

*Fluorescence and
Optoelectronics
Research for the
Communication between
Ecophysiology
and
Agriculture*



DUALEX Scientific



DUALEX Scientific

User's manual

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1.Introduction

Please read and study this manual before using the DUALEX Scientific for the first time, and keep it handy for further reference.

1.1.Description

DUALEX Scientific is a hand-tool leaf-clip combining the use of fluorescence and light transmission of a leaf to determine the leaf status.

This sensor is adapted to determine, on the one hand, the optical absorbance of the epidermis of a leaf in the ultraviolet (UV) optical range through the differential measurement of the fluorescence of chlorophyll. And, on the other hand, to determine the chlorophyll content of the leaf using different wavelengths, in the red and in the NIR.

1.2.Applications

DUALEX Scientific calculates leaf chlorophyll content (Chl), epidermal UV-absorbance (Flv) and a Nitrogen Balance Index (NBI, patented). The latter is based on the ratio of former two.

These information are valuable indicators of the overall condition of the plant in many applications:

- nitrogen fertilization
- leaf greening
- plant senescence
- protection of plants against UV radiation
- pathogens susceptibility
- cultivar selection

Other application-dedicated tools based on DUALEX sensors have been developed:

- for fertilization recommendation
- for grain protein content forecast

2. Measurement basis of DUALEX Scientific

2.1. UV absorbance measurement

The measurement of the UV optical absorbance of the epidermis is based on the fluorescence emitted by the chlorophyll located in the mesophyll. This principle is described below (Figure 1).

It is well known that chlorophyll emits fluorescence when illuminated. This fluorescence is induced by UV light as well as by red light. In a leaf, the epidermis absorbs the UV while it transmits the red. Then by comparing the fluorescence induced by UV and induced by red, the absorbance of the epidermis can be determined. For example in the case of flavonols, the radiation is highly absorbed by the epidermis, whereas in the red range the absorption is very low.

Thanks to its unique patented technology, DUALEX leaf-clip measures quantitatively the optical absorption of the leaf epidermis in UV.

The epidermal absorption is directly linked to the concentration of the leaf polyphenols:

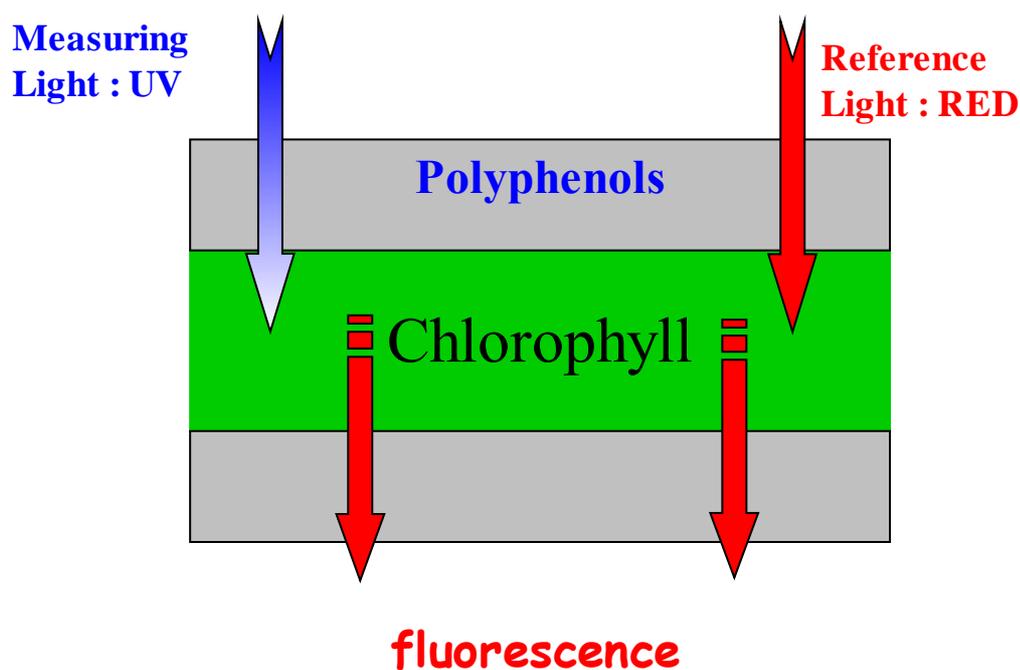


Figure 1: Description of fluorescence and absorption

The optical absorbance of the epidermis in the UV is therefore calculated as the ratio of chlorophyll fluorescence induced by the Measuring Light compared to that induced by Reference Light. It is important to note that the chlorophyll acts, in the case of DUALEX, like an internal detector (sensor) of photons. This method is known as the LogFER method.

