Calculator: nutritive solutions for hydroponics

note: to use the links, download this file and use a pdf-viewer on your PC.

A nutrient solution for hydroponics is the result of diluting one or more fertilizers in water. Obviously the elements present in the used water influence the composition of the final solution.
To have a perfect nutritive solution for the plants we want to grow, which corresponds to our tastes and needs, we need to go through the following steps:

1. Identify an ideal 'target' recipe, linked to a production program.
2. Choose which water to use.
3. Identify the fertilizers to use, their ratio and the dilution to obtain a nutritive solution similar to the 'target'
4. Prepare the stock solution
5. Make the nutritive solution, adjust the pH, check the EC.
6. Keep a diary of cultivation, check expectations

I have created a calculator that simplifies the calculations required in points 2, 3 and 4, essentially for my convenience. After a few years of use I decided to publish it so that other hydroponics fans can simplify their lives.

Concerning the Phalaenopsis orchids (the plants I am growing now in hydroponics with the Ebb and Flow method, v https://github.com/msillano/Sonoff-ebb-and-flow/blob/master/orchis-sonoff-en01.pdf *) I also provide some notes that can be used as a guide for point 1.*

For all other hydroponic cultivations the use of the calculator is always a very valuable help, but you will not find here indications to define the ideal solution.

Installation sw

- *Windows, Linux, OS X:* download ***OpenOffice*** from http://www.openoffice.org/
- Android: install ***AndrOpenOffice*** from *GooglePlay*
  https://play.google.com/store/apps/details?id=com.andropenoffice&hl=en

Download from the `water_en.ods` file and copy it to a known location, for example: `documents/hydroponics` for Windows or `internal memory/hydro` for Android (to copy the file you must use a management program on the PC suitable for your mobile phone).

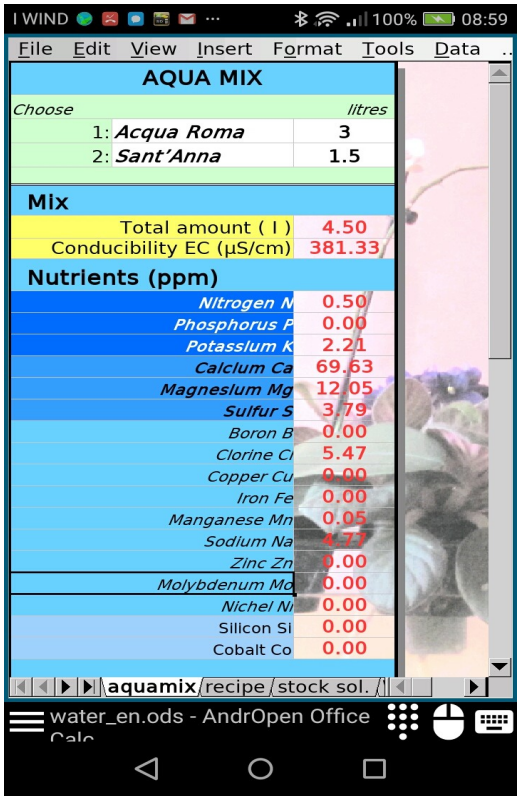
Launch *OpenOffice / AndrOpenOffice,* then from the **File / open** menu upload `water_en.ods`.

Associate '.ods' files with *OpenOffice / AndrOpenOffice* to open them automatically.

You can also create a shortcut to the `water_en.ods` file to launch it quickly.

note: spreadsheet sheets are protected only to avoid accidental changes. The password, for those who want to change them is 'recipe'.

Step 2: Calculator AQUA MIX



Select two different waters and the respective volumes.

Based on available data, the calculator will calculate EC and quantity in ppm of the salts in the mixture, limited to the elements of nutritional interest.

Which water for orchids?

