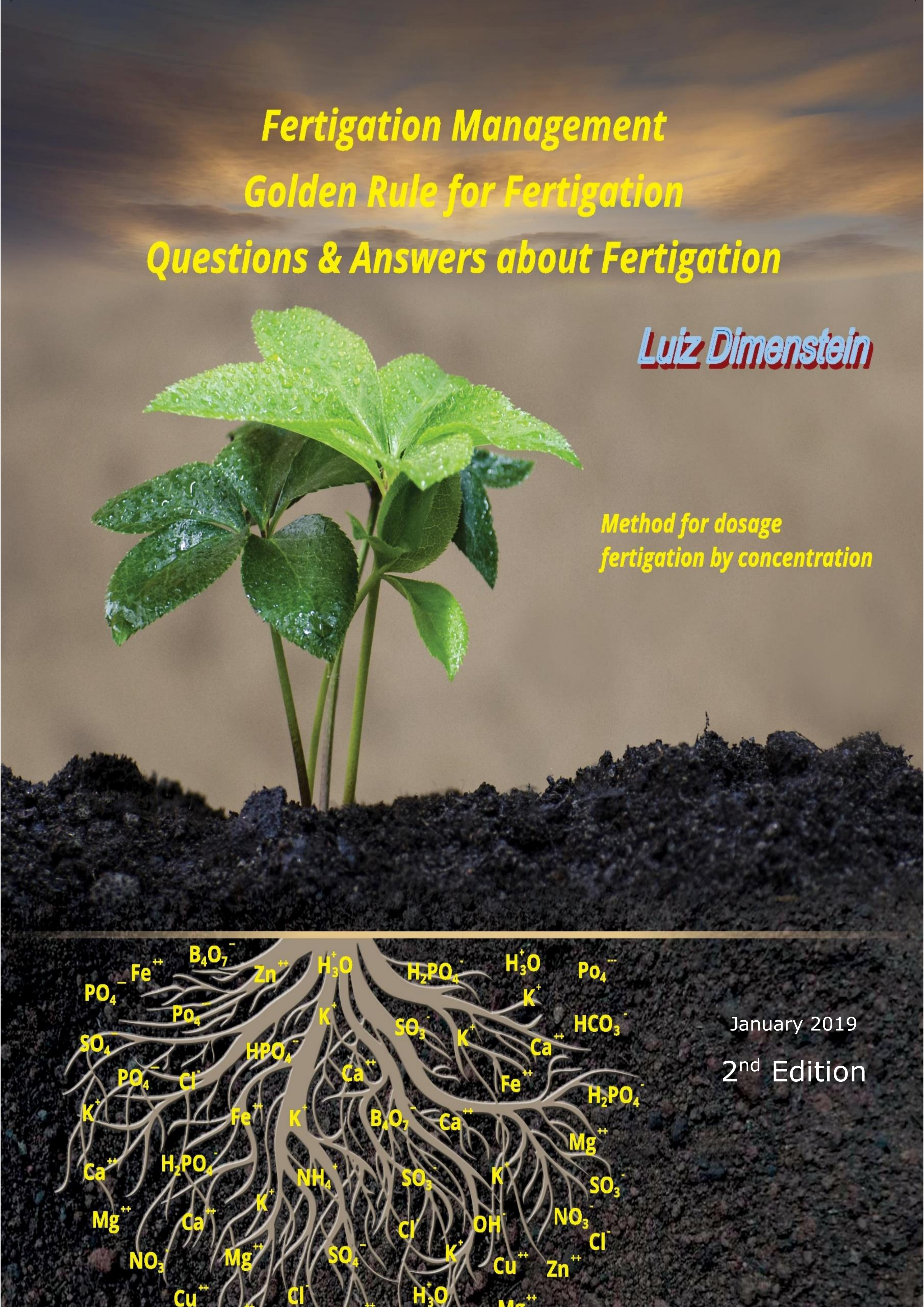
Fertigation Management
Golden Rule for Fertigation
Questions & Answers about Fertigation

Luiz Dimenstein

Method for dosage fertigation by concentration



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Summary

To fill the gap in the agriculture literature about how handle fertigation and stress focus on the word "management", a sequence of assumptions or premises are presented to facilitate the understanding how to act in the fields for irrigated crops and get decisions of doses and sources of soluble or liquid fertilizers for easy adjustments aimed at optimizing nutrition and respecting the plant physiology in order to avoid the constraints of productivity from nutritional origin and inhibit the maximum photosynthesis to occur. Management in fertigation is get decisions, avoiding the **"anti-recipe of cake"** typical for recommendation standard and quantitative fertilizer doses. But now this concept changed for adjusts in which for each irrigation and fertigation we now have simple tools and quick to provide us with updated information on the nutritional status of plants, nutrient

availability, pH levels and salinity (EC) for the roots in different depths into the soil.

The manipulations of salinity by electrical conductivity (EC) and also for pH via fertigation are presented, discussed and illustrated.

Get out of the typical doses of no irrigated crops by quantitative format as kg/hectare (the Americans use pounds/acre) or g/plant to change the concept and adopt doses via concentration of nutrients in irrigation water in **g/m^3** (grams per m^3 of irrigation volume and 1 m^3 = 1,000 liters) that becomes extremely easy after breaking the initial cultural barrier of resistance on relevant part of traditionalists farmers, to shift the new approach for a very practicality and ease in working with doses measured in ppm (part per million) instead of %, only using the new **"Golden Rule of Fertigation"** in that 100g/m^3 of any soluble fertilizer or liquid formula will brings the value of nutrients guarantees to change from **% to ppm**. The fast kits are colorimetric, titration or turbidity, are extremely simple and takes about 1-2 minutes to present the results and only of available nutrients show results already in ppm that is really free along the roots, and the soil solution samples are easily collected with vacuum suction tubes, called **Soil Solution Extractors (SSE)**. It is practically mimicry of the roots that are in fact benefiting directly from the soil solution and we obtain the sample of the actual nutrient cocktail that the roots are absorbing. The collection frequency is flexible and each one can decide when take new samples and measure to check the levels of nutrients available in the soil solution and compare against the previous sample to get the called DELTA (Δ) to understand how dynamic is the changes in fertigation management.

If samples present some problems such as shortages or excesses, leaching, pH or EC levels outside the desired, or because they could be too high or too low…, then it would be prudent to collect samples from the SSE to check them more frequently to quick adjustments and later after you get adequate levels, enter the maintenance phase with larger intervals of soil solution samples. Examples of interpretations of results and how to handle the fertigations are presented.

Parameters for more than 100 different crops are suggested presenting the acceptable ranges for electrical conductivity (EC), pH, Chlorides, Nitrates, Phosphates, Potassium, Calcium, Magnesium and Sulfates. The suggested ranges for these nutrients in which the smaller values apply to young plants or vegetative phase and will increasing along the growing cycle until maturation to the larger values suggested. Most likely, the future research will adjust these values in some cases. Here we present the suggested values up to the present moment, considering values within physiological ranges for a viable performance without falling in **"gross errors"**, which by definition would be unintentional mistakes that practice by simple ignorance of not knowing the nutritional status of that moment. Example: apply fertilizer acid trend i.e. Ammonium Sulfate or soluble Purified MAP, without knowing what is the current pH of soil solution, however if this pH is identified in soil solution already quite acid, assume for instance, about pH ~5, would be a "gross error" insist to continue applications via fertigations of that same acid fertilizers, while proper management would avoid these acids and choose other fertilizers to get more alkaline trend in the soil solution using for examples Nitrates of Potassium and/or Calcium, among others.

Another example of a **"gross error"** would be unnecessarily apply some nutrient whose tests indicate high values, and therefore there would be no need for new applications at that time and could follow accompanying and monitoring these levels of several nutrients in soil solution for the settings on a case by case basis, avoiding both faults and excesses.

The very practical tool of Soil Solution Extractors (ESS) are placed in 3 depths (15, 30 and 45 cm) and if the nutrients and the EC are well distributed between the 3 depths, means that the volume of irrigation watering is adequate, however, if the nutrients and the EC are higher in the SSE tube deeper of 45 cm, indicating clear that the salts are leaching, than it would be a mistake following the same irrigation volume of irrigation, while the correct management would be an obvious reduction of the irrigation volume, since who decides about the irrigation management could get true information from the collection SSE tool and easy measurement by the quick kits. Then the management decisions are very logic and sometimes obvious.

In the following, we present a series of **Questions & Answers** always so common in irrigated agriculture with controversial topics with a focus on management and thus presented in a very didactic way that may be useful.

Let's go to the premises.

Premises

They are truths that serve as a basis to sustain an idea in a logical sequence, based on strong arguments and easy to understand. For the practical purpose of making the fertigation management something accessible and easy within the storyline that evolves throughout the premises, to reach all levels of farmers since the highest academics even those who had no access to studies in a typical rural extension work as the art of make less complex for a subject that until then was treated as "cake recipe". The easy way to achieve this target comes with the "**Golden Rule of Fertigation**" which brings the popular level the day-to-day management of the fertigations making agronomy a science of coherent, practical and effective decisions via fertigation. The details with examples for the use of this golden rule of fertigation are presented here.

Premise No. 1 - Salinity:

Most of soluble fertilizers are salts. On the solid phase salts are neutral, however, after dissolve in water, the components of salts dissociate into positive electrical charges, the cations, and negative, the anions. So, the salts dissolved in water conduct electricity and can be measured by a single use device called the conductivity meter which measures the electrical conductivity abbreviated as EC. Our luck is that the EC is proportional to the concentration of salts in a given volume of water and this facilitates our interpretation of salinity for use via fertigation that we will explain in the sequence of arguments.

A fertilizer or salt or a cocktail of mixed fertilizers, to dissolve at a dose of 1 g/L have a salinity x, then we can say that this same fertilizer or fertilizer cocktail with double the dose in g/L have a salinity of 2x, if it is 3 g/L have salinity of 3x, and so on until the saturation which is already outside the agricultural scale which is above 7 g/L when the high salt concentration is not anymore proportional due saturation of the solution. The normal is working via fertigation in soft and frequent doses so we avoid getting the doses of greater than 7 g/L. In practice, we were usually below 2 g/L which is equivalent to 2 kg/m^3. Means that applying 2 kg of soluble fertilizer in each m^3 (1,000 L) of irrigation, we obtain the EC of twice the same fertilizer with 1 kg/m^3.

EC actual unit is Siemens as a tribute to this scientist. The official international unit is dS/m (deciSiemens per meter). The old unit used before the 90's in the 20th century was used as mmho/cm. It is common to express the unit in centimeter instead of meter, mS/cm (milliSiemens per centimeter). There is also conductivity meter that express in µS/cm (microSiemens per centimeter) which is 1000 x more diluted that mS/cm. The summary of EC units is:

1dS/m = 1mS/cm = 1mmho/cm = 1000 μS/cm

A curiosity was the previous unit mho conductivity mmho because for that is the inverse of electrical resistance expressed as ohm, so they wrote the unit backwards and then used the mho unit per centimeter divided by 1000 getting millimho/cm (mmho/cm).

To get an idea about the levels of salinity in seawater, in the sap of plants (average) and the salinity range considered physiological for most cultivated plants, observe the following table:

Salinity	EC (mS/cm)
Pure water	0
Sea water	53
Sap plants – average	7
The ideal soil solution	1 to 3

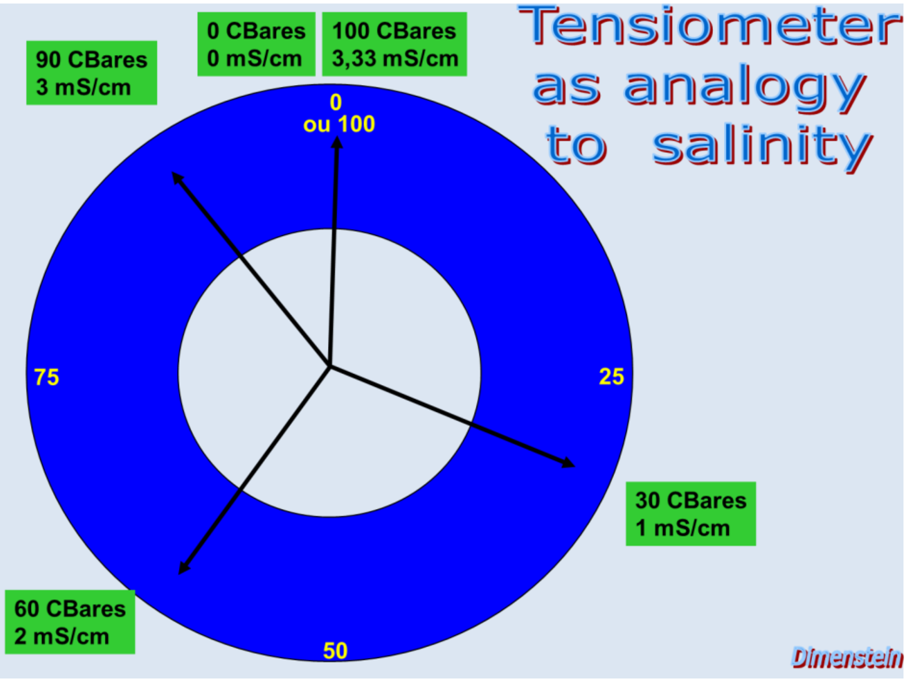
When the soil solution presents low EC or very diluted, the roots absorb this solution very easily, as the plant transpiration occurs, some nutrients enter the plants in this process of new soil solution absorption to replenish water loss.

The opposite case with high EC, slow down and prevents the absorption of soil solution where the salinity retains water in the soil to be difficult absorption by roots. This counter force against the roots can be measured considering the proportion of the EC = 1 mS/cm generates a tension (negative pressure) of -0.3 ATM; for EC = 2 mS/cm the tension against the roots would be double, reaching -0.6 ATM, and follows proportional up to the extent of EC = 7 mS/cm, that would be equivalent to the average of the sap inside the plants. So, if the salinity of soil solution measured as EC will be greater than into the plant, it would suffer dehydration, losing water to the soil. Of course, the proper management tends to keep the salinity of the soil solution around the roots environment to stay between the EC levels of 1 to 3 mS/cm, considered the physiological range where most cultivated plants can extract enough water and the content of nutrients dissolved in the solution at a concentration that is tolerated by the plants and at the same time providing nutrients for the plants.

Manipulate the salinity level around roots in the humid soil volume playing the fertigation management is the great challenge of the agronomy for irrigated crops to optimize the doses of the different salts (fertilizers) throughout the different phenological stages of plant development (vegetative, blooming, filling grains or fruits, maturation and harvest).

EC (mS/cm)	Tension or Negative Pressure ATM
1	**-0.3**
2	**-0.6**
3	**-0.9**
4	**-1.2**
5	**-1.5**
6	**-1.8**
7	**-2.1**

As analogy between salinity measured by the EC and the tension of -0.3 ATM for each EC unit, generating a counterforce to the roots for the absorption of the nutrient solution. If a tensiometer could measure this negative force caused by salinity, it would be like the diagram below, but of course tensiometers will inform only the water availability independent of the salinity:



The EC of 3.33 mS/cm would be equivalent to a full turn of the tensiometer scale that is for the negative -1ATM, indicating that salinity measure of EC = 3.33 mS/cm would cause a water retention in soil resisting absorption by roots similar to a tension meter worth of -1ATM and the diagram is in the range usually of CentiBars (CBars). -100CBars = -1ATM.

This confirms that water stress may occur for plants even with the wet soil, in case of high EC even in presence of humid soils, but the salinity would cause some difficult to the roots to absorb the soil solution. This scenario could be caused by natural soil salinity of irrigation water, or by excessive fertilizer applications. In this latter case, we would have management control by measuring the EC of the soil solution with certain frequency to adjust the doses of fertigations.

The EC meter cannot identify the salt composition of every salt (fertilizer), but only the total salinity. The great challenge of fertigation management is handling the composition and proportions of fertilizer salts. Keep the total salinity measured by the EC within the physiological tolerance of each culture and change the doses of fertigations to get the best agronomic response for each stage of development of the crops.

To better understand the relationship of the main nutrients, present in soluble fertilizers, simply identify what we call in "equivalents", i.e. the molecular weight divided by electric charge of the ion (cation or anion). For Potassium K^+ which is a monovalent cation and its molecular weight is divided 39 by 1 is equal to the same 39, so 1 equivalent of K^+ is worth 39. For the chloride Cl^- that is an anion whose molecular weight is about 35 and also divides it by 1 because it is a monovalent ion to get 35 which is 1 equivalent of chloride.

For the bivalent ions like Calcium Ca^{++} with molecular weight 40 divided by the electric charge 2 to form 1 equivalent of 20. For Magnesium Mg^{++} also bivalent, with molecular weight 24 divide by 2 to form 1 equivalent of 12.

The next step for our best understanding must link the “equivalents” to the electric conductivity, stating that 1 equivalent of any ion has the power to increase the salinity in the EC meter by 0.1 mS/cm. So, for example 5 equivalents of K^+ bring the EC to 0.5 mS/cm. Similarly, 3 equivalents of Mg^{++} contribute to the total EC with the fraction of 0.3 mS/cm that we can read in the device conductivity meter.

