HYDROTOOLS DSS

USER MANUAL

AND

QUICK START GUIDE

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SUMMARY

1 QUICK START GUIDE

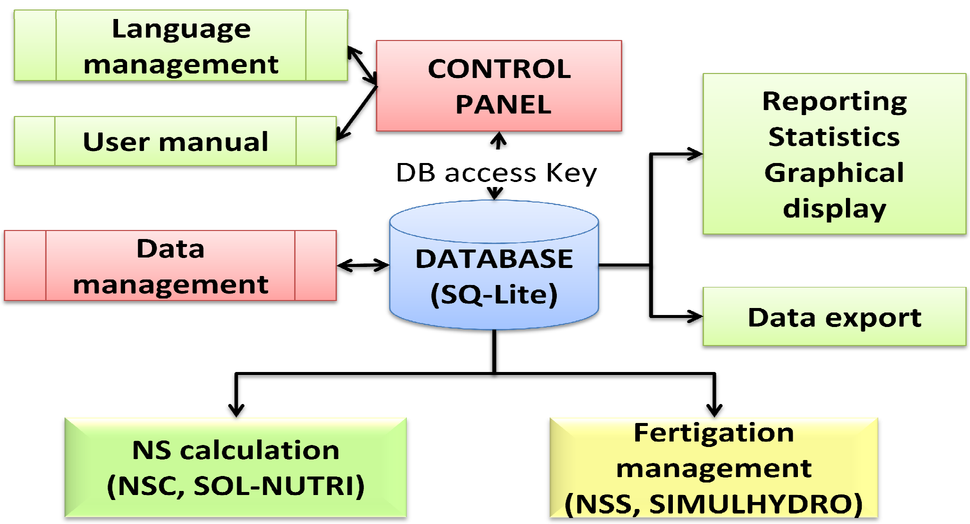
1.1 What is Hydrotools?

Hydrotools is a Decision Support System (DSS) developed in C# Microsoft .Net Frameworks 4.0 with the aim to support the management of greenhouse soilless cultures. Hydrotools uses either English (US) or Italian language.

Hydrotools was developed by the Department of Crop Biology (now, Department of Agriculture, Food and Environment) at the University of Pisa and the Institute of Biometeorology (IBIMET) of National Research Council (Firenze, Italy) in the framework of the EU project EUPHOROS, "Efficient Use of Inputs in Protected HORticulture", (EU-FP7-KBBE-2007-1, grant n° 211457).

The system architecture is based on a central database (SQLite database engine), which stores both input and output data, and two separate calculation tools:

- **SOLNUTRI**, which calculates the salt concentrations of stock solutions used to prepare the nutrient solutions fed to the crop with a pre-set ion concentration;
- **SIMULHYDRO**, which simulates crop plant nutrient uptake and the variations of the ionic composition of the nutrient solution in open, closed and semi-closed soilless systems.



Architecture of HYDROTOOLS.

This version of Hydrotools was checked against all known crashing errors. However, debugging was conducted on a limited number of hardware configurations and operating systems, so software crash may occur if you are using uncommon hardware/software configurations.

In case of crash, the last calculation or simulation is deleted from the database, which could be damaged, thus making the program not to work properly. To restore the functionality of the software, the user must replace the “db” directory in the “Hydrotools” directory tree with its backup. Thus, it is recommended to make a backup of “db” directory on regular time basis. Backup and restore of the “db” directory must be done when Hydrotools is not running.

1.2 Installation

To operate the Hydrotools software the user needs:

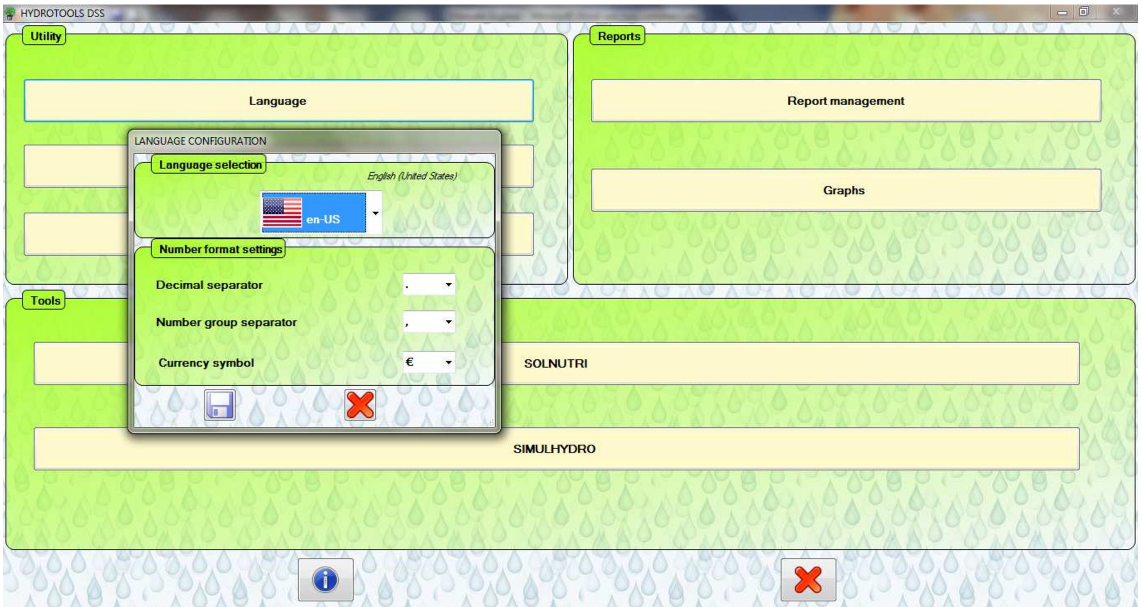
- A PC running Windows XP SP3, Windows Vista, Windows 7 SP1;
- 1GB of RAM and 750 MB of available hard disk space
- Acrobat Reader for reading the documentation (free download from www.adobe.com)

Hydrotools software can be downloaded from (http://www.wageningenur.nl/en/Research-Results/Projects-and-programmes/Euphoros-1/ Calculation-tools.htm).

After download, the user must run the setup file (DSS_Start.exe), which will locate Hydrotools in the “Documents” directory. The user is recommended to accept the default “Documents” directory. The software may not work properly if installed into a new directory.

Freeware versions of the Framework dotNet 4 and the Visual Studio 8 software will be downloaded and installed automatically, following user’s permission, if they are not available on the PC. Therefore, an active Internet connection is necessary during software installation.

When Hydrotools is launched, the user must check the Language utility box and, if needed, select the same number format settings as in the Windows control panel (to check it, press START → CONTROL PANEL→CLOCK, LANGUAGE, AND REGION or REGIONAL AND LANGUAGE OPTIONS → Change the date, time, or number format).



Home page of HYDROTOOLS DSS.

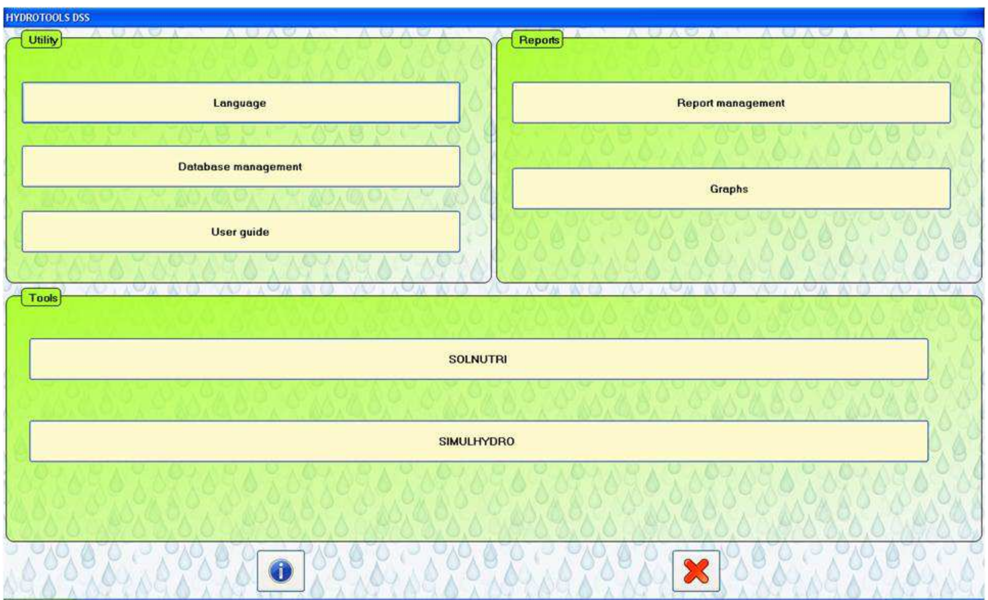
USER MANUAL

1 Control panel of HYDROTOOLS

This dialog-box (see figure above) represents the main control panel of the DSS and allows access to the two main tools available for the management of fertigation: SOLNUTRI and SIMULHYDRO. For the correct operation of the two programs the user must set some parameters in the section "Utility" which is located in the upper left in the dialog "HYDROTOOLS DSS". In particular, in this section, the user can access to the sub-sections for setting language parameters and populate the database; the latter already contains general information for different crops, while other crop parameters can be added by the user. Once you have set the "Utilities" you can go to the "Tools" section:

a) **SOLNUTRI** is a program that allows to calculate the quantities of salts and acids that have to be dissolved in the irrigation water for the preparation of stock solutions (for major details see the example and the help file of the specific program);
b) **SIMULHYDRO** is a program that allows to simulate growth, water uptake, ionic composition and mineral absorption in the root zone of an open, closed and semi-closed soilless system (for more details see the example file and the help of specific program).

To become familiar with the DSS and better understand its features it is advisable to see the examples given in the help file of both the programs SOLNUTRI and SIMULHYDRO. Finally, in the main control panel is reported a "Report" section that displays the data simulated with the programs SIMULHYDRO.



Home page of Hydrotools.

1.1 Data entry and view

The data present in the DSS are displayed in the various dialogs in four different types of cells that correspond to four different colors, as summarized in the following table. To move from cell to cell (yellow cells only), while entering data, you can use TAB, ENTER or the mouse.

Cell type	Description
Blue cell	Default data: these data cannot be modified or deleted
White cell	Data entered and saved by the user in previous sessions: this data can be deleted if necessary
Grey cell	Data calculated by the system: these data cannot be modified
Yellow cell	Data for new entries: the yellow cells are the only cells in which the user can write new data

1.2 Backup and restore system

At end of each work session or on regular time base, it is suggested to make a copy of the file “hydrotools.db” located in the directory “db”. In case of crash of the software the damaged file must be replaced by latest version of the abovementioned file. In the directory “BlankDB” there is also a copy of this file with the default parameters.

1.3 Components of HydroTools and features

To access to the various dialogs of the DSS simply press the correspondent button. Below is reported the structure of the DSS.

