocol

For given sensors such as Fluorescence imaging (FC) and Thermal Imaging (IR) measurement protocol can be specified. When FC measurement is selected (Fig. 44-1), the FC *Select Protocol* window will automatically open. Use the Fluorcam software directly to edit and save FC protocols. For the IR measurement, click Protocol button to open Script Editor to write specific protocol for IR measurement (Fig. 44-2). For more details about the IR protocol script, see the IR technical documentation manual.

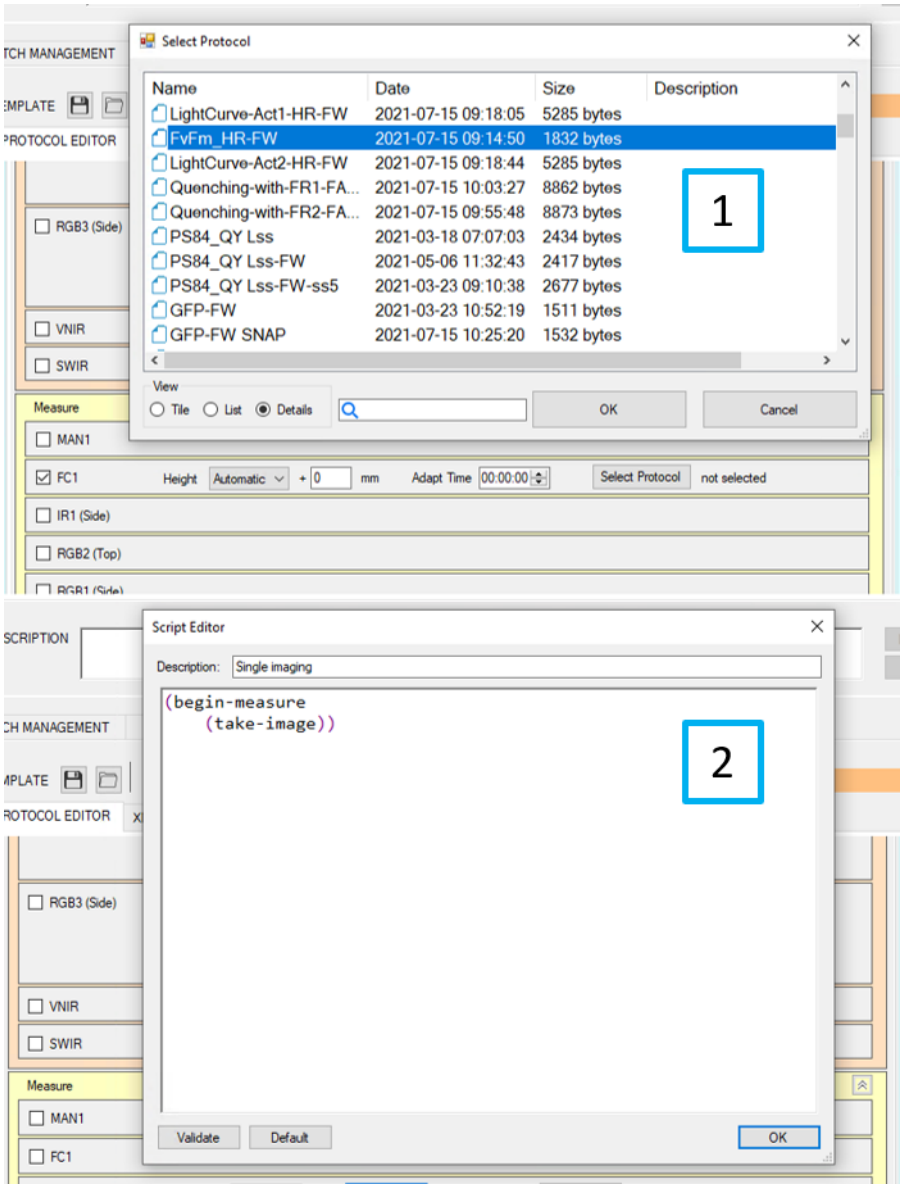


Fig. 44-(1) Protocol window for FC measurement. (2) Script Editor to write specific protocol for IR measurement.

TCC Advanced Settings

Thermo Color Camera service (Fig. 40-6) has only measurement part. Checkboxes define which camera formats are used for the measurement. Images are captured every *Capture Step* for angle range 0-360° (for example, if *Capture Step* is set to 120, images for angles 0, 120 and 240 degrees are captured). If the *Capture Step* is set to 360°, only one image from default angle is captured and rotation table is not used. Section *Light* controls the imaging station light.

Advanced settings control (Fig. 46) of Thermo Color Camera service contains two parts:

- Data formats from Thermal Camera part defines format(s) for thermal data. Digital Data option stores pixel intensities in Tiff format, Thermal Data option stores temperatures (in Kelvin) in Float Image Format.
- In Rotation part, speed of rotation, acceleration, deceleration and jerk (shape of acceleration and deceleration curve) can be set. Jerk 0 means linear speed change.
- If rotation offset is required before capturing start (for example if plant parts movement should be stabilized after rotation acceleration), combination of Angle and Capturing Start needs to be set. Angle should be set to 720 and Capturing Start then defines offset of the capturing process. Two full rotations are done this way. If Angle is set to 360, Capturing Start is 0 and cannot be changed.

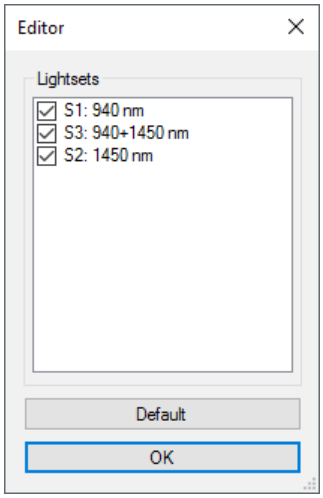


Fig. 45 MSC Lightsets

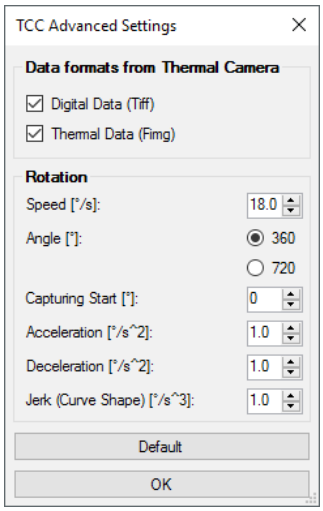


Fig. 46 TCC Advanced Settings

3D Scan Settings

3D Scan service allows a scanning quality choice by the selection menu. Three quality levels are predefined and a custom choice is possible (Fig. 47):

- *High Quality* – Scanning angles for side scan includes 8 angles with a regular spacing of 45° (0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°). Top scan is also used, if system contains it.
- *Medium Quality* – Scanning angles for side scan includes 4 angles with a regular spacing of 90° (0°, 90°, 180°, 270°). Top scan is also used, if system contains it.
- *Low Quality* – Scanning angles for side scan includes 2 opposite angles (0°, 180°). Top scan is also used, if system contains it.
- *Custom Quality* – Selected scanning views (top/side) and scanning angles doesn't respond any predefined quality level.

3D scan quality settings can be edited directly in the *3D Scan Setting* window (Fig. 48), opened by *Settings* button. Individual options are enabled depending on the availability of the given system. The result of the measurement is a point cloud model composed of individual scans according to the chosen selection.

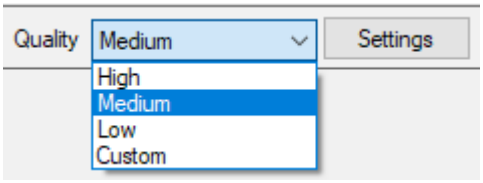


Fig. 47 3D Scan Quality Settings

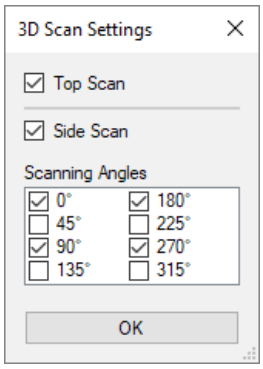


Fig. 48 3D Scan Settings

Watering

This item is used for weighing and watering of plants (Fig. 40-9). Three options for adjusting amount of water added to each pot are available:

- ***None*** option is used for weighing the pots and omitting the watering step.
- ***Reference*** is used to water plants to a reference weight assigned to each pot.
- ***Absolute*** is used to add a constant amount of water to the pot.

The *Store ref* feature is used to automatically assign the actual measured weight as a reference weight of the pot.

Multiple watering tanks can be available for certain HW configurations. *Tank2* function is used to define watering of given position (i.e. pot) from the secondary tank by ticking the given position.

Analysis Block

Analysis block (Fig. 49) provides tools for definition of image analysis pipeline. All features for definition of analysis pipeline for each imaging sensor defined are listed. When the analysis checkbox for the given sensor is checked all measurements and corresponding basic analyses are automatically selected.

	For analysis of certain data source, analysis from different sensor is required, i.e. RGB mask for IR image segmentation. Both analysis and measurement for related sensors are automatically selected in this case.

Most of the parameters defining the analysis procedure can be specifically defined by the user or Default setting can be used. Image analysis pipeline and settings of individual parameters are explained in the following section. All available tools for given sensors and specific image analysis pipeline are described. Detailed description of analysis setting is described in the technical documentation of individual sensors.

Passed plant mask erosion level option (Fig. 49-1) is applied in cases when plant mask created in an analysis from one sensor is used for analysis of data from different sensor e.g.:

- RGB plant mask can be used for IR data segmentation
- VNIR plant mask can be used for SWIR data image segmentation

- Leaf Tracking mask is used for other sensor image analysis when *Use RGB mask for all analyzes* option (Fig. 49-2, see below) is selected.

The *Passed plant mask erosion level* parameter defines level of morphological operation (erosion) applied on re-scaled plant mask. The operation removes border pixels from outside of the plant mask. This is useful for cropping plant-soil border from the plant mask to avoid analysis result distortion. This function can be turned off by settings the value to *None.*

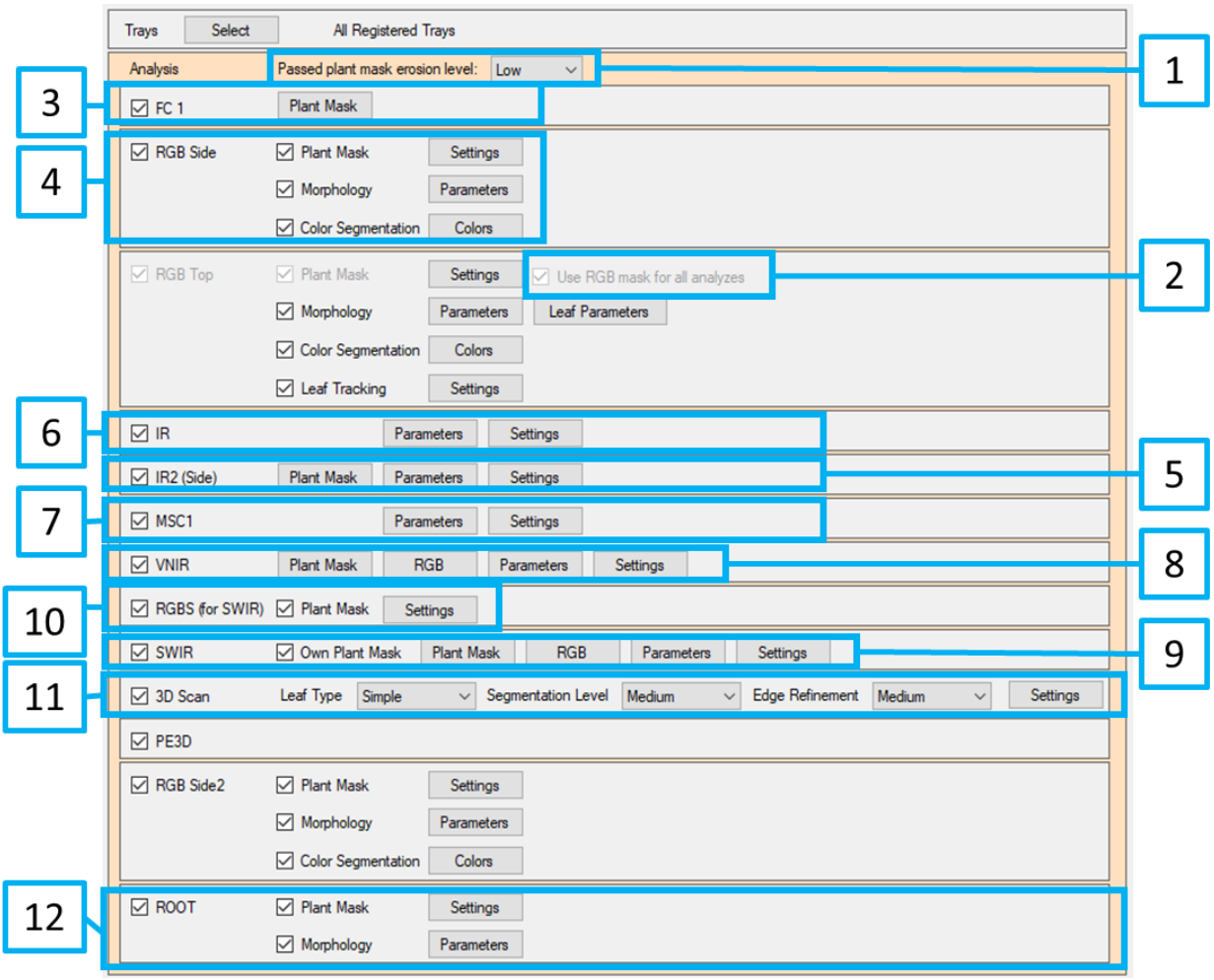


Fig. 49 Analysis block

FC Analysis Settings

In the analysis part of the action protocol, user can adjust the settings for FC plant mask analysis by clicking *Plant Mask* button (Fig. 49-3). FluorCam Analysis allows to set threshold for *Plant Mask* segmentation automatically or manually by adjusting up and down threshold limits for segmentation. Other analysis parameters can be optimized and are described in the table below (Fig. 50, Tab. 5).