Tap water varies from aqueduct to aqueduct. Its composition can be found updated 'on-line' at the various service companies.
For example, the water in an area of Rome has the following composition:

AGGIORNAMENTO: Giugno 2018

Parametro	Unità di misura	Limiti D. Lgs 31/2001 e s.m.i.**	Valori medi rilevati
Conc. ioni idrogeno	pH	6,5 - 9,5 (*)	7,47
Cond. elettrica a 20°C	µS/cm	2.500	580
Bicarbonati	mg/L HCO_3		403
Durezza totale	°F	15 - 50 (*)	33,2
Calcio	mg/L Ca		103,2
Magnesio	mg/L Mg		18,07
Residuo fisso calcolato	mg/L	1.500	415
Cloro residuo libero	mg/L Cl_2	0,2	0,13
Ammoniaca	mg/L NH_4	0,5	<0,03
Nitrati	mg/L NO_3	50	2,92
Nitriti	mg/L NO_2	0,5	<0,01
Cloruri	mg/L Cl	250	8,2
Fluoruri	mg/L	1,50	0,19
Potassio	mg/L K		3,32
Sodio	mg/L Na	200	6,4
Solfati	mg/L SO_4	250	17,02
Arsenico	µg/L As	10	<1,0
Manganese	µg/L Mn	50	0,73

The water of S.F. Circeo (LT) has instead this other composition:

Comune di S.F. Circeo			
Approvvigionamento Acquedotto "Sardellane" / Sorgente Ninfeo / Pozzi Selvapiana			
Punto di prelievo Serbatoio "Mezzomonte Basso"			
Periodo di monitoraggio: I semestre 2018			
Prova	**Unità di misura**	**Limite (D.Lgs 31/01)**	**Valore**
pH	pH	6,5<pH<9,5	**7,39**
Temperatura	°C	25	**15,9**
Colore		incolore	**incolore**
Odore		inodore	**inodore**
Conducibilità elettrica	µS/cm^{-1} a 20°C	2500	**938,3**
Ossidabilità	mg/L O2	5	**< 0,5**
Torbidità	NTU	s.v.a.*	**< 0,4**
Durezza	°F	50	**40,7**
Residuo secco a 180 °C	mg/L	1500	**579,5**
Ione ammonio	mg/L	0,5	**< 0,01**
Sodio	mg/L	200	**83,2**
Potassio	mg/L	n.d.**	**4,0**
Magnesio	mg/L	50	**29,1**
Calcio	mg/L	n.p.	**112,5**
Nitrito	mg/L	0,5	**< 0,05**
Nitrato	mg/L	50	**1,8**
Cloruro	mg/L	250	**170,9**
Floruro	mg/L	1,5	**0,2**
Fosfato	mg/L	n.p.	**< 0,2**
Solfato	mg/L	250	**28,4**
Ferro	µg/L	200	**22**
Manganese	µg/L	50	**18**
Arsenico	µg/L	10	**6**
Disinfettante residuo	mg/L	> 0,2***	**0,21**
Coliformi totali	ufc/100 ml	0	**0**
Enterococchi	ufc/100 ml	0	**0**
Escherichia Coli	ufc/100 ml	0	**0**

* *senza variazioni anomale*
** *non definito*
*** *valore consigliato*

The parameters that I can easily measure (EC and pH) are practically identical to those indicated.

As you can see they are very mineralized waters and not suitable to be used for Orchids, for which it is recommended (2) a water with EC <500.

Note: If tap water contains Chlorine, exposure to 24 hours on the sun (UV) is sufficient. If it contains Chloramine, 1g of vitamin C (ascorbic acid, 30 US$/Kg) per 80 liters (50mg/gallon), dissolve and wait for 12 hours..

What are the alternatives?