DSS	Section	Tool			Description
HydroTools	**Utility**	**Language**			The dialog allows: ✓ Setting the language ✓ Setting the digit group separator and decimal separator
		User guide			Contains examples and explanations
		Database management	**Irrigation water**	**Ionic composition**	The dialog allows: ✓ Viewing the water records already present in the database ✓ Entering a new water analysis record ✓ Deleting a record from the database
			Acids and fertilizers	**Chemical composition**	The dialog allows: ✓ Viewing the products already present in the database ✓ Entering a new product ✓ Deleting a product from the database
			Environmental constraints	**Environmental constraints**	The dialog reports the list of laws that regulate the maximum ion concentrations in the drainage water. The dialog allows: ✓ Consulting laws and regulations already present in the database ✓ Entering new laws ✓ Deleting laws from the database
			Crop parameters	**Crops and stages**	The dialog allows: ✓ Viewing combinations of crop/stage already present in the database ✓ Entering new combinations ✓ Deleting combinations already entered (the elimination of a combination results in the deletion of all parameters associated with it threshold values, nutritive recipes and nutrient uptake concentrations)
				Nutritive recipes	This dialog is used to define the nutritive recipes for the preparation of the nutrient stock solutions with the tool SOLNUTRI. The dialog allows: ✓ Viewing the nutritive recipes already present in

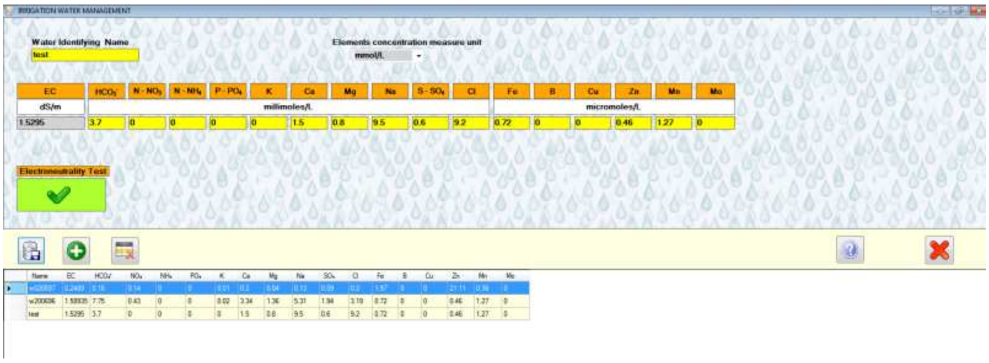
DSS	Section	Tool			Description
					the database ✓ Entering new nutritive recipes
				Ion concentration thresholds	This dialog is used for entering: ✓ Maximum thresholds for water: ionic concentration values at which the irrigation water may cause cultivation problems ✓ Minimum thresholds for the nutrient solution (NS): minimum ionic concentration values allowed in the recirculating NS ✓ Maximum thresholds for the nutrient solution (NS): maximum ionic concentration values that must not be exceeded in the recirculating NS (when this value is reached a total or partial discharge of the exhausted NS is necessary) The dialog allows: ✓ Viewing the thresholds already present in the database ✓ Entering new values
				Uptake concentrations	Thisdialog is used to define nutrient uptake concentrations of the crop, which is the rate of nutrient uptake expressed as millimoles of ions absorbed per L of water absorbed in the same time. The dialog allows: ✓ Viewing the values already present in the database ✓ Entering new values
	Software	**SOLNUTRI**			The program allows to calculate the amount of salts necessary to prepare the stock nutrient solution on the basis of: ✓ Irrigation water ✓ Available salts and acids ✓ Desired nutritive recipes At the end of the calculation, the result can be saved as a pdf file or printed out

DSS	Section	Tool			Description
		SIMULHYDRO			The program allows to simulate growth, water uptake, ionic composition and mineral absorption in the root zone of an open, closed and semi-closed soilless system; at the end of the simulation, graphic and tabular reports summarize the obtained results
	Reports	**Report management**			This dialog allows you to view, as tables, the information provided by the simulation performed with SIMULHYDRO including: ✓ Crop water balance ✓ Nutrient balance ✓ Mean, minimum and maximum nutrient concentrations in the system ✓ Mean, minimum and maximum EC in the system All data can be saved as a pdf file or printed out
		Graphs			This dialog allows to view, as graphs, the information provided by the simulation performed with SIMULHYDRO including: ✓ Nutrient concentration patterns in the system ✓ EC patterns in the system All data can be saved as a pdf file or printed out

2 Database management

2.1 Irrigation water management

This dialog allows to add or delete information related to the water to be used for the preparation of the nutrient solutions and the irrigation of the crop. A table at the bottom of the screen displays information on water saved by the user in previous sessions.



Main dialog

2.1.1 Entry of a new irrigation water

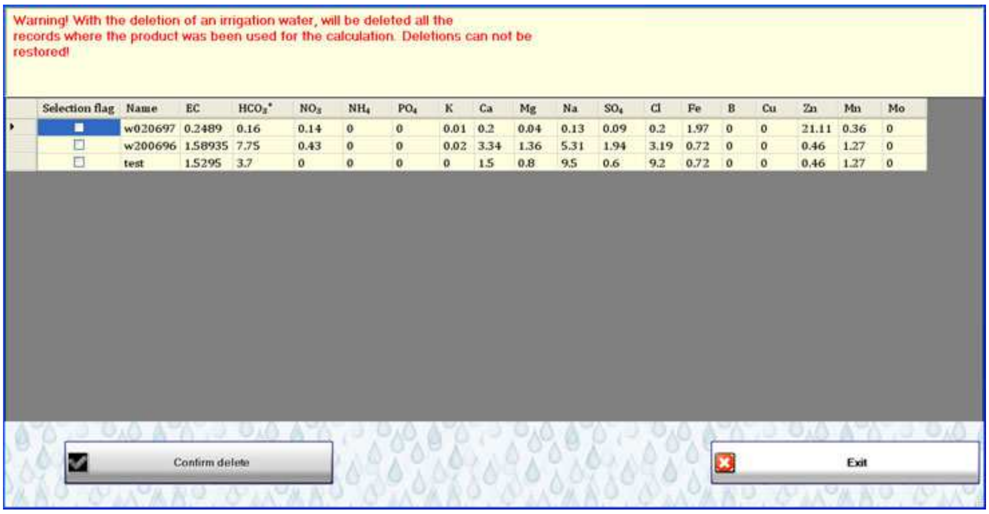
1) Enter a name for the new water.
2) Enter the concentrations of the various ions present in the irrigation water. The values can be inserted as millimoles/L (micromoles/L for the microelements Fe, B, Cu, Zn, Mn, Mo) or ppm: select the appropriate unit from the drop down list.
3) After entering all data, run the test for the chemical electroneutrality, afterward the "Save" button () will be enabled to save the information. Then, it is possible to enter new records by pressing the button to empty the dialog ().

The system will automatically check that:

- the values entered as concentrations are numbers, otherwise an error appears as a red icon ();
- the chemical electroneutrality is satisfied (press the button to run the test): if it is satisfied the corresponding cell is **green**, otherwise it may be **red** if the sum of anions is greater than the sum of the cations (more than 1 mEq/L) or **orange** if the sum of cations is greater than the sum of anions (more than 1 mEq/L);
- the EC value of the nutritive formula is calculated by using the equation proposed by Sonneveld, in which the EC (dS/m) = sum of cations (milliequivalents/L)*0.095+0.19. Small discrepancies between estimated and measured value are possible at low EC and/or with high content of sulphates.

2.1.2 Deletion of an irrigation water

The dialog to delete a record is displayed by pressing the corresponding button ( ).



Dialog box for the deletion of a records in the Hydrotools database.

1) Select a record with a click of the mouse.
2) Delete the record with the button "Delete". Pressing the confirmation button the system will warn that the cancellation is final.

2.2 Acid and fertilizer management

This dialog allows to add, modify or delete fertilizer products in the database. The database contains some default acids and salts summarized in the following table. Default products cannot be deleted or edited with the only exception of their cost. However, more products can be added for each chemical category; all fertilizers in the database can be chosen later from a drop down list in the tool SOLNUTRI used for the calculation of the desired nutritive formula.

The products are grouped into the following families of compounds:

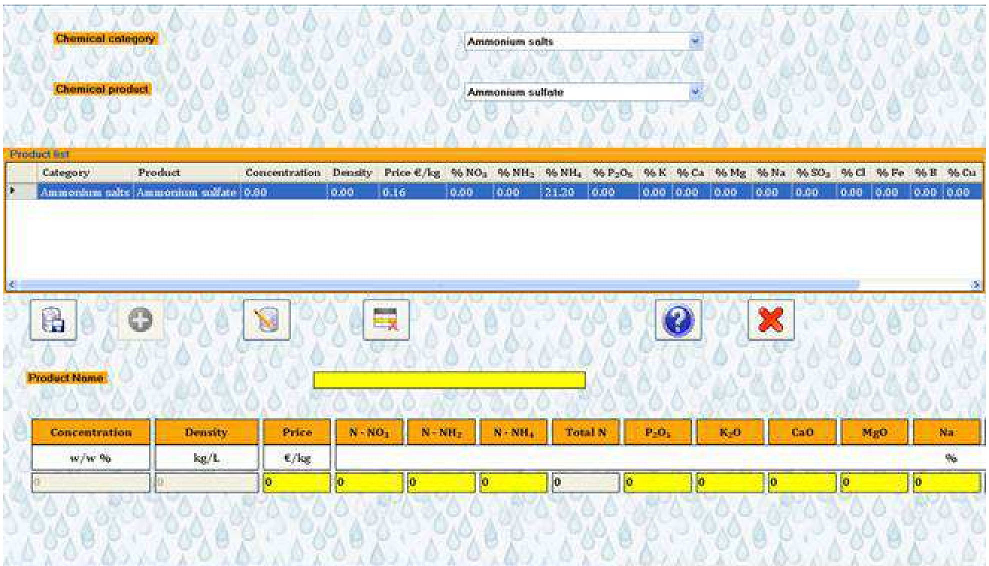
1) Acids
2) Water-soluble products
3) Ammonium salts
4) Calcium salts
5) Phosphorus salts
6) Magnesium salts
7) Potassium salts
8) Iron salts
9) Sodium salts
10) Microelements

Default fertilizers and acids contained in Hydrotools database.							
NH4 salts	**Ca salts**	**P salts**	**Mg salts**	**K salts**	**Fe salts**	**Na salts**	**Microelements**
Ammonium nitrate	Calcium nitrate (technical grade)	Monopotassium phosphate	Magnesium sulphate	Potassium nitrate	Iron chelate (EDTA)	Sodium chloride	Boric acid
Ammonium sulphate	Calcium nitrate (reagent grade)		Potassium nitrate	Potassium sulphate	Iron chelate (EDDHA)		Sodium borate
Monoammonium phosphate	Calcium chloride			Potassium chloride	Iron chelate (DPTA)		Copper sulphate
							Copper chelate (EDTA)
							Zinc sulphate
							Zinc chelate (EDTA)
							Manganese sulphate
							Manganese chelate
							Ammonium molybdate
							Sodium molybdate

2.2.1 Entry of a new product

1) Select the chemical category.
2) Select a chemical product.
3) Enter a name for the new product.
4) Enter the percentage values of various elements for the salts or the density and concentration of acids.
5) After entering, the "Save" button ( ) is enabled to save the information. Then, it is possible to enter more products by the button used to empty the dialog ( ).

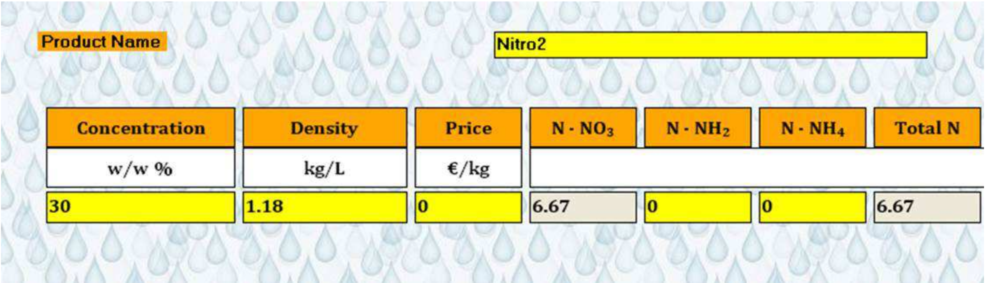
The system will automatically check if the values entered as concentrations are numbers, otherwise an error appears as a red icon ( )



Dialog box to insert a new acid or fertilizer in the Hydrotools database.