2.2. Chlorophyll absorption measurement

The measurement of the chlorophyll content of the leaf is based on the measurement of the difference in transmission of two wavelengths, both in the near infra red (NIR) (Figure 2).

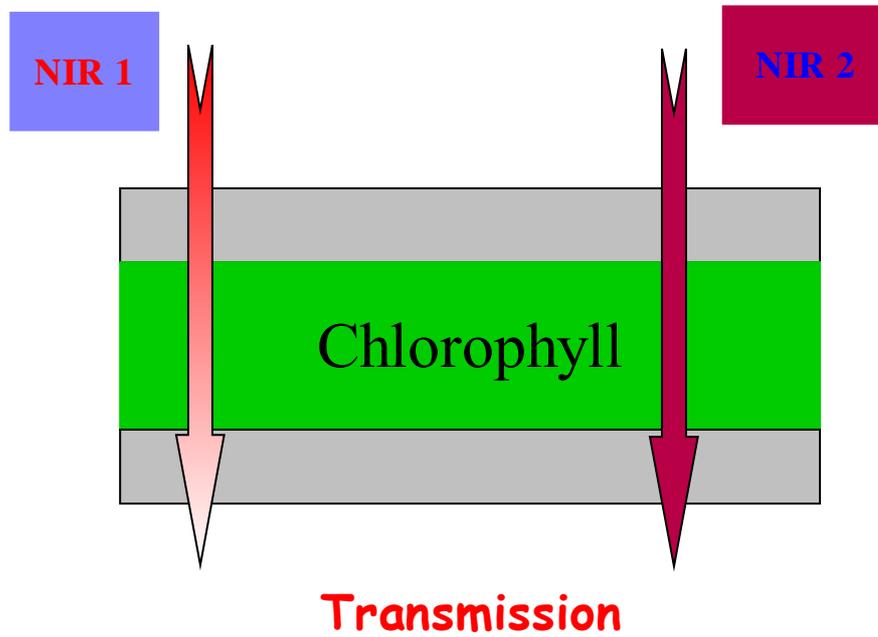


Figure 2: Differential transmission for two NIR wavelengths

A chlorophyll-specific absorption index is calculated as a difference of the optical transmission at two different wavelengths in the NIR.

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3. Material Checklist

The following is a list of what you have received in your DUALEX Scientific case:

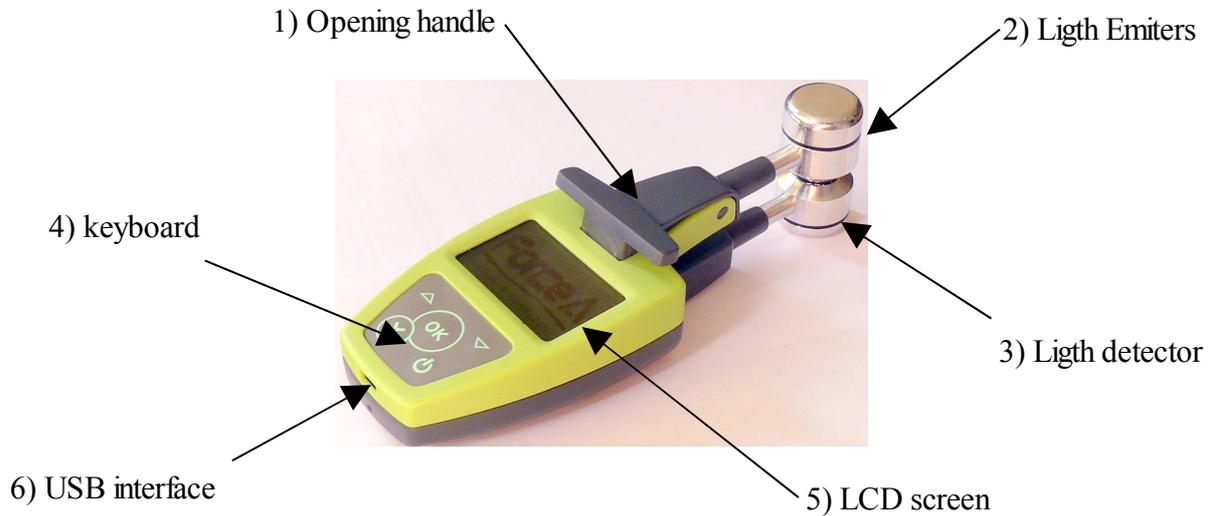
1. This user's guide,
2. DUALEX Scientific leaf-clip,
3. USB cable and a power supply adapter.