- Bidistilled water: almost 0 µS/cm; almost 0 ppm
- Osmosis/demineralized/deionized water: 0 - 5 µS/cm; 0 – 2.5 ppm@0.5
- Rainwater: 5 – 20 µS/cm; 2.5 - 10 ppm@0.5
- Mineral water (bottled): 20 – 100 µS/cm; 10 – 50 ppm@0.5

Not having rain water, osmosis water is widely used. But here I found various surprises (Italian market):

1) Purified water (bought in drugstore) EC measured 2 µS/cm (3 €/liter)
2) Demineralized water, non-potable, industrial uses (from Maury's shop) EC nominal 100 µS/cm, measured 190 µS/cm !! (0.24 €/l)
3) Demineralized water, non-potable, industrial uses (from Esselunga shop) EC nominal (?), measured 14 µS/cm (0.30 €/l)

Some bottled mineral waters have low salinity, for example:

4) Acqua Sant'Anna (fonte Rebruant) EC nominal 25,4 µS/cm, measured 24 µS/cm (0.33 €/l)

Personally I find much more interesting mineral waters than osmosis waters, for the following aspects:

- guarantee of potability, absence of bacteriological pollutants
- absence of chemical pollutants, e.g. PVC
- chemical composition known, constant over time
- presence of micro-nutrients
- ease of supply

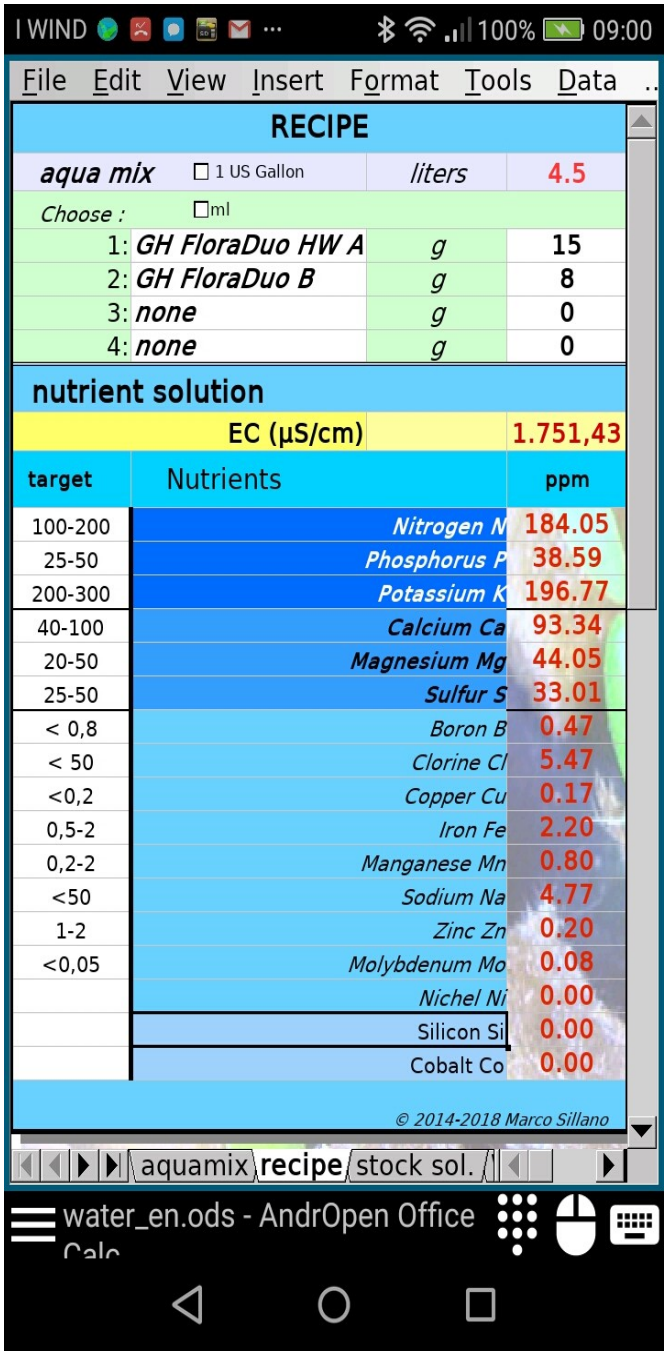
The use of pure osmosis water is not recommended by various sources (1,4) due to the absence of calcium and micro-nutrients essential to plants, which must be added to the fertilizer used.