Suggestions

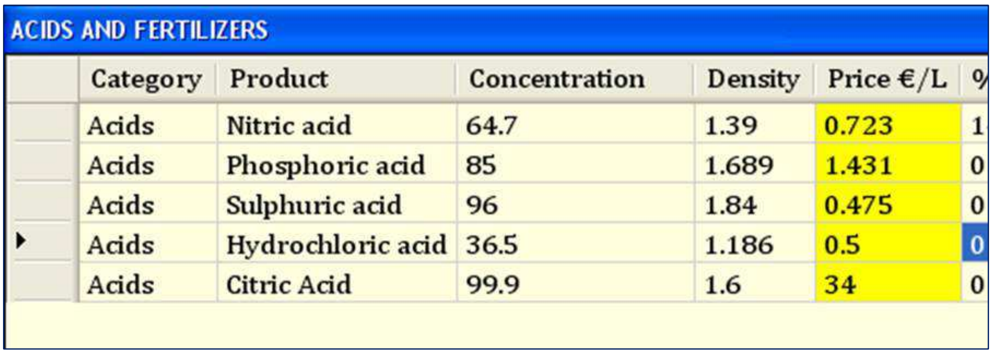
- If you do not choose any chemical category and product the system does not enable the buttons to update or delete products and the cells for input data. The latter will have a different appearance depending on the type of compound.
- It is possible to enter new products by clicking any of the already existing products in the database and then updating it.
- For default products you can only update the price using the "Edit" button.
- For acids, when the concentration value is entered, the system calculates automatically the density and the concentration of the element (the figure shows an example for nitric acid). Since there is a close correspondence between acid concentration and density, the calculated value should not deviate much from the real one; however, the user can enter a different value (i.e. the value reported on the label of the commercial product) and the system will alert if the value deviates too much from the calculated done.



Dialog box for inserting a new acid in the fertilizer database.

2.2.2 Product price change

The following dialog appears after pressing the "Edit" button ( ) that will be enabled only after the selection of the desired chemical category from the corresponding drop down list.



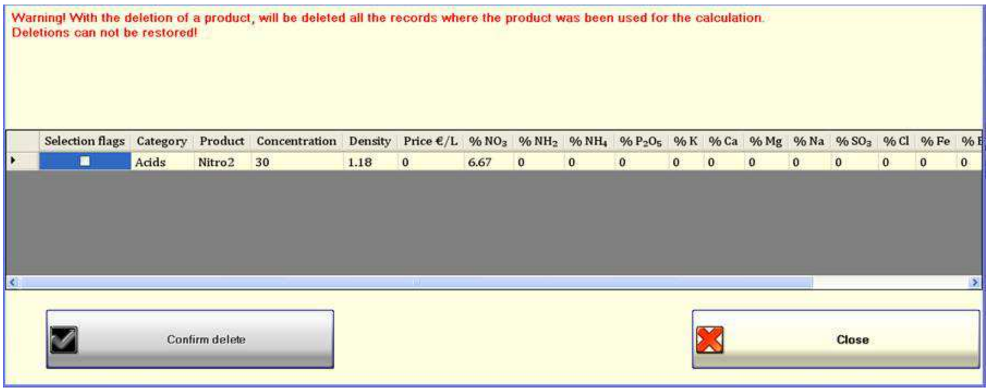
Category	Product	Concentration	Density	Price €/L	%
Acids	Nitric acid	64.7	1.39	0.723	1
Acids	Phosphoric acid	85	1.689	1.431	0
Acids	Sulphuric acid	96	1.84	0.475	0
Acids	Hydrochloric acid	36.5	1.186	0.5	0
Acids	Citric Acid	99.9	1.6	34	0

Dialog box for editing the product price.

1) Enter the new price in the yellow cells using the format corresponding to the selected "Language".
2) After entering you can press the button "Update".

2.2.3 Deletion of a fertilizer

The dialog to delete a product is displayed by pressing the corresponding button ( ).



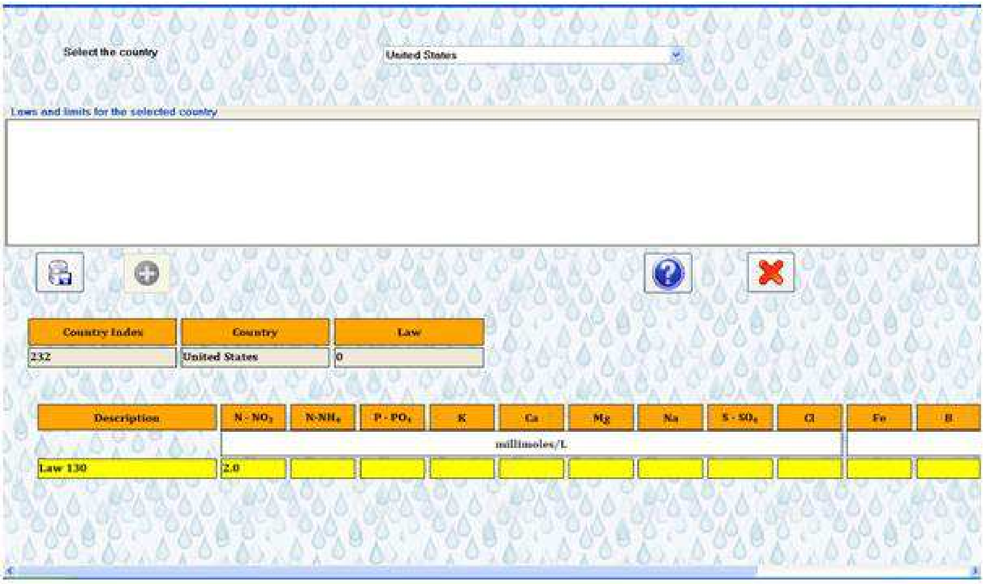
Selection flags	Category	Product	Concentration	Density	Price €/L	% NO_3	% NH_2	% NH_4	% P_2O_5	% K	% Ca	% Mg	% Na	% SO_3	% Cl	% Fe	% F
	Acids	Nitro2	30	1.18	0	6.67	0	0	0	0	0	0	0	0	0	0	0

Dialog box for deleting a product from fertilizer database.

1) Select a product with a click of the mouse.
2) Delete the product with the button "Delete". Pressing the confirmation button the system will warn that the cancellation is final.

2.3 *Environmental constraint management*

This dialog allows to add, modify or delete information concerning any environmental constraint present in the cultivation area (i.e. the maximum concentration of ions allowed in the drainage water).



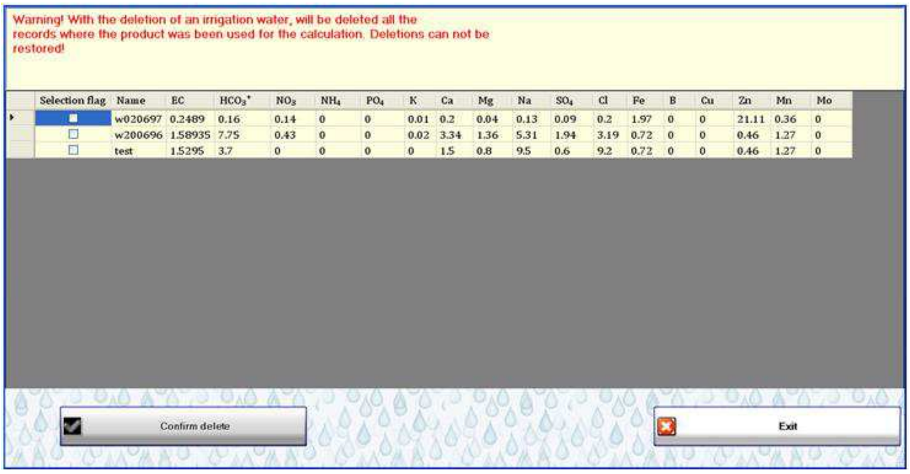
Environmental constraint dialog box.

2.3.1 Entry of new law

1) Enter a name/description for the law or regulation in place.
2) Enter the limit concentrations of various ions considered by the law.
3) After entering, the "Save" button ( ) is enabled to save the information. Then, it is possible to enter new law by pressing the button to empty the dialog ( ).

2.3.2 Deletion of a law

The dialog to delete a law is displayed by pressing the corresponding button ( ).



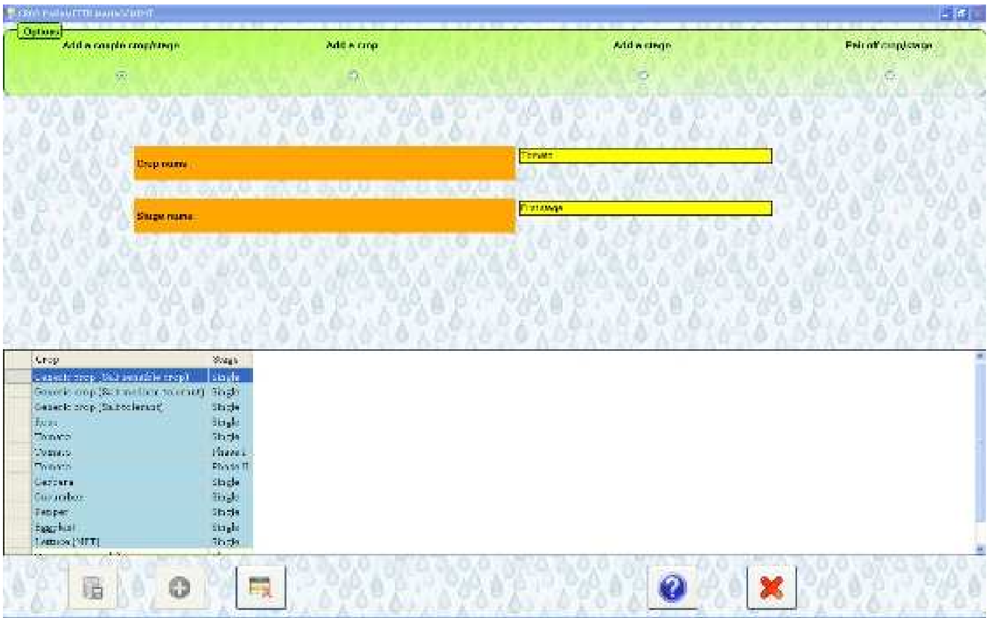
Dialog box for deleting a law from database.

1) Select a record with a click of the mouse (a selected record will appear in red).
2) Delete the record with the button "Delete". Pressing the confirmation button the system will warn again that the cancellation is final.

2.4 Crop parameter management

2.4.1 Crop and stage management

This dialog allows to enter and delete various combinations between crops and phenological stages. Each culture may have one or more reference growth stages. In the first case we say “single stage”.



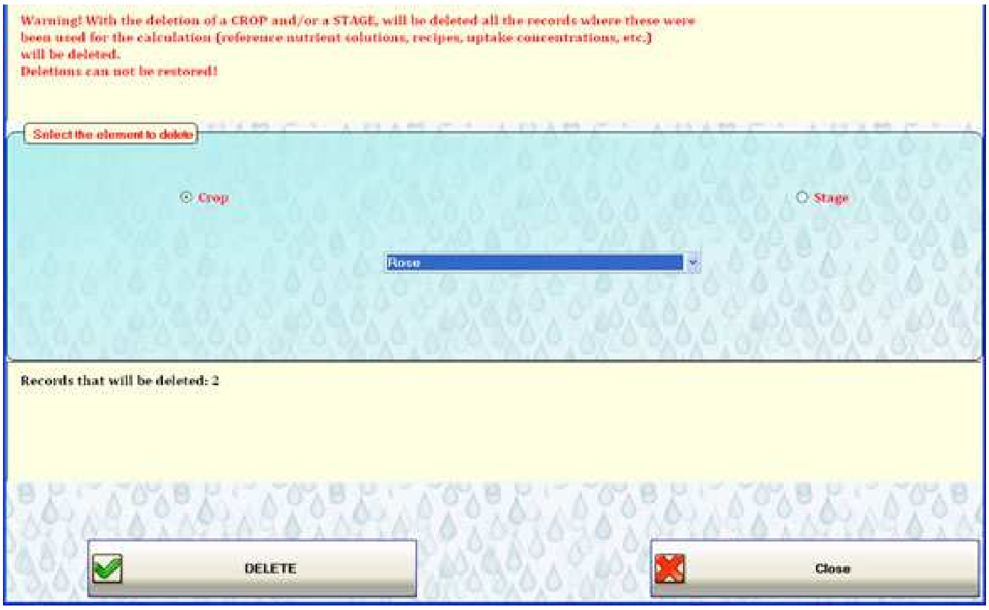
Dialog box for modifying the crop database.