If anything appears to be missing, please contact FORCE-A immediately.

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4. DUALEX Scientific optical leaf-clip

4.1. Description



- 1) Handle to open the clip : when pushing on this handle the clip opens and the leaf can be introduced between the 2 heads. When released the 2 heads hold the leaf allowing the measurement to be done. The clip is normally closed.
- 2) Head that contains 5 different LEDs: a UV-A emitting LED, a visible-emitting LED and three NIR-emitting LEDs. The LEDs are normally switched off.
- 3) Head that contains the optical detector. A PIN photodiode to catch the light.
- 4) Keyboard with 5 buttons : up , down , OK , X  and power switch .
- 5) LCD screen.
- 6) USB-interface that allows to download the data and to charge the DUALEX scientific.

4.2. DUALEX Instrument Case

DUALEX Scientific instrument is delivered in a shock resistant case. It contains the DUALEX Scientific leaf-clip, a USB cable, with a USB wall plug adapter and a user's manual.

DUALEX Scientific is working on internal rechargeable Ion-Li battery. The battery can be charged using the USB cable, directly from the computer, or using the wall plug adapter.

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5. Getting Started

This part is only dealing with the DUALEX Scientific type.

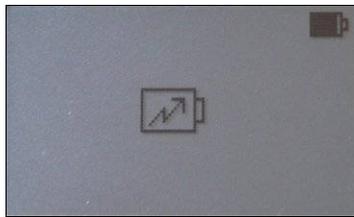
Unpack the DUALEX Scientific, check that there is no evident damage.

The DUALEX is charged before delivery, however depending on storage time, the battery can be discharged.

5.1. Charging the DUALEX.

To charge the DUALEX, connect the USB cable to either :

- the wall plug adapter cable and plug it in a regular power supply (check that voltage and frequency are compatible)
- a USB port in a computer.



At connection, a charge indicator will appear on the screen.

The DUALEX Scientific can be operated when the battery is under charge.

The full charge of the battery will be completed after 4 hours.

From full charge, operating time is 7 hours in continuous use.

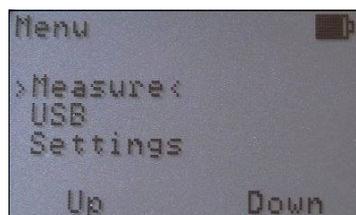
5.2. Switching ON the DUALEX :

To switch ON the DUALEX, press  on the keyboard.

The screen will switch on and the following image will quickly appear :



Then the main Menu will be displayed.



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5.3. General software organization

The software of the DUALEX Scientific is described on the Figure 3. The 5 buttons on the keyboard are used to navigate through the software. The button are multitask, and the action is depending on the state of the tool.

- The button  is used to switch ON and OFF the DUALEX Scientific. Note that the switching OFF of the sensor is accessible only from the main menu.
- The button  is used to enter a selection in a sub-menu, to validate a selection, to acknowledge an action or to make a measurement.
- The button  is used to cancel an action or a selection, in this case the software will come back to previous state.
- The buttons  and  are use to navigate in the menus, to increase the group number and to change the side of the leaf.