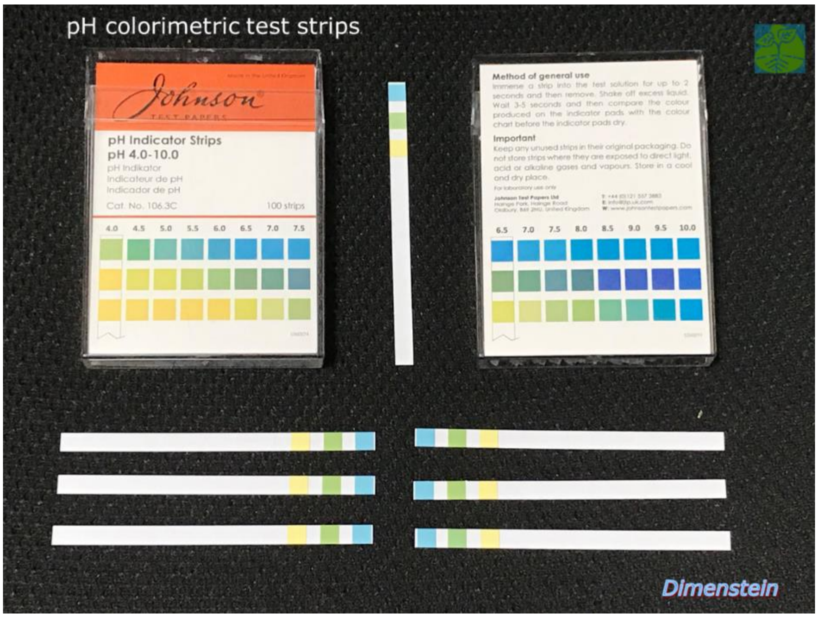
The conductivity meter measures the total salinity. EC = 1mS/cm means that there are 10 equivalents of cations and 10 equivalents of anions, so the total of 20 equivalents to always be half and half cations to anions. For an EC = 2.5mS/cm, the number of equivalents is 25 of cations and other 25 equivalents of anions, to get a total of 50 equivalents of both kind of ions, always being half and half cations to anions proportion.

Any salt dissolved in water releases cations and anions so balanced in number of equivalents. The conductivity meter measures the power of only one of the charged ions, or cations or anions, and so the EC identified x 10 = number of equivalents of one of the charges. To the total number of cations and anions by adding equivalents will be double. Example for EC = 1.5 mS/cm, there are 15 equivalent of cations and other 15 equivalents of anions for a total of 30 equivalents of all ions.

Below is a table with a summary:

EC (mS/cm)	Equivalents Cations	Equivalents Anions
1	10	10
2	20	20
3	30	30
4	40	40
5	50	50
6	60	60
7	70	70
8	Saturation	Saturation
9	Saturation	Saturation

Considering that the grower gets the information of the main nutrient's contribution of the total salinity and dominates the proportion of the salinity composition in the soil solution, this mean that the ECmeter now has an additional function of merely measure the total salinity that plants tolerate, but becomes the tool of manipulation of proportions of nutrients for the best physiological responses influencing on performance of plants in each growth development phase of its cycle. The handheld EC meter is the main instrument to support fertigation management by this method.



Traditional digital devices to measure EC and pH with automatic calibration.

Using the conductivity meter calibration standard solution of 1.4 mS/cm that can be done every 6 months.

Instruction for use:

Digital conductivity meter - Enter only the portion of the sensor and read after 10 to 20 seconds.

Digital pHmeter - Enter only the portion of the pH sensor and wait about 1 minute to read the value of pH.

Premise No. 2 - pH:

Important the pH colorimetric test strips kit to use once in a while only to confirm that the digital pHmeter is calibrated.

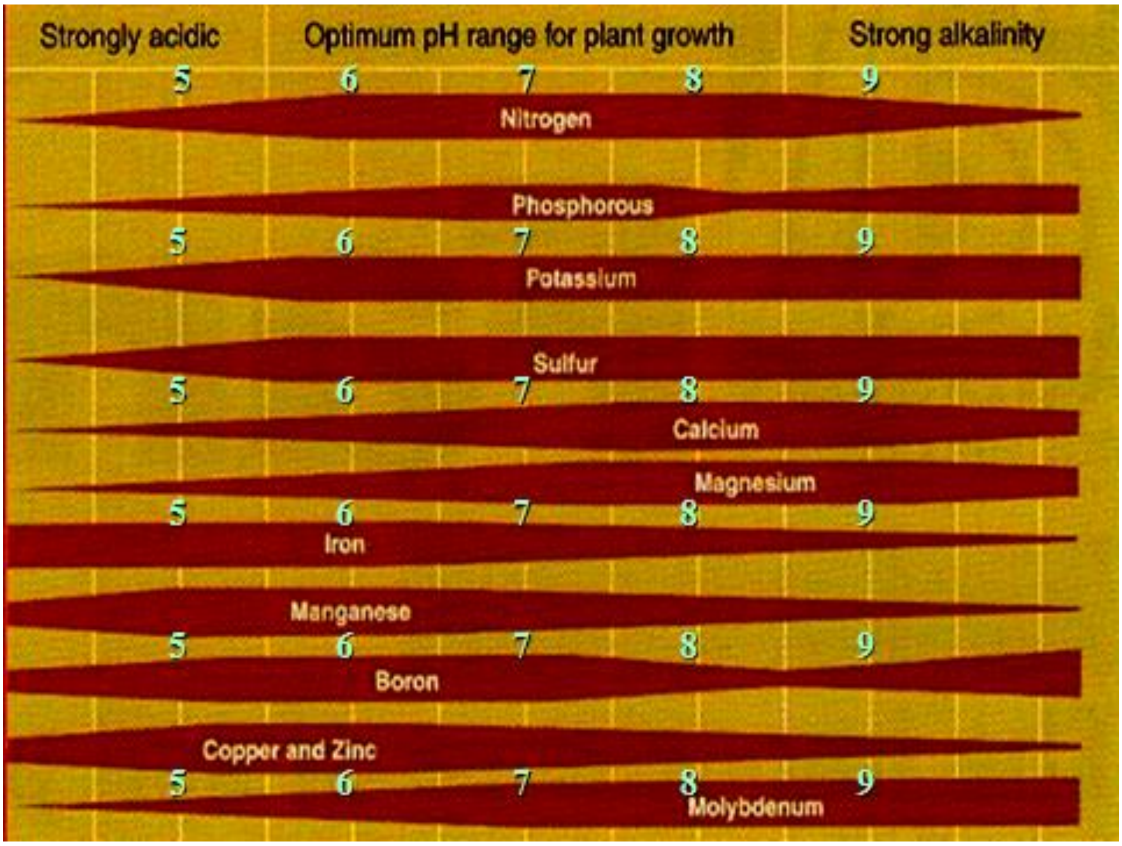
The illustration of the pH meter was presented above together with the ECmeter.

Calibration of pHmeter using two solutions of pH 7 and 4 or 7 and 10 and can be performed where the difference between the digital and the colorimetric pH test strip is more than 0.5 is a good indicative that need calibration.

Instructions on how to use colorimetric pH test strip tape – Insert the tape within the solution for at least 2 minutes before comparing with the scale on the container package. The main advantages of this pH test strip are the absence of calibration needs, results very fast, easy to use and cheap.

The choice of the soluble fertilizers for fertigation will have strong influence on pH of the soil solution into the wet soil bulb along the roots. This will influence also the solubility of nutrients, the compatibility among the nutrients and other no nutrients ions present in the soil and soil microbial flora.

Note in the chart below, the solubility and availability of macro and micronutrients as a function of pH in soil solution. It is clear that the range of balance lies between 5.7 to 7.5 and the midpoint of 6.5 as the average value desirable to keep all the nutrients available in the soluble phase. The choice of soluble fertilizers with tendencies of more acidic or more alkaline will surely influence the pH in the wet bulb along the many fertigations. The use of pHmeter or pH test strips is the key to that decision in the choice of fertilizers which will put the pH of soil solution on track for better absorption by the roots.



The choice of the Nitrogen source should always be based on the pH meter. Urea **($OC(NH_2)_2$)**, Ammonium **(NH_4^+)** or nitrate **(NO_3^-)**. Roots of plants only recognize and absorb electric charges, i.e. cations and anions. The Urea releases (NH_2) which is an amine and with two amines form an amide $(NH_2)_2$, but no electrical charge for amine nor for amide. In the soil the common enzyme called urease breaks the link between the C with N releasing on soil solution two NH_2 amines that are unstable and seek the soil to combine and react with H-free. So, when capturing the first H it forms NH_3 that has the name of Ammonia and Ammonia is a volatile gas, so if it will be shallow layer of the soil close to the surface and at high temperatures of a sunny day, it will surely evaporate. If, however, ammonia is infiltrated into the soil, will win soon one more H-free and will turn finally one cation NH_4^+ called now as Ammonium and as a charged ion cationic, the roots can finally recognize and uptake it.

Note that the first reaction of urea which began with NH_2 gets 2 H-free from the soil solution to switch and form NH_4^+ and so the pH of soil solution with less H-free becomes more alkaline.

However, the Ammonium (NH_4^+) normally found in soil, a rich microbial population that has great affinity for this form of nitrogen and is called nitrifying bacteria of the species Nitrosospiras and Nitrosomonas breaking chemical bonds between N and the 4H releasing all these 4H to the soil solution causing in this sequence its acidification. So, the Urea initially takes from the soil solution 2H and later returns 4H to get the final balance of acidification of the soil solution environment.

After this stage where the N is again free but unstable the next sequence of reaction will be with Oxygen to form first NO and following NO_2^- (Nitrite). From this point another group of soil bacterium called Nitrobacter finally makes the last stage of Nitrification forming NO_3^- (Nitrate). Both NO_2^- and NO_3^- are anions and the roots can recognize and can absorb them. NO_2^- is an intermediate and apparently under normal conditions the nitrifying bacteria complete the process quickly forming NO_3^- that within the plant induces internal production of the enzyme nitrate reductase that turns NO_3^- in NH_2 (Amine) and hence form several kinds of amino acids and then proteins. Unfortunately the plants has low ability to synthesize the enzyme that would decompose NO_2^- (Nitrite) that would be the nitrite reductase and when the roots absorb NO_2^- this takes much longer period of time for this anion to be decomposed than NO_3^- that is a nutrient as fast decomposed into the plants, but NO_2^- (Nitrite) enter into plant and stay inside without decompose and gets excess internally of this anion, locking the absorption of other anions including NO_3^- as there are strong inhibition of Phosphates , Sulfates, Chlorides, Borates and Molybdates. The plants also reduce the ability to produce amino acids and then proteins. In extreme cases can occur in addition to locking growth, flower abortion, small or even developed fruits also abort, and for severe presence of NO_2^- (Nitrite) even whole clusters can be aborted by plants.

Nitrifying bacteria are aerobic and the main cause for the accumulation of Nitrite is the lack of Oxygen in the compacted soil, flood by excessive rain or irrigation. These beneficial bacteria multiply between pH 5 to 8, and therefore outside this range of pH the bacterial populations are strongly reduced in the soil. In cold climates, there is one more factor that inhibits these bacteria that multiply just above 8°C of soil temperature. Apply Urea or Ammonium during the winter in cold regions will take long time to nitrify the full process and get NO_3^- (Nitrate) with serious risk to form the toxic NO_2^- (Nitrite).

When the roots absorb NO_3^- that has a negative charge, it's normal exude hydroxyl OH^- to keep electrically neutral plants, and similarly to absorb NH_4^+ that has positive charge, the roots exude protons H^+ and this means that N source influences on soil solution pH.

Sources of Potassium, with various levels of pH. KNO_3 - Potassium Nitrate when pure has the pH between 8 to 8.5. The KCl- Potash is nearly neutral 6.5. The SOP (K_2SO_4) Potassium Sulfate has variable pH according to the manufacturer because some use larger amount of sulfuric acid to react with KCl and make SOP more acidic, while other manufacturers use less acid and produce alkaline SOP, but without any buffer effect. There are on the market SOP with a pH between 3 to 9. Another source of potassium is MKP – Mono Potassium Phosphate which is also rich in Phosphates beside the Potassium (00-52-34) and the pH of 4.5 with strong buffer effect. The source of potassium more acidic is the PeKacid which is also rich in Phosphate (00-60-20) at pH 2.2 and also with strong buffer effect, based on the composition of MKP

+ Pure Phosphoric Acid in the powder form, but fully soluble. In addition to numerous formulas obtained with mixtures of various raw materials and that can have wide pH fluctuation. What would be the best source of K? The answer must be after you use the pHmeter.

There are several soluble products or liquids that may already have strong influences on pH and can be applied via fertigation. The agronomic decision depends on having the information to make management decisions in choosing the most desired fertilizers characteristics of pH, EC and nutrient content to give the correct answer for plant needs and adjust the doses to be applied.

See in the section Questions & Answers. the question 33 about new products, a large discussion about the PeKacid, AcidNPK formulas, and the pH chock treatment patented for control of pests and diseases.

Premise No. 3 - ppm:

Part per million. There are 6 zeros of differences that can be mg/kg or g/ton, or ml/m^3. 1 kg has 1 million mg; 1 ton has 1 million g; 1 m^3 has 1 million ml.

On the other hand, the percentage % has 2 zeros 1:100

While ppm has 1:1,000,000

Taking out 2 zeros of 1 million we get 10,000, so 1% = 10,000 ppm.

Keeping then the 4 zeros difference, we can say that the concentration of 1000 ppm = 0.1%.

It is preferable to say for example that we have 500 ppm of K than 0.05% K, even if they are exactly the same, to avoid use fractional numbers at level of percentage %.

The nutrient guarantees of commercial soluble fertilizers are all presented on their bags in %.

The nutrients analysis of the fast kits for identifying concentrations in soil solution is all in ppm.

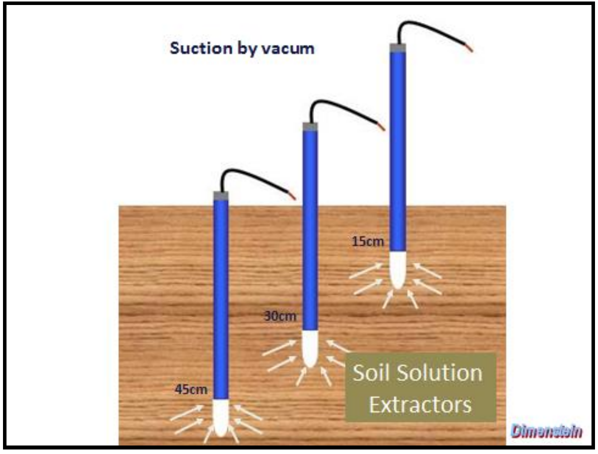
This method presented here aims to bring understanding of fertigation management to be used in ppm, which is a form of dosing concentrations, as well as the numbers presented on the fertilizers bags also in concentrations, but appear in % and we need to do the conversion to use everything in ppm that brings an understanding simple and straight to the farmer that will be able to use the simple golden rule of fertigation described in detail later in this text.

Premise No. 4 – Soil Solution Extractors (SSE) and fast test kits:

For irrigated crops the frequent collection of soil solution for fast analysis, replaces the traditional soil analysis by dynamic and ease in identifying only the available nutrients.

It is very practical compare two sequence collections with time interval, for example weekly, identifies the DELTA (Δ) between the two collections and decide the doses via fertigation. Example: If the nitrate last week was identified at 200 ppm and in the current week went to 150 ppm, we have a Δ = 50 ppm that indicates we lost this nitrogen and have the option to compensate it via fertigation to that dose to fill only the Δ, if the goal is to maintain the previous week's original 200 ppm. It is a game of identifying the current status, comparing with the previous collected sample of soil solution and manipulates the doses of fertigation to the desired values that must consider the sum of all the nutrients for total salinity measured by the EC in the physiological range for each crop.

Identify the Δ of the various nutrient’s parameters have one interpretative weight higher than for absolute values.



The collection samples of soil solution can be done easily through the use of tubes called Soil Solution Extractors (SSE) (see pictures) which must be introduced into the soil in 3 depths, usually 15, 30 and 45 cm, and with the aid of a syringe is done extracting the air to form vacuum and force the suction of soil solution by the porous ceramic tip of these tubes when the soil is wet, i.e. at the end of an irrigation when the soil is close to field capacity near the saturation level of water retention by soil that is the ideal time to trigger the vacuum, and while repeating the removal of air by at least 3 times one can realize that the syringe plunger comes with difficulty indicating that the suction tube is under vacuum. However, if the syringe plunger comes easily is a sign that there is no vacuum. In dry soil you can't do the vacuum. After about 2 hours of waiting under vacuum action to fill the tube with the soil nutrient solution and release the vacuum to collect the sample from the SSE. After release the vacuum in the SSE, use a syringe to collect the samples. The syringe of 60 ml with Luer-Lok tip to allows safe connection to SSE. Then we can start the fast measure the EC to know the level of salinity in each horizon deep where it distributes the nutrients into the wet soil around the root system. These tubes SSE do a mimic to imitate exactly what the roots are absorbing of only the available nutrients from the soil solution in each collected sample depth.

Then the other kits complement the data of pH in soil solution and detail the concentration for each relevant nutrient like N, P, K, Ca, S, Cl, and now the new kits for Micronutrients available for Cu and Fe, to identify only available nutrients and their distribution in 3 depth of soil to ease see if there are leaching or good nutrient distribution around the roots. For the other Micronutrients there is no compatible scale for the agriculture range for B, Mn and Zn. So, soon we hope to get also kits for these nutrients.

The main kits of nutrients of colorimetric titration, test strips and turbidity:

Nitrate &Nitrite - The two reactants in colorimetric test strip represent the concentrations of Nitrate (NO_3^-) to the end reagent whose scale goes up to 500 ppm; and the second reagent to Nitrite (NO_2^-) up to 80 ppm.

Nitrate (NO_3^-) is beneficial and useful nutrient to the plants while the presence of Nitrite (NO_2^-) is toxic to plants, as already explained in the previous text.

Ammonium

There is also a kit colorimetric test strip to measure **Ammonium NH_4^+** that is not suitable for tropical climate or to the hot period in other temperate regions because the speed of Nitrification of Ammonium is 1-2 days when the soil temperature is > 30°C. In this case the ammonium kit would score zero because the whole N would pass quickly to Nitrate. In warmer climes with soil temperatures between 15°C to 25°C the Ammonium is available in the soils between 1-3 weeks. Temperature < 8°C shows no nitrification because below this cold soil temperature nitrifying bacteria cease to reproduce.

Phosphate – Both phosphate kits of the above pictures are colorimetric test strips. The main differences are the use of additional reagents and the scale.