2.4.1.1 Entry of a new combination

1) Choose whether to add a new crop, phenological stage or combination of both. Attention: if you are adding only a new crop or stage, choose the option "Add a crop" or "Add a stage", respectively, but not "Add a pair crop/stage". As an alternative, it is possible to combine a pair crop/stage from existing data using the option "Pair of crop stage".
2) Enter a name.
3) After entering, the "Save" button ( ) is enabled to save the information. After saving, it is possible to insert a new combination by pressing the button to empty the dialog ( ).

2.4.1.2 Deletion of a combination

The dialog for deleting any records is displayed by pressing the corresponding button ( ).



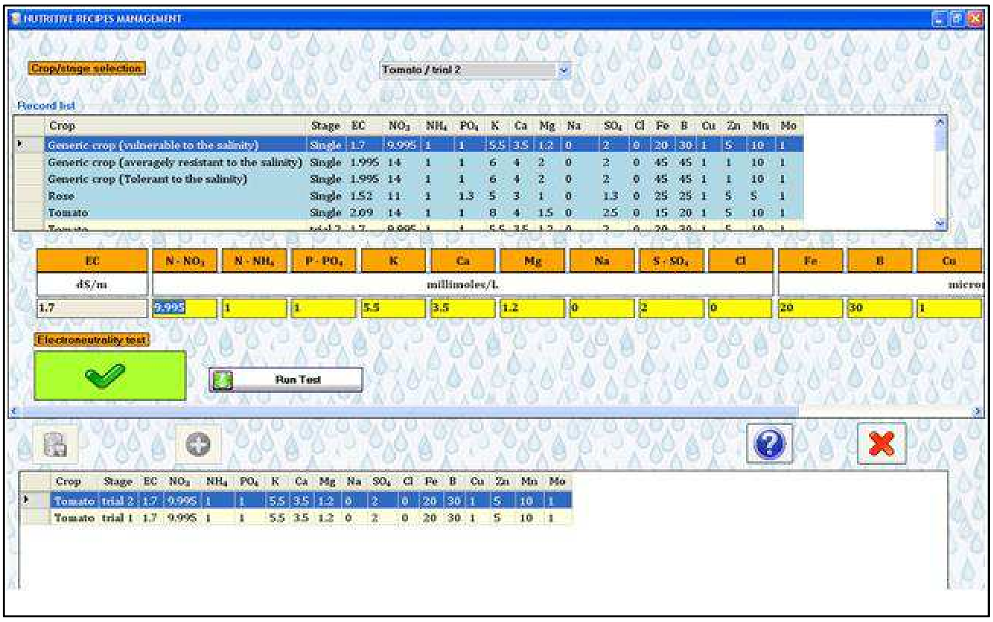
Dialog box for deleting a crop/stage from Hydrotools database.

1) Select a crop or stage.
2) Delete the record with the button "Delete". Pressing the confirmation button, the system will warn that the cancellation is final.

Dialog box for confirming the deletion of a crop/stage from database.

2.4.2 Nutritive recipe management

This dialog allows to add and edit the reference nutritive formulas. Each combination crop/nutrient stage has a reference formula. The database stores some default nutritive formulas. The nutritive formulas entered by the user in previous sessions are displayed in the table at the bottom of the screen.



Dialog box for inserting a new crop recipe.

2.4.2.1 Entry of a new nutritive formula

1) Choose a crop/stage combination.
2) Choose a formula in the default list to match the selected combination crop/stage, or go to step 3).
3) Enter the concentrations of the various ions (15 ions) present in the new formula. The values can be inserted as millimoles/L (micromoles/L for the microelements Fe, B, Cu, Zn, Mn, Mo).
4) After entering, the "Save" button () is enabled to save the information. Then, it is possible to enter a new formula by pressing the button to empty the dialog ().

The system will automatically check that:

- the values entered as concentrations are numbers, otherwise an error appears as a red icon ();
- the chemical electroneutrality is satisfied (press the button to run the test): if it is satisfied the corresponding cell is **green**, otherwise it may be **red** if the sum of anions is greater than the sum of the cations (more than 1 mEq/L) or **orange** if the sum of cations is greater than the sum of anions (more than 1 mEq/L);
- the EC value of the nutritive formula is calculated by using the equation proposed by Sonneveld, in which the EC (dS/m) = sum of cations (milliequivalents/L)*0095+0.19.

Note: it is not possible to delete a nutritive formula in this dialog. Nutritive formulas can be deleted by deleting a crop/stage combination in the respective dialog.

2.4.3 Ion concentration threshold management

This dialog allows to add and edit information related to the maximum and minimum ion concentrations tolerated by the crop in the root zone.

Dialog box for managing the threshold of reference ion concentration.

2.4.3.1 Entry of a new threshold values

1) Choose a combination crop/stage.
2) Enable the list for the maximum threshold values in the irrigation water through the apposite button.
3) Choose the default values from the list or change them as desired.
4) Repeat the above procedure for minimum and maximum thresholds in the nutrient solution.
5) After entering, the "Save" button ( ) is enabled to save the information. Then, it is possible to enter a new formula by pressing the button to empty the dialog ( ).

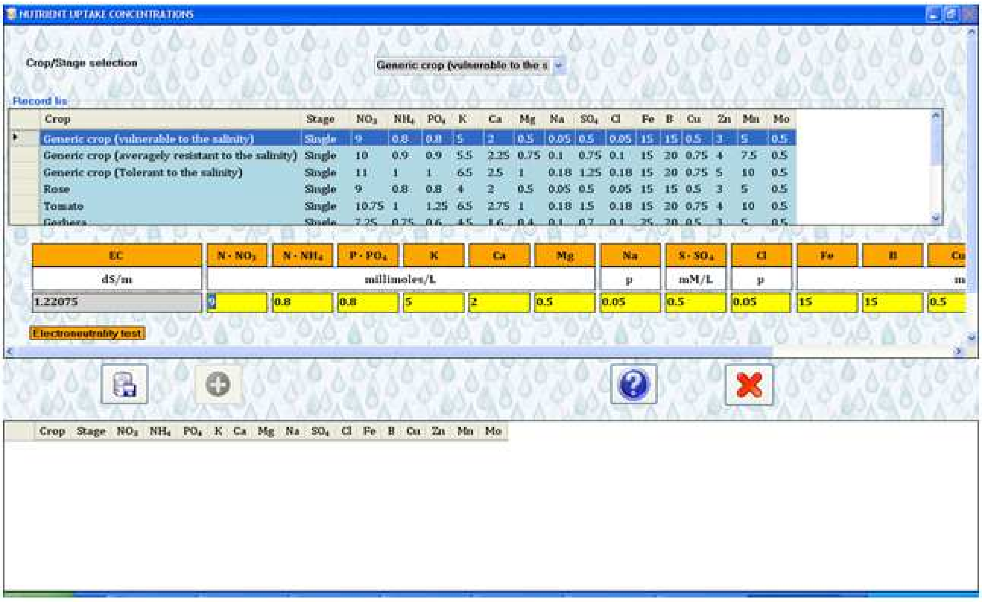
Suggestions

The maximum threshold concentrations in the irrigation water are referred to the sensitivity of the plant to a particular ion. This information is important for the preparation of the nutrient solution and fertigation management. The minimum and maximum thresholds of the nutrient solution represent the range of oscillation to which the root zone can be subjected. This information is used to decide the time for nutrient solution discharge in semi-closed loop systems.

Note: it is not possible to delete combinations of threshold values in this dialog. Combinations of threshold values can be deleted by deleting a crop/stage combination in the respective dialog.

2.4.4 Management of crop uptake concentrations

This dialog allows to add or modify the nutrient uptake concentration values of the crop for the different ions. A table in the bottom part of the dialog box displays information saved by the user in previous sessions.



Dialog box for modifying nutrient uptake ion concentration.

2.4.4.1 Enter a new value of nutrient uptake concentration

1) Choose a combination crop/stage.
2) Choose uptake concentration values in the default list to match the selected combination crop/stage, or go to step 3).
3) Enter the uptake concentrations for the various ions as desired. The values can be inserted as millimoles/L (micromoles/L for the microelements Fe, B, Cu, Zn, Mn, Mo).
4) After entering, the "Save" button ( ) is enabled to save the information. Then, it is possible to enter a new value by pressing the button to empty the dialog ( ).

The system will automatically check that:

- the values entered as concentrations are numbers, otherwise an error appears as a red icon ( );
- the chemical electroneutrality is satisfied (press the button to run the test): if it is satisfied the corresponding cell is **green**, otherwise it may be **red** if the sum of anions is greater than the sum of the cations (more than 1 mEq/L) or orange if the sum of cations is greater than the sum of anions;
- the EC value of the nutritive formula is calculated by using the equation proposed by Sonneveld, in which the EC (dS/m) = sum of cations (milliequivalents/L)*0.095+0.19.

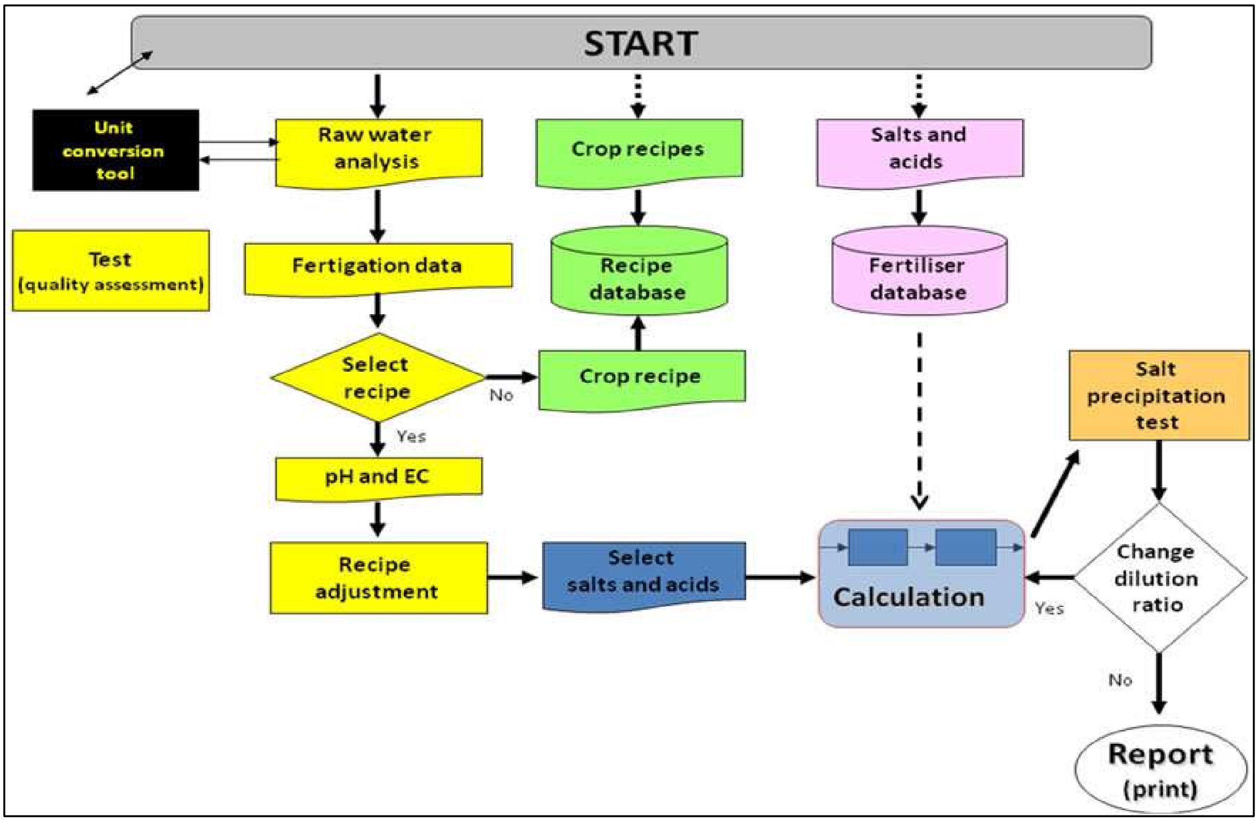
Note: it is not possible to delete combinations of uptake concentration values in this form. Uptake concentration values can be deleted by deleting a crop/stage combination in the respective form.