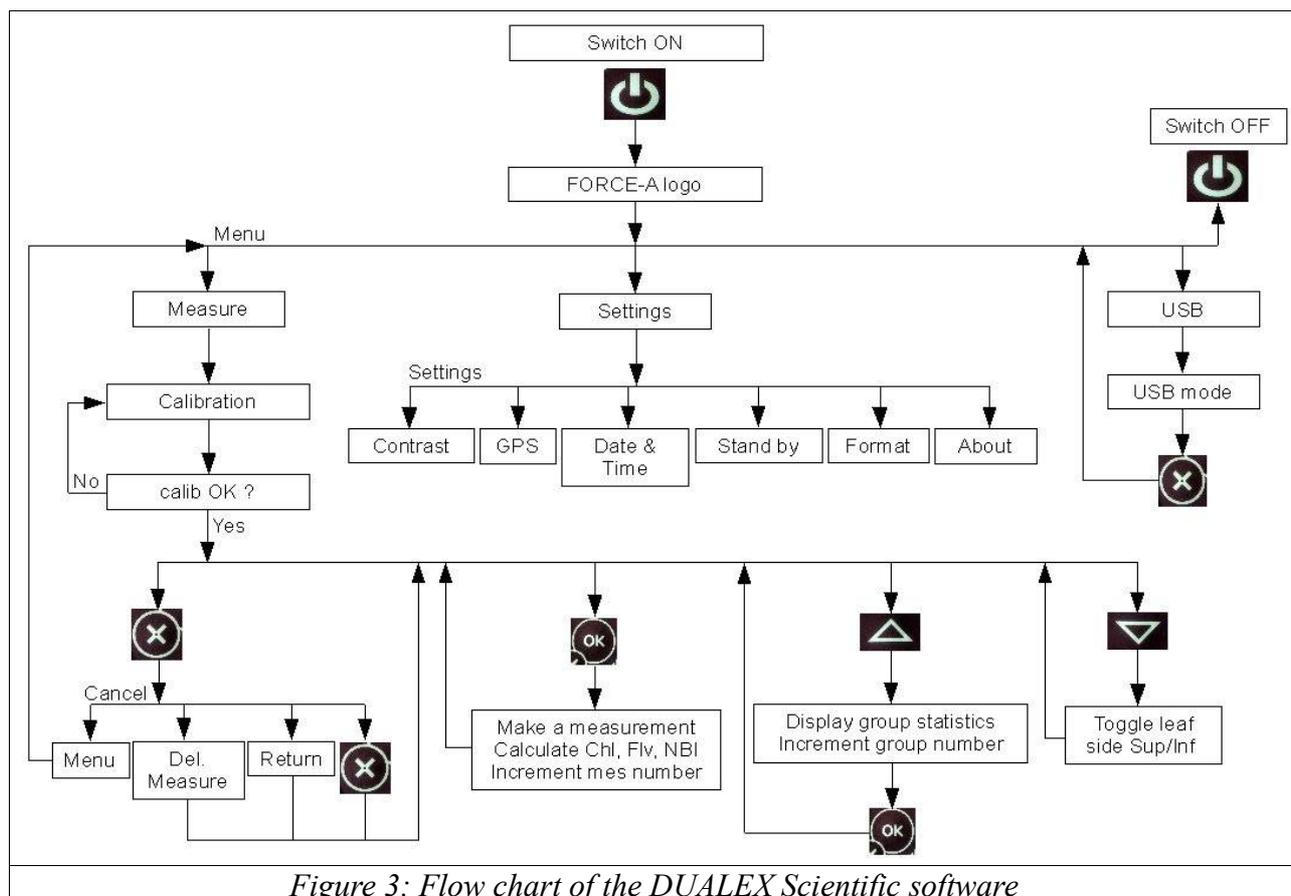
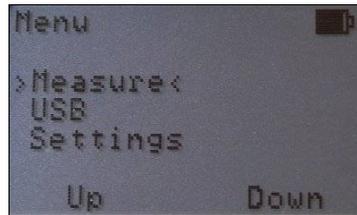


Figure 3: Flow chart of the DUALEX Scientific software

To start press , DUALEX Scientific will prompt for the main menu.

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In the main menu there are 3 sub menus :

- 1.Measure : perform a measurement,
- 2.USB : download data to a computer,
- 3.Settings: give access to various setting such as Contrast, GPS, Date & Time, Stand by, Format and About

The navigation in the menu is done using the up  and down  key on the keyboard.

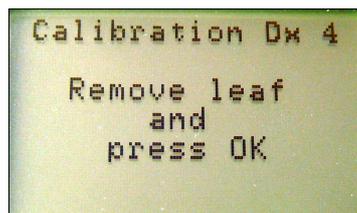
The selected sub menu will be highlighted with 2 arrows (> <). Use the  to select the sub-menu.

5.4.Measure sub menu

To initialize a measurement select the Measure sub menu and press  button.