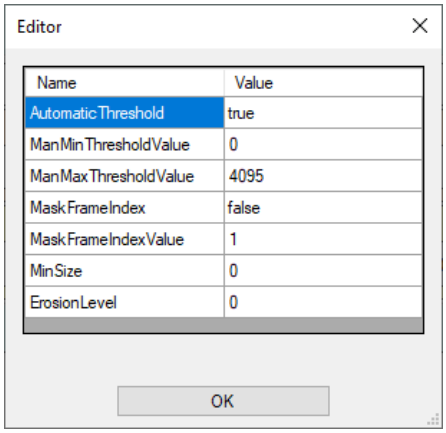


Fig. 50 FC Plant mask settings in action protocol

Parameter	Description
Threshold	true – Plant segmentation is performed automatically false - Plant segmentation is performed based on user-defined thresholds (ManMinThresholdValue, ManMaxThresholdValue)
ManMinThresholdValue	Minimum threshold value. Used only when Automatic Threshold is false.
ManMaxThresholdValue	Maximum threshold value. Used only when Automatic Threshold is false.
MaskFrameIndex	true - For plant mask detection the frame with user defined index (MaskFrameIndexValue) is used false - For plant mask detection the TimeVisual frame is used (defined in FC protocol)
MaskFrameIndexValue	Index of frame to use for plant mask detection. Used only when MaskFrameIndex is True.
MinSize	Minimal size of the mask element [px]
ErosionLevel	Parameter defining the number of iterations for morphological operation – erosion. This step removes N pixels from object (region of interest) boundaries.

Tab. 5 Description of parameters used for FC plant mask selection.

RGB Analysis Settings

Settings for Plant Mask analysis (Fig. 52), selection of morphological Parameters, definition of colors for *Color Segmentation* and if available *Leaf Tracking* settings can be optimized for RGB images (Fig. 54).

If the *Use RGB mask for all analyzes* checkbox (Fig. 49-2). is checked, resulting RGB plant mask is used for all other sensors which are included in the measurement. The plant mask is positioned on the images from the other sensors based on the calibration that is done during the system installation.

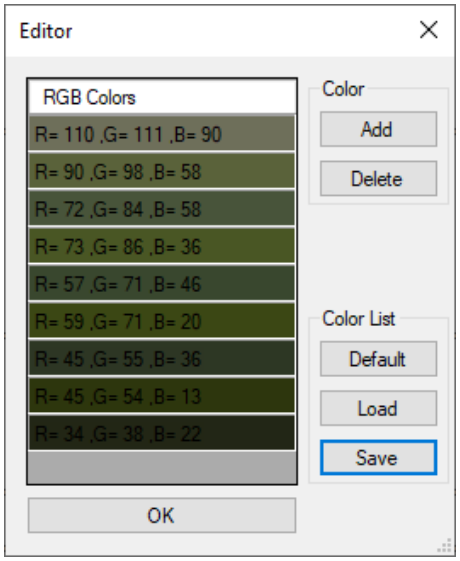


Fig. 51 RGB colors

For the color segmentation Color settings are pre-defined. RGB Colors (Fig. 51) are defined by their position in RGB color space, ranging from 0-255 for each channel. Colors can be changed manually using *Add* and *Delete* button or loaded from txt. file containing colors definition.

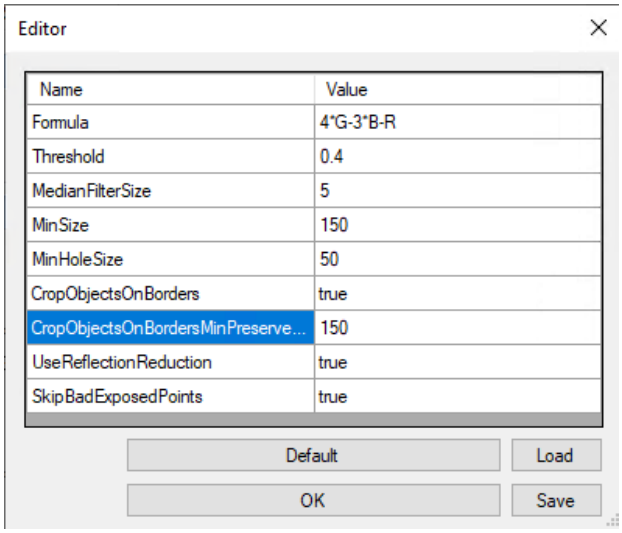


Fig. 52 RGB Plant mask settings

Parameter	Description
Formula	Formula definition for object mask generation. Formula can contain constants (1, 2, 3, …), operators (+, -, *, /, min, max, ln, log, sqrt, ^) and variables (R, G, B), which define color component used.
Threshold	Threshold for the object mask generation
MedianFilterSize	Size of the median filter, used for object mask generation, odd number only
MinSize	Minimal size of the mask element [px]
MinHoleSize	Minimal size of holes in the mask element [px]
CropObjectOnBorders	Flag to crop small mask elements on the borders of the mask area [true/false]
CropObjectOnBordersMinPreserveSize	Minimal size of object cropped as small mask element on the borders of the mask area
UseReflectionReduction	Flag to use different mask generation algorithm. Works better if reflections and dark spots are present in the image [true/false]
SkipBadExposedPoints	Flag to crop over/under exposed pixels from the plant mask [true/false]. Under/over exposed pixel has at least one color channel (R/G/B) set to its minimum/maximum (0 and 255 for 8 bit per channel format)

Tab. 6 Description of parameters used for RGB plant mask selection.

Parameter	Description
AREA_PX	Object area [px]
AREA_MM	Object area [mm2]
PERIMETER_PX	Object perimeter [px]
PERIMETER_MM	Object perimeter [mm2]
ROUNDNESS	Roundness of the object, computed as a ratio of area and perimeter (4Pi x Area) / Perimeter2
ROUNDNESS2	Roundness of the object, computed as a ratio of area and convex hull perimeter (4Pi x Area) / Perimeter2
ISOTROPY	Isotropy of the object, computed as ratio of area and perimeter of the polygon created by object vertices (4Pi x Area) / Perimeter2
COMPACTNESS	Compactness of the object, computed as ratio of the object area and area of the object convex hull.
ECCENTRICITY	Eccentricity of the object, computed as difference between the object convex hull area and area of the circle with its center in the object center
RMS	Rotational symmetry of the object, based on the fitting of the ellipsis with identical second central moment as the analyzed object.
SOL	Slenderness of the leaves
WIDTH_PX	Object width [px], side view camera only
WIDTH_MM	Object width [mm], side view camera only
HEIGHT_PX	Object height [px], side view camera only
HEIGHT_MM	Object height [mm], side view camera only

Tab. 7 RGB Morphology Parameters

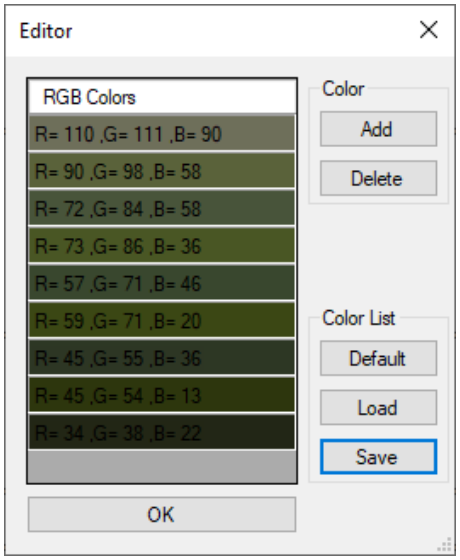


Fig. 53 RGB Color Segmentation Settings

Parameter	Description
R	Red subcomponent of the color, range <0,255>
G	Green subcomponent of the color, range <0,255>
B	Blue subcomponent of the color, range <0,255>

Tab. 8 RGB Color Segmentation

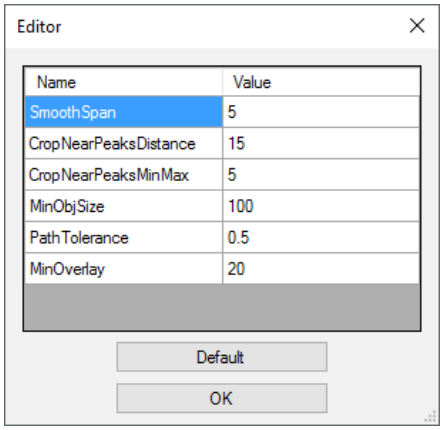


Fig. 54 Leaf Tracking Settings

Parameter	Description
SmoothSpan	Level of smoothing plant outline before local extremes detection. Removes small teeth on plant outline to prevent false leaves detection. Too low value can create more leaves than expected, too high value can fail to detect some leaves.
CropNearPeaksDistance	Distance for cropping near peaks (local extremes) of the same type(leaves tipsor leaves joints)
CropNearPeaksMinMax	Distance for cropping near peaks (local extremes) of the opposite type (leavestips and leaves joints)
MinObjSize	Minimum object size to keep [px]. Removes separate objects smaller than thegiven value
PathTolerance	Tolerance for finding path from plant centroid to nearest point of separated leaf. Too low value can remove some separated leaves, too high value cancause joint of more separated leaves into one.
MinOverlay	Minimal overlay to identify leaf compliance [px]. Too low value can cause assignment of a new leaf to some different leaf from previous image, too highvalue can cause disagreement of the same leaf between two images.
CenterHoleDiam	Diameter of circle placed in the center of the area, which is discarded fromthe analysis

Tab. 9 Leaf Tracking Settings

IR Analysis Settings

Parameters for *Plant mask* analysis can be set for HW configurations with background heating wall integrated, for the configurations when IR images are acquired from side view respectively. User can adjust the settings for plant mask analysis by clicking *Plant Mask* button in the analysis part of the action protocol. (Fig. 49-5, Fig. 55, Tab. 10). *Parameters* window allows to view and modify pre-defined parameters. *Settings* tab allows to define additional settings used for plant mask analysis, i.e. minimal percent of the valid pixels for computation. For the TOP view, a mask generated by RGB analysis is usually recalculated and placed on the thermal data.

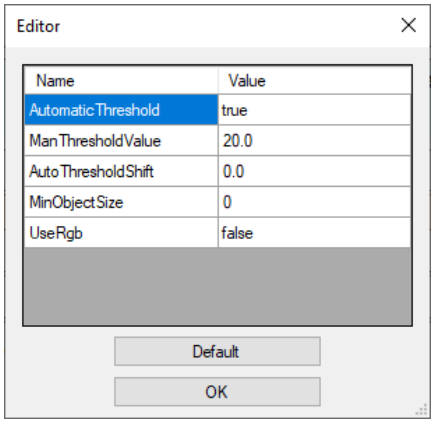


Fig. 55 IR side view plant mask settings

Parameter	Description
AutomaticThreshold	Using automatic threshold for the object mask generation [true/false].
ManThresholdValue	Manual threshold for the object mask generation.
AutoThresholdShift	The value of the offset that is added/subtracted from the automatic threshold
MinObjectSize	Minimal size of the mask element [px].
UseRgb	[true/false]. If true, mask from RGB side image is used for analysis.

Tab. 10 IR side analysis parameters description

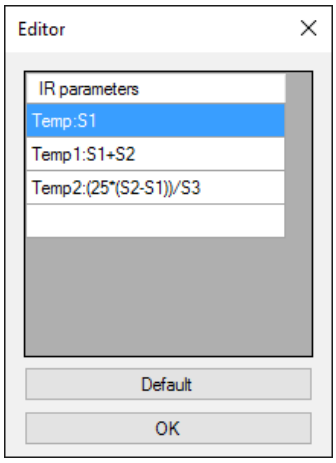


Fig. 56 IR Parameters

Parameter	Description
Temp:S1	User defined parameters. Name of the parameter is before the colon, equation for its computation after the colon. Equation can contain constants (1, 2, 3, …), operators (+, -, *, /, min, max, ln, log, sqrt, ^) and variables (S1, S2,...), which define number of the frame used for computation.

Tab. 11 IR Parameters

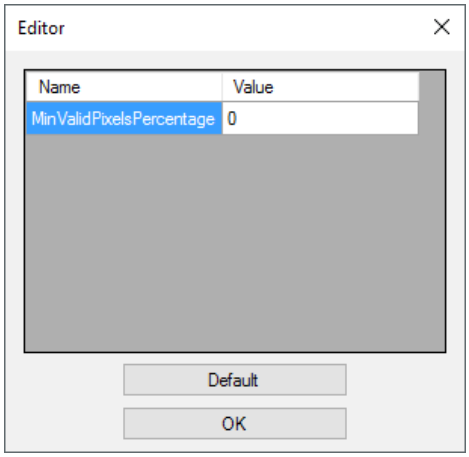


Fig. 57 IR Settings

Parameter	Description
MinValidPixelsPercentage	Minimal percent of the valid pixels for computation. Invalid pixel is defined as pixel, for which the equation gives invalid result (division by zero, …). These pixels are discarded from the parameter computation. If the valid pixel percentage is lower than the threshold, whole computation of the corresponding parameter is flagged as failed. If 0 is set, any number of invalid pixels is accepted. If 100 is set, all pixels have to be valid.

When imaging from top view, the RGB plant mask is automatically used for the IR analysis and the plant mask button is not available (Fig. 49-6).

Parameter	Description
Water Content	Pre-defined parameter for water content. User can define it's own parameters. MSC parameters: User defined parameters. Name of the parameter is before the colon, equation for its computation after the colon. Equation can contain constants (1, 2, 3, …), operators (+, -, *, /, min, max, ln, log, sqrt, ^) and variables (R740, R1450, ...), which define wavelength used. Variables wavelengths must be from valid range defined by the camera.
Parameter	**Description**
MinValidPixelsPercentage	Minimal percent of the valid pixels for computation. Invalid pixel is defined as pixel, for which the equation gives invalid result (division by zero, …). These pixels are discarded from the parameter computation. If the valid pixel percentage is lower than the threshold, whole computation of the corresponding parameter is flagged as failed. If 0 is set, any number of invalid pixels is accepted. If 100 is set, all pixels have to be valid.