These fast phosphate kits present results in PO_4 and not in P_2O_5. To pass P_2O_5 for PO_4 multiply by 0.75. Example: NPK Formula 30-20-10, the 20 of P_2O_5 worth 15 of PO_4. The curiosity is that the agronomy of the 1920's years supposed that the plant roots absorb nutrients in the form of Oxides and they calculate the Phosphorus and Oxygen combination to get the P_2O_5 and then the fertilizer industry till today use P_2O_5 while later it was concluded that for Phosphorus the roots absorb Phosphates PO_4. The most available form is Orthophosphate HPO_4^{--}.

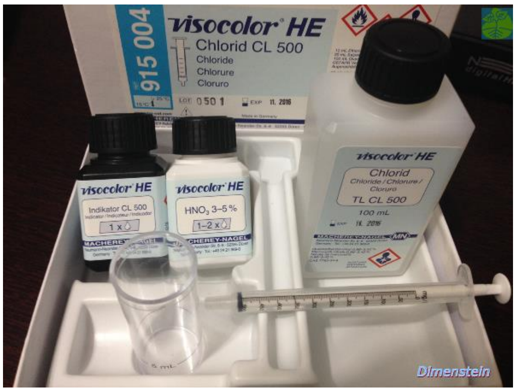
Optimal levels of PO_4 in soil solution depend on soil texture. 25 ppm for heavy clay and 50 ppm for light sandy soils. Intermediary levels for soil textures moderate to be between 30 – 40 ppm. Above 50 ppm, only for hydroponics that can stay between 60 to 100 ppm of PO_4.

Potassium – The scale of the Potassium kit starts at 200 ppm. It is normal in the early stages of growing, vegetative stage of crops keep the K^+ below 200 ppm and in this case may have the false impression that the value would be zero, but remember that 200 ppm is about 5 K^+ equivalents (39 x 5 = 195 ppm) and this implies that the K^+ may be contributing to up to 0.5 mS/cm in the EC, even if this test strip doesn't show at least 200 ppm that is limiting the scale of this colorimetric kit. However, in the following phases of the crops with greatest needs of K^+ range caters well to the goal of monitoring between 200 and 700 ppm.

The Potassium kit read the ion K^+, while the commercial fertilizers present Potassium as K_2O as oxide based on the same criterium from the 1920’s years when the agronomy supposed that the plant roots absorb nutrients as oxides and for Potassium, they got K_2O, but later it was concluded that the correct is the cation K^+. The fertilizer industry continues using K_2O as the commercial content of this nutrient in the fertilizers. The conversion of K_2O to K multiplies by 0.83. Example: KCl with 60%, K_2O is 60 x 0.83 = 49.8 that is around ~50 of pure K.

The industries of fertilizes still use format of Oxides presented to the commercial fertilizers like for phosphates and for potassium, they use also for Calcium CaO instead of the correct Ca^{++}, for Magnesium MgO instead of Mg^{++} and for Sulfur is more complicated because they got SO_3^{--} (Sulfite) while the correct is really one Oxide but with one additional Oxygen to get SO_4^{--} (Sulfate), and some countries adopt the pure S.

Calcium- Fill the container with 5 ml of the solution sample collected in soil solution extractors. Add 2 drops of reagent "**NaOH 5-20%**" and give a brief stirred and the sample may be turbid (when the solution is not fully transparent). Add 2 drops of the other reagent on the black small bottle that is an indicator solution "**Indikator CA 20**" and again give a brief stirred and the solution will turn red. However, if the solution turns blue means no calcium is present in the sample. If the color is red continue the test. Now fill the syringe with the solution of the larger bottle called "**Calcium TL CA 20**", is the bottle of 100 ml. Syringe has two scales in ºd or in mmol/L. The best suggestion is to use the scale in mmol/L, whereas 1 mmol/L = 40 mg/L (ppm) of calcium. On another scale would be conversion to 5.6°d = 40 mg/L (ppm). So, let's drip enough solution with the syringe until the red color changes to blue in a simple titration. When the color flip from red to blue just watching in the syringe as you spent and for each 1 mmol/L x 40 = ppm calcium concentration in the sample. If you spend the entire volume of the syringe worth 3.5 mmol/L x 40 = 140 ppm and color not turn from red to blue, you must continue refill the syringe to continue the titration indicates that the sample must contain a greater concentration of calcium.



Chloride – There are titration kits available. One of them uses the 3rd reagent in ml used to change the yellow to blue/violet color and multiply by 1000 to get the result in ppm. Observe the scale used in the syringe that has scale to 1 ml to identify how much spent on that scale of the syringe and the result multiply by 1000 to get mg/L = ppm. If you spend for instance, half the volume of a syringe will be 0.5 ml x 1000 = 500 ppm of chloride in the sample. If for example, spend 0.3 ml x 1000 = 300 ppm chloride. If you double the initial sample volume instead of 5 ml to be 10 ml, the volume spent on syringe for the third reagent would be multiplying by 500 instead of 1000 due the dilution. Example: spent in the syringe to the solution turn violet for the volume of 0.5 ml x 500 = 250 ppm.

Other manufacturer of Chloride kits is similar, but the syringe presents the result already in ppm.

Sulfate –It is a different test kit of turbidity. See in the picture that the tube on the left side has one **X** on the bottom of the container and the cloudy solution will be added gradually as you observe from above of this tube until you no longer can see the **X** on the bottom of the container covered by the cloudy solution that has been prepared in another tube on the right side of the photo it can be for 10 or 20 ml. The normal procedure is with 20 ml of the sample. They add the 10 drops of reagent **SO_4^-1** (there are 2 equal bottles of that first reagent); then add the second reagent **SO_4^-2** that is the measure of a small spoon in the small black bottle that is a salt, and shake the tube to mix. At this moment the solution gets a cloudy and turbidity aspect only if there are Sulfates in this solution. If the solution stays clear and transparent crystalline, we can conclude that no Sulfates in the sample. Now if you add gradually blurred solution in another tube that has the **X** mark on the bottom of the container and is observed over the tube until you no longer get to see this **X** and read the value of the scale of this tube that goes from 25 to 200 mg/L (ppm). If you want to duplicate the scale of 200 to 400 mg/L (ppm), just fill the tube on the right since the beginning with only 10 ml of sample and make up to 20 ml with pure water.

As already commented before, the absorption form of Sulfur is Sulfate ($SO4^{--}$) while on the commercial fertilizers bags it is presented as Sulfite ($SO3^{--}$). To convert Sulfite to Sulfate we need to multiply by 1.2. To convert from Sulfite to pure S we need to multiply by 0.4. Example: For the fertilizer SOP – Sulfate of Potassium that contain 45% of Sulfite. 45 x 1,2 = 54% of Sulfate. 45 x 0,4 = 18% of pure S.

Based on the same conversion principle, for the Potassium content in the SOP - Sulfate of Potassium with content of 50% K_2O and to get the pure K we need to multiply by 0,83 to get 41,5% of K.

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Magnesium – Fill the container with 1 ml of the solution sample collected in soil solution extractors + 4 ml of pure water or tap water with EC close to zero. Add 1 ml of reagent "**MG-1**" and a small spoon of the reagent “**MG-2**” that is a salt and will immediately dissolve after give a brief stirred and the sample will turn red or pink. Now start the titration drop by drop using a syringe of 1 ml with the reagent “**MG-3**” till the solution color changes to blue and check the volume used in the scale of the syringe. Observe that for the used volume of 0,01 ml = 3 ppm of Mg; at this same proportion, for a volume of 0,1 ml of this last reagent “MG-3” means = 30 ppm of Mg and for a full syringe using 1 ml = 300 ppm de Mg.

Copper

Copper – Is a colorimetric test strip. Fast and simple of use with a very friendly scale and we suggest maintain the Cu level in the soli solution between 10 to 30 ppm. This is a security range to get compatible concentration for this micronutrient avoiding wastes for high application rates.

Important observation: This kit is sensitive only for the ionic form, but not for chelates. If the grower uses via fertigation with Copper in the chelates, it will be available to roots, but this specific kit will show zero because it is sensitive only to the ionic form and the chelates capture the cations and then release them to roots.

Iron – Same as described above for Copper.

Other Micronutrients – Still not available in the market of fast test kits and for few tests we find them, the scale is out of the agronomic ranges for fertigation. So, kit for Manganese, Zinc, Boron, Molybdenum, and also for Cobalt and Nickel we expect to get them for the future.

Interpretations

In fertigation the relative interpretation is the most appropriate, identifying the DELTA (Δ) between two analyses of the soil solution. Let's compare for each item, the current collection against the previous collection to identify the Δ.

If for example the pH was 6 and for one new collection it was 5.5 implies that the Δ was 0.5 more acidic and this indicates a tendency to acidify the soil solution which can be confirmed in the next collection of samples.

If for example the Nitrate kit presented 300 ppm and 200 ppm in the next collection presented, implies that we lost 100 ppm and the management decision is apply or not this rate of lost Nitrogen, considering that the desired Nitrate level would be 300 ppm in this example.

If the Phosphate was identified as 10 ppm and the next week, we got some increase to 25 ppm, but the ideally desired level would be 50 ppm. Then we would still have to apply +25 ppm of Phosphate. Even with improved in relation to previous collection, was not enough to reach the desired concentration. This approach will inform the availability of nutrients and the grower must adjust the dose for the next fertigation and optimize the availability for the roots.

Quick kits are easy and giving practical guidance on nutrient levels, salinity (EC) and pH are valued information to facilitate decision making by minimizing the mistakes in choices of fertilizers and in doses to be applied. The majority of management errors are due to lack of minimum information about the availability of the nutrients, total salinity (EC), pH and leaching nutrients by exaggerated irrigation, that we can identify if the SSE at high depth (45 cm) get more nutrients and EC than the less depth SSE at 30 and 15 cm.

Would be unlikely for one grower after identify the soil solution pH as acid and continue new applications of acid fertilizer via fertigation to increase the size of the problem such as ammonium sulfate, Urea, Phosphoric Acid, etc. The opposite decision is the coherent and logic to immediate avoids the use of acid sources and give preference for some alkaline fertilizers such as Calcium Nitrate and Potassium Nitrate among others.

Would be unlikely also for one grower after identify in soil solution for example Calcium levels above 150 ppm when it would be sufficient between 60 and 100 ppm. The farmer that insists to apply more Calcium in this case get more than only a waste of fertilizer and money, but will cause more competition against other cations like K and Mg, beside the total salinity of excess of fertilizers.

The interpretations are intuitive and according to clear parameters and always the decisions for any fertigation correction are making logic by avoiding management mistakes just by tweaking of dosages and choice of the sources of fertilizer without kick and without gross errors. The monitoring is an effective tool to alert to avoid many errors of management decisions of fertigation and errors that the "recipes of cake" are subject to occur and fleeing, but now is very easy and obvious to identify and correct.

Premise No. 5 – Quantity X Concentration

Irrigated agriculture has inherited the quantitative criteria from no irrigated agriculture that typically uses the expressions such as kg/hectare or g/plant. This criterion defines quantities to apply over a crop season and using the irrigation only to split the doses that are already previously defined. From the mathematical point of view, it is OK. From the physiological point of view, we are light-years far from the ideal handling of the called fertigation. This distribution of fertilizers is now treated as "cake recipe", does not use any agricultural interpretation for decision, but use the estimated amounts of nutrients to get the desired productivity.

The uptake by roots of nutrients from a soil solution occurs under concentrations of salts (fertilizers) dissolved and we can handle the supply of these soluble fertilizers via frequent fertigations and manipulate the salt concentrations in mild and soft doses to keep the salinity within the desired limits and tolerances of each crop measured by EC and beyond influence decidedly in the composition of the salts that form the EC by changing the proportions according to the crop growth stages of development from vegetative, flowering, fruit, grain or tubers filling, ripening and harvest.

To work "concentration" we will need to migrate to another criterion of doses that is **g/m^3**.

Now let's bring the irrigated volumes to m^3 instead of using time in hours, when the irrigate farmer turn on the irrigation system for a period of time. It is common to say that irrigated an area for 3 or 4 hours, etc. If we know the flow of the emitters in L/hour, the number of emitters per line and number of lines per hectare, there will be a total volume that watering in m^3. It is important define volume of each irrigation to work concentration in **g/m^3**.

Another way to identify volume is when the irrigation company that developed the project, reports the irrigation capacity in mm and the conversion of mm x 10 = m^3/hectare. Example: a 4 mm irrigation = 40 m^3/hectare.

Solved the criterion and the identification of the irrigated volume in **m^3**, let's go to the next premise that will bringing the expressed guarantees of fertilizers, usually presented as percentage **%** on the fertilizers commercial bags to be expressed in **ppm** to be in the same concentration level of the used in the various fast kits presented in this methodology and no more recommend as quantity, but yes in concentration of each nutrient and the total salinity in soil solution.

The next step is a very practical method for decide doses of fertigation and bring all handling to be in ppm.

Premise No. 6 - "Golden Rule of Fertigation"

100 g/m³ = formula guarantee goes from % to ppm

This initial dose of 100g/m^3 converts % of nutrients of soluble fertilizers per each m^3 of irrigation to ppm.

The most important thing is that it is proportional, i.e. twice the concentration, would be 200g/m^3 provides double the warranty of the formula already presented in ppm. The proportionality is applied also for reduction, for instance if we use half the starting dose would be 50g/m^3 provides half the formula guarantee in ppm.

Example with a very popular soluble NPK formula 16-08-32 to apply via fertigation in a volume of 5 mm = 50 m^3 to irrigate 1 hectare. When using the "Golden Rule of Fertigation" in original proportion of 100g/m^3 x 50 m^3 would be a dose of 5kg per hectare of this formula during that irrigation day and each emitter (drip, micro sprinkler, other) would provide exactly 16 ppm N, 08 ppm of P_2O_5 and 32 ppm of K_2O in that area.

If we apply the default initial dose 5x, shall be 500g/m^3 and the guarantee of the formula goes from % to ppm 5x more concentrated, going from 16-08-32 (5x) to get 80-40-160 all in ppm of N-P_2O_5-K_2O.

The fertilizer industry uses for phosphorus and potassium **Oxides** expressions since the years 1930' because at that time the science believed that plants would absorb nutrients by roots in the oxide forms although we know nowadays that instead of P_2O_5 the correct absorption form is ionic as PO_4^{--} (Phosphate) and Potassium instead of K_2O the ionic form is the cation K^+ pure, without Oxygen. The kits presented here measure PO_4^{--} and not P_2O_5. The conversion from P_2O_5 to PO_4^{--} is multiply by 0.75. Also, the test kit for Potassium is K^+ and converts K_2O to K need to multiply by 0.83.

In the example above which applied 500g/m^3 reaching 80-40-160, the 40 ppm of P_2O_5 multiply by 0.75 = 30 ppm of PO_4^{--} and 160 ppm of K_2O multiply by 0.83 = 133 ppm of K^+.

The Oxides for other nutrients also need conversion:

CaO to Ca multiply by 0.71.

MgO to Mg multiply by 0.6.

For Sulfur the case is more curious because the oxide format used is SO_3, but the ionic form of absorption by roots is SO_4. The industry presents the % guarantees as SO_3 or as pure S. To convert SO_3 to SO_4 divide by 0.83. To convert SO_3 to S multiply by 0.39. To convert SO_4 to pure S multiply by 0.34.

Example or the Golden Rule of Fertigation using Urea 45% N and applying the standard dose via fertigation of 100g/m^3 provides exactly 45 ppm of N. If the volume is for instance 40 m^3/hectare, there will be 100g x 40 m^3 = 4 kg of Urea to apply in this fertigation day per hectare and from each emitter (drip or other irrigation equipment) this dose will give 45 ppm of N.

As this rule is proportional, just decide the dose per m^3 to get proportional dose in ppm. If we double the standard proportion to 200 g/m^3 it will provide 2x the guarantee for Urea 45 x 2 = 90 ppm.

Example using soluble white KCl with 60% K_2O and we want to apply for instance, 300 ppm of K_2O. If 100g/m^3 provides the guarantee of

60, to achieve the level of 300 ppm would be 5x, then 500g/m^3. If the watering volume desired for this irrigation would be 7 mm = 70 m^3/hectare, then 500 g x 70 m^3 = 35 kg of KCl and you apply in this hectare the 300 ppm of K_2O.

Convert 300 ppm of K_2O to pure K multiplies by 0.83 = 249 ppm of K and we can consider the round number of 250 ppm of K applied.

Parameters - suggested for some crops using the fast kits for the soil solution analysis. The suggested range for the nutrients considers the larger values for advanced growth stages up to maturation and the lower values for vegetative and flowering stages. Consider for Chloride values as the tolerance limit above this value the yields tend to decrease.

For the range of pH balance to the various nutrients are in soluble phase should be above and below 7.5 5.7.

The actual values given as parameters are intended to serve as a reference for future adjustments that according to research that will make case-by-case basis.

The experience we observe during several years in the irrigated fields alert us for the common and so-called "no intentional errors" that choose of wrong fertilizer as well wrong doses of application of certain fertilizers sometimes by excess or deficiency, due lack of data on which to base these decisions on the fertigations. The more important thing using this fertigation method is not to achieve 100% efficiency, but avoid wastes due feasible information that we can get ease access to minimize the “no intentional errors”.

Why one farmer would apply an acid fertilizer like ammonium sulfate or purified MAP, or phosphoric acid, if the pH identified in the soil solution collected by the SSE was < 5? For those cases that are common to occur this monitoring of soil solution will be helpful and serve as a guideline for choose some alkaline fertilizer trend as Calcium Nitrate, Magnesium Nitrate or Potassium Nitrate and get higher pH to correct the pH level in the soil solution.

If a farmer needs 150 ppm of Calcium and identified that there is already in the soil solution 200 ppm available, it doesn’t make sense to apply new fertigation to supply more calcium in this case unnecessary? It would be a waste and harmful causing overdose of this nutrient that would compete with other cations like Mg, K, and the micros as Mn, Zn, Cu and Fe.

These tables are the current parameters and sure they will be improved and adjusted in the future, however now they are our best reference for minimize involuntary errors of fertigation managements.

The following tables with the suggested parameters in soil solution for various cultures like fruit, vegetables, flowers, grains and forestry.