5.4.1.Calibration

When the Measure sub-menu is selected the DUALEX Scientific, before any measurement, will prompt for a calibration process, the following screen will appear:



Take care that there is no leaf between the heads of the leaf-clip, and that the clip is closed.

To cancel the calibration procedure, press  the software will return to the main menu.

To acknowledge the calibration procedure and proceed to measurement press .

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5.4.2.Measurement

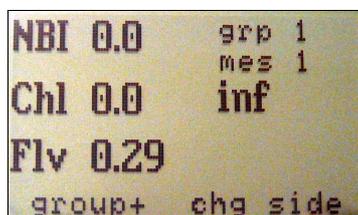
At this level the DUALEX Scientific will prompt for measurement, the following image will be displayed:



To perform a measurement, open the clip by pressing the handle and insert a leaf, the face must be as specified by the **sup** or **inf** information.



Release the handle and press . The result of the measurement is then displayed on the screen.



NBI is the Nitrogen Balance Index measured as the ratio of Chl and Flv.

The range of this index is between 0 to 100, if the value is outside this range, the display will indicate : ***, and the measurement data is stored in the memory with value "NaN".

Chl is an index related to the chlorophyll content.

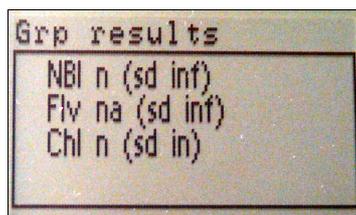
The range of this index is between 0 to 150, if the value is outside this range, the display will indicate : ***, and the measurement data is stored in the memory with value "NaN".

Flv is an index related to the flavonol content.

The range of this index is between 0 to 3, if the value is outside this range, the display will indicate : ***, and the measurement data is stored in the memory with value "NaN".

Grp "x" indicates the group number. A group is a set of measurement related to the same type of measurement, for further statistical analysis. Press  (group+) to increase the group number. The statistics group results will be displayed.

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If the data are not valid, the results appear as '***'. To return to the measurement menu press .

Mes “y” indicates the number of measurement done for the group. The mes value is incremented at each individual measurement.

sup / inf indicates if the next measurement is done from the adaxial (**sup**) or abaxial (**inf**) face of the leaf. To change the leaf side information by pressing  (chg side). The information of leaf side is stored in the result file.

Notice : there is no specific limitation in the number of measurement per group or in the number of group. The internal flash memory capacity (1.8 Go) corresponds to 10 000 measurements. However, we recommend to download the data to your computer through the >USB< command after a measurement campaign. After downloading the file, delete this with your operating system in the computer.

5.5.USB sub-menu

The USB command allows to transfer the measurement to your computer.

5.5.1.Connection

Connect the USB cable to the USB mini connector located on the bottom side of the DUALEX and to any USB port of the computer.



DUALEX side

Computer side



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Select the >USB< sub-menu on the DUALEX and press , the screen will display:



The DUALEX is seen as a removable disk, similar to a USB mass storage key.

A removable disk folder is created. Using the explorer command of your operating system, open the removable disk folder. There is a file named “DX-----” which contains all the measurement data of your DUALEX. The “-----” indicate the date of the measure.

Copy the file to your computer to analyze data.

We recommend to delete the file in the USB storage after copying.

The DUALEX Scientific cannot make measurement when connected in USB mode.

To exit from USB mode press . The software will return to the main Menu.

5.5.2.DATA analysis

The data generated by the DUALEX are coded in ASCII, they can be transferred to any spreadsheet software. The data delimiter is a space. The decimal delimiter is the full stop (".").

The structure of the file is :

Header 1 is the Dualex type : *#Dualex_Scientific*.

Header 2 is the software release and serial number (for example): *#version:1.3.0 – DX4_09_100* .

Header 3 is the date of the file : *#Date:2009/01/15 (yyyy/mm/dd)*.

This header is printed each created “DX” file.

Header 4 is the label for measurement data. This header is printed before each measure group:

##h:mm:ss latitude NS longitude WE temp group measure face Chl Flav NBI Calib

For each measurement there are 13 measurements data stored. The field are delimited by a space, the line is ended by a Carriage Return (CR).

Field 1 : time of the measure.

Field 2 : NMEA latitude indicator.

Field 3 : NMEA North/South indicator.

Field 4 : NMEA longitude indicator.

Field 5 : NMEA West/East indicator.

Field 6 : temperature of the emitter head in °C.

Field 7 : group number.