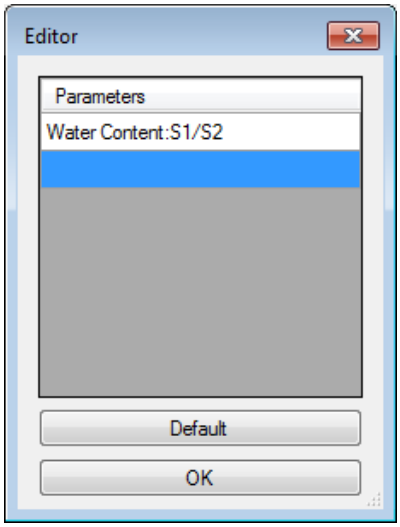


Fig. 58 Parameters editor in Analysis tab

VNIR Analysis Settings

In the analysis part of the action protocol (Fig. 49-8), user can adjust the settings for plant mask analysis and image background subtraction settings by clicking Plant Mask button. The settings of the Plant Mask Analysis can be optimized as described in Tab. 12 Description of VNIR analysis parameters. The selection of wavelengths to display the data as a pseudo RGB image can be done by clicking the *RGB* button (Tab. 13). Calculated parameters can be defined in *Parameters* editor (Tab. 14). The *Settings* button is used for advanced settings (Tab. 15).

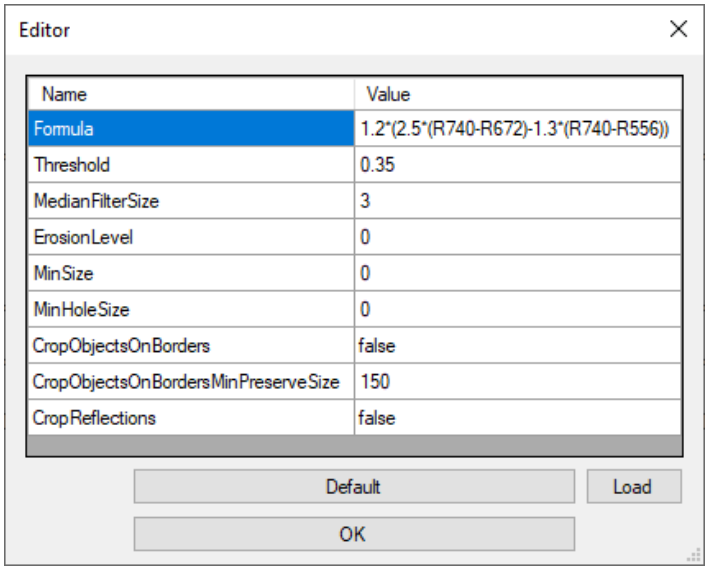


Fig. 59 Plant Mask settings window

Parameter	Description
Formula	Formula definition for object mask generation. Formula can contain constants (1, 2, 3, …), operators (+, -, *, /, min, max, ln, log, sqrt, ^) and variables (R740, R672, ...), which define wavelength used. Variables wavelengths must be from the valid range defined by the camera. o Formula for computation of the object mask utilizes spectral features, e.g. absorption bands of chlorophyll, to determine regions of interest
Threshold	Analysis results in binary image – mask. Pixels with subthreshold values computed by aforementioned formula are excluded as background. Pixels with calculated values greater than or equal to the specified threshold are evaluated as plant-specific pixels.
MedianFilterSize	Defining window size for median filtration. o Lower value: more precise object borders, more sensitive to salt and pepper noise o Higher value: increased filtering performance, worse identification of edges
ErosionLevel	Parameter defining number of iterations for morphological operation – erosion. This step removes N pixels from outside of the objects / regions of interest. This is useful considering relatively low spatial resolution of hyperspectral camera, where border pixels (plant tissue and soil transition) can influence the parameter statistics and bring ambiguity in resulting spectra. o Low or none: preserves object shape o Higher: Better performance in terms of average vegetation indices computation
MinSize	Minimal size of the mask element [px]
MinHoleSize	Minimal size of holes in the mask element [px]
CropObjectsOnBorders	[true/false] - Set to true to crop small mask elements on the borders of the mask area.
CropObjectsOnBorders MinPreserveSize	Minimum size of objects that will not be removed even if they are on the edge of the area specified by the tray mask (objects smaller than this value will be cropped on the borders)
CropReflections	[true/false] – If true, a pixel that is at or just below the white calibration intensity is considered a light reflection and will not be added to the plant mask even if it meets the threshold value. Only the wavelengths selected by the masking formula are compared, not the entire range.

Tab. 12 Description of VNIR analysis parameters

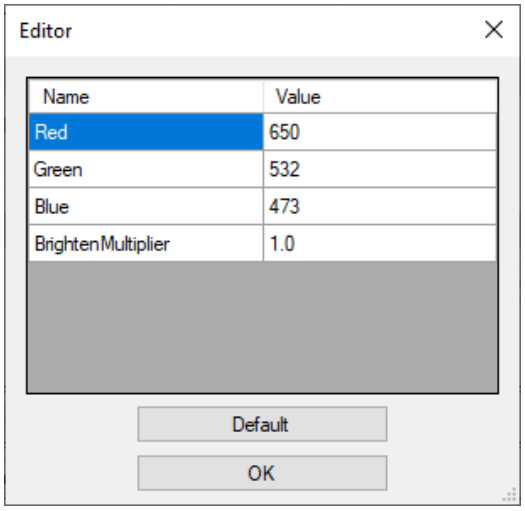


Fig. 60 Selection of wavelengths used for RGB image

Parameter	Description
Red	Wavelength used as red color for RGB image
Green	Wavelength used as green color for RGB image
Blue	Wavelength used as blue color for RGB image
BrightenMultiplier	RGB value multiplier. If greater than 1, image is brighter, if lower, image is darker

Tab. 13 RGB image settings

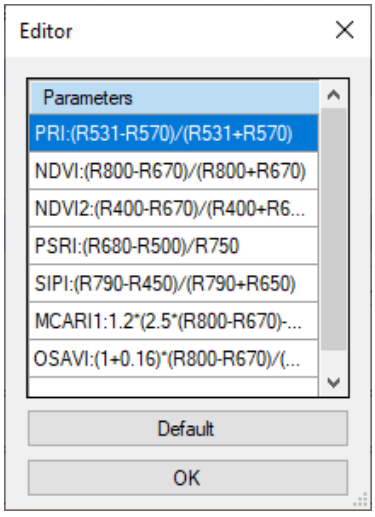


Fig. 61 VNIR parameters editor

Parameter	Description
VNIR parameters	User defined parameters. Name of the parameter is before the colon, equation for its computation after the colon. Equation can contain constants (1, 2, 3, ⋯), operators (+, -, *, /, min, max, ln, log, sqrt, ^) and variables (R740, R672, ...), which define wavelength used. Variables wavelengths must be from valid range defined by the camera.

Tab. 14 VNIR parameters definition

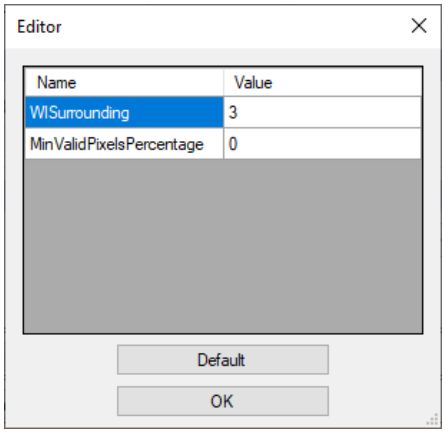


Fig. 62 Settings window

Parameter	Description
MinValidPixelsPercentage	Minimal percent of the valid pixels for computation. Invalid pixel is defined as pixel, for which the equation gives invalid result (division by zero, ⋯). These pixels are discarded from the parameter computation. If the valid pixel percentage is lower than the threshold, whole computation of the corresponding parameter is flagged as failed. If 0 is set, any number of invalid pixels is accepted. If 100 is set, all pixels have to be valid
WISurrounding	Parameter for camera noise reduction. Defines number of neighboring pixels (both in spectral and spatial dimensions), which are averaged and resulting value is used for the parameter computation. If set to 0, the original pixel value is taken

Tab. 15 Settings parameters description

4.7.6.1 SWIR Analysis Settings

In the analysis part of the action protocol (Fig. 49-9), user can define the settings for plant mask analysis. Use *Own Plant Mask* option if SWIR data are segmented based on SWIR images. Otherwise VNIR or RGB data, depending on the HW configuration, can be used for plant mask segmentation. Background subtraction settings can be optimized by clicking *Plant Mask* button. The settings of the Plant Mask Analysis can be optimized as described in Tab. 12. The selection of wavelengths to display the data as a pseudo RGB image can be done by clicking on the *RGB* button (Tab. 16). Calculated parameters can be defined in *Parametrs* editor (Tab. 17). *Settings* button is used for advanced settings (Tab. 18).

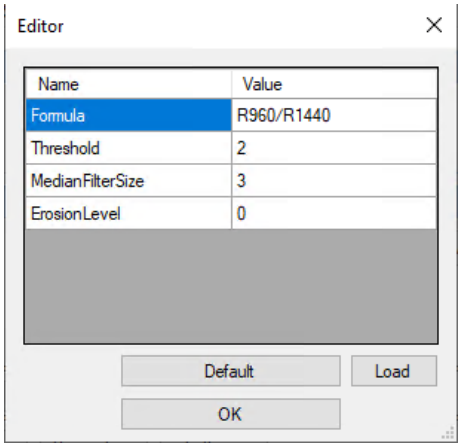


Fig. 63 Plant Mask settings window

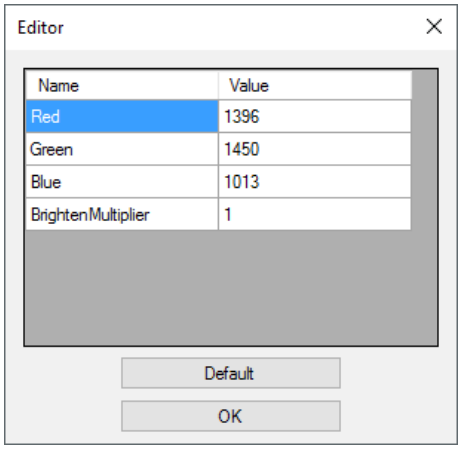


Fig. 64 SWIR RGB image settings

Parameter	Description
Red	Wavelength used as red color for RGB image
Green	Wavelength used as green color for RGB image
Blue	Wavelength used as blue color for RGB image
BrightenMultiplier	RGB value multiplier. If greater than 1, image is brighter, if lower, image is darker.

Tab. 16 SWIR RGB

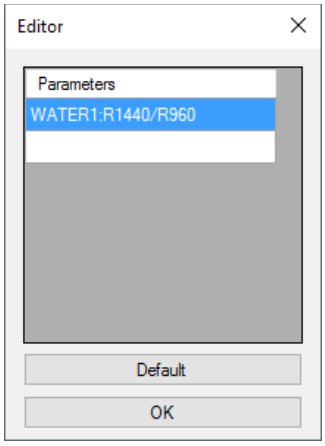


Fig. 65 SWIR Parameters

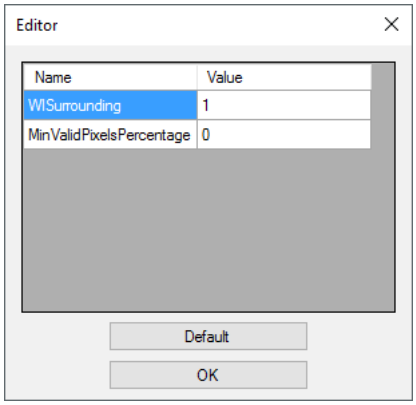


Fig. 66 SWIR Settings

Parameter	Description
WATER1:R1440/R960	User defined parameters. Name of the parameter is before the colon, equation for its computation after the colon. Equation can contain constants (1, 2, 3, …), operators (+, -, *, /, min, max, ln, log, sqrt, ^) and variables (R740, R672, ...), which define wavelength used. Variables wavelengths must be from valid range defined by the camera.

Tab. 17 SWIR Parameters

Parameter	Description
WISurrounding	Parameter for camera noise reduction. Defines number of neighboring pixels (in spectral dimension), which are averaged and resulting value is used for the parameter computation. If set to 0, the original pixel value is taken.

Tab. 18 SWIR Settings

4.7.6.2 3D Analysis Settings

3D Scan analysis (Fig. 49-6) offers a selection of optimized analysis by plant *Leaf Type*. The choice for Segmentation Level and Edges Refinement is available for each *Leaf Type* with except of *Experiment*al option. Both parameters are used to improve the model triangulation process. Further information about this setting is explained in the 3D technical documentation.

Parameter	Description	
Leaf Type	Selection of settings affects model triangulation approach. The Leaf Type is primarily defined by the shape, arrangement, and margins of plant leaves. Two leaf types are predefined and the Experimental choice is possible:	
	Simple	entire shape with smooth, toothed or undulate margin, mostly pinnate veins
	Parallel	entire, linear, long and narrow sword-shaped leaves, with smooth margin, mostly parallel veins
	Experimental	is used to set experimental triangulation rules. See below.
Segmentation Level	Allows influence the level of plant segmentation to the leaves:	
	Low	Parts of the point cloud models are merged into larger units. When merging multiple leaves together, it is advantageous to increase this level. This level is suitable for small or uneven leaves.
	Medium	stands somewhere between low and high levels.
	High	The individual parts of the point cloud model are more separated. If one leaf is divided into several parts, it is advisable to lower this level. This level is more suitable for straight leaves.
Edge Refinement	Improves the curvature of the leave edges in the triangulated model:	
	Low	Achieves better results on oval leaves with a smooth margin. The edges of the toothed and undulate leaves are considerably simplified.
	Medium	stands somewhere between low and high levels.
	High	Achieves better results for undulate leaves. This level leads to in- creased computational difficulty and analysis may take longer, especially when combined with a large number of points in the model.