The suggested ranges of nutrients levels in ppm in the soil solution to consider the smaller values for young plants or vegetative phase and should increase gradually over the growth cycle until reaching maturation for the higher values and the goal would be to avoid the extremes, adjusting the fertigations to get values of nutrients within the suggested ranges. The experience teaches us that it is very common to be outside the ranges causing nutritional imbalances and inhibiting better performance and productivity of the potential possible.

Crop	EC mS/cm	pH	Cl^- (ppm)	NO_3^- (ppm)	PO_4^{--} (ppm)	K^+ (ppm)	Ca^{++} (ppm)	Mg^{++} (ppm)	SO_4^{--} (ppm)
Coffee arabica	**1 - 2,5**	**5,7 - 7,5**	**< 350**	**100 - 300**	**25 - 50**	**200 - 400**	**50 - 80**	**25 - 40**	**100 - 150**
Coffee conilon/Robusta	**1,5 - 3**	**5,7 - 7,5**	**< 450**	**150 - 350**	**25 - 50**	**200 - 500**	**80 - 120**	**40 - 60**	**80 - 120**
Citrus General	**1 - 3**	**5,7 - 7,5**	**< 400**	**100 - 300**	**25 - 50**	**200 - 600**	**60 - 120**	**30 - 60**	**90 - 180**
Orange	**1 - 3**	**5,7 - 7,5**	**< 400**	**100 - 300**	**25 - 50**	**200 - 600**	**60 - 120**	**30 - 60**	**90 - 180**
Limon	**1 - 2,5**	**5,7 - 7,5**	**< 400**	**150 - 300**	**25 - 50**	**200 - 450**	**60 - 100**	**30 - 50**	**90 - 180**
Tangerine	**1,5 - 3,5**	**5,7 - 7,5**	**< 400**	**100 - 300**	**25 - 50**	**200 - 600**	**60 - 120**	**30 - 60**	**60 - 120**
Greapfruit	**1 - 3**	**5,7 - 7,5**	**< 400**	**150 - 300**	**25 - 50**	**250 - 500**	**60 - 100**	**30 - 50**	**60 - 120**
Banana	**1,5 - 2,5**	**5,7 - 7,5**	**< 300**	**100 - 300**	**25 - 50**	**300 - 700**	**50 - 120**	**25 - 60**	**60 - 100**
Banana Plantain	**1,5 - 2,8**	**5,7 - 7,5**	**< 300**	**100 - 300**	**25 - 50**	**300 - 800**	**80 - 120**	**40 - 60**	**90 - 180**
Papaya	**1,5 - 3**	**5,7 - 7,5**	**< 300**	**150 - 300**	**25 - 50**	**200 - 600**	**50 - 80**	**25 - 40**	**60 - 100**
Grapes for wine	**1,5 - 4**	**5,7 - 7,5**	**< 300**	**150 - 250**	**25 - 50**	**300 - 800**	**80 - 120**	**40 - 60**	**60 - 100**
Grapes for table	**1 - 3**	**5,7 - 7,5**	**< 300**	**150 - 300**	**25 - 50**	**200 - 600**	**80 - 200**	**40 - 100**	**100 - 150**
Grapes seedless	**1 - 3**	**5,7 - 7,5**	**< 300**	**150 - 250**	**25 - 50**	**200 - 600**	**80 - 200**	**40 - 100**	**80 - 120**
Mango	**1 - 2,5**	**5,7 - 7,5**	**< 200**	**100 - 300**	**25 - 50**	**100 - 500**	**50 - 150**	**25 - 75**	**60 - 100**
Avocado	**1,5 - 3**	**5,7 - 7,5**	**< 350**	**150 - 300**	**25 - 50**	**200 - 500**	**60 - 120**	**30 - 60**	**60 - 100**
Passion fruit	**1,2 - 2**	**5,7 - 7,5**	**< 250**	**100 - 250**	**25 - 50**	**200 - 400**	**40 - 80**	**20 - 40**	**50 - 100**
Coconut	**1 - 2,5**	**5,7 - 7,5**	**< 600**	**150 - 350**	**25 - 50**	**200 - 500**	**40 - 80**	**20 - 40**	**40 - 80**
Peach Palm	**1,5 - 2,5**	**5,7 - 7,5**	**< 500**	**200 - 350**	**25 - 50**	**200 - 500**	**60 - 100**	**30 - 50**	**60 - 100**
Kiwi	**1,5 - 3**	**5,7 - 7,5**	**< 500**	**200 - 400**	**25 - 50**	**300 - 600**	**80 - 150**	**40 - 75**	**50 - 100**
Tamar	**2 - 4**	**5,7 - 7,5**	**< 1200**	**150 - 350**	**25 - 50**	**300 - 500**	**60 - 120**	**30 - 60**	**80 - 120**
Apple	**1,5 - 3**	**5,7 - 7,5**	**< 400**	**200 - 350**	**25 - 50**	**200 - 500**	**80 - 150**	**40 - 75**	**60 - 100**
Pear	**1,5 - 2,5**	**5,7 - 7,5**	**< 400**	**200 - 300**	**25 - 50**	**200 - 500**	**80 - 150**	**40 - 75**	**60 - 100**
Olive	**2 - 4**	**5,7 - 7,5**	**< 800**	**100 - 300**	**25 - 50**	**200 - 500**	**60 - 120**	**30 - 60**	**60 - 100**
Persimmon	**1,5 - 2,5**	**5,7 - 7,5**	**< 400**	**150 - 300**	**25 - 50**	**250 - 500**	**60 - 120**	**30 - 60**	**80 - 120**
Lychee	**1,5 - 3**	**5,7 - 7,5**	**< 400**	**150 - 350**	**25 - 50**	**250 - 550**	**60 - 120**	**30 - 60**	**60 - 100**
Cocoa	**1 - 2,5**	**5,7 - 7,5**	**< 300**	**100 - 300**	**25 - 50**	**150 - 500**	**50 - 150**	**25 - 75**	**60 - 100**

Crop	EC mS/cm	pH	Cl^- (ppm)	NO_3^- (ppm)	PO_4^{--} (ppm)	K^+ (ppm)	Ca^{++} (ppm)	Mg^{++} (ppm)	SO_4^{--} (ppm)
Pomegranate	**1,5 - 3,5**	**5,7 - 7,5**	**< 500**	**200 - 300**	**25 - 50**	**300 - 600**	**80 - 150**	**40 - 75**	**80 - 120**
Peach	**1,5 - 3**	**5,7 - 7,5**	**< 400**	**200 - 350**	**25 - 50**	**200 - 500**	**80 - 150**	**40 - 75**	**60 - 100**
Loquat	**1,5 - 3**	**5,7 - 7,5**	**< 400**	**200 - 350**	**25 - 50**	**200 - 500**	**60 - 120**	**30 - 60**	**60 - 100**
Plum	**1,5 - 3,5**	**5,7 - 7,5**	**< 400**	**200 - 400**	**25 - 50**	**250 - 550**	**80 - 150**	**40 - 75**	**80 - 120**
Apricot	**1,5 - 3**	**5,7 - 7,5**	**< 400**	**200 - 350**	**25 - 50**	**200 - 500**	**60 - 120**	**30 - 60**	**60 - 100**
Ciruela	**1,5 - 2,5**	**5,7 - 7,5**	**< 400**	**150 - 300**	**25 - 50**	**250 - 500**	**60 - 120**	**30 - 60**	**80 - 120**
Cherry	**1,5 - 3,5**	**5,7 - 7,5**	**< 400**	**100 - 300**	**25 - 50**	**300 - 600**	**80 - 150**	**40 - 75**	**60 - 100**
Fig	**1,5 - 3,5**	**5,7 - 7,5**	**< 500**	**200 - 300**	**25 - 50**	**300 - 600**	**80 - 150**	**40 - 75**	**80 - 120**
Almonds / Nuts	**1,5 - 3,5**	**5,7 - 7,5**	**< 600**	**150 - 300**	**25 - 50**	**300 - 600**	**80 - 150**	**40 - 75**	**80 - 120**
Pistachio	**1,5 - 3,5**	**5,7 - 7,5**	**< 600**	**150 - 300**	**25 - 50**	**300 - 600**	**80 - 150**	**40 - 75**	**80 - 120**
Macadamia	**1,5 - 3,5**	**5,7 - 7,5**	**< 600**	**150 - 300**	**25 - 50**	**300 - 600**	**80 - 150**	**40 - 75**	**80 - 120**
Carambola	**1 - 2,5**	**5,7 - 7,5**	**< 300**	**100 - 300**	**25 - 50**	**150 - 500**	**50 - 150**	**25 - 75**	**60 - 100**
Pitanga	**1 - 2,5**	**5,7 - 7,5**	**< 300**	**100 - 300**	**25 - 50**	**200 - 500**	**50 - 150**	**25 - 75**	**60 - 100**
West Indian Cherry	**1,5 - 3**	**5,7 - 7,5**	**< 450**	**200 - 300**	**25 - 50**	**250 - 600**	**60 - 120**	**30 - 60**	**90 - 140**
Casheu	**1,5 - 3**	**5,7 - 7,5**	**< 500**	**200 - 300**	**25 - 50**	**250 - 600**	**80 - 150**	**40 - 75**	**80 - 120**
Jackfruit	**1 - 2,5**	**5,7 - 7,5**	**< 400**	**150 - 350**	**25 - 50**	**250 - 500**	**50 - 150**	**25 - 75**	**60 - 100**
Spondias mombin	**1 - 3**	**5,7 - 7,5**	**< 350**	**150 - 300**	**25 - 50**	**200 - 600**	**80 - 120**	**40 - 60**	**100 - 150**
Sugar apple	**1,5 - 3,5**	**5,7 - 7,5**	**< 400**	**150 - 300**	**25 - 50**	**200 - 500**	**80 - 150**	**40 - 75**	**80 - 120**
Hancornia	**1 - 3**	**5,7 - 7,5**	**< 350**	**150 - 300**	**25 - 50**	**200 - 600**	**80 - 120**	**40 - 60**	**100 - 150**
Soursop	**1,5 - 3,5**	**5,7 - 7,5**	**< 400**	**150 - 300**	**25 - 50**	**200 - 500**	**80 - 150**	**40 - 75**	**80 - 120**
Guava	**1 - 2,5**	**5,7 - 7,5**	**< 400**	**100 - 300**	**25 - 50**	**200 - 450**	**50 - 120**	**25 - 60**	**60 - 100**
Raspberry	**1,5 - 3**	**5,7 - 7,5**	**< 500**	**200 - 300**	**25 - 50**	**250 - 600**	**80 - 150**	**40 - 75**	**80 - 120**
Blackberry	**1,5 - 3**	**5,7 - 7,5**	**< 500**	**200 - 300**	**25 - 50**	**250 - 600**	**80 - 150**	**40 - 75**	**80 - 120**
Pineapple	**2 - 3,5**	**5,7 - 7,5**	**< 800**	**100 - 300**	**25 - 50**	**500 - 800**	**60 - 100**	**30 - 50**	**100 - 150**

Crop	EC mS/cm	pH	Cl^- (ppm)	NO_3^- (ppm)	PO_4^{--} (ppm)	K^+ (ppm)	Ca^{++} (ppm)	Mg^{++} (ppm)	SO_4^{--} (ppm)
Tomato	**1,5 - 3**	**5,7 - 7,5**	**< 500**	**150 - 300**	**25 - 50**	**200 - 600**	**60 - 150**	**30 - 75**	**70 - 120**
Cherry Tomato	**1,5 - 4**	**5,7 - 7,5**	**< 700**	**150 - 300**	**25 - 50**	**300 - 800**	**60 - 150**	**30 - 75**	**90 - 140**
Melon / Watermelon	**1 - 3**	**5,7 - 7,5**	**< 400**	**100 - 300**	**25 - 50**	**200 - 600**	**60 - 100**	**30 - 50**	**60 - 100**
Onion / Garlic	**1 - 1,8**	**5,7 - 7,5**	**< 300**	**150 - 300**	**25 - 50**	**200 - 400**	**60 - 100**	**30 - 50**	**70 - 120**
Pepper	**0,8 - 2**	**5,7 - 7,5**	**< 300**	**100 - 300**	**25 - 50**	**150 - 400**	**40 - 80**	**20- 40**	**60 - 100**
Hot Pepper	**0,8 - 1,5**	**5,7 - 7,5**	**< 300**	**100 - 200**	**25 - 50**	**150 - 300**	**40 - 80**	**20 - 40**	**50 - 80**
Piper Nigrum	**1,2 - 2,5**	**5,7 - 7,5**	**< 400**	**100 - 300**	**25 - 50**	**200 - 400**	**60 - 100**	**30 - 50**	**100 - 150**
Potato	**0,8 -2,2**	**5,5 - 6,5**	**< 300**	**100 - 300**	**25 - 50**	**100 - 600**	**40 - 60**	**20 - 30**	**60 - 100**
Sweet Potato	**1 - 2**	**5,7 - 7,5**	**< 300**	**100 - 300**	**25 - 50**	**200 - 400**	**50 - 100**	**25 - 50**	**40- 80**
Lettuce	**0,6 - 1,8**	**5,7 - 7,5**	**< 200**	**150 - 250**	**25 - 50**	**100 - 250**	**60 - 100**	**30 - 50**	**40- 80**
Rucola	**0,7 - 1,5**	**5,7 - 7,5**	**< 200**	**150 - 250**	**25 - 50**	**100 - 250**	**60 - 100**	**30 - 50**	**40- 80**
Chard	**1,2 - 1,8**	**5,7 - 7,5**	**< 300**	**150 - 300**	**25 - 50**	**150 - 300**	**60 - 100**	**30 - 50**	**50 - 100**
Cress	**0,7 - 1,5**	**5,7 - 7,5**	**< 200**	**150 - 250**	**25 - 50**	**100 - 250**	**60 - 100**	**30 - 50**	**40 - 80**
Cabbage	**1,2 - 1,8**	**5,7 - 7,5**	**< 300**	**150 - 300**	**25 - 50**	**150 - 300**	**60 - 100**	**30 - 50**	**50 - 100**
Strawberry	**0,8 - 2,2**	**5,7 - 7,5**	**< 300**	**150 - 300**	**25 - 50**	**150 - 550**	**60 - 80**	**30 - 40**	**60 - 100**
Cucumber / Zucchini	**1,2 - 2**	**5,7 - 7,5**	**< 300**	**150 - 300**	**25 - 50**	**150 - 300**	**60 - 100**	**30 - 50**	**40 - 80**
Pumpkin	**1,5 - 2,5**	**5,7 - 7,5**	**< 350**	**200 - 300**	**25 - 50**	**250 - 400**	**60 - 120**	**30 - 60**	**50 - 100**
Eggplant	**1,2 - 2**	**5,7 - 7,5**	**< 300**	**150 - 300**	**25 - 50**	**150 - 300**	**60 - 100**	**30 - 50**	**50 - 100**
Beet / Sugar Beet	**1,5 - 3**	**5,7 - 7,5**	**< 500**	**150 - 300**	**25 - 50**	**200 - 500**	**60 - 150**	**30 - 75**	**70 - 120**
Carrot	**0,8 - 1,8**	**5,7 - 7,5**	**< 300**	**100 - 200**	**25 - 50**	**100 - 300**	**50 - 100**	**25 - 50**	**40 - 80**

Crop	EC mS/cm	pH	Cl^- (ppm)	NO_3^- (ppm)	PO_4^{--} (ppm)	K^+ (ppm)	Ca^{++} (ppm)	Mg^{++} (ppm)	SO_4^{--} (ppm)
Yam	1,2 - 1,8	5,7 - 7,5	< 400	100 - 300	25 - 50	200 - 400	60 - 100	30 - 50	40 - 80
Chayote	1,2 - 2	5,7 - 7,5	< 300	150 - 300	25 - 50	150 - 300	60 - 100	30 - 50	40 - 80
Gumbo	1 - 2	5,7 - 7,5	< 300	150 - 250	25 - 50	200 - 400	50 - 100	25 - 50	40- 80
Ginger	1 - 2	5,7 - 7,5	< 300	150 - 250	25 - 50	150 - 300	50 - 100	25 - 50	40 - 80
Spinach	1 - 2	5,7 - 7,5	< 300	100 - 300	25 - 50	150 - 300	50 - 100	25 - 50	40 - 80
Couve / Broccoli	1,2 - 1,8	5,7 - 7,5	< 300	150 - 300	25 - 50	150 - 300	40 - 80	20 - 40	50 - 100
Parsley / Coriander	0,7 - 1,5	5,7 - 7,5	< 250	150 - 250	25 - 50	100 - 250	60 - 100	30 - 50	40 - 80
West Indian Gourd	1 - 2	5,7 - 7,5	< 300	150 - 250	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80
Mustard	1 - 2	5,7 - 7,5	< 300	100 - 300	25 - 50	150 - 300	50 - 100	25 -50	40 - 80
Turnip / Radish	0,8 - 1,8	5,7 - 7,5	< 300	100 - 200	25 - 50	100 - 300	50 - 100	25 - 50	40 - 80
Scarlet Eggplant	1 - 2,5	5,7 - 7,5	< 400	100 - 300	25 - 50	200 - 450	60 - 100	30 - 50	40 - 80
Peas	0,8 - 1,3	5,7 - 7,5	< 250	50 - 120	25 - 50	150 - 300	40 - 80	20 - 40	50 - 70
Peanut	1 - 2	5,7 - 7,5	< 350	50 - 120	25 - 50	150 - 300	60 - 100	30 - 50	40 - 80
Asparagus	2 - 4	5,7 - 7,5	< 800	150 - 350	25 - 50	300 - 500	60 - 120	30 - 60	90 - 140
Cassava	1,2 - 1,8	5,7 - 7,5	< 400	100 - 300	25 - 50	200 - 400	60 - 100	30 - 50	40 - 80
Arracacha	1 - 2	5,7 - 7,5	< 400	150 - 350	25 - 50	200 - 450	60 - 100	30 - 50	40 - 80
Mint	1 - 2	5,7 - 7,5	< 300	100 - 300	25 - 50	150 - 300	50 - 100	25 - 50	40 - 80
Basil	1 - 2	5,7 - 7,5	< 300	100 - 300	25 - 50	150 - 300	50 - 100	25 - 50	40 - 80