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Field 8 : measurement number in the group.

Field 9 : take the value “sup” or “inf” depending on the side measured on the leaf.

Field 10 : Chlorophyll content in the leaf. If the measurement is outside the range, the data stored is 'NaN'.

Field 11 : Flavonol content in the leaf. If the measurement is outside the range, the data stored is 'NaN'.

Field 12 : NBI index. If the measurement is outside the range, the data stored is 'NaN'.

Field 13 : Indicates that a calibration has been done.

If the “group+” key is pressed the following information are stored.

Header group, there are 7 fields separated by a space, the line is ended by two Carriage Return (CR). : #group Chl Chl_sd Flav Flav_sd NBI NBI_sd.

Field 1 : indicates the group number.

Field 2 : indicates the mean value of chlorophyll content for the group.

Field 3 : indicates the standard deviation value of chlorophyll content for the group.

Field 4 : indicates the mean value of flav content for the group.

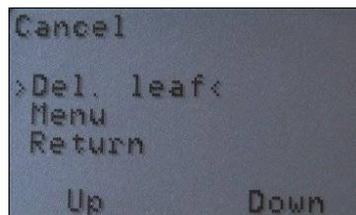
Field 5 : indicates the standard deviation value of flav content for the group.

Field 6 : indicates the mean value of NBI index for the group.

Field 7 : indicates the standard deviation value of NBI index for the group.

5.6. Cancel menu

This menu offers the possibility to delete the last measurement or to return un the main.



5.7. Switching off

To switch OFF the DUALEX, from the Main menu and press .

To return to the main Menu press  and select “Menu” in the cancel menu.

Notice : the DUALEX cannot be switched off when the battery is charging.

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5.8. Settings sub-menu

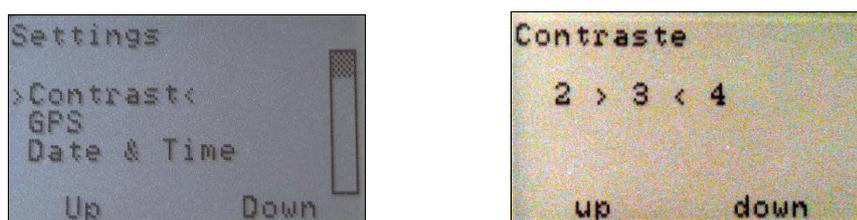
The Settings sub-menu give access to 6 informative or settable adjustments:

1. Contrast: adjust the contrast of the display.
2. GPS: toggle the GPS ON or OFF (under development).
3. Date & Time: adjust the date and the time.
4. Stand by: adjust the stand by delay (under development).
5. Format: format the data built in flash memory.
6. About: display the software version and the serial number.

The adjustment will be kept and stored by using  button, or discarded by using  button. The software will go back to the main menu.

5.8.1. Contrast

From main menu select the contrast sub menu and press  The following screen will appear :

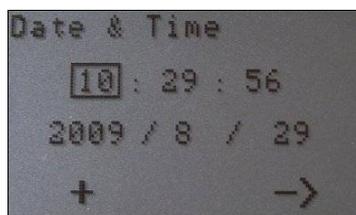


Adjust the screen contrast pressing  (up) and  (down) key. After adjustment return to the main menu by pressing .

5.8.2. GPS

Under development

5.8.3. Date & Time



This screen allows to set the time and the date. To edit a number, press the “+” button and to change the digit, press the “->” button. Once the date and time is adjusted, press  to save it.

Cancel is available at any time without saving by pushing the button .

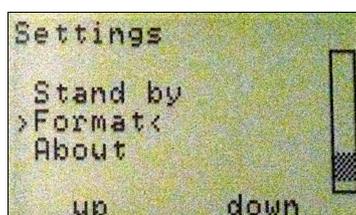
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5.8.4.Stand by

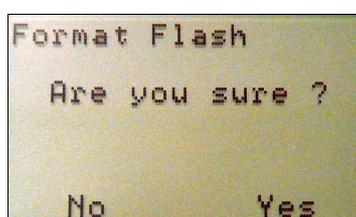
Under development

5.8.5.Format

Select the Format command to erase all data from the DUALEX.