3 SOLNUTRI

The program allows to calculate the amount of salts that must be utilized to prepare the stock nutrient solution on the basis of:

a) irrigation water analysis
b) available salts and acids
c) desired nutritive recipe

At the end of the calculation, the result can be saved as a pdf file or printed out.



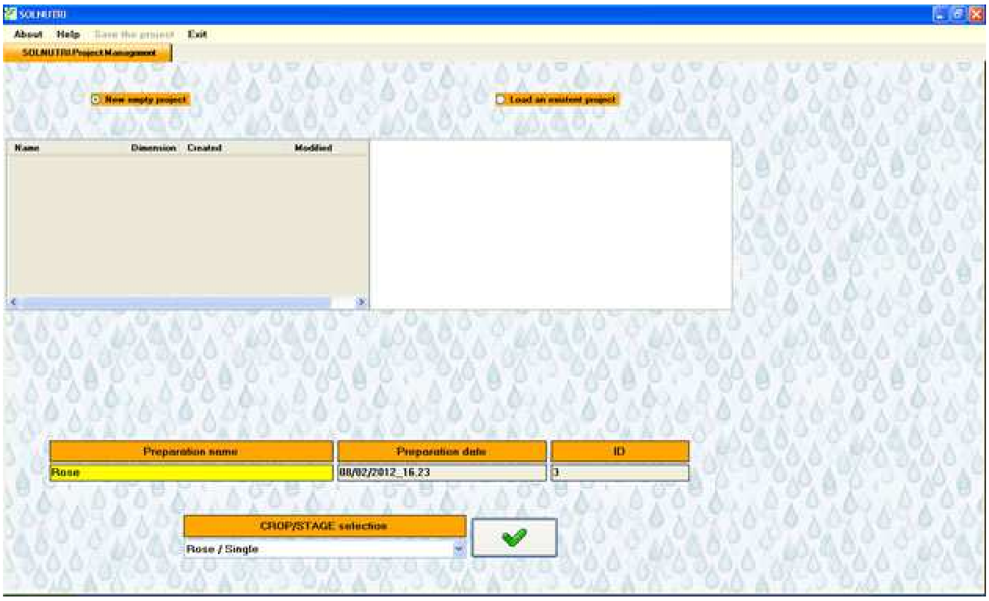
Conceptual framework of SOLNUTRI.

3.1 Wizard of calculation

The calculation is done through a wizard procedure that guides the user to the final result.

3.1.1 Dialog 1: project management

1) Choose whether to create a new project or open a project saved in previous sessions.
2) If you choose a new project, give a name to the project.
3) Choose a combination crop/stage set previously in the database of HYDROTOOLS --> Utility (Database management) --> Crop parameters (Crop/stage)
4) Continue with the confirmation button ().



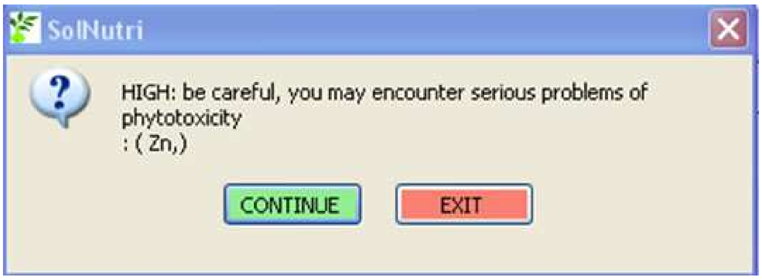
Dialog box to start a new SOLNUTRI project.

3.1.2 Dialog 2: irrigation water

1) Chose from the drop down list the record corresponding to the water to be used for irrigation: the ion composition of the water must have been previously entered into the database of HYDROTOOLS --> Utility (Database Management) --> Irrigation water (Ionic composition).

Dialog box to select a water source from the database.

2) If the irrigation water contains a given element at a concentration considered too high for the crop, a warning message appears as reported in the following picture. The maximum concentrations of a given element must have been previously set in the database of HYDROTOOLS -->Utility (Database management) --> Crop parameters (Ion concentration thresholds).



SOLNUTRI: result of the irrigation water test.

3) If you want to continue with the selected water, you can choose "continue" and then proceed with the confirmation button (✔).

3.1.3 Dialog 3: nutritive formula

1) Enter the desired concentration of the stock solution and the volume of the containers.
2) Continue with the confirmation button (✔).
3) At this point the form displays the data about the selected nutritive formula for small adjustments if necessary (only for EC and pH). The nutrient solution associated with the combination crop/stage must have been previously set in the database of HYDROTOOLS --> Utility (Database management) --> Crop parameters (Nutritive recipes).
4) Continue with the confirmation button (✔).

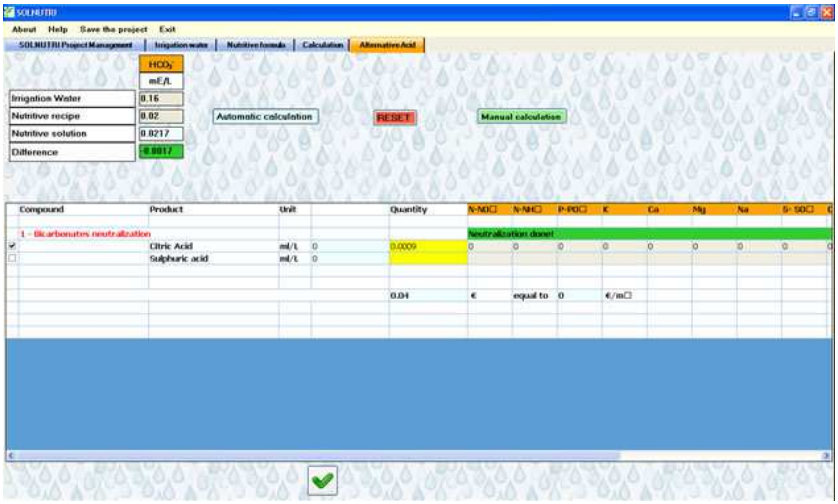
Dialog box to insert SOLNUTRI input.

3.1.4 Dialog 4: calculation

1) Select fertilizers and acids to be used in the calculation. The fertilizer products must have been previously entered in the database of HYDROTOOLS --> Utility (Database management) --> Acids and fertilizers (Chemical composition).
2) If "automatic calculation" is selected, the program will balance automatically the amount of salts; alternatively, select "manual calculation" and enter (in the yellow cells) the values suggested by the program or the user-defined ones.

SOLNUTRI calculation dialog box.

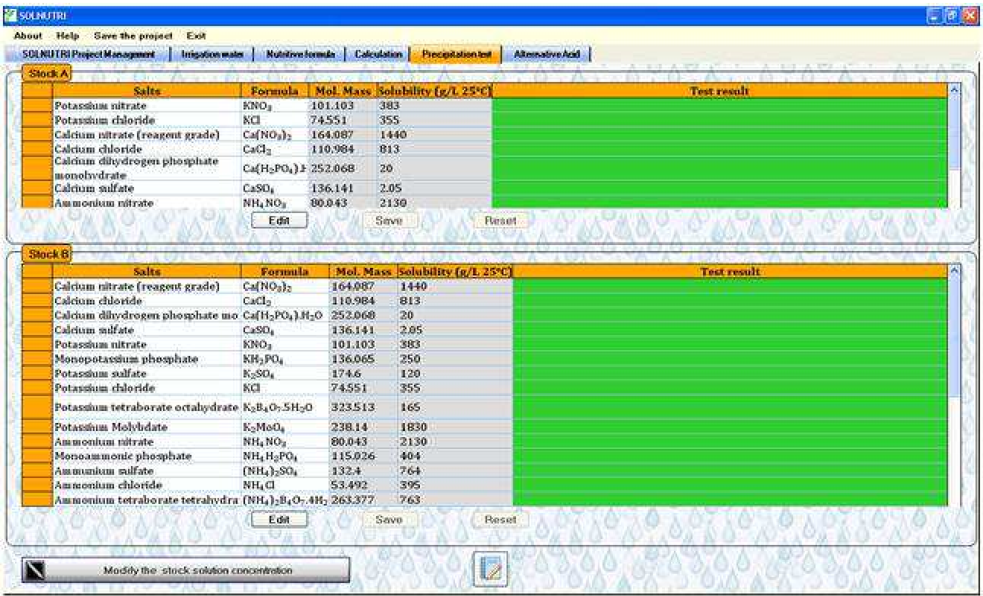
3) Continue with the confirmation button (✔). An alert box will be displayed that asks whether to use an acid other than nitric and phosphoric acid to acidify the water used for substrate washing or during nutrient depletion (see section “a little theory” in the help file of SIMULHYDRO) in semi-closed systems. These settings are particularly important for simulations with the program SIMULHYDRO.
4) Choosing a different acidification for the water, the program will open the **Dialog 5** (alternative acid) that can be filled in as shown for the **Dialog 4**; otherwise, it goes to the next form.



Dialog box for the calculation of an alternative acid to the bicarbonate neutralization.

3.1.5 Dialog 5: precipitation test

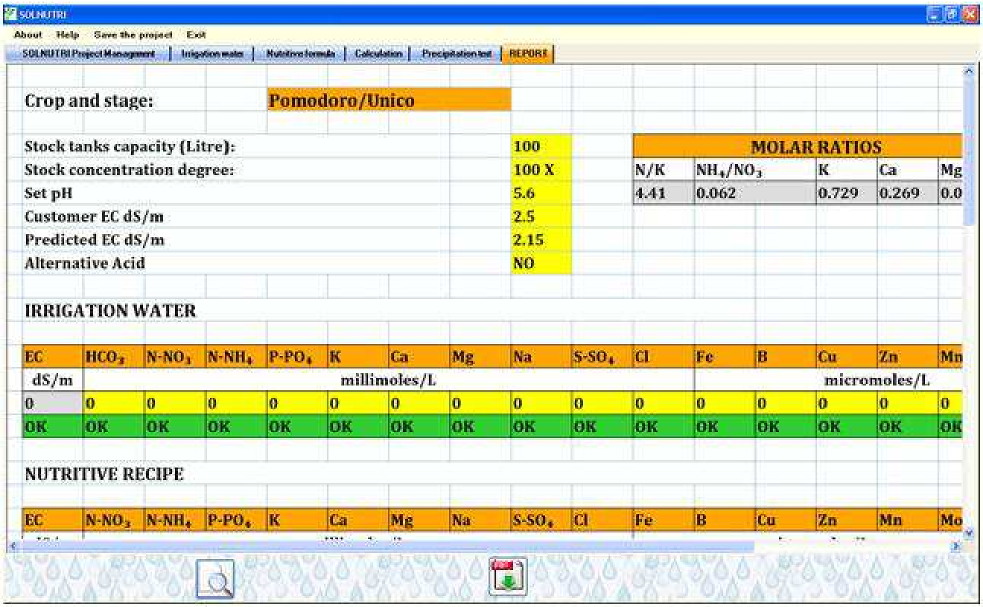
1) If the test is positive, salt precipitation might occur; this problem can be solved out by modifying fertilizer products or lowering the concentration of the stock solution by the "Modify the stock solution concentration" button.
2) If the test is negative, you can see the final report using the corresponding button ().