Tab. 19 3D Scan analysis – Leaf type

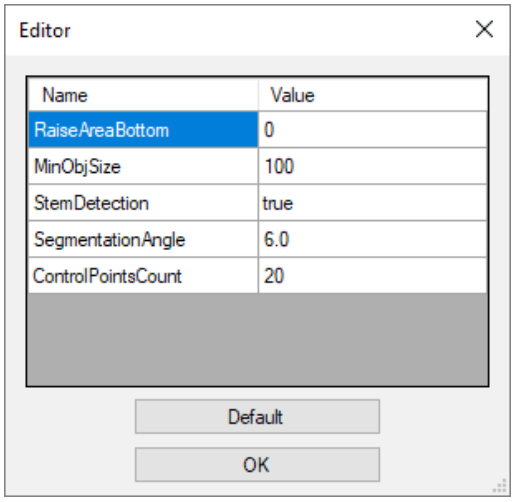


Fig. 67 3D Settings

Parameter	Description
RaiseAreaBottom	Offset for the tray cut-off. It is the distance from the tray cover to top of thepot [mm].
MinObjSize	Minimum object size in the point cloud model that will can be taken as a leaf[number of points].
StemDetection	Flag for stem detection in the model [true/false].
SegmentationAngle	The angle between normals used as the threshold value for point cloud segmentation [°], the parameter is only available for *Experimental Leaf Type*. Segmentation Angle supplants the Segmentation Level of the previous setting. Parameter represents the threshold for the angle between the normals of the model points. Values can be entered between 0 – 180°. At smaller angles, segmentation is higher, at larger angles lower. The higher values lead to increased computational difficulty and analysis may take longer, especially when combined with a large number of points in the model.
ControlPointsCount	The number of points that will be used during triangulation to smooth the edges of the leaves [number of points], the parameter is only available for *Experimental Leaf Type*. *ControlPointsCount* supplants the leaf Edge Refinement from the previous setting. Parameter represents the number of model points to be tested during triangulation for smoothing the edges of the leaves. Values can be entered between 10 – 200. Increasing the value can lead to better results for the undulate or toothed edges of the leaves. The higher values leads to increased computational difficulty and analysis may take longer, especially when combined with a large number of points in the model.

Tab. 20 3D Settings

Experimental Leaf Type option provides advanced triangulation settings if predefined *Leaf Types* do not achieve satisfactory results. The *Segmentation Level* and *Edge Refinement* options described above are not available for this choice. These settings are replaced by new parameters in the analysis settings. The parameter *Editor* opens with the *Settings* button and contains other parameters.

4.7.6.3 Root Analysis Settings

Morphological analysis is performed on the binary Black and white images (Fig. 52-12). User can adjust the settings (Fig. 68) for plant mask analysis and image background subtraction by clicking *Settings b*utton. The settings of the Plant Mask Analysis can be optimized as described in table Tab. 22. Calculated parameters (Tab. 21) can be defined in *Parameters* editor.

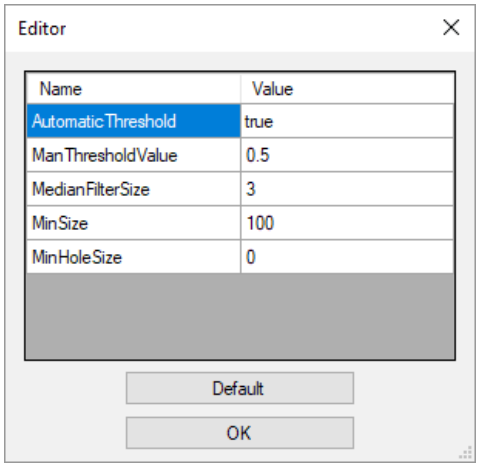


Fig. 68 Root morphology and background subtraction

Parameter	Description
HEIGHT_PX	Object height [px].
HEIGHT_MM	Object height [mm].
WIDTH_PX	Object width [px].
WIDTH_MM	Object width [mm].
ASPECT_RATIO	Ratio between the width of the object and the height of the object.
AREA_PX	Object area [px].
AREA_MM	Object area [mm2].
COMPACTNESS	Compactness of the object, computed as ratio of the object area and area of the object convex hull.
PARIMETER_PX	Object perimeter [px].
PERIMETER_MM	Object perimeter [mm].
TOTAL_LENGTH_PX	The number of pixels in the skeleton of the object (wide roots reduced to one pixel) [px].
TOTAL_LENGTH_MM	The number of pixels in the skeleton of the object (wide roots reduced to one pixel) converted to millimeters [mm].
RMS	Rotational symmetry of the object, based on the fitting of the ellipsis with identical second central moment as the analyzed object.
DISTRIBUTION_MEDIAN	The median number of object pixels in each row of the image.
ENDPOINTS	The number of root pixels that adjoins only one pixel.
NODES	The number of object pixels that have more than two neighbors.
WIDTH_PX	Object width [px].

Tab. 21 ROOT Morphology Parameters

Parameter	Description
AutomaticThreshold	Using automatic threshold for the object mask generation [true/false].
ManThresholdValue	Manual threshold for the object mask generation.
MedianFilterSize	Size of the median filter, used for object mask generation, odd number only.
MinSize	Minimal size of the mask element [px].
MinHoleSize	Minimal size of holes in mask element.

Tab. 22 Root Plant Mask Settings

4.7.6.4 UNSAVED CHANGES

Any subsequent changes to the pending protocol are indicated with the Unsaved changes warning sign (Fig. 69). Use the *Save Action* button save the changes to the actual protocol.

	Any changes in Measure Block and/or Analysis Block that are not saved to DB will NOT be executed in the subsequent measurement round.

When an action is added and saved it appears in the action list (Fig. 70).The status column value is one of the following:

- Ok – action ended successfully
- ActionConflict – action was not run, because the device was in busy state at the scheduled time. Typically, this occurs when previous action was still running, or when there are more action scheduled at the same time.
- Error - action ended with an error, the detailed information can be displayed in the DataAnalyzer application.
- Running– action is being run at the moment
- Pending– action is scheduled

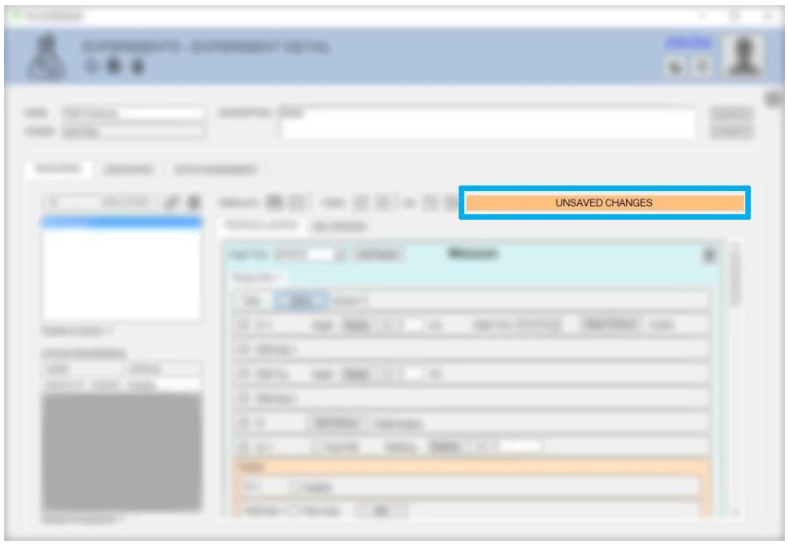


Fig. 69 Unsaved changes

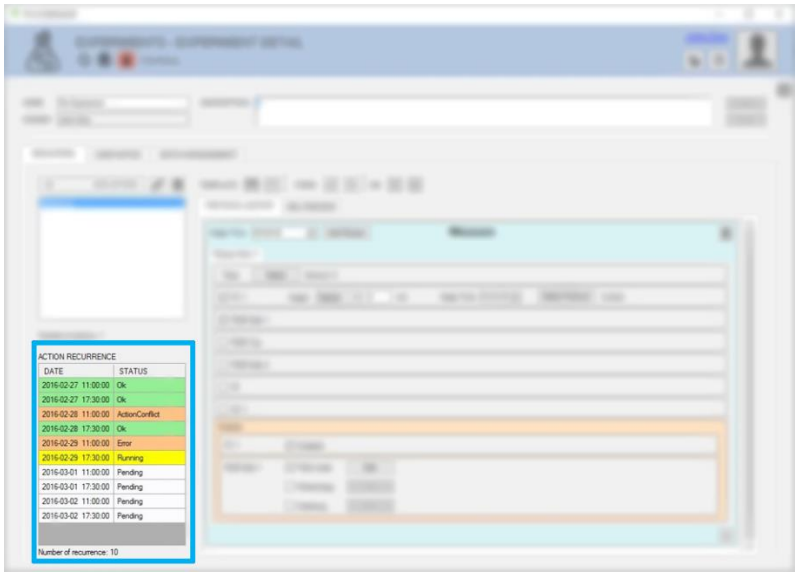


Fig. 70 Action list

5 TRAYS

The *Trays* section is opened by clicking the *Trays* icon on the Main screen (Fig. 71). It contains three tabs use for tray registration: *Tray list* (Fig. 72-1) for plant to tray assignment, *Batches* (Fig. 72-2) for creating named group of trays and *Tray types* (Fig. 72-3) for working with tray types.

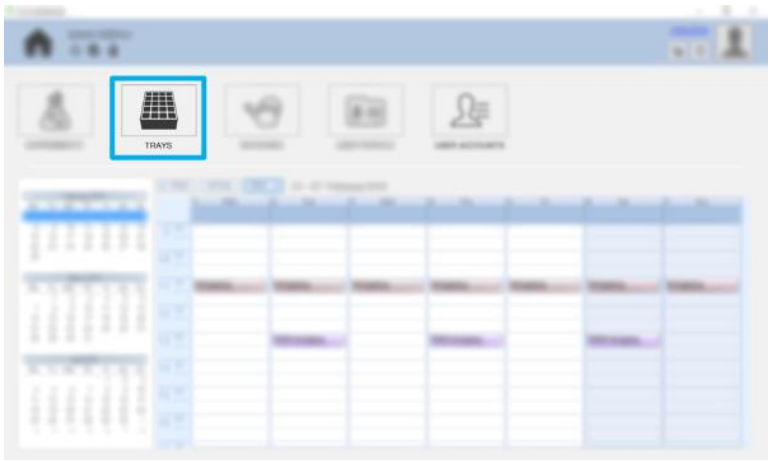


Fig. 71 Trays picture button on the Main screen

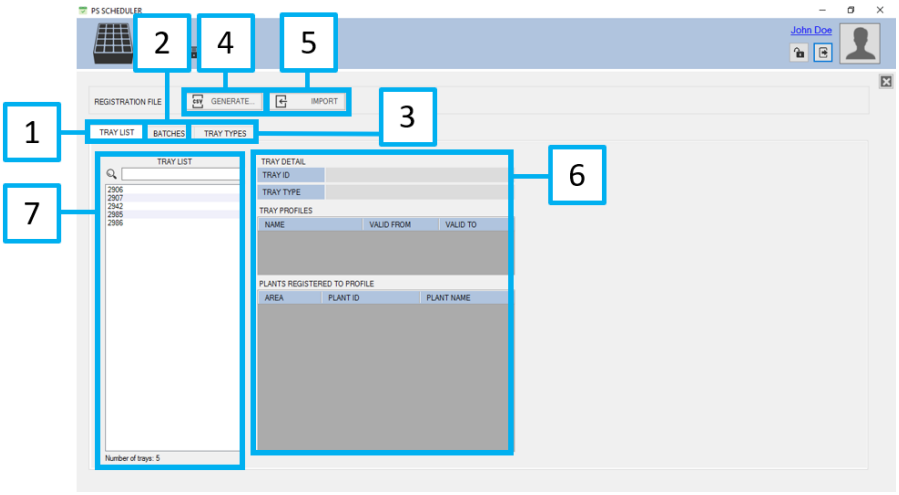


Fig. 72 Trays management window

Before starting the experiment, it is necessary to do the plant to tray assignment, one of the key steps when plants are assigned to the positions defined by the tray mask. This registration step when *Tray profile* is assigned to specific *Tray ID* is temporary and is valid until the new assignment is made. It is used during the analysis, where parameters are computed for the areas defined by the *Tray Mask* and later paired with plant using the *Tray profile*.

Buttons *Generate* (Fig. 72-4) and *Import* (Fig. 72-5) enable plant to tray registration. Tray detail window (Fig. 72-6) displays all details about the selected tray.

5.1 Tray Registration

Before starting any measuring action, it is necessary to register plants to the system. This can be done by creating a registration table with all trays used in experiment marked by unique tray ID number. In the table each tray ID contains positions defined by the tray mask. Each position is assigned the plant ID. Only registered trays can be used in the system for automatic measurement, watering and image processing.

Each tray in the system must be identified by unique ID code represented by QRcode in most system configurations. Individual plants are assigned to these positions by plant ID number. The assignment of plant ID to the tray type can be changed and the tray ID reused for multiple experiments.

	Tray mask is selected during the tray registration. Tray mask defines areas on the tray, which are used for analysis. Tray mask cannot be changed later. The assignment of tray type to the tray ID is invariable.

5.1.1 Registration table

To register plants to the system, registration table in csv format must be created in the first step. To obtain a template of the table click *Generate button* (Fig. 72-4). The *Generate registration* file window opens (Fig. 73-1). Select or type *Number of trays* and select the *Tray type*. *Generate Tray ID* checkbox can be used for automatic generation of tray IDs using prefix and counter (Fig. 73-2).

	It is necessary to register each tray before setting up experiment. Tray IDs must fully correspond to QR codes labels on trays. Each tray ID is assigned a certain tray type only once and this cannot be changed later.