So the idea behind this calculator is the following: use tap water mixed, if necessary, with other waters with lower EC to obtain the desired EC value and at the same time you know the amount (ppm) of the various elements present in the mixture resulting.

For orchids, the following limits should be kept in mind (8):

Water Quality Parameters						
	pH (units)	Alkalinity (ppm)	Calcium (ppm)	Magnesium (ppm)	TDS (ppm)	Sodium (ppm)
Desirable Levels	*6 – 7.5*	*< 150*	*40 - 100*	*20 – 50*	*< 500*	*< 10*

Step 3: Calculator RECIPE



Choose up to 4 fertilizers and the respective total amounts in grams or ml.

The water volume is automatically taken by the AQUA MIX calculator, or you can choose 1 US Gallon (many recipes are in ml/Gallon)
N.B. This volume is conventional and will be modified by calculating the stock solution.

In the target column, enter the desired values as a reference (optional).

The calculator provides both an EC estimate of the solution and its composition in ppm.

You can use both complete commercial fertilizers and individual liquid components.

This calculator does not have the goal of designing fertilizers (like SOL-NUTRI (14)) but is a guide to calibrate simple recipes.

Notes for Phalaenopsis

The Phalaenopsis are the most popular orchids grown today and offer everything that orchid growers admire: they are quick and easy to grow, they bloom for many months; their flowers are elegant and are available in a wide range of colors. They have fairly modest light requirements and grow well in the temperatures commonly found in homes. There is no specific type that is easier to grow, so we can choose the plants that most appeal to us.

A first consideration is to always keep in mind the link between the main variables that regulate the metabolism of an orchid: temperature, light, nourishment.

A good starting point is the following table which presents a production schedule for Phalaenopsis (from 6, modified) :

Simplified program for the production of phalaenopsis orchids in 5-inch (12.5 cm) pots.						
		Production phase				
	Units	***Vegetative growth***	***Cooling (*)***	***Finishing (to flowers)***		
Duration	***weeks***	***until plant maturity***	***4 a 6***	***20***	***14***	***10***
Temperature	°C	28 - 32	17 - 25	17	20	23
	F	82 - 90	63 - 77	63	68	73
Light intensity	lux	5000 - 15000	10000 - 15000	10000 - 15000		
	foot-candles	500 - 1500	1000 - 1500	1000 - 1500		

(*) In addition to thermal shock, flowering can be induced by chemical shock: 30 days of 10 g/liter (1tbsp/gal) of magnesium sulfate (Epsom salts) instead of the usual nutrient solution (7).

Another important factor is the cultivation support used: in particular its ability to retain moisture, to promote the aeration of roots and the ability to supply nutrients to orchids, in particular micro-nutrients.

Comparison between some substrates for Orchids (10):

CHARACTERISTIC	BARK	PEAT	ROCK-WOOL	PERLITE
pH OF MEDIUM	SL ACID	ACID	SL ALK	NEUT
FERT. CONTROL	GOOD	GOOD	GOOD	v-GOOD
LEACHING	EASY	FAIR	FAIR	v-EASY
AERATION	GOOD	FAIR	FAIR	v-GOOD
DISPOSAL	EASY	EASY	HARD	EASY
HEALTH HAZARD	CARE	CARE	CARE	CARE
STERILITY	NO	NO	YES	YES
MANAGEMENT	f-EASY	f-EASY	f-EASY	v-EASY
SIMPLICITY	FAIR	FAIR	FAIR	v-SIMPLE
WEEDING	f-EASY	f-EASY	f-EASY	v-EASY
AVAILIBILITY	GOOD	V-GOOD	FAIR	v-GOOD
COST	**VARIABLE**	**VARIABLE**	**HIGH**	COMPETATIVE
EASE OF POTTING	GOOD	GOOD	GOOD	v-GOOD
REPOTTING TIME	1-2 YRS	1-2 YRS	1-2 YRS	2 YRS ++
NUTRIENT	MIN.	MIN.	NIL	NIL
OVERWATERING	YES	YES	YES	NO
REWETTING CATION	FAIR	FAIR	v-POOR	EASY
EXCHANGE	YES	YES	NO	NO
BUFFERING	SLIGH	ACID	NO	NO

The orchid grower tends to use a substrate that brings him closer to the hydroponic culture. If the substrate is inert (rook-wool, perlite, expanded clay...) we are in full hydroponics. This requires us to supply the nutritive elements from the outside with each irrigation to achieve optimal and balanced growth.