Report of the salt precipitation test.

3.1.6 Dialog 6: report

1) Use the buttons at the bottom of the screen to print out the summary table, or save it as a pdf file. The project can also be saved in the database using the tools menu on the top of the dialog.



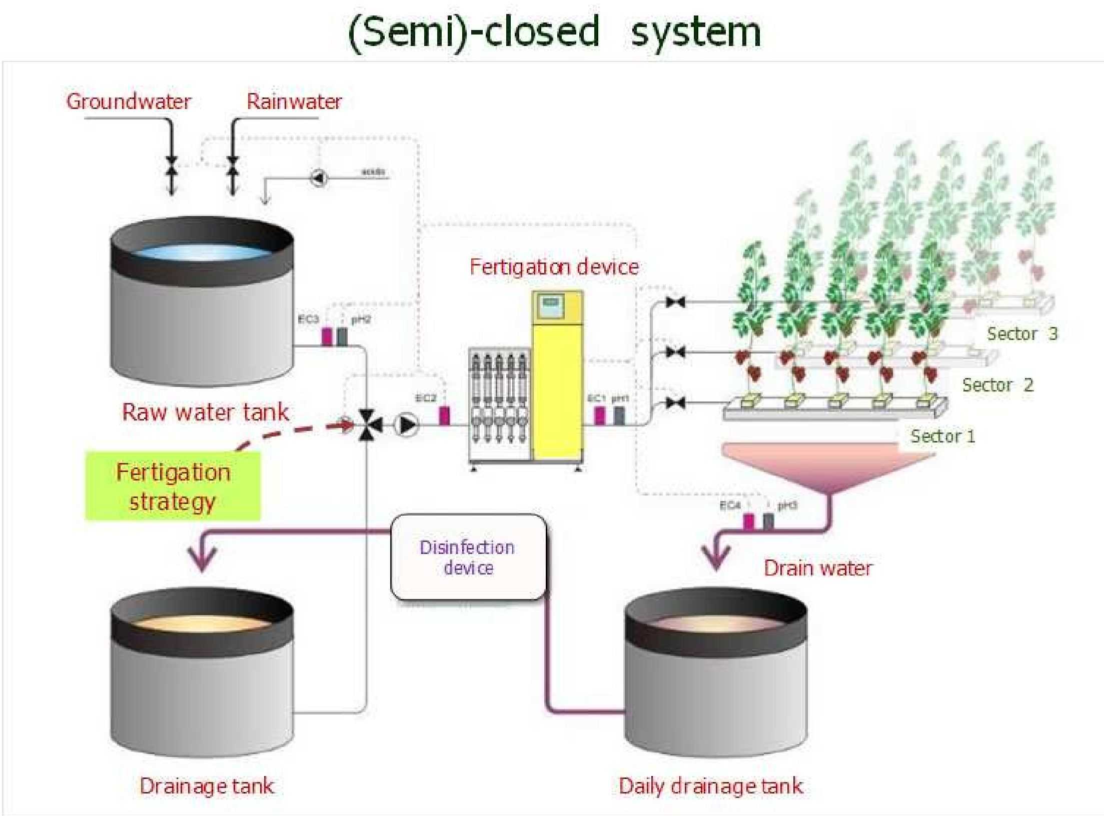
SOLNUTRI: final report.

4 SIMULHYDRO

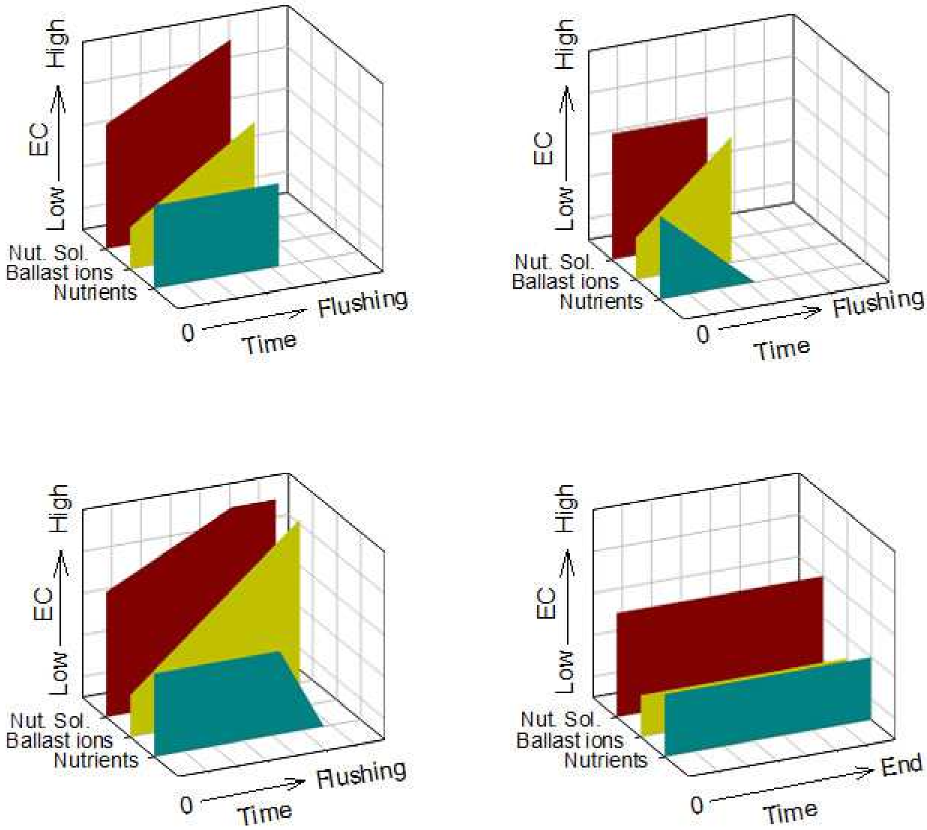
This program allows to simulate growth, water uptake, mineral absorption and ionic composition in the root zone of crops grown in soilless condition (open, closed and semi-closed cycle). At the end of the wizard procedure, the user obtains graphic and tabular reports summarizing the parameters simulated by the program.

4.1 Model outline

SIMULHYDRO was designed to simulate closed, semi-closed and open soilless systems. In open cycle, the water that drains from the substrate is not collected and the culture is continuously irrigated with "fresh" nutrient solution. In systems with closed cycle, instead, the water that drains from the substrate is captured, disinfected, chemically controlled and corrected to be recirculated during successive irrigations. When the irrigation water contains ions at higher concentrations than crop uptake concentrations, these ions accumulate in the recirculating solution up to reach levels that can be phytotoxic. A typical example is the accumulation of saline ions (Na, Cl, etc..), poorly absorbed by plants, that cause a direct increase of EC in the root zone. When EC, or the concentration of any ion, reaches thresholds potentially toxic to the crop, the nutrient solution, so-called exhausted, is drained out from the system and totally or partially replenished: this kind of management is defined semi-closed cycle. SIMULHYDRO can simulate commercial closed and semi-closed systems similar to those shown in the figure below.



Layout of a commercial closed-soilless growing system.



Graph	System	Nutrient solution replacement	Effect on EC	Nutrient depletion
Top left	Semi-closed cycle	Fresh nutrient solution	Variable EC	NO
Top right	Semi-closed cycle	Nutrient solution prepared according to a preset EC value	Costant EC	YES
Bottom left	Semi-closed cycle	Mixed: firstly fresh nutrient solution and then only raw water	Variable EC	YES
Bottom right	Open cycle	Fresh nutrient solution	Costant EC	NO

Different types of soilless nutrient solution management that SIMULHYDRO can simulate.

In soilless systems, the replenishment of the nutrient solution can be accomplished by following two main criteria as described below.

1) The nutrient solution lost by evapotranspiration is replaced by nutrient solution in which fertilizers are added as a function of a preset EC value: in these systems, the accumulation of ions scarcely absorbed by the crop corresponds to a parallel decrease in the concentration of those ions that are largely absorbed until they reach a minimum threshold, then, the exhausted nutrient solution is flushed out (flushing).
2) The nutrient solution lost by evapotranspiration is replaced with "fresh" nutrient solution: this method is applied in the case of both open and closed systems. If some ions are present at higher concentrations than crop uptake concentrations, the system accumulates

ions. In closed cycles, such accumulation causes an increase in the EC that will rise up to a maximum threshold depending by the crop, then the exhausted nutrient solution is flushed out (flushing). In presence of environmental constraints that regards the presence of polluting ions in the drainage water, the crop can be used for “phytodepuration” (nutrient depletion): in this case, before flushing, the nutrient solution lost by evapotranspiration is replaced with only raw water (acidified with acids different from nitric or phosphoric acid) until the pollutants (nitrates, phosphates, etc..) reach the limit imposed by the law. Finally, the exhausted nutrient solution is flushed out (flushing).

3) In the open cycles, the nutrient solution lost by evapotranspiration is replaced with "fresh" nutrient solution. In this case the accumulation of salts scarcely absorbed by the crop can be controlled by increasing the percentage of leaching. The different types of nutrient solution management are summarized in the above picture.

To better understand the different types of management of the nutrient solution in soilless systems it is suggested the study of some specific publications that explore and explain the topic in detail:

1) Massa D., Incrocci L., Maggini R., Bibbiani. C., Carmassi G., Malorgio F., Pardossi A. 2011. Simulation of crop water and mineral relations in greenhouse soilless culture. Environmental Modelling and Software 26, 711-722.
2) Massa D., Incrocci L., Maggini R., Carmassi G., Campiotti C.A., Pardossi A. 2010. Strategies to decrease water drainage and nitrate emission from soilless cultures of greenhouse tomato. Agricultural Water Management 97, 971-980.

4.2 Wizard of calculation

The program opens by clicking the corresponding button on the main screen of HYDROTOOLS.

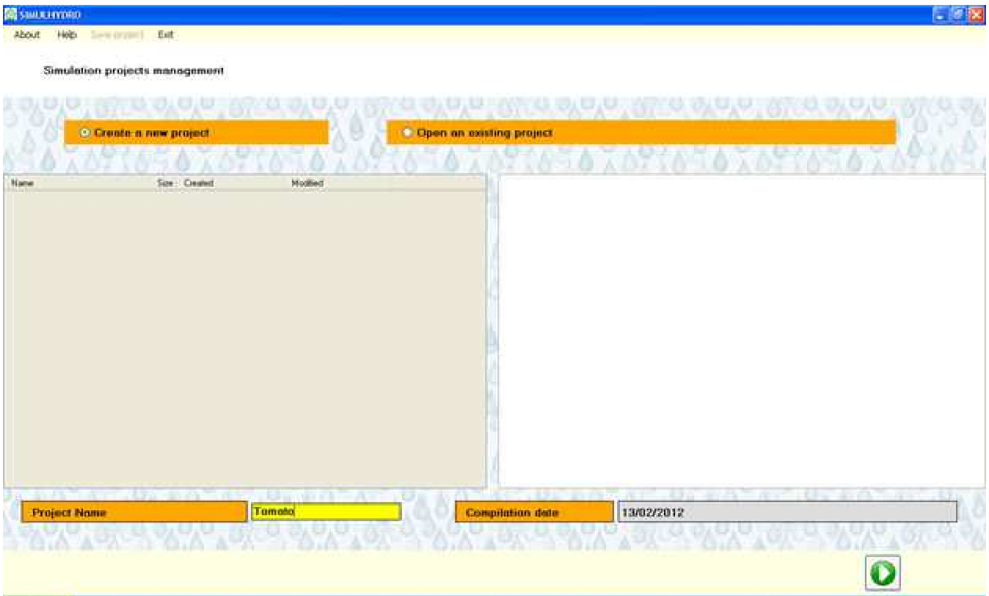
4.2.1 Dialog 1: introduction to the wizard

1) The first welcome page explains that the entry of data will be accomplished by wizard.
2) Press the "next" button () to continue.