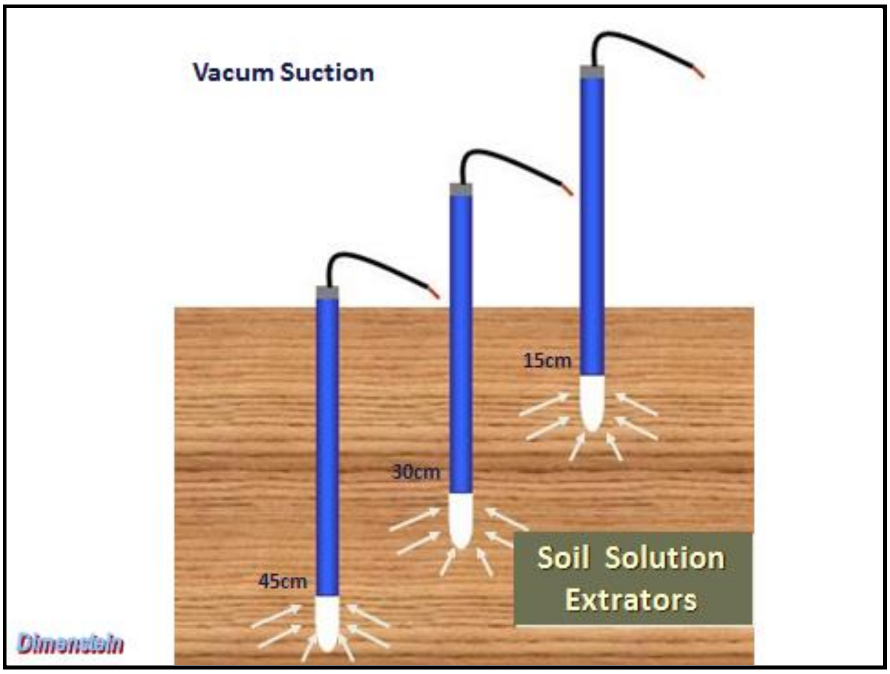
Crop	EC mS/cm	pH	Cl^- (ppm)	NO_3^- (ppm)	PO_4^{--} (ppm)	K^+ (ppm)	Ca^{++} (ppm)	Mg^{++} (ppm)	SO_4^{--} (ppm)
Eucalyptus	0,8 - 1,5	5,7 - 7,5	< 350	100 - 200	25 - 50	150 - 300	40 - 60	20 -30	40 - 80
Pinus	1 - 2	5,7 - 7,5	< 400	100 - 300	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80
Rubber Tree	1 - 2	5,7 - 7,5	< 400	100 - 250	25 - 50	150 - 350	50 -80	25 - 40	40 - 80

Crop	EC mS/cm	pH	Cl^- (ppm)	NO_3^- (ppm)	PO_4^{--} (ppm)	K^+ (ppm)	Ca^{++} (ppm)	Mg^{++} (ppm)	SO_4^{--} (ppm)
Flowers (General)	1 - 2	5,7 - 7,5	< 200	100 - 300	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80
Roses	1,2 - 2,5	5,7 - 7,5	< 200	100 - 300	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80
Orchid	0,8 - 1,5	5,7 - 7,5	< 200	100 - 250	25 - 50	150 - 300	50 -80	25 - 40	40 - 80
Alpine	1 - 2	5,7 - 7,5	< 200	100 - 300	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80
Heliconia	1 - 2	5,7 - 7,5	< 200	100 - 300	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80
Carnation	1,2 - 2,5	5,7 - 7,5	< 200	100 - 300	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80
Anturios	1 - 2	5,7 - 7,5	< 200	100 - 300	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80
Gerbera	1 - 2	5,7 - 7,5	< 200	100 - 300	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80
Gipsofilo	1 - 2	5,7 - 7,5	< 200	100 - 300	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80
Impatins	0,8 - 1,5	5,7 - 7,5	< 200	100 - 250	25 - 50	150 - 300	50 - 80	25 - 40	40 - 80
Violet	1 - 1,8	5,7 - 7,5	< 200	100 - 300	25 - 50	200 - 350	50 - 100	25 - 50	40 - 80
Tulip	1 - 2	5,7 - 7,5	< 200	100 - 300	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80
Lisianthus	1 - 2	5,7 - 7,5	< 200	100 - 300	25 - 50	200 - 400	50 - 100	25 - 50	40 - 80

Crop	CE mS/cm	pH	Cl^- (ppm)	NO_3^- (ppm)	PO_4^{--} (ppm)	K^+ (ppm)	Ca^{++} (ppm)	Mg^{++} (ppm)	SO_4^{--} (ppm)
Cotton	1,2 - 3	5,7 - 7,5	< 700	150 - 400	25 - 50	250 - 800	80 - 140	40 - 80	70 - 120
Bean / Soybean	0,8 - 1,3	5,7 - 7,5	< 250	50 - 120	25 - 50	150 - 300	40 - 80	20 - 40	50 - 70
Corn	1 - 2,5	5,7 - 7,5	< 500	100 - 300	25 - 50	150 - 400	50 - 100	25 - 50	70 - 120
Sorgho	1,5 - 3	5,7 - 7,5	< 500	100 - 300	25 - 50	200 - 450	60 - 120	30 - 60	70 - 120
pasture	1,5 - 2,5	5,7 - 7,5	< 700	200 - 400	25 - 50	150 - 400	60 - 120	30 - 60	90 - 140
Wheat	1,5 - 2	5,7 - 7,5	< 400	150 - 300	25 - 50	200 - 400	50 - 100	25 - 50	60 - 100
Rice	1 - 2	5,7 - 7,5	< 400	100 - 250	25 - 50	150 - 300	40 - 80	20 - 40	90 - 140
Sunflower	1 - 2	5,7 - 7,5	< 350	100 - 250	25 - 50	100 - 400	60 - 120	30 - 60	60 - 100
Castor Bean	1,5 - 3	5,7 - 7,5	< 500	150 - 300	25 - 50	200 - 500	60 - 150	30 - 75	70 - 120
Oat	1,5 - 2,5	5,7 - 7,5	< 500	100 - 300	25 - 50	150 - 400	60 - 120	30 - 60	90 - 140
Canola	1,5 - 2,5	5,7 - 7,5	< 500	100 - 300	25 - 50	150 - 400	60 - 120	30 - 60	90 - 140
Rye	1,5 - 2,5	5,7 - 7,5	< 500	100 - 300	25 - 50	150 - 400	60 - 120	30 - 60	90 - 140
Barley	1,5 - 2,5	5,7 - 7,5	< 500	100 - 300	25 - 50	150 - 400	60 - 120	30 - 60	90 - 140
Sugar Cane	1 - 2	5,7 - 7,5	< 500	100 - 250	25 - 50	100 - 400	40 - 80	20 - 40	60 - 100

Questions & Answers about Fertigation

1. **Why use 3 depths of Soil Solution Extractors (SSE) and why 15, 30 and 45 cm?**



Identify whether the distribution of salts (fertilizers) in the soil horizons are homogeneous or heterogeneous. Compare the EC on 3 depths and observe if the difference is less than 0.5 mS/cm that is tolerated to be considered homogenous.

Example:

EC to 15 cm = 1.5 mS/cm,

EC to 30 cm = 1.7 mS/cm,

EC to 45 cm = 2 mS/cm.

Homogenous and this means that the irrigation volume is correct.

However, if the difference is greater than 0.5 mS/cm and the SSE tube of 45cm, indicating leaching by excess of irrigation water applied, or eventually due rain. See example below:

EC to 15 cm = 1 mS/cm,

EC to 30 cm = 1.8 mS/cm,

EC to 45 cm = 2.5 mS/cm

Note that in this example we have far greater salinity at 45 cm indicating strong leaching. The handling in this case would be to reduce watering and adjust the volume to get the objective of homogenous EC distribution inside the soil with difference of EC < 0.5 mS/cm between the 3 depths.

Similarly, the opposite interpretation for SSE tube at 15 cm has the higher EC indicates that the irrigation volume was insufficient to better distribute the fertilizer salts to the deeper horizons.

Ideally, the 2 tubes of ESS of the depths of 15 and 30 cm should dominate the desired nutrition, while the third tube in the depth of 45 cm is our guarantee that there is no waste of nutrients out of the dominant active root system, if the deeper tube has EC higher, is a strong indication that even deeper will be with higher EC of presence of nutrients wasted. Deep nutrition is typical of dryland agriculture, whereas in irrigated, should induce the emission of roots and radicles in the upper soil horizons that improve the ability to absorb, while nurture deep roots or far apart laterally is far more expensive and inefficient because these roots are more for physical support and less for absorption because they suberized and woody when they pass a dry period.

2. How to choose the fertilizer for fertigation and how to choose the source of N among the options of Urea, Ammonium or nitrate?

The answer is always based on the pHmeter.

Although many agriculturists choose fertilizers due the nutrient guarantees and prices, it would be prudent before identifying the pH of soil solution before deciding to apply fertilizers.

Example:

Let's choose a source of Nitrogen for the next fertigations after identify the soil solution pH is between 8 and 8.5.

We know that ammonium sources are acidifying, as well as Urea tends to be acidifying at the end of process in spite of the first reaction of Urea is alkaline, but the second reaction in the sequence is more acid. On the other hand, the sources of nitrate are alkalizing.

If the soil solution has already acid pH between 5 and 5.5, we should minimize the use of Ammonium and urea to give preference to Nitrates. The choose of the best fertilizers is really a question to the device pHmeter and keep the soil solution pH in levels that all nutrients will be soluble and available to roots uptake.

Soil solution pH between 5.7 to 7.5 is the range target and we must use different sources of fertilizers to maintain the pH into this range. If we use only one type of fertilizer throughout the crop growing cycle, the tendency is to get out of the proper range and frequent monitoring of soil solution would easily give us the necessary information about pH to direct the decisions about choose the correct fertilizers.

It is clear that this pH manipulation is done with many other fertilizers in addition to the sources of nitrogen from the example above.

For many years believed that there was a relationship between Nitrate/Ammonium to recommend based on an old trial with melon that had given the best result in proportion of 80% Nitrate / 20% Ammonium, however some years later proved that this ratio was suitable for irrigation waters acidic with pH between originally 5 to 5.5 and that ratio of Nitrate and Ammonium arrived at an excellent level of pH in soil solution between 6 and 7. Certainly this ratio with dominant Nitrates will elevate the pH and if the original irrigated water is already alkaline this recommendation doesn't make sense. So, there is no proportion ready to recommend between Nitrate/Ammonium but, only the pH in soil solution obtained with that ratio. Of course, there is no one best proportion previously defined, but in every case, we must make the adjustments considering the original irrigation water pH and pH obtained in soil solution and after some adjustments of doses to reach the desired pH and the ratio of Nitrate/Ammonium will not be never a ready recommendation and must be frequently checked to possible new adjust.

3. Fertigation is a complement of the conventional fertilization or should be 100% of the nutrients applied via fertigation instead of part of the fertilizer applied as base and side dressing? Is possibly eliminate the traditional soil fertilization to get total nutrition via fertigation?

This is a natural evolution that will occur as the educational level of the farmer increases. The main limit factor is cultural due the tradition practiced during long periods since before modern irrigation arrived to the market. The reliability and trust in fertigation efficiency is the key to migrate to 100% of nutrition via fertigation and it will occur gradually when the farmer confidence in the fertigations increases after some practice and convince the grower to this decision and he will identify without any doubt that there are doubly advantageous at lower cost and greater efficiency. This process can take time, as it enables the field teams for the correct handling with the soluble fertilizers and it is a trend in increasing fertigations and reducing the conventional fertilization. It is one education process and the manpower with compatible qualification is the bottleneck to pass stage and advance for the next step.

4. Doses of soluble phosphorus fertilizers via fertigation are small and frequent. Why?

The traditional soil fertilizers for phosphorus usually for base dressing is applied at very high amounts but at very low absorption efficiency due the limitations of low availability, that would be immobilized by clays presence in soil texture and the narrow pH range very restricted to keep the phosphates in soluble phase, besides reactivity with other ions causing precipitation. Below pH 5.7 phosphates starts reactions with Aluminum and even more acid below pH 5 phosphates reacts with Aluminum and also Iron and Manganese, forming insoluble precipitates. On the other side above pH 7.5 phosphates precipitates with dominant Calcium and at less intensity also with Magnesium.

The secret to the availability of soluble phosphorus applied via fertigation would be through small doses and very frequent, keeping the concentration in the soil solution between 40 to 60 ppm of P_2O_5. Example with a soluble formula of NPK 15-**10**-30, whose P_2O_5 is 10% and using the **"Golden Rule of Fertigation"** where **100 g/m^3**, the formula goes from **% to ppm**, and if in this example the volume per hectare is 50 m^3/hectare, it would be necessary to apply 100 g/m^3 x

50 m^3 = 5 kg of this formula 15-10-30 to supply the concentrations of 15 ppm of N, 10 ppm of P_2O_5 and 30 ppm of K_2O. In this context to achieve using this formula at least 40 ppm of P_2O_5 so the dose of this formula would be 4 x larger than the original "Golden Rule of Fertigation" of 100 g/m^3 to get the proportion 4x higher we get now 400 g/m^3 x 50 m^3 = 20 kg of formula. So, we reached the desired level of injection of P_2O_5 to be 40 ppm. Observe that the other nutrients of this formula also have provided N and K_2O 4x more than the guarantee of formula in ppm, that is 15 x 4 = 60 ppm of N, and 30 x 4 = 120 ppm of K_2O. In this case, the phosphorous was the base for the recommendation and to supply the usual higher demand for N and K_2O, other sources of these nutrients can be added.

The frequency of soluble phosphorus applications via fertigation must be at least 2 x a week for sandy soils and more frequent in clay soils of 3 x or more a week, and always in small doses to get between 40 to 60 ppm of P_2O_5. Applications at very small doses at daily base would be excellent and would need automation by a controller computer or a timer. The analysis of soil solution with quick kits will identify only the available nutrients free in that solution, but not the fixed and immobilized nutrients. The analyses identify phosphorus in the form of $PO_4^{--}$and not P_2O_5. The conversion is by multiplying by the factor 0.75 to pass P_2O_5 for PO_4. For Potassium analyses are always with the pure element K and not in the K_2O the conversion of K_2O to K is multiplying by 0.83.

Unit conversion example:

60 ppm of P_2O_5 converts by multiplying by 0.75 to get 45 ppm of PO_4.

100 ppm of K_2O converts by multiplying by 0.83 for 83 ppm of K.

To be clear this issue about Phosphorus let's give more detail and exemplify the management. The applications of conventional Phosphates in the form of granular fertilizers for application and incorporation into the soil is a traditional practice of dryland agriculture which is still widely practiced in irrigated agriculture. This is an evil heritage that has low efficiency in supply phosphorus to plants. Well, the secret is to be provided in small and frequent doses. Sources of soluble phosphorus which can be provided via fertigation only make sense, in the agronomic point of view if they are applied at low doses and repeatedly at high frequency. Phosphates are hold easily in the clays in a few days and new applications are necessary to ensure that there is available in soil solution. Example of dose to apply using a source of soluble phosphorus and very rich which is the Purified MAP (12-61-00). This has 61% P_2O_5 fertilizer and based on the "Golden Rule of Fertigation" where applying **100 g/m³** the formula goes from **% to ppm** and in a medium soil texture sandy-clay, it would be appropriate to take approximately 40 ppm of phosphate (PO_4) which is the form obtained in the tests of soil solution analysis. The conversion of P_2O_5 in PO_4 is done by multiplying by 0.75 and so 61 x 0.75 = 46 as rounded value. Therefore, if you apply the Golden Rule in a volume per hectare with irrigation of 50 m^3 as an example of volume, would be 100g x 50 m^3 = 5kg Purified MAP to be applied and from each dripper or irrigation emitter, would we be applying 46 ppm of PO_4 and this would be totally available phosphate for the roots absorption during 1 to 2 days and when the soil will be dry again, the phosphate would hold to clays and only a small fraction would be free and available, but then new fertigation would apply again phosphates in certain frequency to keep the soil solution next to 40 ppm. In addition, the use of Phosphate kit will inform you about the actual nutrient availability for the soil solution and the dose to be applied would be just missing to achieve the desired 40 ppm and the right decision of management would be to apply a mild dose of maintenance, if we have all 40 ppm available, and that's because this phosphate will soon become trapped in soil and unavailable. Therefore, the traditional fertilization of soil with large amounts of phosphorus are of low efficiency, expensive and require a logistics to apply and incorporate. If the farmer has irrigation system, it is much cheaper, simple and efficient to provide phosphates via fertigation and always in small and frequent doses.

In soluble NPK formulas for use via fertigation, give preference to low-phosphorus formulations and maintain higher NK because demand for plants for NK is much higher among these 3 nutrients.