Personally I have chosen the controlled pH expanded clay, cheap and easy to find. (2,7,13).

In general, for the Orchids we can consider the following table (8):

Table 5 - **Mineral Nutrition for Orchids**

	Continuous Feed (ppm) Fertilize at Least Weekly	Periodic Feed (ppm) Fertilize Less than Weekly
Macronutrients		
Nitrogen, N	60 - 100	100 - 200
Phosphorus, P	10 - 20	20 - 40
Potassium, K	60 - 100	100 – 200
Calcium, Ca	40 - 80	80 - 160
Magnesium, Mg	20 - 40	40 – 80
Sulfur, S	15 - 25	25 - 50
Micronutrients		
Boron, B	trace	< 0.8
Iron, Fe	>0.5	2
Manganese, Mn	> 0.2	2
Zinc, Zn	1	2
Copper, Cu	trace	< 0.2
Molybdenum, Mo	trace	<0.05

Source: adapted from Bob and Lynn Wellenstein, AnTec Laboratory

In particular, for the Phalaenopsis, (2) recommends:

Nitrogen	*100*	***150***	***200***

Phosphorus	*25*	*50*	
Potassium	*200*	*300*	
EC	*1000*	*1500*	

from (8) we have the further indications:

Calcium	*40*	*100*	
Magnesium	*20*	*50*	*(Calcium/Magnesium = 2)*
Sodium	*< 50*		

Similar values from (9):

> *"During the vegetative growth the plants should receive 200 ppm of N for each irrigation, phosphorus only 25-50 ppm. It should also be noted that in colder climates and with flowering, nitrogen levels must be lower than 150 ppm. The pH of the solution must be higher than 5.5 and EC must be kept around 800 - 1200 µS/cm. "*

More specifically, among the indications of special recipes we find:

- from (5): Peters hydrosol + magnesium sulphate MgSO4 • 7H2O + calcium nitrate Ca(NO3)2. (5: 2: 4).
  Nitrogen from 100 to 200 ppm and fixed composition all year long.
- from (7): Peters Excel 21-5-20,
  at 100 ppm of Nitrogen.
- A conservative recipe for perlite substrate is as follows (10):
  Plantprod (Plantex) 7-11-27 + calcium nitrate Ca(NO3)2 (3: 2)
  Dilution 1: 100, EC = 600 µS / cm, pH = 5.8

Element	ppm	Element	ppm
N	54	Fe	0.31
P	14.7	Cu	0.0136
K	70	Mo	0.027
Ca	37	Zn	0.094
Mg	11.5	Mn	0.27
SO4	15	B	0.08

- More recipes in (8)

These are recipes that use complete commercial fertilizers, to exploit their micro-elements, sometimes in conjunction with corrective components. In general, the more aggressive recipes lead to faster growth, provided that the plants have the optimal temperature and light conditions.

However, a criterion is always valid:

> The plants absorb only the nutrient solution that can metabolize, depending on the stage of development, temperature, light: therefore in a recirculation system, if EC falls in the days following the renewal of the solution the plants are absorbing nutrients: it is possible to increase concentrations. On the other hand, if EC rises, the plants absorb more water than nutrients and the concentrations must be reduced.
>
> This test is very simple using Flower Care, see https://github.com/msillano/Sonoff-ebb-and-flow/blob/master/orchis-sonoff-en01.pdf, which provides weekly and monthly EC charts

As a consequence, if you grow in a greenhouse with stable and optimal conditions (temperature, light) you can always use the same recipe or vary it only according to the growth stage of the plants. Without stable conditions it may be necessary to change the concentration or the nutritious recipe often.