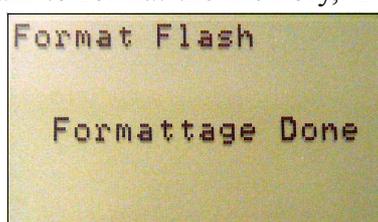


Press , the following control screen will ask a confirmation, press  (No) and  (Yes) key:



If the  (No) or the  is pressed the data are not erased and the software return to the main Menu.

If the key  (Yes) is pressed, all data are erased from the memory and the DUALEX will prompt with the following screen. But if the error occurs during formatting, the screen will display “Error format”. If an error occurs, try again to format the memory, if the trouble continue, switch off the



unit and charge the battery. If the problem is still existing contact us.

Press , the DUALEX will return to the settings sub-menu.

Notice that DUALEX uses a FAT 12 format. Do not try to format the memory of the DUALEX Scientific from the explorer of your operating system.

5.8.6.About

The About sub-menu display the software release and the DUALEX Scientific serial number.

Please refer to these information when FORCE-A is contacted

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6. Specifications of the DUALEX Scientific

•Target Samples:	Plant leaves
•Measured Parameters:	Optical Absorbance at 375 nm Optical transmittance at 3 wavelengths in the NIR
•Measured Surface:	5 mm diameter
•Absorbance range in the UV (Flav):	0 to 3.0
•Accuracy:	5% (standard deviation)
•Repeatability (1 σ)	2.5%
•Reproducibility (1 σ)	3.5%
•Chlorophyll concentration	0 to 150 (in DUALEX unit)
•Repeatability (1 σ)	1.3 %
•Reproducibility (1 σ)	4.5%
•Acquisition Time:	less than 500 ms
•Light Sources:	5 light-emitted diodes (LED): UV-A, Red, 3 NIR.
•Photodetector:	1 Si Photodiode
•Data Storage:	10 000 multiparametric measurements
•Users Interface:	LCD screen
•Computer communication:	USB port
•Operating Temperature:	5°C to 40°C, for a drift in absorbance less than 2%
•Battery:	proprietary rechargeable Li-ion battery pack
•Operation Autonomy:	7 hours
•Charging Time:	4 hours
•Total Weight:	400 gr
•Leaf Clip Dimensions:	200 mm x 70 mm x 40 mm

All specifications are subject to change without notice.

7. Maintenance

7.1. Environmental Conditions

DUALEX is designed to be used directly in the field under different environmental conditions. The absorbance and transmission measurements are not sensitive to the ambient light. The instrument is resistant to the natural humidity of the plant material. In the range from 5°C to 40°C, the temperature is continuously monitored and taken in account for the measurement result.

7.2. Mechanical Vibrations and Shocks

When using DUALEX Scientific, avoid strong vibration and shocks.

7.3. Storage Conditions

Always switch off the power when you have finished the measurements.

Store the DUALEX in regular environmental conditions (>0°C or < 40°C), in a clean and dry atmospheric conditions.

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7.4.Cleaning Operation

Clean the DUALEX instrument (case and leaf clip) each time you return in the laboratory from the field, using a slightly wet dust cloth with a water and alcohol mixture.

Use a compressed air bomb to remove the dust from the optical parts of the leaf clip. Gently apply the air pressure.

7.5.Battery Change

If the battery of the DUALEX need to be replaced, contact FORCE-A. The battery are specially designed for the tool, any attempt to replace the battery by a non certified one can destroy the DUALEX unit.

8.Warranty

The DUALEX absorbance meter carries a one-year warranty (from date of shipment) against material and/or workmanship defects, when used under normal operating conditions.

Any attempt by an unauthorized person to alter or repair the product voids the warranty.

DUALEX is a device for data acquisition. FORCE-A is not responsible for the interpretation of the data resulting from absorbance measurements.

In case of malfunction, contact FORCE-A office to obtain a return authorization number. The material should be returned to:

FORCE-A
Centre Universitaire Paris-Sud
Bât. 503
91893 Orsay Cedex
France

Tel : +33 1 69 35 88 39

Fax : +33 1 69 35 88 97

e-mail : info@force-a.fr

Claims

To obtain warranty service, contact FORCE-A office, with a description of the problem, transportation and insurance prepaid to FORCE-A. FORCE-A will, at its option, repair or replace the defective product free of charge. However, if FORCE-A determines that the failure is caused by misuse, alterations, accident or abnormal condition of operation or handling, you will be billed for the repair and the repaired product will be returned to you, transportation prepaid.