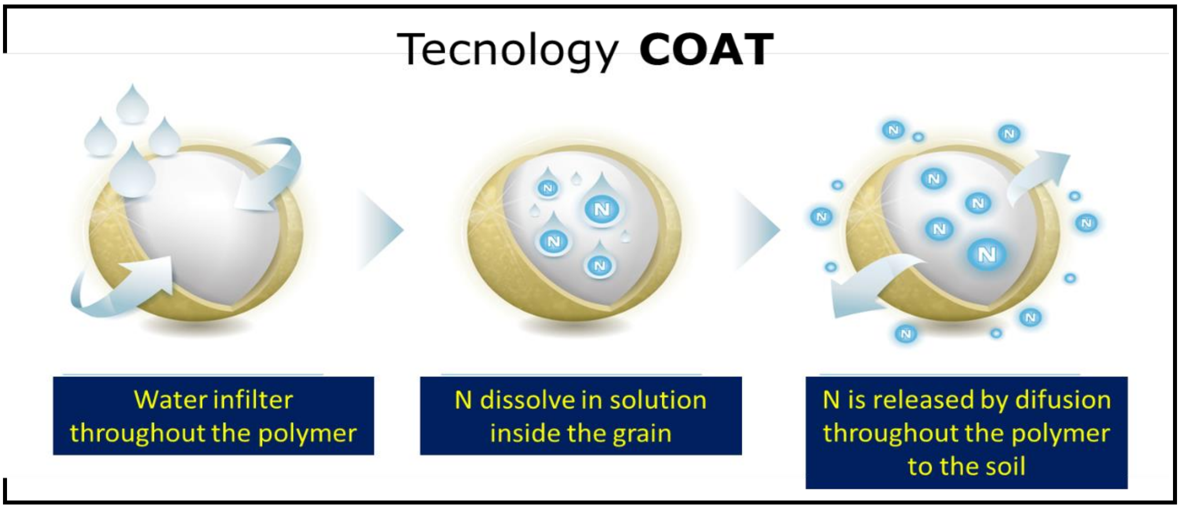
See in the question Nº33 about new products for fertigation, some descriptions and comments about the use of polyphosphate as part of raw materials for NPK blends that will do a revolution on the question of phosphate availability in soil.

Also, in the same question Nº33, the use of a new additive that we call as **RNA*** but it is not *ribonucleic acid* in this specific case, we change the abbreviation of these initials for **Release Nutrient Additive**, and it is a new development based on long chain amino acid that is a precursor of a new biodegradable chelate and patented by ADOB from Poland, called IDHA. This RNA* has strong influence in the release some cations from the soil by chelating them to release to the roots, and beside this phenomenon the preliminary trials of this new additive also release part of the phosphates from clays to the roots.

5. How should we act for fertigation during the rainy season that typically gives generous water during at least 3-4 months of the year?

Conventional fertilizers for soil application and products for soluble via fertigation are easily leached during these months of abundant rain, besides that the farmer normally does not trigger the irrigation during this period. However, we have some management options to discuss how applications of small irrigation just to have the sufficient time to apply concentrated nutrients whereas the soil is already wet, meaning it wouldn't be to give more water, but just to provide some nutrients via fertigation in runtime. This is feasible only in drip or micro sprinkler irrigation, but it would not be possible in pivot because time of watering for this type of equipment is too long, even at the highest speed that it can works.

Another management alternative for the rainy season during these 3 to 4 months is applied in soil fertilizers protected by cover of polymers, known as controlled or slow release fertilizers. The term controlled release is more suitable because the nutrient release rate is practically constant in controlled doses over time of release, called longevity. So, there are individual fertilizers based on Urea, or granulated soil MAP, or KCl, Potassium Nitrate, SOP and NPK in the same grain or blends of different NPK sources, that have usually longevities between 2 to 6 months depending on the thickness of the cover layers of polymers which will involve the grain of fertilizer. There are possibilities to get higher longevities using more thick layers, but this would be expensive. Below is a diagram illustrating the polymer technology to coat and protect the Urea. Considering the pure traditional Urea between 45% - 46% N, to cover with a thin layer of polymers formed N 44% with longevity up to 2 months. Increasing the thickness of polymers on Urea will also increase the longevity and decreases evidently N content, forming N 43%, or 42%, or 41% with longevities increasing to 3 up to 6 months when the N is released day by day at small and constant rhythm and minimize the leaching risk caused by the rains. There are different polymers for granular MAP and KCl and also different longevities. All of those fertilizers called COTES, protected by polymers can form different formulations blends and sure will certainly be very efficient to provide throughout the rainy season an interesting alternative when the fertigations nutrition would be less attractive.



Infiltration very little water through the polymer, but mainly water steam goes well easily within the grain, which will be condensed and dissolve the nutrient internally to form a solution that tends to escape by diffusion at constant rate by spreading gradually and steadily over time scheduled.

6. How often you should do fertigations?

The ideal is always that if you irrigate do a fertigation.

However, this question is unanswered, due to wide variation of practice in the field. The higher the frequency of fertigation with small doses, we consider the better situation regarding less salinity (EC) variations. If we have daily irrigations, but weekly fertigations (example), we will have on the day of fertigation 7 days of accumulated dose at once and this will increase suddenly the salinity which will be diluted over the next 6 days when it will receive only water. So, the EC strongly increases at the day of fertigation and is being diluted and washed in the rest of the week. The sequence of repetition of this practice at weekly base will cause ups and downs in the EC concentration of soil solution like accordion (music instrument) do causing the effect of frequent increases and decreases in soil solution salinity. This causes some physiologic stress to any plant.

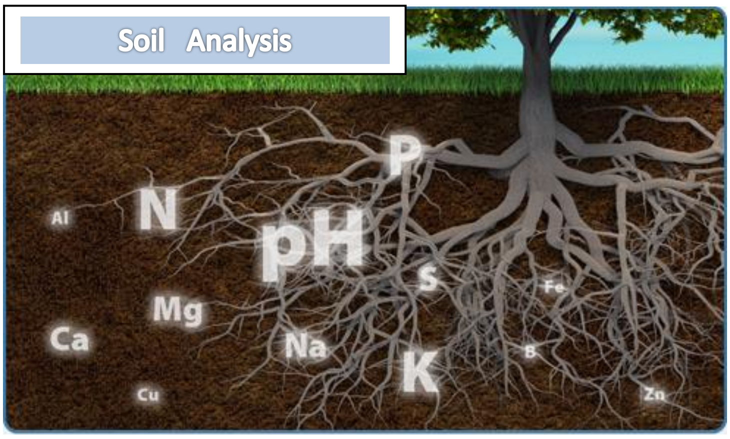
The evolution is controlling with automation via timers or small computers that open and close solenoids (electronic faucet) that meet the command via computer, tablet or even via mobile smartphone, to open and close the injection of dissolved fertilizer solutions from reservoirs with automation. There are no restrictions to prepare the fertilizer solutions previously. These solutions are stable and do not spoil.

Check the soli solution frequently is an important tool to get the information of the strong variations of the nutrients and total EC, if the fertigation intervals will be long and this will alert the grower to use more frequent fertigations and smooth fertilizers doses.

7. How proceed the correction if the original irrigation water (river, Lake, pond, well) have pH outside of the ideal range, or too acid or too alkaline?

The identification of the original pH of water is the first step for choosing the fertilizers for use via fertigation and later identify following the pH of soil solution using SSE tubes to get samples to check after the various nutrient's interaction with the components of the soil forming a stable solution in the wet bulb of soil. From there make frequent follow-up dose adjustments using the fertilizers with acid or alkaline trend to gradually achieve desired pH. In sandy soils this process is fast and easy using relatively mild doses, however for clay soils, the buffer power of these soils can be quite resistant to pH changes in soil solution and demand high doses of fertilizers and could take more time to get corrections of the pH to the desired levels.

8. Traditional soil analysis can help?



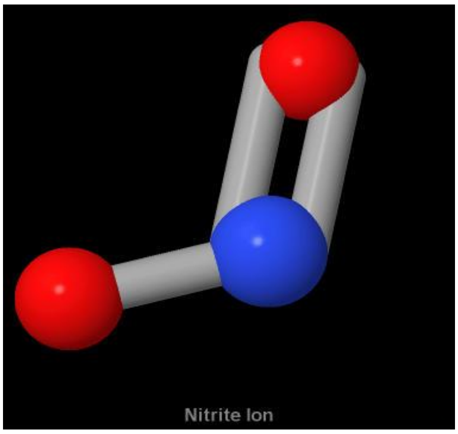
No. It cannot help. Often a traditional soil analysis makes confusion and causes some disturbs on get frequent decisions regarding fertigation handling because the nutrients status in irrigated soil is so dynamic that would need updates also very frequent, but nobody would execute soil analysis more than once per season or once for 2 seasons. For sure, it is not enough for irrigation areas. This is because the fertigations are very dynamic and the soil analysis become obsolete very quickly. For every fertigation, everything changes in relation to nutrients, besides traditional soil analyses measuring the available + fixed nutrients not available. Also, the method of measuring such analyses of soil saturated extract using 1 portion of soil to 2.5 parts water and use distilled water and this proportion is different from what is in nature soils and also the distilled water should be replaced by the irrigation water to be more faithful to reality. As soon as the soil analyses do not meet what we want of up-to-date information and faithful the reality of the field. Unlike the soil solution collected with suction tubes Soil Solution Extractors (SSE) are faithful to the roots are absorbing only from the available nutrients and this reality ideal for management and make decision on selection of appropriate fertilizers for fertigation and their doses.

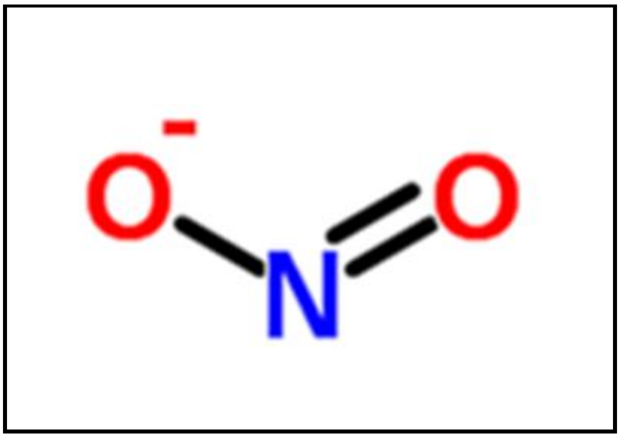
9. What about foliar and tissue analysis?

The foliar or tissue analysis are just the confirmation that the nutrients arrived or not from soil solution to these sink places in plants that seems healthy and productive to serve as reference of good nourish level for leaves and/or tissues. If identify any nutrient at low level, this cannot be conclusive that this nutrient lacks in soil. The availability in soil can be pH-dependent in spite of the quantity of this nutrient in the soil. Other situation is even at good quantity in soil, if other nutrient is present at exaggerated level and cause by competition deficiency in leaves and tissues. This kind of analysis is not enough to use them for fertigation management and decide the fertilizers sources and rates of application.

Example: one grapes producer collected for every 4 months intervals leaves samples for foliar analysis and repeat them again and again every 4 months during 2 years, that sum the total of 6 times of these foliar analysis and always got Iron and Phosphorus deficiencies. During these 2 years he increased the fertigation rates for both Iron and Phosphates, every time he applied larger doses of iron and phosphorus, using different fertilizers sources including chelates for Iron and different soluble Phosphates available in the market. However after 2 years without resolving the problem of the lack of Iron and Phosphorus in foliar analysis, we identified that it was not a quantitative problem, since the farmer applied high doses of these missing elements in the leaves, but we have identified in soil solution the real problem was the high pH in the soil solution between 9 and 9.5 whereas the original water above pH 8 and improper choice of fertilizer alkaline trend with lots of Nitrate Nitrogen in addition to excess of Calcium. After some fertigations using several acid fertilizers like Ammonium Sulfate, SOP, Nitric Acid, among other acid options till get the soil solution the reduction of pH between 6.5 and 7, all nutrients appeared well on the following foliar analysis including iron and Phosphorus. In this specific case the foliar content for both Iron and Phosphorus were above the ideal because it became available and fully soluble in the soil solution at high concentration. We know that it's called soluble Iron Fe^{+2} which is stable up to pH 7.5 which passes for the reduced form insoluble Fe^{+3} above pH 7.5. In relation to the Phosphorus some precipitation starts above pH 7.5 and increase to full precipitate between pH 8 to 9 due reactions with Calcium to form insoluble Calcium Phosphate.

10. What to do if we identify that appears Nitrite (NO_2^-) which is toxic to plants?





There are two typical situations to appear Nitrite (NO_2^-) in the fast test kit of colorimetric analysis: or lack of Oxygen in the soil either by compaction, excess water from the rain and/or the irrigation, that inhibiting the action and proliferation of nitrifying bacteria groups that are formed by aerobic Nitrosomonas, Nitrobacters and Nitrosospiras.

Or alternative inhibition due the extreme pH range in the soil solution < 5 or 8 >, since these bacteria reproduce only in this pH range between 5 and 8.

There is another factor that should be considered only for cold climate regions, outside the tropical areas, because the nitrifying bacteria need soil temperatures > 8°C and can reduce the population of these bacteria during the cold winter period extending the normal nitrification timing of normal soil temperatures between 15ºC to 25ºC the period of 2 – 3 weeks to longer periods if the Nitrogen source came from Urea or Ammonium to form some Nitrite (NO_2^-) due the low bacteria population to fast convert the N to Nitrate (NO_3^-).

11. Why can't we mix in the same dissolution tank Calcium with Phosphates and Sulfates?

Calcium reacts easily with Phosphates and Sulfates forming insoluble precipitates. Only in very acidic pH < 4, Calcium does not react with Phosphates. It is prudent not to mix in the same tank these elements. Calcium Phosphate and Calcium Sulfate (Gypsum) are at low solubility or even insoluble at all. Blends of fertilizers for fertigation must be compatibles and at high solubility.

Note that there are no restrictions for example, for blends of Calcium sources with fertilizers free of Phosphates and Sulfates such as Urea, KCl, Potassium Nitrate, Ammonium Nitrate, Magnesium Nitrate, etc.

12. What is the best choice: use straight soluble fertilizers as individual products or ready mixes fertilizers that form blends of NPK + secondary Macros + Micros?

The ready formulas NPK are always easier to use because of the difficulty of labor to make the mixes on the farms. Use some options of formulations and choose different proportions are always the best and most practical way to do fertigations. Some straight fertilizers always could be added as complementary sources if need. Only as explained before, avoid Calcium which is incompatible with Phosphates and Sulfates. It's nice to have the option of providing the individual Micros in the tank with the other fertilizers and preferably chelated for the cations and salts for anions. Zn, Mn and Cu can be used as EDTA. To use EDTA-Fe only if irrigation water has pH < 6.5 because only for EDTA-Fe, this chelate decomposes if pH is > 7. No decomposition for other cations with EDTA like Zn, Mn, Cu as well Ca and Mg, those are very stable in a wider range of pH. Only Fe for alkaline water must be changed for other chelates like DTPA, EDDHA, HBED, this last one is relatively new in the market and is the most stable chelate for alkaline pH specific for Iron. Who have alkaline pH should avoid EDTA-Fe and give preference to other chelating agents that are more stable to alkaline water.

The trend is that the formulations will be at most competitive prices due to increased competition in recent years, avoiding the high values of other times when there were few players in this market.

NPK formulas should have preferably low Phosphorus content because this nutrient is wasted by its low efficiency easily is immobilized in the clays. There's no advantage in applying high doses of phosphorus.

Also, soluble P is always an expensive raw material in the formulas. Some examples of low soluble NPK with low content of P and certainly cheaper on the market: 16-02-36; 32-02-16; 24-04-24; 06-06-46; 16-08-32; 09-09-39. On the contrary, if you use formulas rich in P, will force the farmer to use more than one formula in fertigations because always the plant demands for N and K are larger than for P. Use low P content in NPK blends will avoid unnecessary expenses, more work and less efficiency.

Another trend is that companies of NPK fertilizers and blenders offer enriched formulations with additives and chelates micronutrients. The additives may be different within the wide range of bioestimulants group rich in organic acids, such as humic and fulvic acids, amino acids, growth regulators, seaweed extracts, antioxidants, buffers, surfactants, anti-evaporating, etc. Thus, soluble fertilizers would be vehicles for providing various useful products to be applied via fertigation and some of them also via foliar.

13. Any restrictions for fertigations between drip and pivots?

Actually, the micro-irrigation (drip and micro-sprinklers) takes advantages of fertigation management for having homogeneous applications. For drip and also other micro irrigation systems, the irrigated soil portion receives similar dose for each plant and at the same time. On the other hand, the pivot to give a full circumference in one area takes several hours and large variations of evapotranspiration losing homogeneity. However, the pivots also evolved with use of some improvements trying to be a more restricted application without wetting the total area by passing along the rows using low sprinklers. When comparing against the extensive non-irrigated agriculture there are immense advantages for pivots, and the main advantage is for the pivots for cereals grain crops wetting total area. For perennials such as coffee, citrus and fruit-growing and also for horticulture, the localized micro irrigation is much more efficient concerning the use of water and if it is to compare the fertigations no doubt is even more efficient than pivots. The great advantage of micro irrigation is the flexibility in the handling of fertigations that are much easier and practical to handle than via pivots.

Micro-irrigation with drips and micro-sprinklers could be turned on shortly only to supply the nutrients during a short period, even during the rain timing while this practice would be infeasible for pivots

We must avoid to compare these 2 kinds of irrigation system, to check if they would be the most compatible choice for all cases, but they are not. If we use pivots for irrigation some extensive crops very traditional for dry land that would get water only from the rains, like grains, cereals and cotton. What we can observe here? These are fast crops by season during few months in the field. The growers can produce these extensive crops in large areas and the main competitor here is the not irrigated area for the same crop, that is the traditional and dominant cultivation. If the market price for these crops are attractive and with trends to keep good profit according to market evaluation, the grower can choose the alternative crop to plant under the pivots to optimize the benefit/cost relation and amortize the investment. Here, the pivots have some advantages. On the other hand, for horticulture, in spite of be also short time crops of few months as well, but the investment per hectare is far more expensive than grains and cereals, and for sure, the equipment that is more efficient to fertigation managements can make the difference for the best performance. For perennial crops like fruit-growing and coffee, the drip and micro-sprinklers are far more efficient compared against pivots for all water and nutrient managements. Also, for topography not flat, the micro-irrigation is the best option.

14. Can we consider Chlorides harmful via fertigation? What is the tolerance level?

The chlorides are very inexpensive sources of fertilizers as KCl and $CaCl_2$, among others, and the needs of plants for Cl are at level of Micro for few ppm between 5 to 20 ppm of plant demand. The main point is identifying a level of tolerance for the presence of Chlorides to allow the supply of the accompanies cations like K, Ca, Mg, others. The Cl level in soil solution can be measured by a fast titration kit and identified its concentration to help direct decisions of doses using cheap Chlorides fertilizers up to the crop tolerance. Most vegetables can tolerate between 200 to 300 ppm, for fruit-growing the tolerances are bigger up to about 400 ppm. It is manageable to handle the fertigation levels using Chlorides as long as you perform the tests regularly to avoid excesses and choose other sources of K and Ca when the presence of Chlorides is high in soil solution.