Simulhydro wizard for inserting data input.

4.2.2 Dialog 2: project management.

1) Select a project saved in previous sessions (see at the bottom of this page for details) or, if you want to create a new project, go to step 2.
2) Enter a name for the new project.
3) Press the "next" button ( ) to continue.

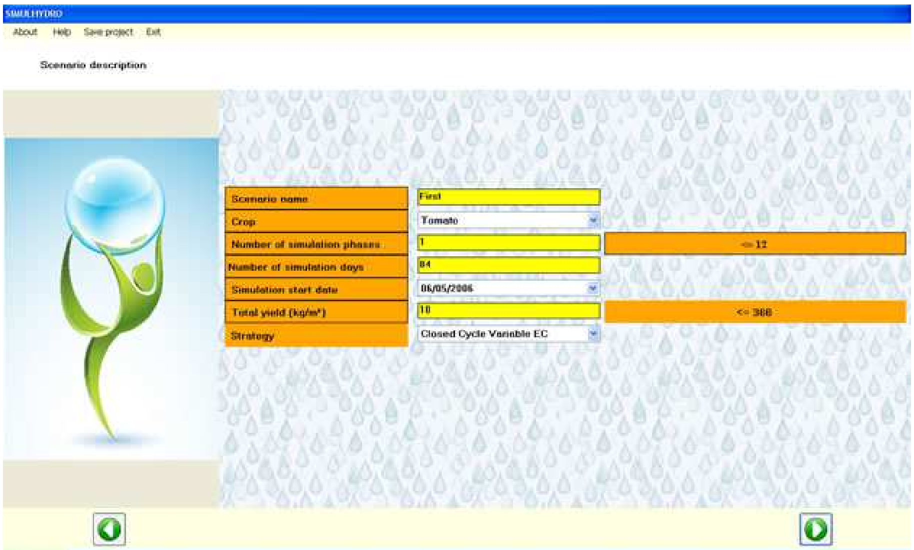


Simulhydro dialog box to create a new project or to load an existent simulation.

4.2.3 Dialog 3: description of the scenario.

This dialog is used to define the scenario that will be simulated according to the type of crop and nutrient solution management.

1) Enter a name for the scenario.
2) Choose the crop.
3) Enter the number of phases to be simulated: the simulation period can be divided into different phenological phases, for example it can have two different steps for vegetative and reproductive plant phase. For each phase different parameters can be chosen that define the cultivation environment and the needs of the crop. These parameters must have been previously entered in the database of HYDROTOOLS -->Utility (Database management) --> Crop parameters.
4) Enter the total number of days of simulation and the start date.
5) Insert the expected production. This may be based on the average production of the last three years.
6) Choose the management option of the nutrient solution (see the section "model outline" for details).
7) Press the "next" button () to continue.



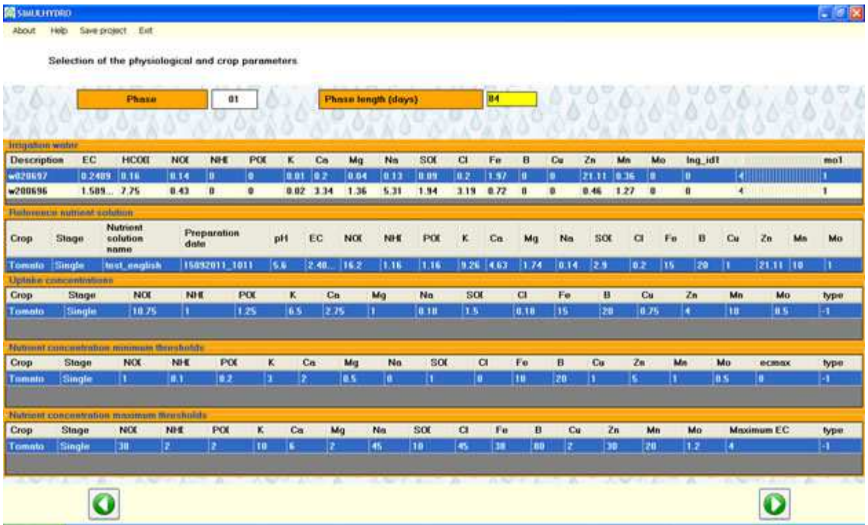
Simulhydro dialog box to create a new project or to modify a saved project.

4.2.4 Dialog 4: selection of physiological and crop parameters.

This dialog allows to associate each simulation phase to different parameters that define the system of cultivation and the needs of the crop. These parameters must have been previously entered in the database accessible from the main screen of HYDROTOOLS -->Utility (Database management) --> Crop parameters.

1) Enter the number of days of the first phase.
2) Choose the irrigation water to be used for the first phase by clicking (click the first column) among those present in the database.

3) Choose the nutrient formula to be used for the first phase.
4) Choose the minimum and maximum ion concentration thresholds to be used for the first phase. These parameters define the limits for the flushing.
5) Repeat for the other phases, if present.
6) Press the "next" button ( ) to continue.

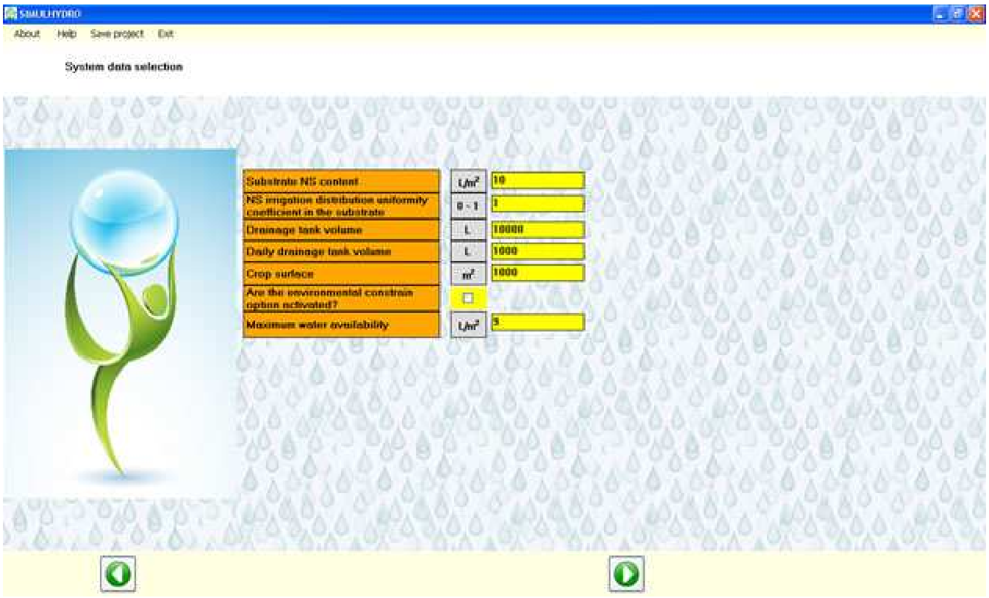


Example of dialog box for inserting physiological crop parameters.

4.2.5 Dialog 5: cultivation system parameter selection

This dialog allows to define the characteristics of the cultivation system.

1) Enter the amount of water retained by the substrate: this data depends on the specific characteristics of the substrate used.
2) Insert the uniformity coefficient: this coefficient represents the degree of uniformity with which the nutrient solution is distributed in the substrate during irrigation events. It varies depending on the type and degree of use of the substrate: the longer the time of use, the lower the value of the coefficient.
3) Enter the volume of the tank used to collect the cumulative drainage (see the section "a little theory").
4) Enter the volume of the tank used to collect the daily drainage (see the section "a little theory").
5) Enter the surface area of the crop.
6) Select the "environmental constraints" in case there are specific laws on the management of drainage water (see the section "a little theory"). These parameters must have been previously entered in the database of HYDROTOOLS -->Utility (Database management) -->Environmental constraints.
7) Enter the maximum water availability: this parameter represents the total water volume available for the crop. If the water is potentially unlimited, enter a very big number.
8) Press the "next" button ( ) to continue.

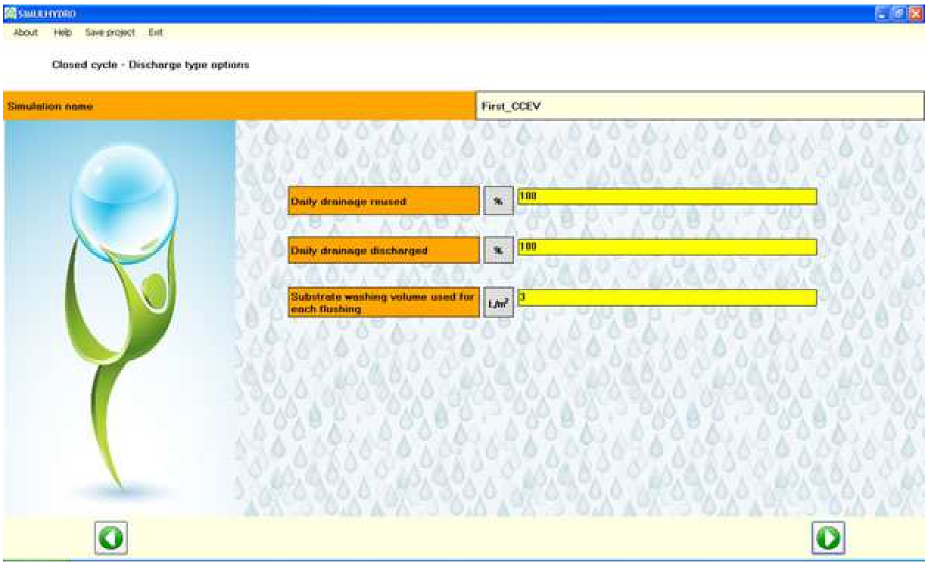


Simulhydro: dialog box for inserting system parameters.

4.2.6 Dialog 6: discharge options

This dialog allows to define the flushing procedure.

1) Enter the percentage of drainage water reused every day. Generally, this value corresponds to 100% for closed systems.
2) Enter the percentage of water to be flushed out in occasion of a flushing (only semi-closed systems), you may decide to remove all the exhausted nutrient solution or just a part of it from the drainage thank.
3) Enter the volume of washing: during the flushing you can run a substrate washing or not (0 L/m^2).
4) Press the "next" button ( ) to continue.

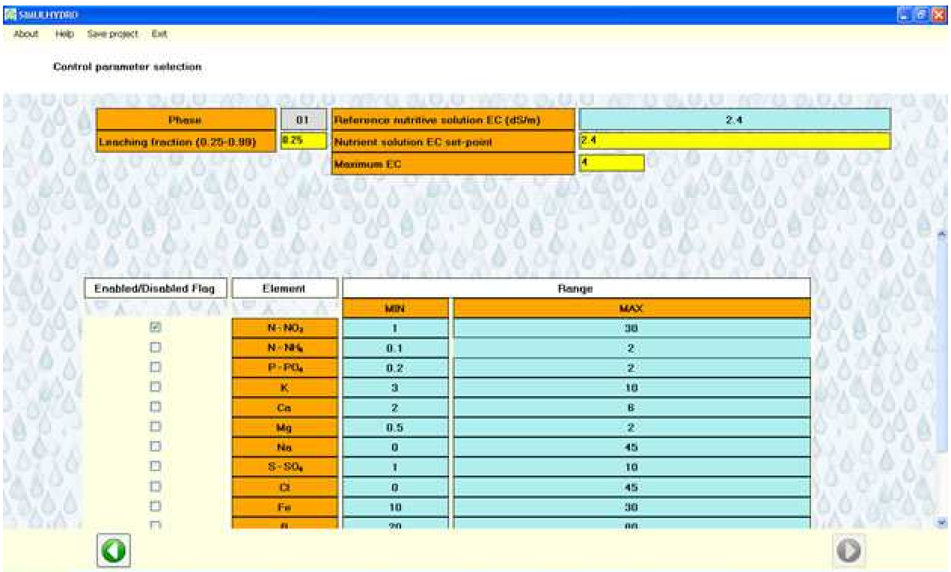


Simulhydro: dialog box for the setting of the nutrient drainage solution options.