With these summary indications it is possible to establish a nutritional strategy for Phalaenopsis according to our needs and preferences.

The two references (11) and (12) are useful sources for information on the composition of commercial fertilizers, even if the actual composition may differ from that indicated by the

manufacturer. For safety, analysis should be performed.

Step 4: Mother solution calculator

After finding the correct recipe (with the RECIPE calculator) we can find the amount of fertilizer to use for any volume of nutritive solution, even concentrated (stock solution).

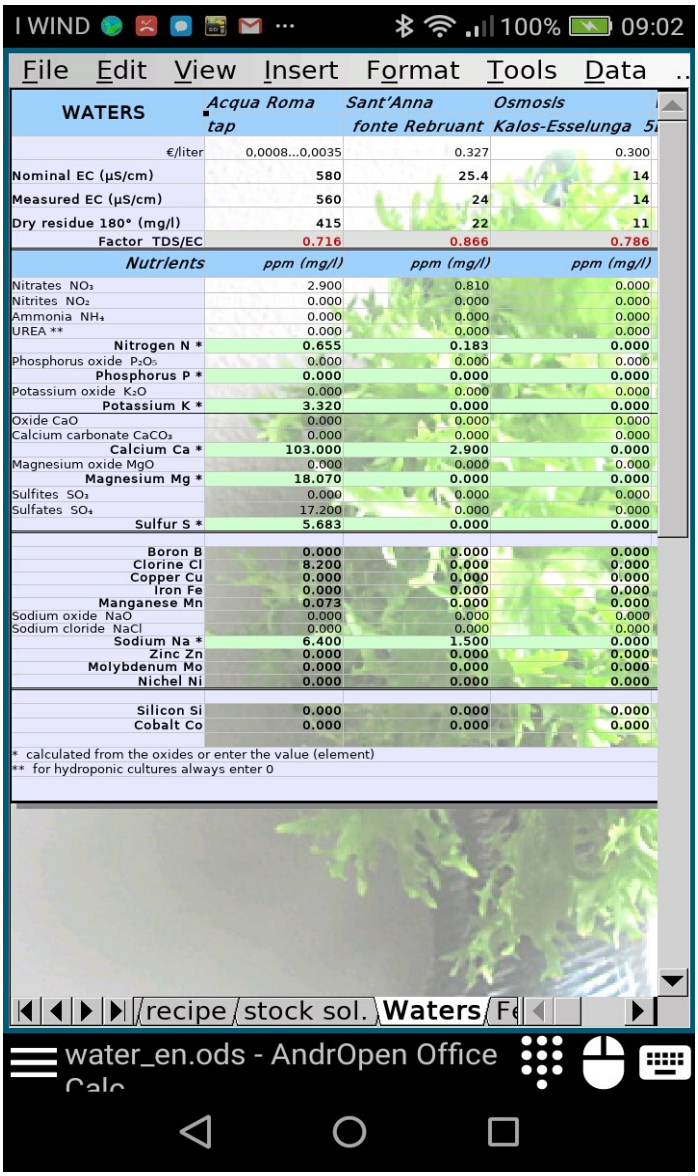
Being a single mother solution, the concentration can not be too high, but it is always an useful job simplification to have a single solution ready at 1:20.

For simplicity, the quantities are by weight, so a scale is sufficient for precise measurements.

The precautions to be taken to make the stock solution are the usual: dilute the various fertilizers separately, and mix them very carefully. Make the solution to the mark.

Check that no precipitates are formed.

Table: Waters



This table acts as a database for waters: data of 5 different waters to be mixed can be entered.

The table is prepared for the conversion from Oxides (mg/l) to element (mg/l) (5).