Chlorides are easily leached by a good irrigation or rainfall, removing from the root's region the Cl excesses, since there is a good drainage. In compacted soils and drainage-impaired, the chlorides rise by capillarity action, as well as other salts also could be harmful to the roots.

Remembering that the molecular weight of Cl is ~35 and as a monovalent, also its equivalent is divided by 1 to get the same 35 and we can say then that 35 ppm of Cl in soil solution has the power of salinity in the EC = 0.1 mS/cm. It is proportional, then the level of concentration of 70 ppm of Chlorides will have an EC = 0.2 mS/cm. And follow this proportion. The important thing is that the total Chlorides in vegetables does not exceed 30% (~1/3) of the total EC and to fruit and grains up to 40% of the total EC which are reasonable tolerance levels, avoiding the 8 or 80 conception of all or nothing. Zero

Chlorides in the soil solution is not the best economic choice, considering the tolerance of these cheap fertilizers based on Chlorides, the agronomic management is to handle the plant nutrition based on physiology optimum response and best relation of benefic/cost.

Example: For vegetables with EC total 1.5 mS/cm, up to 5 equivalents (~ 175 ppm) Chlorides are within tolerance. If the EC increases to 2.5 mS/cm we can arrive without problems until 8 equivalents (~ 280 ppm). So, keep the Chloride level in the soil solution always below 1/3rd of the total EC and this level is about 30% of the EC as the tolerance level for this anion. The hard part is to estimate doses without measure EC and without measure the Chlorides. The fast kits are easy tools for the best agronomic decision and to adjust the doses safely respecting the physiology of plants.

15. What is Salt Index we found on bags of fertilizers?

The Salt Index expression was rather used in the past between the 40's and 60's of the 20th century, to compare the saltiness against a default standard salt chosen to be the Sodium Nitrate to be the index 100. Any salt dissolved in water in the same concentration was compared against the standard in your osmotic pressure. However, without consider de application dose in fields, it would be only a chemical data not relevant for irrigated agriculture.

With the evolution of soluble fertilizers from the years 60's, the use of Salt Index lost practical function because it is an absolute value and does not represent the risk of salinity for the crops because it depends on the application rate. So interpreting salinity became far more important from the dissolved concentrations in water and much better expressed by electrical conductivity (EC). The use of fertilizers at low Salt Index at high quantities per area will cause of course, high EC and the use of only the Salt Index to classify risk of salinity is not enough, but would need the dose used to identify the salt concentration in soil solution. For no irrigation crops the salinity risk depends on the solubility of the fertilizers, the amount of rain to dissolve these fertilizers to identify the EC formed in the soil solution. This is contrary to the irrigation crops due the advantage of injection manipulation of soluble fertilizers by fertigation and easy control the salinity according to the EC of the sum of all fertilizers applied.

In Brazil, a **curiosity** was adopted few years ago a "**New Salt Index**" that also has no practical purpose of use. It is an adaptation of measure the EC of the target fertilizer at a fix dose of 10 g/L and the EC of Sodium Nitrate in the same concentration. Then divide the value of EC of the first by the second and the result is multiplied by 100. This is the New Salt Index method and it is used only in Brazil. No one adopts it in the world, but the Brazilian legislation adopted and requires that this new index must be presented on bags of fertilizers. It has no practical purpose for farmers, which do not use that information for anything. It seems that is just another bureaucratic requirement unnecessary.

The only relevant data to be presented on the soluble fertilizer bags would be the nutrient content, pH, EC and solubility in water. These are useful data for the grower. All the other information is unnecessary bureaucracy and increase the costs of the fertilizer companies.

16. How important is the degree of accuracy of the fast test kits? Will we really need tests more accurately?

These fast kits are quite useful even with approximate values that are enough to give a guideline in doses via fertigation for the farmer level. The main objective is getting an indicative level for the nutrients availability and also identifies the DELTA (Δ) between two sequences of samples tested and then the tendencies for loss or accumulation of each nutrient. Also, for the total salinity and pH variations between 2 samples tested in a sequence.

A good analogy to clarify the accuracy importance would be one person that wanted to do a diet to reduce his weight considered by the weighing machine that got the value of 100 kg. After the period of 15 days of diet, he got at the same weighing machine the new weight value of 98 kg, therefore the Δ was 2 kg. This information about the Δ is more important than the accuracy of the weighing machine. Think about the possibility to identify that the balance was not calibrated and the correct starting weight would be 105 kg and after 15 days of diet the weight would go to 103 kg. Note that the Δ remained the same in reduction of the same 2 kg indicating the most important information is that the diet worked.

Fast kits are sufficient to identify trends and the Δ always between current collection analyzed and previous collection.

If for example the Nitrate test present the value of 150 ppm now while in previous collection was 200 ppm, we know that the Δ is for the loss of 50 ppm of Nitrate. If the accuracy instead of 50 ppm is a little more or a little less, that is not relevant for the purpose of this monitoring that only want to identify trends. Also, the Equivalent of Nitrate is 62 ppm (N = 14; O_3 is 16 x 3 = 48; the sum 14 + 48 = 62) as the molecular weight of NO_3^- and this ion is monovalent anion the Equivalent is equal to the weight and 62 ppm of Nitrate contributes to the total salinity with 0.1 mS/cm in the EC, this mean that few variations in the value of macronutrients is not important as absolute value. If the Nitrate contributes with 4 Equivalents would be 4 x 62 = 248 ppm and the contribution to total EC from the Nitrate is 0.4 mS/cm. In this case the accuracy of the test is secondary and we can accept without problems about half Equivalent of tolerance for this kind of test kit.

It is common through this monitoring with fast kits to frequently find some surprises and in most cases to identify excess fertilizers with high levels of nutrients far above the desired because many farmers provide more nutrients without considering these measurements and cause waste of nutrients and money, besides salinization by excess fertilizers that can inhibit plant best development. In some cases, we can find the opposite scenario with low nutrient levels and this is the main objective to adjust the correct nutrition level.

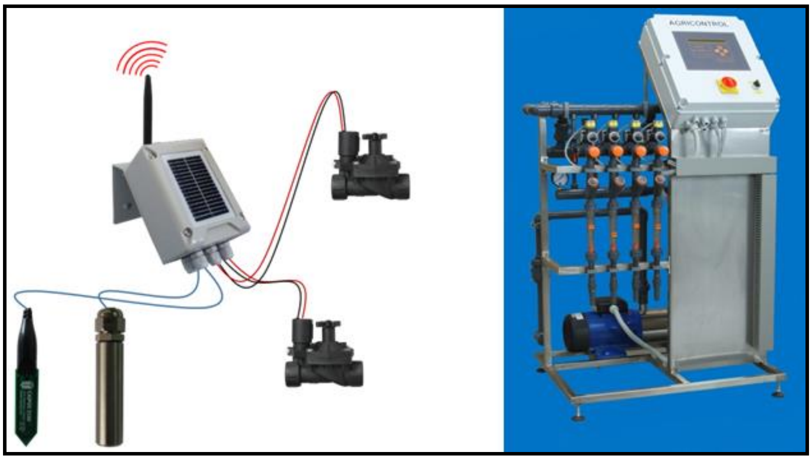
The use of more accurate laboratory tests is unnecessary for our goal of fertigation management, but are useful for researchers wishing to publish scientific articles, and we should consider that the cost of the more sophisticated tests is expensive, time-consuming and more complex for grower level, leaving the target user that want a simple and fast tests field to help decide the only handling of next fertigations.

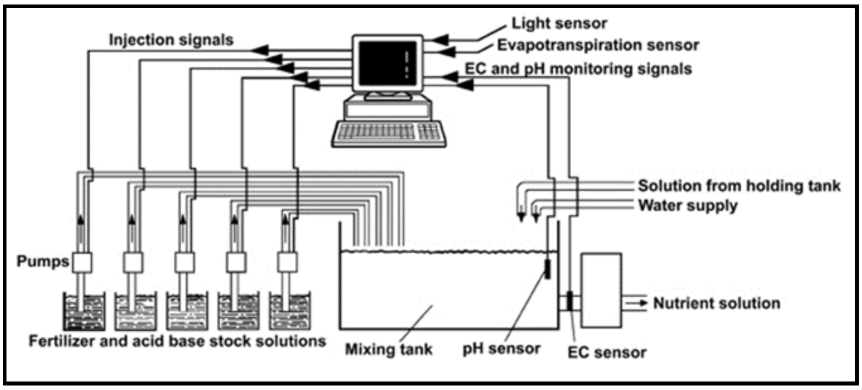
The main objective of the farmer is getting less errors. We do not have the ambition of hitting the shot on the center of the target, but don't miss the direction at all. Of course, everything in management is an evolution. After a few adjustments in the levels of each nutrient and salinity (EC), also adjustments to set the proper pH range, always we want to optimize and improve and this will come naturally with time. Agronomy in intensive agriculture will bring great advances and for the most professional people, the fertigations will be adapted for increase efficiency.

17. Among the micronutrients, only Iron and Copper are commercially available in the fast kits market. Why there are no fast kits for the other Micronutrients?

Scales of colorimetric or titration fast tests are very wide and jump to large intervals which are acceptable for Macros, while the values we need for Micros are very low in the range between only 5 to 30 ppm and the labs are not able to offer this kind of fast tests kits for Micros compatible scale. Recently, Iron and Copper colorimetric test kits based on easy test strips were launched in the market and they are good tests, but they are sensitive only for the ionic form and if the grower use chelates these tests will show zero. We still wait new developments for the other micronutrients at compatible agronomic scale, for Manganese, Zinc, Boron, Molybdenum, Cobalt and Nickel.

18. Software and applications for computers, smartphone, tablets, that automate irrigation and use pH and EC sensors to define types and doses of fertilizer to apply by fertigation, are they efficient? Can we be comfortable and confident that these automations will do correct fertigation management?





The impulse to treat all day-to-day problems with computer facilities through applications and software strong attract the new generations that use this for several activities as routine for fast and easy handlings. It is clear that this tool works with mathematical logic and restricted to a sequence of questions that only admit two answers: yes or no. We list and explain below **four premises** to understand how complex will be develop algorithms to command compatible fertigation management due lack of uniformity in field reality conditions.

First premise: "Biology is not Mathematics".

We split the Fertigation in two steps: the mathematical and biological phases.

Mathematics stage it is also the hydraulic phase, i.e. the access to water source, pumping and transport of water that occurs inside the pipes till the exit of the solution at the trickle, micro-sprinkler, sprinkler... At this stage we have the possibility to control mathematically the various components that are open or close a valve, to inject doses of fertilizers, irrigation, set to inject a more alkaline or acid solution, more saline or less saline fertilizers, with more of the nutrient, A, B or C. Program the system to work based on time or volume, respond to temperature range or humidity sensors, etc... These many facilities are an illusion that the “agronomic management” would be restricted to the mathematical phase and so delegate for a software some complex technical interpretations that are not mathematics.

The biologic phase starts from the output of the irrigation/fertigation solution that leaves the dripper or sprinkler and infiltrates into the soil/substrate. Now we don't have answers type “yes or no”. The miscellany of factors is very complex and heterogeneous based on multi-factors with dynamic interactions with the environment, microbiology, other participants of biology, root systems, phenology crops phases, different soils types, water-holding capacity of the soil/substrate, nutrient fertilization base dressing and side dressing as part of the nutrients applied versus the soluble or liquid fertilizers, influence on pH and on salinity EC, soil depth variations of soil layers, rainy season, heterogeneous and a very wide range of biotic and abiotic stresses that together form a dynamic ecosystem in which the agronomist's role is to interpret and take responsibility for management whereas the fertigation is only a tool for handling through small and frequent adjustments, respect the physiology of the plant and provide optimal conditions for obtain the best benefit/cost relation to overcome the limiting factors, where the first and more important is the water availability, then, the next limit factors are the nutritional to supply plants grown to do the maximum photosynthesis that agronomic management could achieve. How handle these incognita using the system of single answers of “yes or no” based on algorithms. The actual level of this technology is still not ready for this target and maybe it will never be fully automatic. How beautiful is the difference in fields where every plant is unique while the statistical methods try to get uniformity data or at least get the average to bring to mathematical level what will never be homogeneous.

Second premise: "Agronomy is an intervention in nature".

Third premise: "Statistic used in biology phase considering the average variations is dangerous".

Mathematic, physics and chemistry applied in biology loses the proportionality. Statistics on agronomy is an attempt through some samples to apply the logical reasoning on the diversity of the biology, but the beauty of physiology response is the diversity. It is the treatment of individuals X populations. In agriculture there are so many variables and interactions to evaluate, while the standardize the same fertigations and the possible variables for each situation, will demand kind of applications and software with complexes and sophisticated algorithms, or we will need to accept high tolerance range level for errors.

Fourth premise: "Software and applications to biological phase will come a day in the future, perhaps, when programmers studying deeply plant physiology and all interactions with nature environment and the day that a machine can understand the word *management*".

Summary: Use of pH, EC and humidity sensors to inform the software to decide the handling of fertigation is a source of mistakes by negligence. It would be nice if the automation with a program could consider the several factors and their interactions that occur within the soil where the roots and all of biology and abiotic react differently with the variables.

As the irrigation of a plot with unequal topography, possible areas of soil types with different textures and water-holding capacity, with dispersion of beneficial microorganisms and pathogens, nematodes, insects, distribution and availability of nutrients via conventional fertilizers applied on soil and even incorporated deeply are common practices and complements of nutrition using soluble fertigation are partial or total supply of nutrients. There are other arguments as whether all irrigation will be with fertigation or if the fertigations would be only once in a while. Sometimes the irrigation is only irrigation without fertigation.

The automation is a tool that in irrigation and fertigation should fall into the hands of professionals who are able to adjust the doses, choose the appropriate fertilizers to handle according to agronomic interpretations. The so-called "auto-pilot" is dangerously and request prudence by strong limitations to deal with biology as mathematics.

19. **The irrigation projects in the world evolved a lot since the 80’s, while professional courses of Agronomy, and other relative technician capacitation seems to stagnated regarding prepare this kind of skillfulness to handle irrigated crops. These courses are very conservative and maintain one old curriculum program, still focused on not irrigated crops as dominant. How to modernize to contribute at academia to surpass the educational bottleneck to offer to the fast increase demand in the agriculture market for professional to handle irrigation and fertigation?**

The market has regulated these new demands in many sectors of human knowledge, but noted a strong inertia in the agricultural sector. In the middle of the 20th century, the agricultural training was directed to form a polyvalent for multipurpose function on farms with general knowledge to be a big manager, but without specification and handle diverse activities inside the farms like rural buildings, livestock, agricultural crops, mechanization, pests and diseases, administration, etc. Today however, the work in agribusiness needs a team of experts. Education for irrigated agriculture needs an urgent upgrade because the irrigation market is growing fast and the shortage of skilled and qualified professionals is immense. Agronomic associations, universities, irrigation, fertilizer and seeds companies should participate in this debate and contribute to the changes.

20. How many stations of Soil Solution Extractors (ESS) put on irrigated areas in one farm? What area size an ESS cover?

The best criterion is for homogeneity, first according to soil type, especially texture; the second criterion is the cultivated species and varieties; the third is the ages of the crops, and finally the topography.

Example of homogenous area: area with 200 hectares in a type of medium-textured soil cultivated with banana and the whole area with only the Pacovan variety, of the same age and with flat topography. Note that all is homogeneous even in an area of 200 hectares and technically would only need one station of ESS. One ESS contain 3 depths, usually 15, 30 and 45 cm.

Another example would be with some variables: 200 hectares area with mango composted by 150 hectares in clay soil and 50 hectares of sandy soil. Here need ESS stations separated. Consider the age of this mango orchard planted at rhythm of 20 hectare per year to for the total of 200 hectares after 10 years and get plants at different age’s very heterogeneous situation. Also, in this example the grower starts with variety of mango Tommy Atkins of 100 hectares + 60 hectares with variety Haden and other 40 hectares with variety Palmer. Also, we have 80% of the area flat topography and 20% of the area with slopes of up to 15%. Note that variables make the scenario heterogeneous. The grower must choose some stations which are representative of dominant situations because it's not practical exaggerate the number of several SSE stations, but decide for few stations to be representative of dominant situations. Each one must check his situation with good sense and choose the number of SSE stations.

21. How to treat the Soil Solution Extractors (ESS) in soils with extreme textures, or high sandy content or high clay content?

In dominant sandy soils, the time to trigger the vacuum in the suction pipes SSE is very important because we will only be able to make vacuum in wet soil and this is easier at the end of the irrigation and until 1 hour before the end of the watering. After the soil dries, no vacuum is possible and we have to wait for the next irrigation to try again.

In heavy clay soil, the main problem can occur that the porous ceramics tips can be sealed avoiding the suction of the soil solution. In this case of very heavy soils, we recommend opening a hole in the soil and fill the bottom space of the largest hole with coarse sand only in depth that will have contact with the ceramic tip to avoid ceramic sealing by thin clay while the sand is inert material that will not influence on the readings of the tests. Then fill the rest of the hole with the normal soil.

22. How to handle via Fertigation the BRIX or formation of sugars in fruits, or sugar cane, or sugar beet or industrial tomatoes or cherry tomatoes, based on the EC manipulation level and the nutrients that participate in the metabolism of sugars?

In the biochemistry of the formation of sugars is a general process and is very clear that plants have a phosphate absorption peak some few weeks before begin maturing stage, because plants need accumulate ATP molecules as power reserve so that during the maturation that energy can break the long-chain polysaccharides to form mostly sucrose, glucose and fructose that will give the sweet taste. During all plant cycle development, the photosynthesis forms and accumulates polysaccharides, but during maturation process the plant needs energy to break the big sugars (carbohydrates) to form small sugar molecules and some of them with sweet taste. This prosses consume energy and the demand of phosphorus to form ATP occurs in large intensity during the growth stage just before maturation, but it is zero during the maturation stage. So, there is the right timing to handle the P supply using fertigation tool for it.