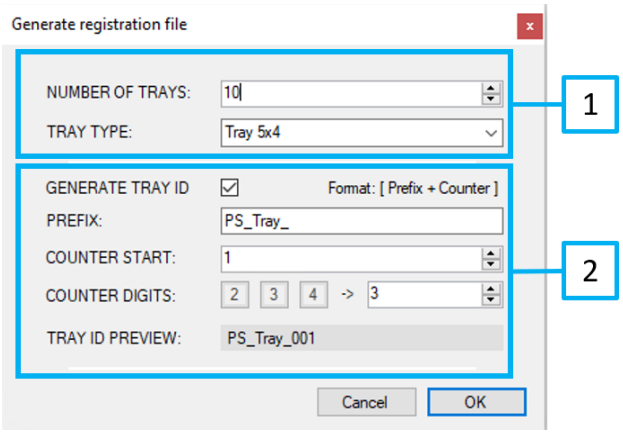


Fig. 73 Registration file generation

After confirming the *Generator* settings with *OK* button, registration table template is stored to computer local storage. Then, the file is opened as a table with a spreadsheet processing software (e.g. MS Excel). There are 7 columns in the template – *TrayID*, *TrayInfo*, *TrayTypeName*, *Area*, *PlantID*, *PlantName* and *PlantInfo* (Fig. 74).

- *TrayID* field (Fig. 72-6) - identify trays with unique ID numbers. Cannot be blank.
- *TrayInfo* is user information about the tray. Can be blank.
- *TrayTypeName* and *Area* columns are related to the tray type and position of the plant on the tray. These columns are already pre-filled and cannot be blank.
- *PlantID* is user ID of the plant. It uniquely identifies the plant in the whole system andcannot be blank. If *PlantID* is not found in the database, new record is created. If *PlantID* already exists in the database, measured data and analyses results are stored for the existing plant.
- *PlantName* is user name of the plant. It is displayed in the PlantScreen Data Analyzer software and cannot be blank. This name can be used for sorting or grouping purposes during data analysis.
- *PlantInfo* is user information about the plant. Can be blank.

After all required fields are filled the file (Fig. 74) must be saved back to csv format.

	A	B	C	D	E	F	G
1	TrayID	TrayInfo	TrayTypeName	Area	PlantID	PlantName	PlantInfo
2			Tray 5x4	A1			
3			Tray 5x4	A2			
4			Tray 5x4	A3			

Fig. 74 Registration file template

5.1.2 Data Import

Import button (Fig. 72-5) is used to load user-edited registration file back to the system. Imported records are then displayed in the list (Fig. 75) and validated if required fields are not blank. In the imported registration table, errors in the syntax of the required data are highlighted in red, and error description is displayed in the last column *Check result.* If wrong data were loaded the error message dialog window describing the error pops out. All errors must be corrected in the original csv file and then the corrected file should be reloaded until all data is in correct format.

When the last column in the loaded table is displayed in green with *OK* notification in all rows the registration must be saved to database by clicking the *Store to DB* button (Fig. 75-2). Any detected error (e.g. ID number duplication, missing values) prevents storing the file to database. The registered trays with assigned plants are then displayed in the *Tray List* window (Fig. 72-4).

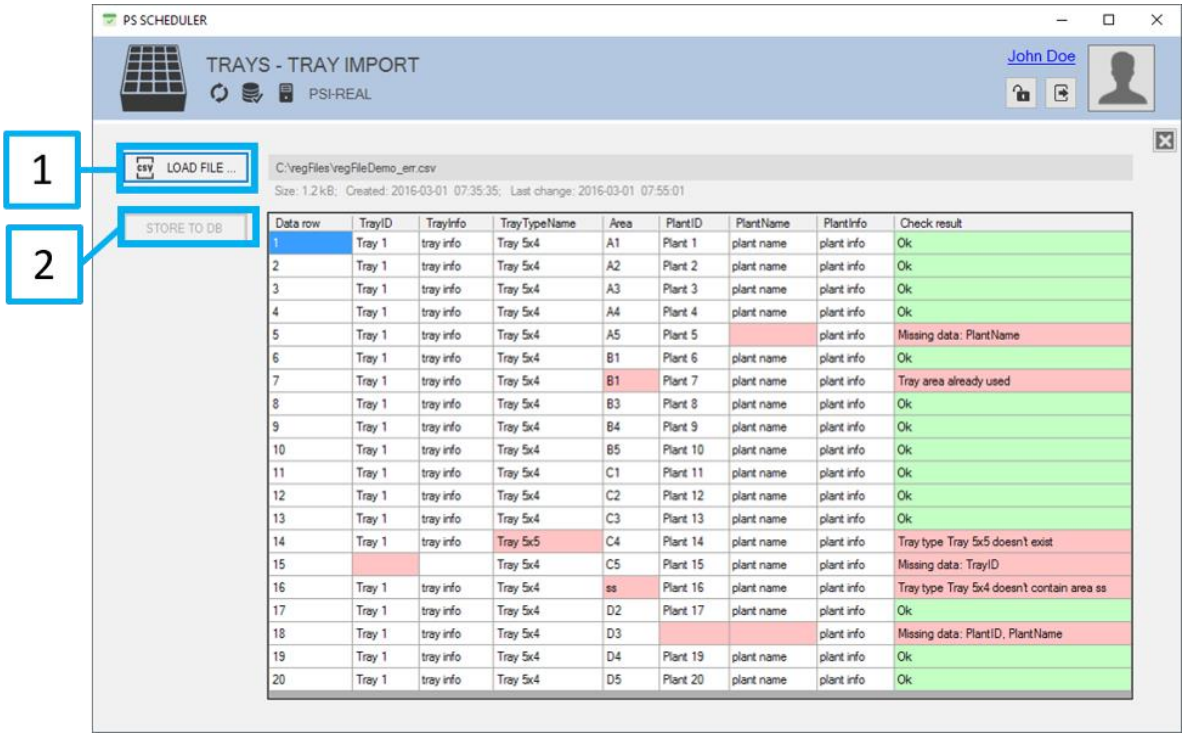


Fig. 75 Registration import result

5.2 TRAY LIST

All trays registered to the system can be viewed in the *Tray List* window (Fig. 76-1), items can be filtered by name using the search icon. *Tray list* tab contains controls for displaying *Tray profiles.* When a tray is selected, *Tray Details* are displayed:

- *Tray Detail* – shows name, type and creator account for the selected tray (Fig. 76-2)
- *Tray Profile* (Fig. 76-2)– shows history of registered Tray Profiles and current profile with details of the selected profile. *Overview* (Fig. 76-4) shows tray layout (based on the tray type) and positions of *Plant IDs* registered to the tray areas valid for the given time period (Fig. 76-3).

Single tray is selected from the list by mouse left click and the tray detail is displayed on the right side in *Tray Detail* tab (Fig. 76-2), *Tray Profiles* tab (Fig. 76-2) and *Plant Registered to Profile* (Fig. 76-3) and *Tray Overview* tab (Fig. 76-4). These tabs show the current and past tray status, list of plant IDs registered to the tray and top view of registered areas given by current registration of plant positions to the tray.

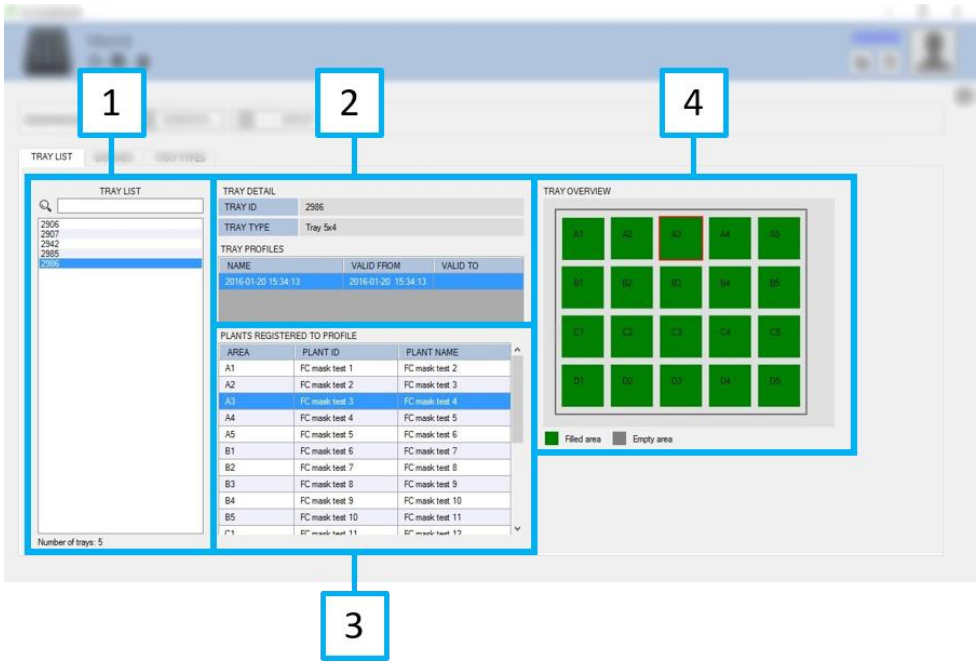


Fig. 76 Tray list

5.3 BATCHES

Batch management tab contains controls for creating, editing and deleting groups of trays. Batch refers to a set of trays to be measured with a pre-defined protocol and must contain at least one tray. The batch is then selected in the *Measure Item* of the measurement protocol using *Add Recipe* button (see chapter 4.7.6.) Multiple recipes with different protocols and batches can be used in a same action.

For more information about batches please refer to the paragraph 4.5.

5.4 TRAY TYPES

5.4.1 TRAY TYPE WINDOW

Tray type determines the areas for which plant specific features are measured and analyzed (e.g. standard tray type 5x4 contains 20 defined areas A1-D5). All stored tray types are displayed in the *Tray Types* window (Fig. 77-2). New tray types can be edited after clicking the *New Tray Type* button (Fig. 77-1). For details how to create a new tray type, please refer to the next chapter 5.4.2.

When single tray type is selected from the *Tray Types* list by mouse left click, tray type details are displayed on the right side in the *Tray Type Info* tab (Fig. 77-3). For the selected tray the *Size* parameters, *Top mask* and *Side mask* preview are shown (Fig. 77-3). Under side and Bottom masks (Fig. 77-5) are provided when specific tray types are used (e.g. *RhizoBox*).

Fig. 77 *Tray types* tab in the *Trays* window

Edit Scales-Area Assignment button (Fig. 77-4) is used to assign scales to the areas in the tray. In the A*rea to scales assignment* window assign all or subset of pot positions in the tray to the actual TOP mask areas (Fig. 78-2). For the convenience the top mask is also displayed next to the window (Fig. 78-1). The range of areas depends on the type of scale used for weighing the particular tray type. When SC1 scale is used the ranges A1 – A5, B1-B5, etc. are used for the five scale positions used in a row. The *Scales-Area Assignment* is further described in chapter *Watering* paragraph 6.1.

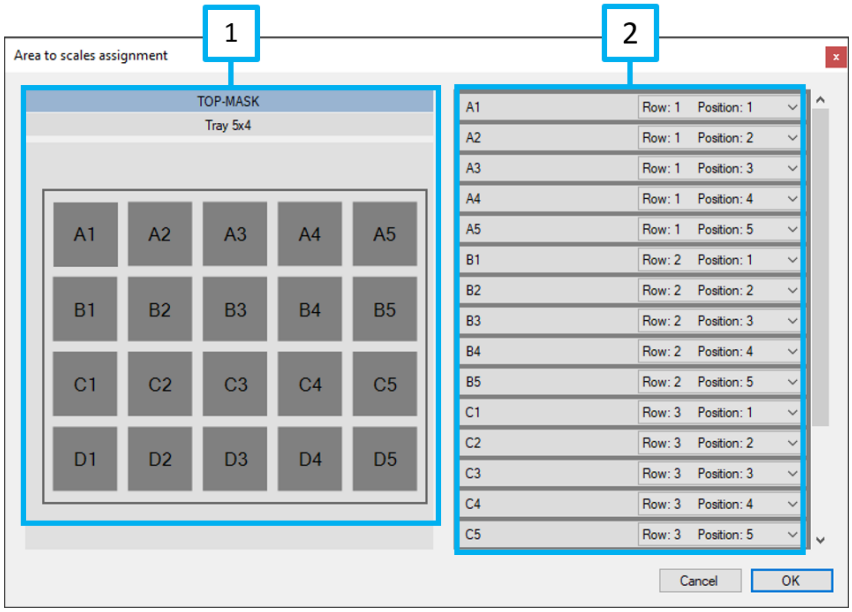


Fig. 78 *Area to scales assignment* window

5.4.2 Creating New Tray Type

New tray type button (Fig. 77-1) displays a window used for creating a new tray type. The first parameter, *Tray type name* (Fig. 79-1) has to be unique in the system. Next, fill the textboxes with description of the *tray type* (Fig. 79-2), *tray dimension* (Fig. 79-3) and definition of *tray mask areas* (Fig. 79-4).

	When creating more types of masks (TOP, SIDE, …) the name of each particular area (A1, A2, B1….) should correspond to the same area in all mask types.

Tray Mask defines one or more areas on the tray, which allows to distinguish and identify the plant for analysis and compute separate sets of parameters for each plant.

New tray mask can be created as follows:

1. In the *Tray Type* window select the type of mask to be created (TOP Mask, SIDE Mask, etc) (Fig. 79-3).
2. Prepare the image of the tray with plants and the *Tray info* file. For this purpose insert a tray with plants to the system and use the *Server* application in *Service* mode to control the FluorCam or the RGB camera. Take image of the tray and save the image as well as the *image info* file.
3. Click the *Create Mask* button (Fig. 79-4) and select the stored image.
4. The image is displayed in the *Mask source parameters* window (Fig. 80-1). Use the *Load* button (Fig. 80-2) to load the image mask parameters *Pixel size X Axis, Pixel size Y Axis*, *Tray center X* and *Tray center Y* from the previously stored *Tray Info* file (Fig. 80-3) or type the values directly to the textboxes.
5. After confirmation the graphical tool *Mask Builder* opens. Proceed to the next chapter *Mask Builder* to draw the new tray mask. Confirm the completion with *OK* button.
6. In the last step store the new tray type to database with *Store to DB button* in *Tray Type* window (Fig. 79-5). Proceed to define each mask type (TOP, SIDE, etc). When completed save the new tray type to database with the *Store to DB* button (Fig. 79-5).