Starting from the top we have:

line-1: name (used in lists)

line-2: other information

line-3: € / liter as a reminder

line-4: nominal EC, used for the factor TDS/EC
(if unknown, enter the measured value)

line-5: measured EC, used in calculations

line-6: nominal Total Dissolved Solids

line 7: calculated TDS/EC factor

other lines: Nutrients: we have 3 cases.

*1) Simple element (e.g. **Boron B**):*
enter the mg / l value

*2) Element with Oxides (e.g. **Potassium K ***) and the value for the element is known:*
enter the element value in mg / l

*3) Element with Oxides (e.g. **Sulfur S ***) and the value for oxides is known:*
enter the mg/l value of the oxide,
the element is calculated automatically.

Note: To restore the formula that calculates an element from its oxides, disable sheet protection, show column C, copy cell ## (column C, formulas) in the water column (D-I) of the same row. Set sheet protection.

Note: Due to the high times required for assimilation, UREA is not useful in hydroponic cultures (5): always enter 0 for orchids.

Note: Pay attention to the cases in which the values refer to the element and not to the oxide: e.g. N = 5: 3 (nitrates), 2 (ammonium)

Note: This page is big and will be changed rarely: it is recommended to use the PC to modify it and not the smartphone.

Table: Fertilizers

This table acts as a database for fertilizers: data from 5 different liquid fertilizers can be entered.

The table is prepared for the conversion from Oxides (%) to element (%) (5).

Starting from the top we have:

line-1: name (used in lists)

line-2: other information

line-3: specific weight, g / ml
nominal, measured or estimated, used per ml

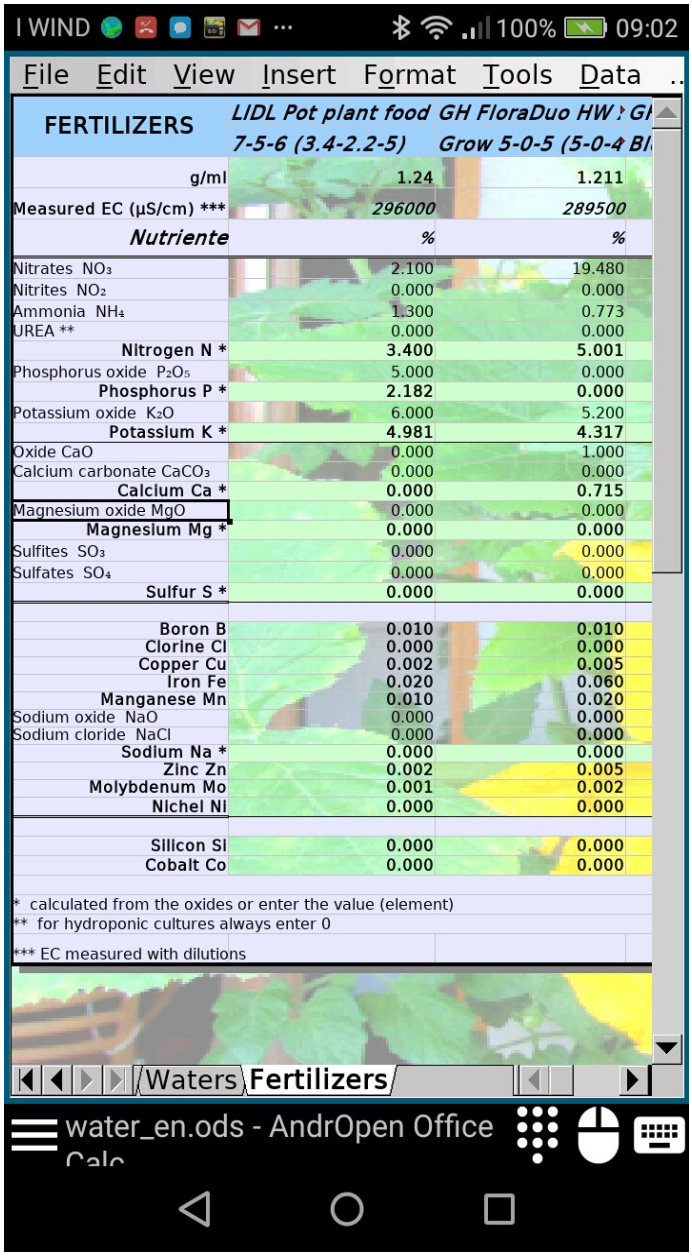
line-5: measured EC, used in calculations

other lines: Nutrients in% - we have 3 cases

*1) Simple element (e.g. **Boron B**):*
enter the % value

*2) Element with Oxides (e.g. **Nitrogen N ***) and the value for the element is known:*
enter the % value of the element