4.2.7 Dialog 7: control parameters for discharge events

This dialog allows to decide which ions define the range of oscillation of the recirculating solution: the maximum and minimum thresholds represent the concentration of any ion or EC value at which the exhausted nutrient solution will be discharged. The minimum and maximum levels must have been previously set in the database, this dialog is used only to decide which ions, in addition to EC, must be taken into consideration.

1) Set the EC value and select the desired ions.
2) Press the confirm button ( ).
3) Repeat for all phases.
4) Press the "next" button ( ) to continue.

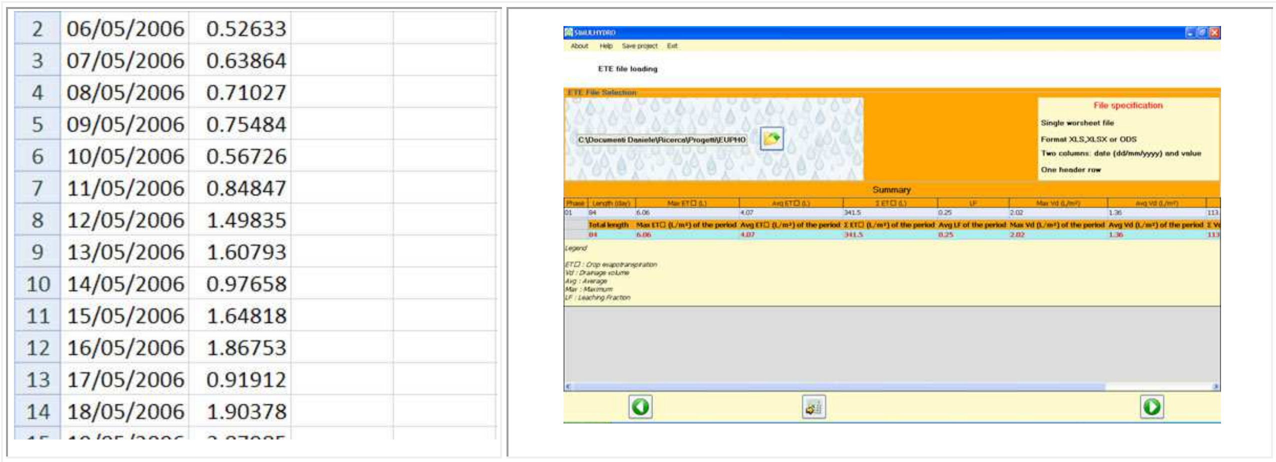


Simulhydro: dialog box for setting the parameters required to discharge recirculating nutrient solution.

4.2.8 Dialog 8: ETE (effective evapotranspiration) file upload

This dialog allows to import the file with the daily ETE. The file must be saved as xls, xlsx or ods and must contain two columns, one titled "Date" with incremental simulation days and the second entitled "Ete" with ETE (L/m^2).

1) Choose the desired file.
2) Press the "next" button ( ) to continue.

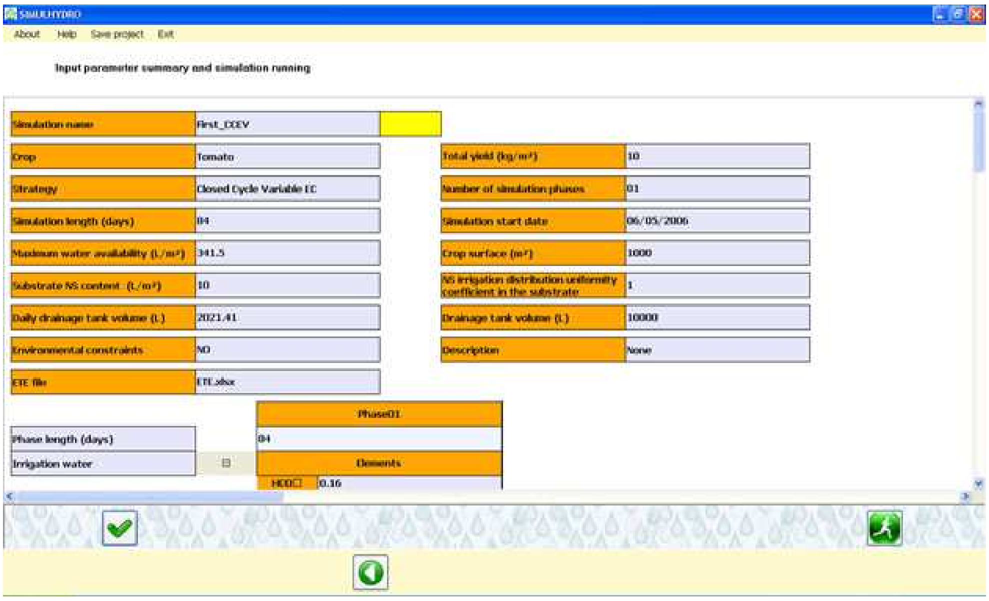


Simulhydro: dialog box for loading crop evapotranspiration file.

4.2.9 Dialog 9: Summary of input parameters and simulation start

This dialog resumes all the parameters set for the simulation.

1) After verifying the correctness of the parameters, enter an identification code in the yellow cell on the top of the screen and press the confirmation button ( ).
2) Run the simulation with the corresponding button ( ).
3) Wait for data processing and check simulation data in the "Report" in the main mask of HYDROTOOLS.



Simulhydro: summary of inputs inserted by the user before to launch the simulation.

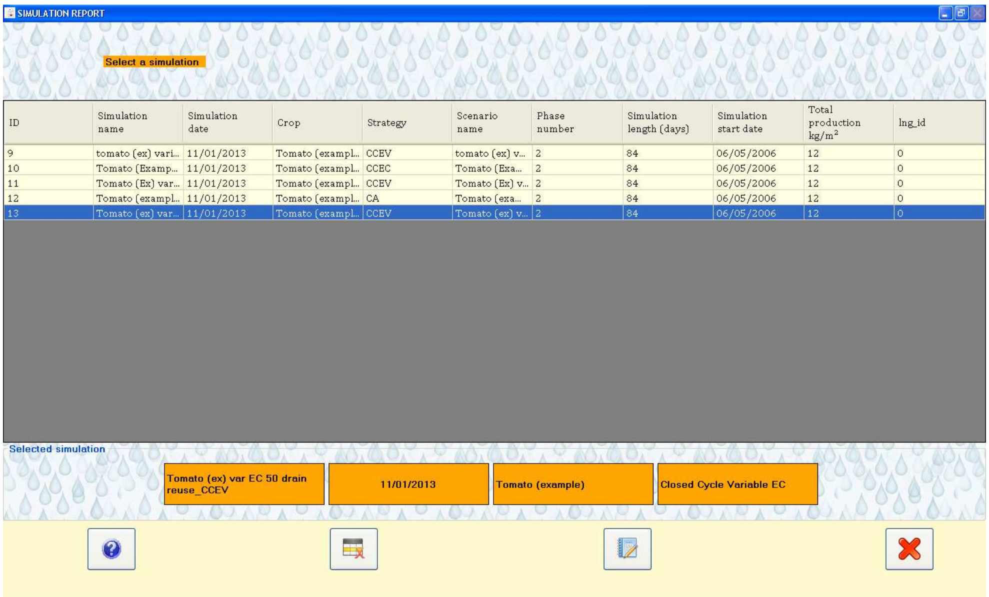
4.2.10 Select a project saved in previous sessions

Dialog 2 can be used to edit projects already saved. When selecting a project the simulation already done can be viewed, and a different simulation can be performed on the basis of the existing one. In this new simulation all the parameters can be changed as shown from the step 2 to step 9 with the exception of the control strategy of the nutrient solution in the dialog 3 that cannot be changed.

NOTE: When you make a new simulation based on an existing one you must enter a different identification code in dialog 9.

5 Report management

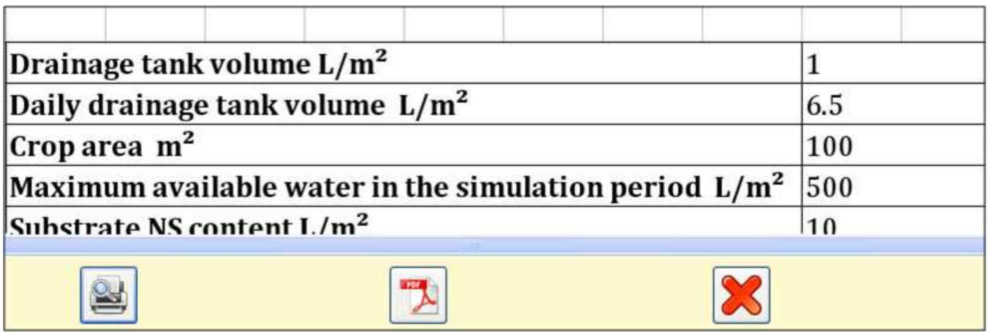
This dialog allows to view as tables the information provided by the simulation performed with SIMULHYDRO.



Simulhydro: dialog box for the selection of a simulation to view.

5.1 Viewing and printing data

1) Select a record in the main dialog and press the button to create the report ( ).
2) In the next dialog press the buttons at the bottom of the screen to save the tables as a pdf file or print out them.

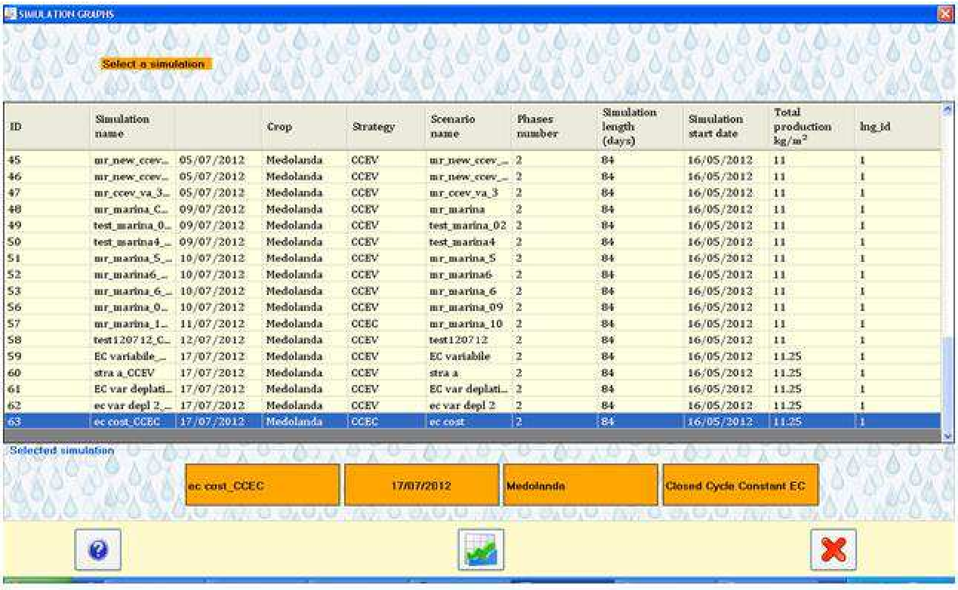


Drainage tank volume L/m²	1
Daily drainage tank volume L/m²	6.5
Crop area m²	100
Maximum available water in the simulation period L/m²	500
Substrate NS content L/m²	10

Simulhydro: example of a simulation report.

6 Graph management

This dialog allows to view the information provided by the simulation performed with SIMULHYDRO as graphs.



SIMULHYDRO: selection of a simulation for creating a graph report.

6.1 Viewing and printing data

1) Select a record in the main dialog and press the "Create" button ().
2) In the next dialog select the parameter of interest and press the proper button at the bottom of the screen to save the graph as a pdf or png file.

Simulhydro: example of graph report.