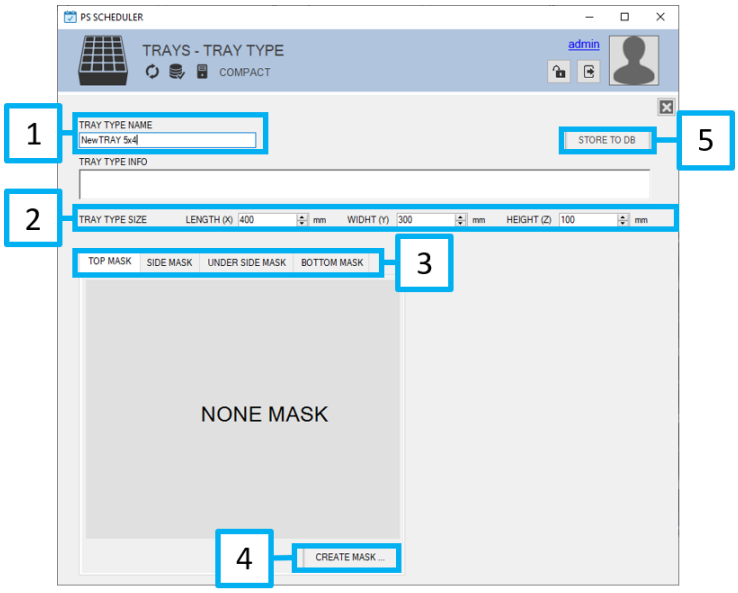


Fig. 79 New tray type window

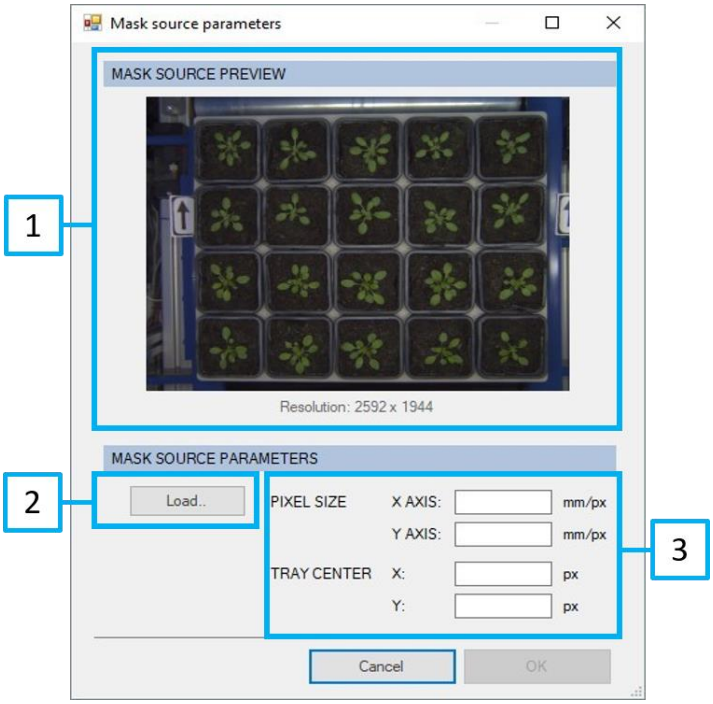


Fig. 80 Mask source image and parameters

	Tray mask is stored as XML file with list of areas. Area parameters are name, type, and the coordinates.

Mask Builder

The *Mask Builder* graphical tool is used to create tray masks. *Tray mask* is a group of named areas on the tray, which are used to define plants on the background. The tray mask allows to put more objects on the tray and distinguish them in analysis, thus computing separate set of parameters for each of the objects. Four area drawing tools are available (Fig. 81-2):

- rectangle
- ellipse
- pie
- polygon

Fig. 81 Mask builder tool

Other drawing tools can be activated with the following buttons (Fig. 81-3,4,5):

-  actual selection is copied to the clipboard
-  clipboard content is pasted to the drawing area
-  actual selection is deleted
-  toggles the area names display
-  toggles between zooming in and out of the image

Drawing mode is activated by selecting one of the area types. New area is created by clicking and holding the left mouse button and moving the mouse over the drawing window (Fig. 81- 1). The drawing mode is deactivated automatically after drawing a single area and clicking the mouse. If you want to draw more of the same area, select the sample area/areas and use the copy and paste area buttons (Fig. 81-3). Custom (polygon) shape is drawn in different way. Selection of the custom area type activates the drawing mode, and clicking of the left mouse button adds one point on the position of the mouse pointer. When right mouse button is clicked, area is closed if it contains at least three points – the last point is connected with the first one. If the three points condition is not met, area is discarded. Custom shape drawing mode is then deactivated. If drawing mode is not active, existing areas can be selected by clicking the left mouse button.

Multiple areas can be selected/unselected both in the list of areas (Fig. 81-7) and directly in the image (Fig. 81-1) by clicking the left mouse button while holding the Ctrl key. Select multiple areas in the list of areas (Fig. 81-7) by holding the SHIFT key while clicking the mouse – all areas between the first and second selected area are marked. The selected areas are shown with red border line, green border line denotes unselected areas. When mouse cursor is placed over the selected area(s), it is changed to action icon corresponding to the cursor position in the area, allowing it to be moved or resized.

When more areas are selected, the parameters in the Selected Item group box are displayed only if the selected areas are of the same type. Values of the parameters are displayed only if they are identical across the all-selected areas. If parameter is changed, it is changed for all selected areas.

	If CTRL key is pressed while changing the area dimensions, area width and height are changed evenly, so perfect square or circle is created instead of rectangle or ellipsis.

Content of the actual selection is displayed in the *Area* field (Fig. 81-7) and details of the selected areas in the *Selected Item* group box (Fig. 81-6). Name and parameters can be changed by typing the value to the corresponding field and pressing the ENTER key. *Tray Info* as Pixel size, Tray center X and Tray center Y are displayed for the uploaded image used to create the *Tray Mask* (Fig. 81-9).

	Area name has to be unique in the mask scope. A check is done before the mask is saved, if the condition is not met, areas with the same name are put to a selection and warning dialog is displayed.

The tray mask can be loaded to the image by clicking *Load Mask* button and saved to a local storage with the *Save Mask* button (Fig. 81-8). After completing the tray mask confirm with *OK* button.

New tray type can be also created and applied after measurement in local analysis of the PlantScreen Data Analyzer application. In Local Analysis > Settings click the button Create New Tray Type to open Mask Builder.

6 WATERING

6.1 ASSIGNING SCALES TO AREAS

For watering and weighing it is necessary to assign individual pots to positions on the scales.

The *Tray type* window contains predefined assignment for each position in the tray. When clicking *Edit scales area assignment* button (Fig. 82) the default assignment is shown and must me confirmed with OK button (Fig. 14A). Re-assignment of scale and area positions is necessary whenever positions of pots are changed and re-registered. Every change in the assignment must be confirmed with the OK button.

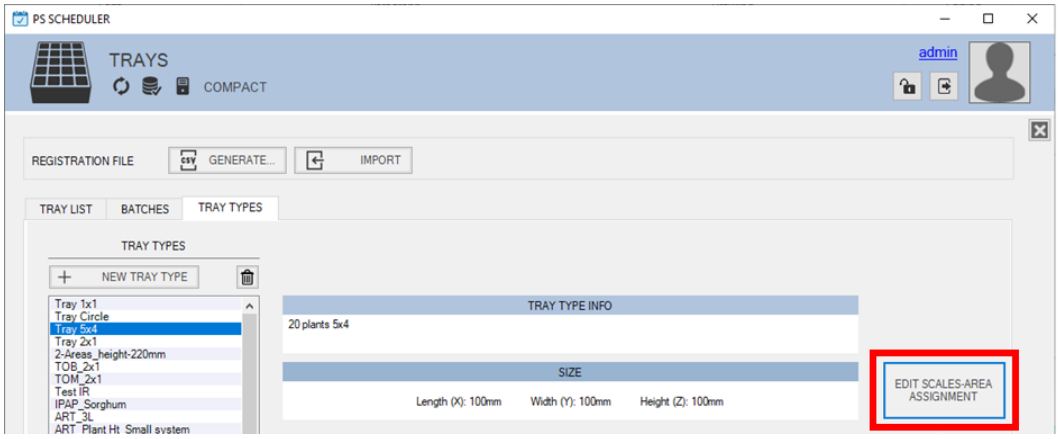


Fig. 82 Tray type window

The example in Fig. 83 shows the tray type 5x4 default settings with 20 areas and 20 pots in tray type 5x4. The columns shown in the editor are named positions and are numbered as the watering pipes in SC1 watering and weighing station.

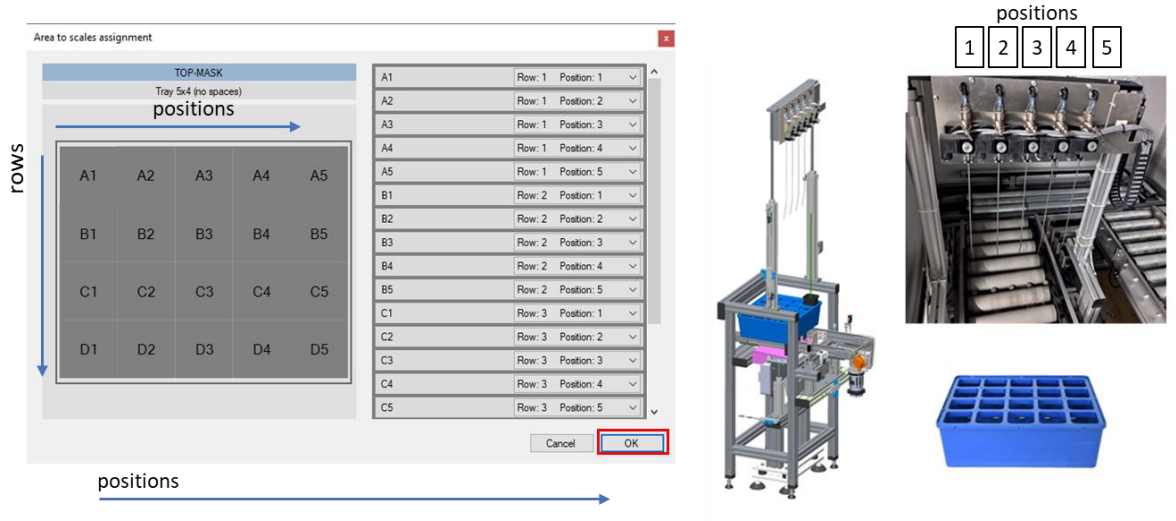


Fig. 83 Scales-area assignment for 20 small pots in the tray 5x4

In example shown in (Fig. 84) the number of pots was reduced to 5 and the areas in the tray mask were also changed. The scales area assignment was changed accordingly.

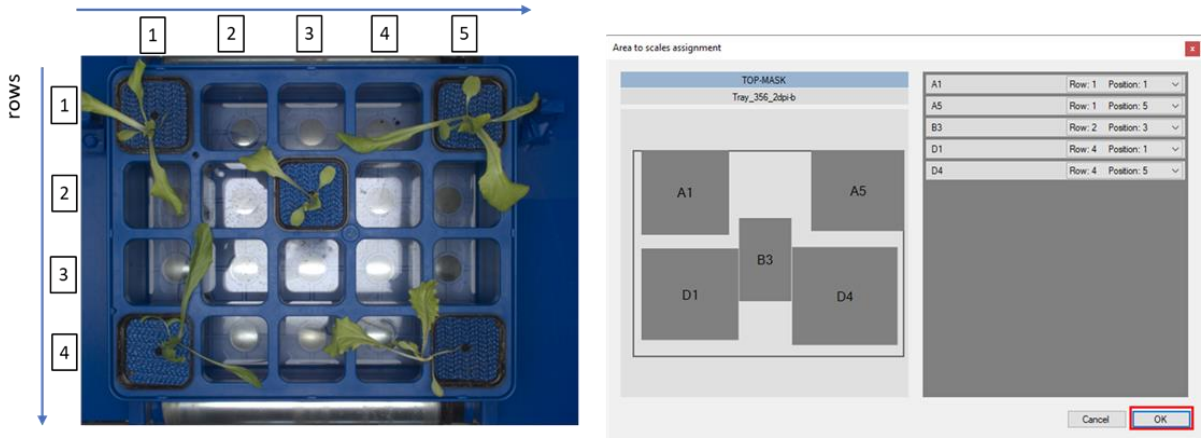


Fig. 84 Scales-area assignment for 4 small pots in the tray 5x4

In example shown in Fig. 85 scales-area assignment of 1, 2 and 4 large pots to the tray types 1x1, 2x1 and 2x2 is shown. Please note that due to compatibility issue with automation of the SC2 unit all positions are considered as they were aligned in one row (i.e. row1).

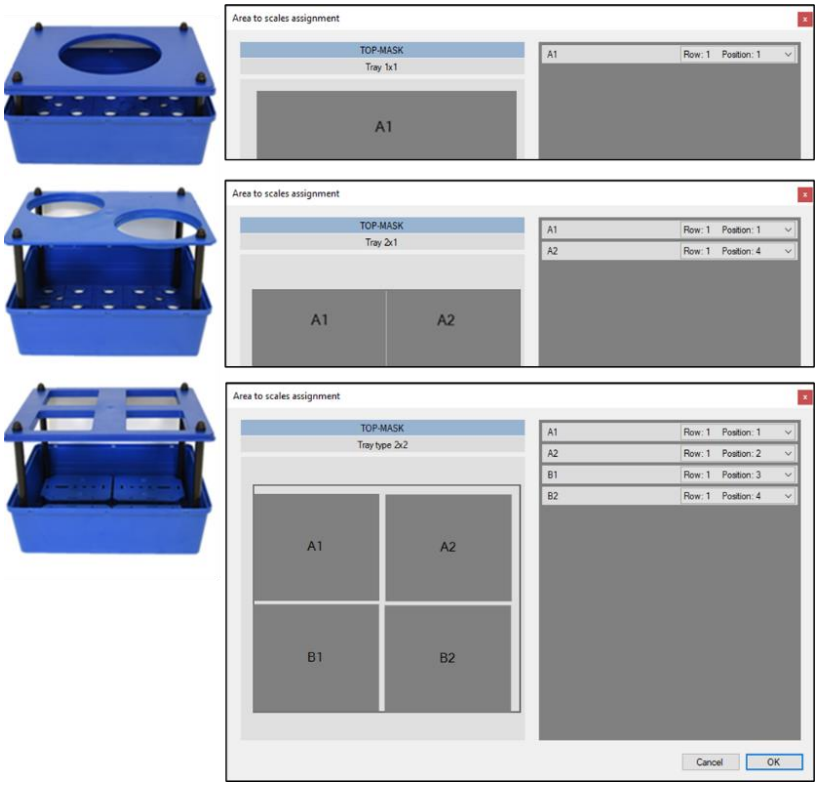


Fig. 85 Scales-area assignment for 1, 2 and 4 large pots to the 1x1, 2x1 and 2x2 trays

6.2 WATERING OPTIONS

Three options for adjusting amount of water added to each pot are available – *None*, *Reference* and *Absolute*.