*3) Element with Oxides (e.g. **Potassium K ***) and the value for oxides is known*
enter the % oxide value,
the element is calculated automatically.



Note: To restore the formula that calculates an element from its oxides, disable sheet protection, show column C, copy cell ## (column C, formulas) in the fertilizer column (D-H) of the same row. Set sheet protection.

Note: Due to the long times required for assimilation, UREA is not useful in hydroponic cultures (5): always enter 0.

Note: Pay attention to the cases in which the values refer to the element and not to the oxide: e.g. N = 3,4: 2,1 (nitrate), 1,3 (ammonium) = "Total nitrogen 3,4 %: of which 2,1 % from nitrates and 1,3 % from ammonium"

Note: This page is big and will be changed rarely: it is recommended to use the PC to modify it and not the smartphone.

References:

1) *Do you really need ro water? Science in hydroponics (https://scienceinhydroponics.com/2017/03/do-you-really-need-ro-water.html)*
2) *Andy W., Growing the Best Phalaenopsis Part 2, Napa Valley Orchid Society (http://nv-os.org/index.php/the-potting-bench/culture-information/phalaenopsis-vanda-alliance/phalaenopsis/culture/item/300-growing-the-best-phalaenopsis)*
3) *US Patent for Plant fertilizer compositions and related methods Patent (Patent # 9,073,798) (https://patents.justia.com/patent/9073798)*
4) *GROWTH TECHNOLOGY ORCHID FOCUS CROISSANCE 500 ML (http://www.hoadeco.fr/ochidfocus-c-500ml.html)*
5) *G. Torelli, Impariamo a fertilizzare (http://www.orchid.it/articoli/fertilizzanti2.htm)*
6) *Andy W., Growing the Best Phalaenopsis Part 4, Napa Valley Orchid Society (http://nv-os.org/index.php/the-potting-bench/culture-information/phalaenopsis-vanda-alliance/phalaenopsis/culture/item/300-growing-the-best-phalaenopsis)*
7) *Dave Holder, Orchids - Methods for Growing the Perfect Phalaenopsis (http://statebystategardening.com/state.php/articles/orchids_-_methods_for_growing_the_perfect_phalaenopsis/)*
8) *Sue Bottom, Choosing your Fertilizer based on your water quality (da https://staugorchidsociety.org/PDF/WaterQualityandFertilizersRev2.pdf)*
9) *Besgrow-Orchiata-Phalaenopsis-growing-guide (http://acadiansupply.com/wp-content/uploads/2015/12/Besgrow-Orchiata-Phalaenopsis-growing-guide.pdf)*
10) *Wally Thomas and Barb Thomas, Orchid Culture in Perlite (http://www.simplyhydro.com/orchids.htm)*
11) *ShroomDr's Nutrient Formula Elemental NPK parts-per-million List (https://www.icmag.com/ic/showthread.php?p=3610000#post3610000)*
12) *Calcolator for fertilizers: (https://docs.google.com/spreadsheets/d/1nF5htNxSEPCzLH2Uk6eDqmHQzCDp4tRxWkmKxgsfye8/edit#gid=0)*
13) *Cultivation in different media*
    (Part 1: http://www.hortorumcultus.actapol.net/pub/9_3_85.pdf)
    (Part 2: http://www.hortorumcultus.actapol.net/pub/9_3_95.pdf)
14) *SOL-NUTRI*
    http://www.cespevi.it/softunipi/solnutri.html