- *None* option in the list means that only weighing and no watering will be done in the measuring round.
- *Reference* option uses reference weight value assigned to each pot prior to protocol creation. The water amount added is equal to the difference of the reference weight stored in the database and measured weight.
- *Absolute* option entails adding constant amount of water specified in the textbox on the right side.

In the measuring protocol select the scales item: SC1 is used for small 250 ml pots and SC2 is for larger pots (Fig. 86-1). In the *Watering* option select one of the three watering options from the drop-down list (Fig. 86-3). In the default settings the protocol uses water from tank 1. Other options, such as tank 2 or mixing might be included in the SC1 or SC2 item. Each checkbox (Fig. 86-4) represents one water pipe numbered from 1 (left) to 5 (right).

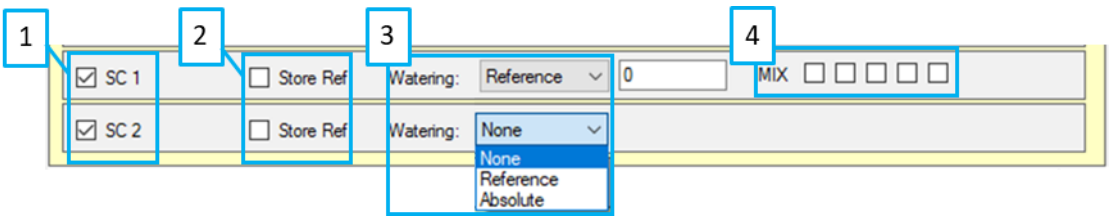


Fig. 86 Three watering options available are shown in the measuring protocol

6.3 WATERING TO REFERENCE WEIGHT

This option of watering to reference weight is used for watering to a certain weight of the pot. The WW station keeps adding water to each pot until the reference weight assigned to each pot is reached. For watering management (assigning reference weight etc.) in the Scheduler application click the *Watering* picture button (Fig. 87) on the Main menu and the *Watering* window opens (Fig. 88).

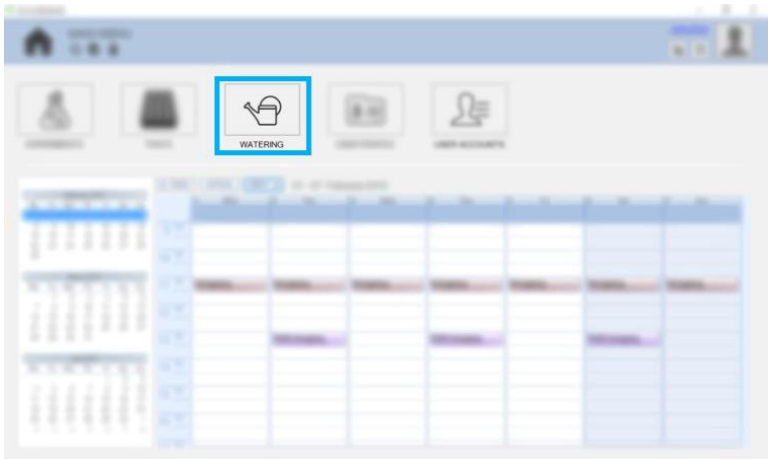


Fig. 87 Watering picture button on the main screen

The reference weight can be assigned to the pots in three different ways.

6.3.1 AUTOMATIC ASSIGNMENT

Weighing action with *Store Ref* option is used to assign actual weight of pot as reference weight. In the *Measure* block for SC unit select *Store reference* checkbox in the protocol *Measure* item (Fig. 86-2). Then, run a weighing round with a batch including pots intended for reference weight assignment and actual weight is assigned to the pots automatically.

6.3.2 EDITING THE TRAY LIST TABLE

After selecting one or more trays by the left click in the *Tray List* box (Fig. 88-1) registration details of the selected trays appear on the right side of the table (Fig. 88-3). Several columns with the tray information are shown in the *Watering table*. The last column named *Reference weight* shows the actual ref. weights.
One option is to type the *reference weight* values directly into the last column of the table (Fig. 88-3). Another option is to assign the same reference weight to selected plants use the textbox and the *Reference Weight* textbox and the *Set to All Plants* button (Fig. 88-2).

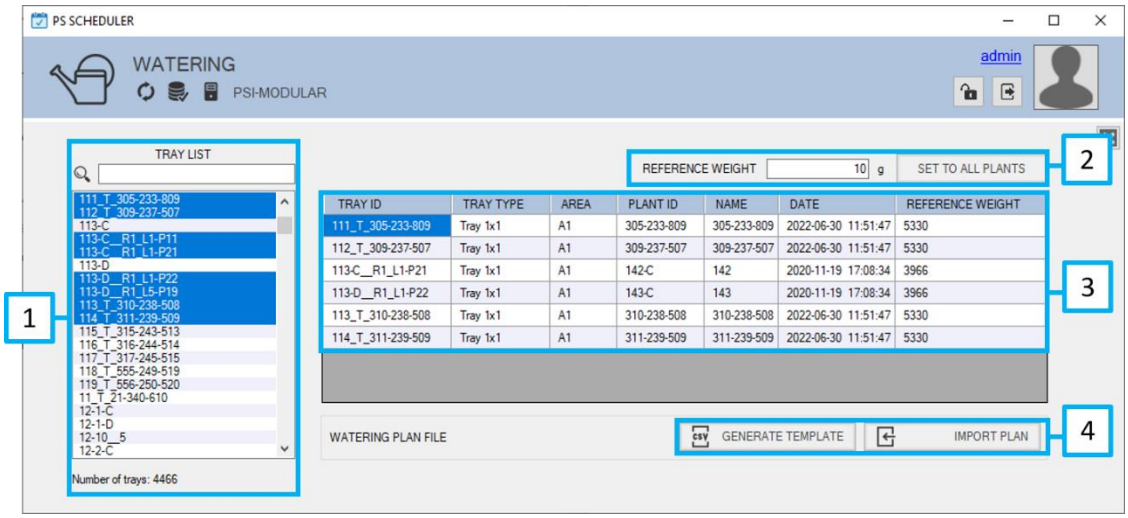


Fig. 88 Reference weight management

6.3.3 REFERENCE WEIGHT REGISTRATION

By registering the reference weight in watering registration step. This is done via registration file. To generate registration file select trays in the Tray List box (Fig. 88-1) and click Generate Template (Fig. 88-4) to save a template csv file. Since all trays used for watering registration are registered trays the template file is pre-filled with known tray information except for the last column (i.e. *RefWeightValue*).

Open the template table in a spreadsheet processor and fill the column *RefWeightValue,* note that values are given in grams. Store locally the edited csv file and import it back to Scheduler application with *Import plan* button (Fig. 88-4) and then *Load file* button (Fig. 89-1). The resulting watering registration table is displayed with last column named *Check result*, which evaluates compatibility of the reference weight values for saving to database (Fig. 89-2). When all entries have the status *OK* the table must be stored to database with *Store to DB* button. This step is necessary to complete the watering registration procedure.

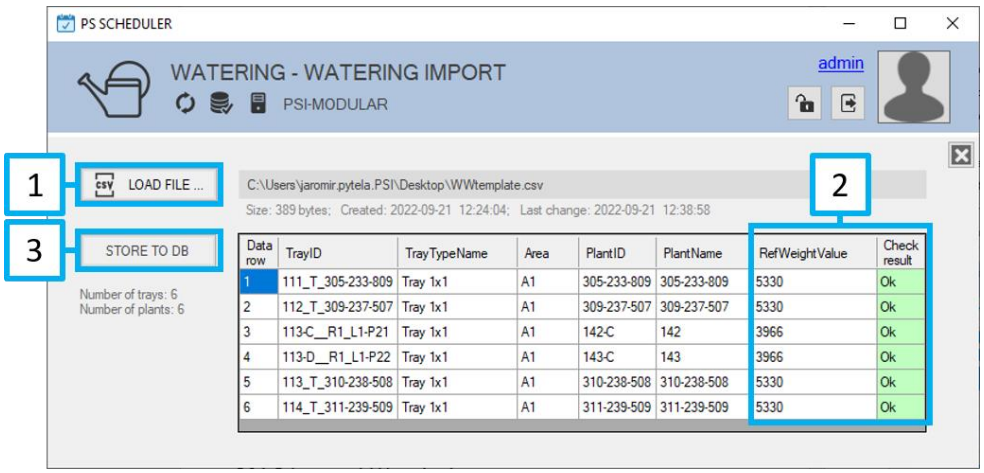


Fig. 89 Reference weight file import

6.4 WATERING TO REFERENCE WEIGHT WITH OFFSET VALUE

After weighing the resulting weight is compared to reference weight for decision whether the pot should be watered or not.

The pot is watered only if the weight falls below the reference value, and it is watered to the reference value raised by the value defined in the textbox. In other words, the Reference is the threshold value for watering but not the final weight after watering if the offset value is higher than 0.

	The stored reference weight value is stored in database and can be changed only in the watering part of the Scheduler application. The measuring protocol can optionally add the offset value and could not change the reference weight.

After selecting *Reference* watering mode (Fig. 90-1) add the offset value to the textbox (Fig. 90-2). The offset value (unit: grams) should be typed in the textbox.

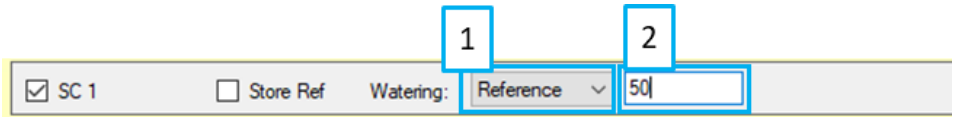


Fig. 90 Selected weighing and watering step in the measuring protocol is set to water the pots to reference plus offset 50 g

Several examples with a pot registered to reference weight 1000 g with offset value 50 are shown in Tab. 23.

Reference weight 1000 g Protocol: *Reference* + 50 g	Weighed value (g) (Weight before watering)	Weight after watering
Example 1	1025	Not watered
Example 2	990	Watered up to 1050 g
Example 3	1000	Not watered

Tab. 23 Examples of watering of pots with different weights with same reference weight

7 USER PROFILE

User profile is accessible from the Main screen by clicking the User profile picture button(Fig. 91).

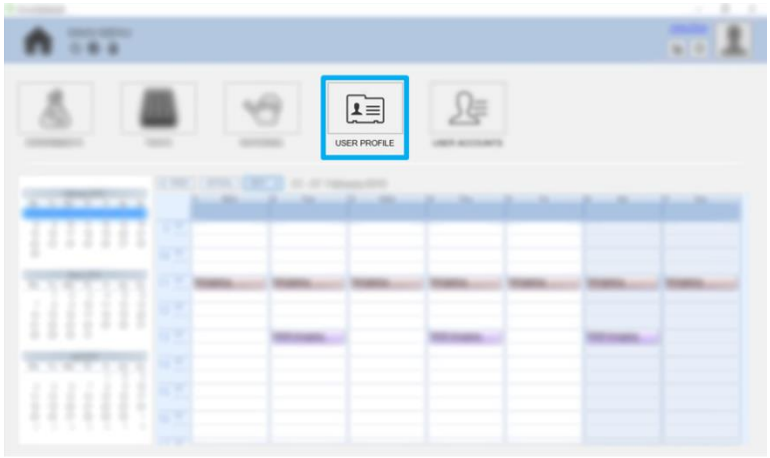


Fig. 91 User profile picture button on the Main screen

User profile detail (Fig. 92) is divided into two parts, the first one shows *User details*:

- Login
- First name
- Surname
- Phone number
- E-mail

The second part contains fields for *User Password* change.

The *OK* button saves changes and closes the window; the *Apply* button just saves the changes, but leaves the window open. *Discard* button or close dialog picture button close the window and discard the changes.

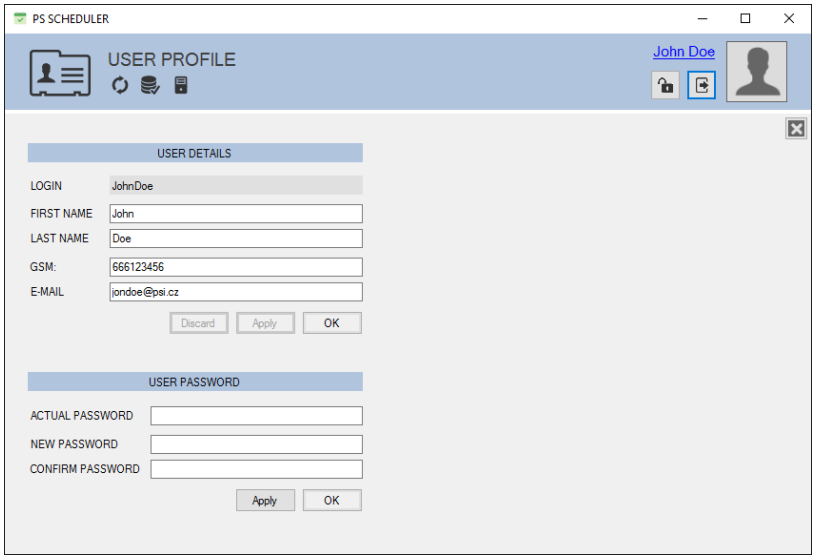


Fig. 92 User profile details window

8 User Accounts

PlantScreen™ System requires user authentication, which is common to the whole PlantScreen™ application package. Five authorization roles are available in the PlantScreen™ system to authorize (permit) the user to certain software functionality and data accessibility. User accounts window contains controls for system account management. The *User Accounts* icon on the Main screen (Fig. 93) is displayed only if logged in user has the administrator level permissions.

	Only accounts which do not own any experiments can be deleted.

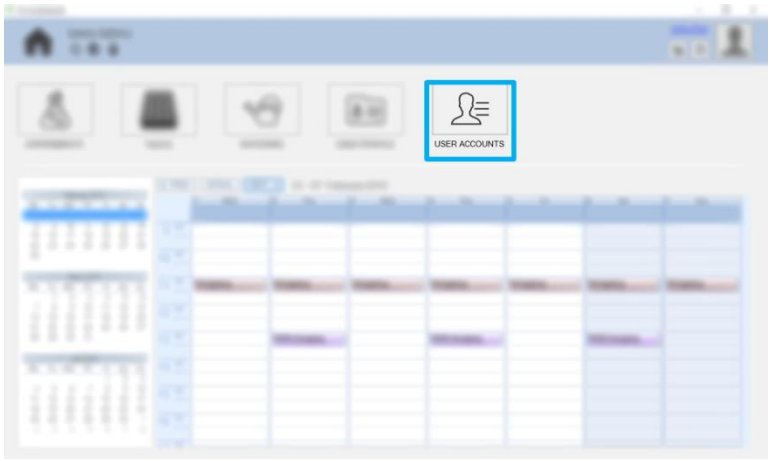


Fig. 93 User accounts picture button

8.1 Account Roles

User roles assignment, i.e. *Account Roles* window, is displayed in the rightmost part of the *User Accounts* window (Fig. 94-11). New account does not have any role assigned by default with default access only to own experiments without rights to manage other user accounts or logging to the Server application. Multiple account roles can be assigned to one account by selecting multiple checkboxes. Full access to all system features and account roles requires all account roles. Rights to each of the account roles are summarized in Tab. 24.

Account role	Description
User Administrator	Complete administration of user accounts (new user creation, roles assignment)
Server user	Can login to Server app
Experiment Viewer	Can view experimental data of other accounts without access to perform any changes
Experiment Editor	Can start measurement for experiments of other accounts
Experiment Master	Can backup, restore and delete experiments of other accounts
Validator	Can validate system calibration
No account role	Can view and manage only own experiments

Tab. 24 Description of account roles

System accounts can be changed only by a user authorized as User Administrator.

Only accounts which do not contain own experiments can be deleted.

8.2 PERMISSIONS

PlantScreen™ System requires user authentication, which is common in the whole PlantScreen™ software package including Server application. Five authorization roles are available in the PlantScreen™ system:

- *User Administrator* – Account can manage user accounts, give them the experiment rights.
- *Server User* – Account can be used to login to the *Server application.*
- *Standard User* – when user doesn't have set any rights, it means, that user can manage only his/her experiments (observe, change, delete, analyze, …).

In the experiment management there are 3 different approaches, which are selected by *User administrator*:

- *Experiment viewer* – can view or observe the experiments of other accounts, but without changes.
- *Experiment editor* – can view, observe and change the experiments of other accounts.
- *Experiment master* – can view, observe, change and delete the experiments of other accounts. Usually is intended for the administrator.

The given roles authorize (permit) the user to certain software functionality and data accessibility. For example, users authorized with *Server User* role can access Server application. *User Administrator* can create, modify or delete user accounts of other users on request.

User accounts can be created and managed only with Scheduler application.

8.3 USER ACCOUNT MANAGEMENT

To manage system accounts in Scheduler application, log in as administrator and click *User Accounts* icon on the Main screen (Fig. 93). After clicking the button, user administrator window opens up (Fig. 94). New user account can be added to a list with *Add User Account* button (Fig. 94-1). Use this button to create a new profile. In the *Fill Account Details* window (Fig. 95) fill user details and confirm with OK button. Newly created account has only standard user rights, no roles are assigned by default.

List of accounts shows created user accounts (Fig. 94-4). Items can be ordered by values in any column by clicking on the corresponding column header. Filtering of user accounts can be done either by a name (Fig. 94-2) or by a status (Fig. 94-3). To filter by a name type in the *Name* combo box and matches in any of the columns (*Username*, *First name* or *Last name*) appear in the list below. Leaving the combo box empty disables filtering. The other option is filtering by account status. Select one of the three options available in the status listbox: All, Active or Disabled and matches appear in the list below. Leaving the list box in status All disables filtering.

Selected account details are displayed in the right part of the window. User account tab (Fig. 94-8) contains account *Username* and user profile details. Forward and backward arrows (Fig. 94-5) enable browsing through registered accounts. Information about account activity are displayed in the Account tab (Fig. 94-9). *Failed login counter* field displays number of unsuccessfull login attempts on the account username. 5 login attempts are allowed prior the account is blocked for the use. The value can be reset by the *Reset* button.

The *Account Active* checkbox in the Account tab (Fig. 94-9) allows to activate the account. When checked, account status is active and can be used to login to the system. Otherwise, the account is disabled and remains in the system future activation. If unchecked, account is disabled and cannot be used to login, but still remains in the system and can be activated again when needed.

Editable items such as *User details* and *Contact t*abs (Fig. 94-8) can be changed by rewriting information in the corresponding textboxes. The current account can be deleted by the *Delete Account* button (Fig. 94-7).

Account password can be changed using the *Change Password* button (Fig. 94-6). Changes in the account profile can be saved to the database (Fig. 94-10) using the *Save* button or discarded with *Discard* button.

	When setting up the passwords following general rules is recommended. The ideal length is at least six characters. It is recommended that the password contains both uppercase and lowercase letters, numbers, punctuation and symbols (e.g. #, %, !). It is also recommended to keep the password in a safe place and do not share it with anyone.

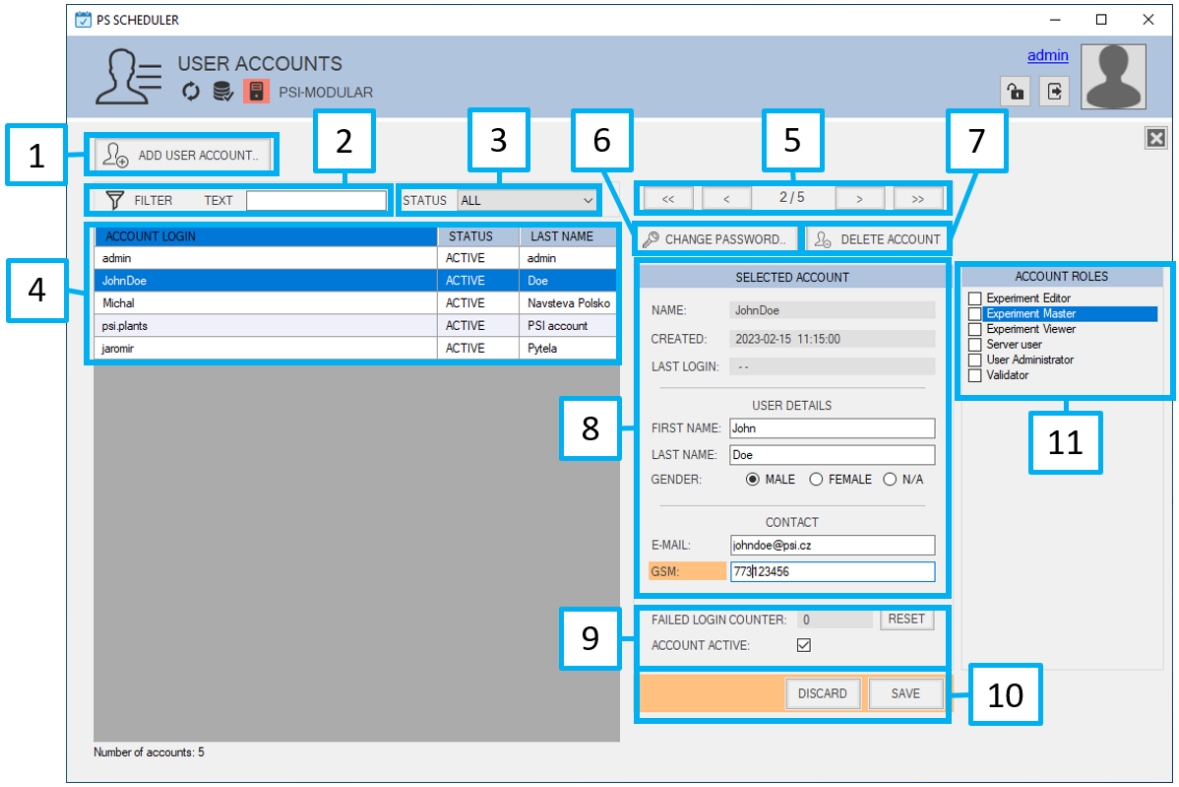


Fig. 94 User accounts window

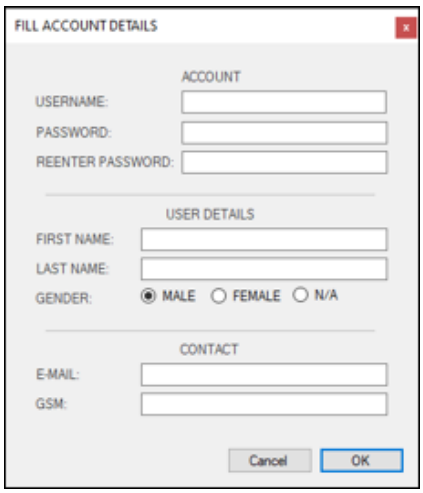


Fig. 95 Fill account details

9 List of Keywords

- **Action** – time defined and planned event Experiment – user created and defined set of measurements. Experiment results in block of data that are linked together (e.g. data measurement initialized at same time and/or measured together with either same or different protocols).
- **Action Schedulling** – action planner.
- **Analyse** – part of recipe used to select type of analysis.
- **Automatic Mode –** Server mode when multiple scheduled actions can be created and launched automatically at specified date and time. Actions must be created and scheduled in the Scheduler application.
- **Batch** – virtual set of trays to be measured with same pre-defined protocol.
- **BatchPicker** – graphic tool for tray batch selection.
- **Color Segmentation Image** – indexed plant image. Iindividual hues are approximated using established hues and these are projected back on original image and their occurrence is counted to provide information about color changes (e.g. related to stress responses and plant senescence).
- **Date list** - index of dates with defined times, when given measurement will beinitiated.
- **Experiment ID** – unique ID of experiment.
- **Experiment Manager** - user role with higher level of permissions, who can inspect and manage experiments of other users.
- **Experiment Owner (Responsible)** – owner and creator of the experiment.
- **Experiment Round** – one time-point executed measurement, which corresponds to one measurement step.
- **Fish eye corrected** – color image with barell distortion corrected.
- **Fish eye masked** – color image with barell distortion corrected and cropped by plantmask.
- **IR Frame** – raw thermal image.
- **IR Frame Masked** – auto scale thermal image cropped based on plant mask.
- **IR Frame Auto Scale Bitmap** – color image created from thermal raw data where color shades are spread on values by automatic range (from minimal value to maximal value of the raw image) and the selected color scale.
- **Leaf Tracking** – analysis mode when analysis is done for single leaf of the plant (Note:This is valid only for top view image analysis).
- **Manual Mode –** Server mode when single action can be created and launched immediately.
- **Measure** – one of the steps in protocol. Measure is collection of recipes.
- **Morphology** – morphological analysis
- **Original Image** – captured raw image.
- **Parameters** – result of analysis. Computed value from measured data by its specificmethod.
- **Parameters Images** – images (FloatFrame format) where each pixel containsparameter value.
- **Plant ID** – unique ID of the plant (number or text with maximum length of 200characters).
- **Plant Mask** – based on analysis automatically extracted plant area. Tray Type Mask defines area in which PlantMask is searched for.
- **Plant Name** – non-unique plant name.

- **Probes** – environmental values measured by installed probes.
- **Protocol** – sequence of steps to be executed. Protocol consists of multiple steps (e.g. Measure, SetLight, TrayLoad,…) and is used for selection of batches and selection of required analysis.
- **Protocol editor** – graphic tool used to design measurement protocol.
- **Recipe** – part of measurement step. Recipe refers to measurement defined for single batch (e.g. type of sensor, settings for the given sensor, selection of device protocol and specification of analysis).
- **Recurrence** – repetition of given action.
- **Reference Weight** – registered weight of the plant used as target weight.
- **Registration file** – .csv file used for bulk plant registration. Registration file must contain specific information such as Plant ID, Tray ID, Plant Name, Tray Type and Area.
- **Round protocol** – measurement and analysis settings for the particular experiment round.
- **Scales** – weight of plants provided by weighing station.
- **Service Mode** – enables various maintenance and settings tasks prior to running an action. The service tasks include system calibration, single snapshot image acquisition, inspection of sensor or protocol settings. No actions can be run in service mode.
- **Time list** – index of times per day, when given measurement will be initiated.
- **Tray** – holder for one or more plants registered with unique ID and specified by given type. Tray 5x4 is standard tray type for compact PlantScreen Systems, Tray 1x1 is standard tray type for modular PlantScreen Systems.
- **Tray ID** – unique ID of the tray (number or text with maximum length of 200 characters).
- **Tray list** – list of all registered trays.
- **Tray Profile** – registration of plants to the tray areas valid for given time period.
- **Tray Type** – type of tray defined by specific mask. Tray Type is specified by given name, top mask and side mask.
- **Tray Type Mask** – user defined area of interest, where plant features are extracted and analysed (Tray 5x4 is standard tray type for compact PlantScreen Systems, Tray 1x1 is standard tray type for modular PlantScreen Systems).
- **User Administrator** – user role with highest level of permissions (e.g. new account registration, update of passwords…).
- **User Profile** – GUI for own user account management.
- **User Roles** – user roles given by user administrator that authorize (permit) the user to certain software functionality and data accessibility

10 LIST OF FIGURES

11 LIST OF TABLES