The other key element is potassium which is a mobile element in plants without being part of the cellular structures, but rather as osmotic regulator and mainly on activation of more than 60 enzymes in the metabolism of plants, with about 40 of these enzymes are activated during ripening with direct influence in the formation of sugars into end of cycle. Plant demands for K is gradually increasing during the season and the peak occurs during maturation.

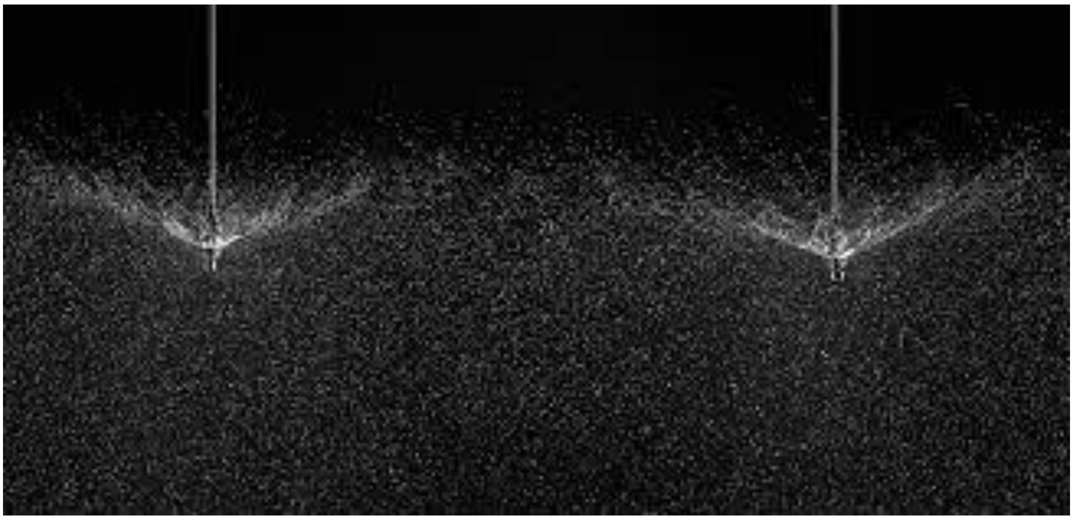
To a lesser extent the micros Fe, Zn and Mn are also enzyme activators in the maturation of few but important enzymes. Magnesium along with nitrogen on a small scale has great significance in the maintenance of chlorophyll before senescence to ensure metabolites of photosynthesis in formation of sugars and reserves of carbohydrates. Application of nutrient formulas rich in P, K, Mn, Fe, Zn and Mg via fertigation as well as foliar sprays will help before start maturation and is useful for increase BRIX for every plant with potential to accumulate sugars.

Let's see now how to influence the Brix by controlling the EC via fertigation. It's almost a paradox when increasing the salinity in the soil would increase the sweetness in fruit or crops that accumulate sugars! Yes, that's right. We know that after the development of plant and fruits have reached the desired level and we are waiting the ripening to harvest. From this specific phase we want to reduce water uptake by the roots and increase the solutes in soil solution mainly with potassium as dominant ion but other salts can contribute to increase the EC. Each EC unit causes tension (negative pressure) against the roots capacity of solution uptake of the order of -0.3 ATM and it is proportional, so EC = 2 mS/cm creates a tension of -0.6 ATM. EC levels below 3 mS/cm is relative easy for solution absorption by roots and with more water into the plant from a diluted solution the fruit or plant product will also get dilution due more water and little solute and the Brix falls. We should keep growing the soil salinity for the last period before harvest, suggested 4 – 6 weeks with EC always above 3 mS/cm and may overcome 4 mS/cm for intention to get higher salinity of the soil solution during the maturation period to force some difficult for the roots to absorb water and thus the Brix gets louder. In previous phases of crop cycle when the plant and the fruits are still in development, the EC should stay smoother between 1.5 to 2.5 mS/cm for most crops to avoid inhibition in water absorption which is very important to ensure high productivity. On the other hand, maintenance of EC lower than

1.5 mS/cm certainly will make the plant at bed nourishment with insufficient supply of nutrients to the desired maximum development. It's a game of manipulation of the salinity via fertigations to improve the Brix in the right moment.

In parallel there is the supply via some foliar nutrients that always participate in the biochemical metabolism of sugars that can serve as a stopgap for not irrigated crops that do not have the possibility of supplying them via fertigation, and these essential nutrients by easily sprayed containing P, K, Zn, Fe, Mn and Mg to prevent nutrient limiting for the previous phases and during maturation.

23. The nocturne timing for irrigation to take advantage of the cheaper energy at night in some countries, has any agricultural advantage? How is the absorption by roots during the night?

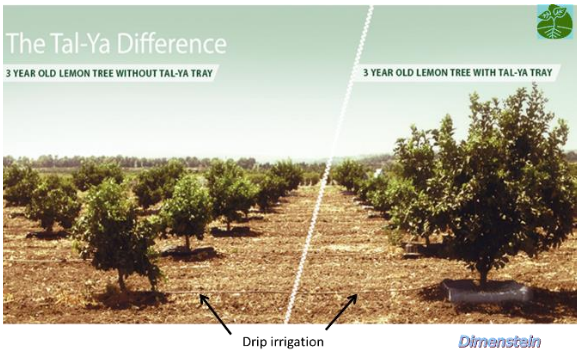


The absorption by the roots occurs only when the plants transpire and it usually occurs when the stomata open and gas exchange occurs catching the CO_2 for photosynthesis. In clay soils with good water retention, the nocturnal irrigations are welcome because the next morning when the stomata open and plants transpire there will be soil solution absorption by the roots.

On the other hand, in sandy soils with low water retention capacity and easily occur leaching and loss most of the water applied by the nocturne irrigation and when the morning sun appears to open stomata and starts root absorption, the water could be not available anymore due fast drainage. For sandy soil, the correct irrigation management is split the timing during the day for several small irrigations. Avoid long timing irrigation and avoid nocturne irrigation.

For sandy soils there are some new agronomic developments and one of them is incorporate into these soils polymers that have high water retention capacity and some of them can hold between 300x to 500x the weigh in water. So, 10g of these polymers could hold between 3 to 5 liters of water and avoid leaching or fast evaporation, while this volume is available for roots uptake. These polymers are original from starch or cellulose and can rehydrated after new irrigation or rain. The idea is spread these polymers into the soil to allow the water to be hold near the roots for longer time and avoid fast drying process for hot climate and sandy soil texture.

Other tools to keep longer the humidity in the soil are the mulching, organic matter and the very interesting development called Tal-Ya trays, that is patented from Israel, very simple for use. See pictures:

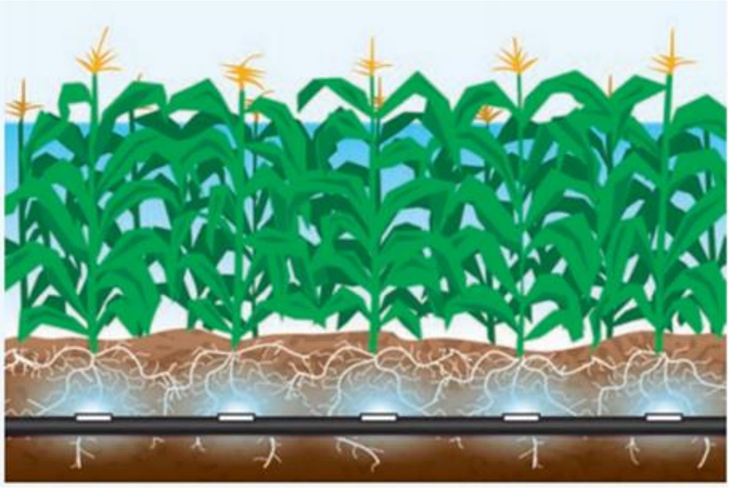


There are several Tal-Ya trays sizes and the idea is to collect the water around the plant and avoid evaporation. The source of water can be irrigation, rain and dew that is normal in several regions during the night and early in the morning if there is air humidity and temperature variation higher than 8ºC between day and night. Example to form dew: Day temperature is 30ºC and night temperature 22ºC. The delta temperature got at least 8ºC between day and night and if the relative humidity present in the air will be enough to form dew, the weather condition will be present. Observe the architecture of the Tal-Ya tray that drains the water to the center of the tray and spread the water below itself protected from evaporation of direct soil radiation. The 3 conditions that Tal-Ya promotes are: keep humidity close to roots, shadow and lower temperatures. These conditions improve the roots uptake efficiency. The temperature below the trays in cold regions during the winter causes the opposite effect to keep the roots at higher temperature. Avoid also the use of herbicides or weeding. Below the Tal-Ya trays we find the best synergy for use the fertilizer technology of slow and controlled fertilizers, that enjoy the humidity, mild temperature and shadow.

24. Subsurface irrigation. How to make fertigation management?

The soil texture is critical to the depth and spacing of the drip lines which can be between 15 - 30 cm depth. In clay soils the solution spreads and disperses in all directions by gravity and capillarity. In sandy soils the gravity is dominant and we have to choose low flow of discharge volumes by drippers and increase the frequency of watering to avoid leaching and put the drip lines only few cm deep into the soil between 10 - 15 cm depth.

From there with few adjusts to calibrated and uniform irrigation, fertigation management is very similar to that of the surface. The efficiency of urea via fertigation is high because there are no practically losses by volatilization. The water economy can be between 20% - 30% compared against surface drip irrigation and this mean also energy save. Also, the subsurface protect the drip lines from sun radiation and other injuries as well as regional animals.



Subsurface drip irrigation (SDI)

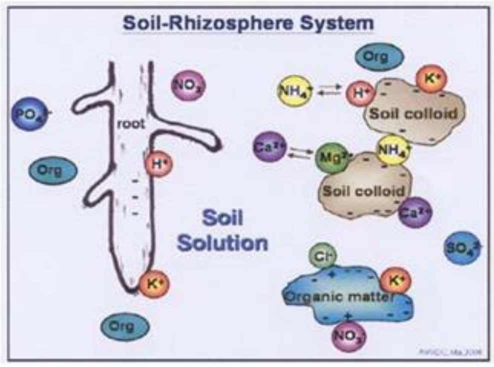
25. Why urea does not have electrical conductivity?

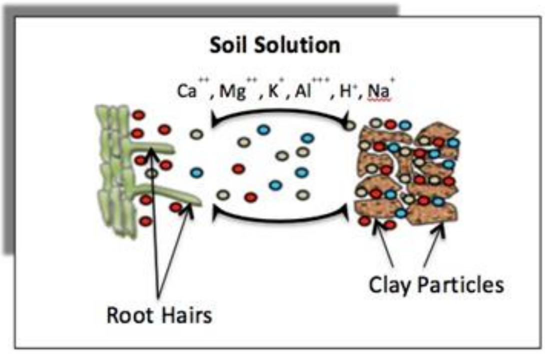
Urea granules and formula containing Carbon and 2 Amines.

It is not a salt.

Observe the chemical composition of the Urea **$CO(NH_2)_2$** containing one Carbon and so it is an organic molecule and not a salt. Salt while on the solid phase is neutral and after dissolves in water form ions that are cations and anions. These ions lead electricity measured in the ECmeter. Urea not being salt, not form ions in solution and does not conduct electricity. The vast majority of fertilizers are inorganic salts (no Carbon) and that's the difference.

26. Must we consider the contribution of the ions no nutrients in the EC, such as Bicarbonates, Aluminum, Sodium, etc.?





Yes. The EC does not identify the origin of salts. The EC measured by the ECmeter, identifies only the total salinity without knowing if came from fertilizers or soil or water. Just read the sum of total salts dissolved.

27. Are the relations between the 3 main cations K, Ca and Mg in soil solution depend on the phenology phase of crop development?

The phenology stages are fundamental for better distribution of 3 main cations in soil solution.

Vegetative phase must have about 50% Ca, 25% K and 25% Mg;

Bloom stage must have around 40% Ca, 40% K and 20% Mg;

Fill fruits or grains must have around 25% Ca, 60% K and 15% Mg;

Maturation must have about 10% Ca, 85% K and 5% Mg.

Here we cannot apply the traditional proportion used for no irrigated crops for Ca – Mg – K where Calcium is the triple concentration of Magnesium and Magnesium the triple of the Potassium. The dynamic in the soil solution diverges of the soil and the criteria adopted changed completely.

28. What would be the appropriate level in ppm of Calcium, Potassium and Magnesium for potato cultivation during filling stage of tubers? Would these nutrients be relative to soil solution salinity measured by total Electric Conductivity (EC) according to each growth stage of potato crop?

The approximate distribution of these 3 cations in soil solution must keep the proportion of 25% Ca, 60% K and 15% Mg, in this phase of filling tubers. If for example the EC = 2 mS/cm the distribution of 25% of Calcium among the cations would provide 0.5 mS/cm of the total EC which would be 5 equivalents of Calcium and we know that each equivalent has the salinization power of 0.1 mS/cm in the EC and that

1 equivalent is the molecular weight divided by valence charge of the ion and for Calcium weight is 40 while the charge as bivalent cation is 2. So, divide the weight 40 by 2 to get the equivalent of Ca = 20 we can say that 5 equivalents are 5 x 20 = 100 ppm of Ca and contributes with 0.5 mS/cm in total EC. However, if the EC was lower with only 1.6 mS/cm, the ideal level for keeping Calcium 25% of EC's suggestion would be only 4 equivalents of Ca to get 4 x 20 = 80 ppm of Calcium and the contribution of this element to the total EC of 1.6 mS/cm was 0.4 mS/cm.

For Potassium the equivalent is equal to its own weight because as a monovalent cation, divide by 1 is the same weight. K = 39 and every 39 ppm of K contributes to total EC by 0.1 mS/cm. During the filling tubers stage would be suitable to have 60% of the EC from K among the cations and if the EC = 2 mS/cm the 60% would be 1.2 mS/cm to be 12 equivalents and each equivalent multiply by 39 ppm to get 12 x 39 = 468 ppm of K. Using the same example of EC reduction to 1.6 mS/cm and keep the contribution of K in 60% would be about 9.6 equivalents 9.6 x 39 to form = 374 ppm of K, always preserving the ratio of cations in soil solution at that stage to potato phenology.

The calculation for Magnesium: Bivalent with 24 weight dividing by 2, we'd have 12 ppm for 1 equivalent of Mg and we suggest to get 15% contribution of Mg in the EC, if the EC is = 2 mS/cm 3 equivalents would be contributing 0.3 mS/cm and 12 ppm x 3 equivalents = 36 ppm of Mg. Changing the EC and we maintain the 15% contribution of Mg in the EC of soil solution we will have excellent distribution of cations in filling stage the tubers in potato.

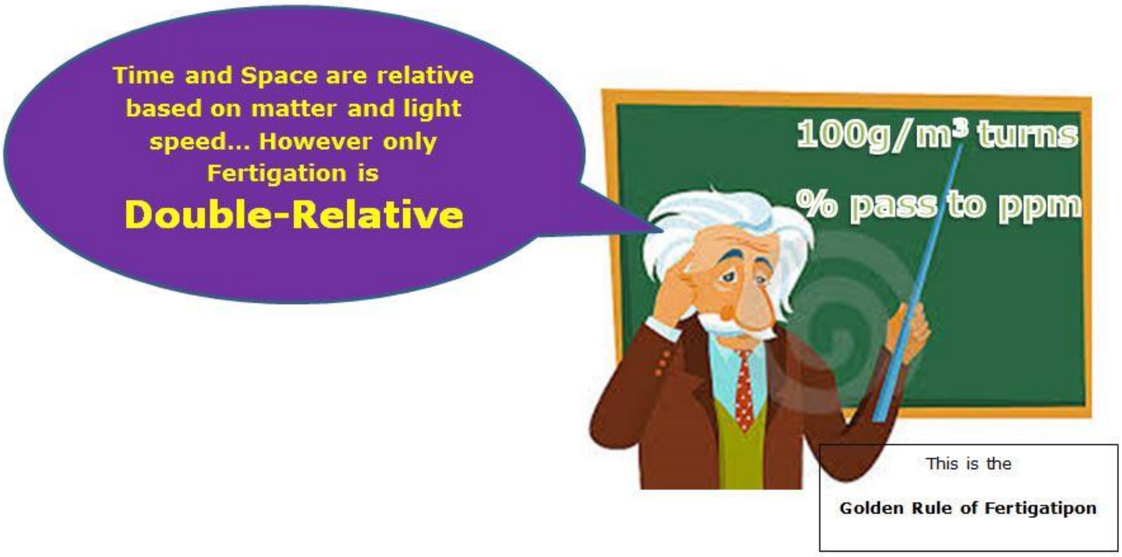
Observe that it is a dynamic game of dose settings by manipulating the proportions according to the stages of development of the crops and simple EC measurements in soil solution for the distributions of nutrient ions are appropriate in harmonization of demands and reduce competitions and antagonism of the nutrients. The main objective is to try the reduction of management mistakes and identify the levels of nutrients and the total EC of soil solution. Make the settings via fertigation to get the desired proportion of nutrients on that stage and total salinity to stay within the range of tolerance to mitigate possible stresses. As well as the EC and each nutrient, pH is another important factor to be manipulated according to fertilizers chooses and applies via fertigation.

It is worth remembering that the EC x 10 = the number of equivalents of cations and an equal number of anions. Example for EC = 2 mS/cm we have 20 equivalents of cations and other 20 equivalents of anions. Total of 40 equivalents, always 50% - 50% between cations and anions.

29. Fertigation when the irrigation volume is below the actual needs. What happens when the water deficit practice of irrigation supply less than would be ideal?

Many irrigation projects are projected intentionally at low volume only to minimize the dry season effect, but this irrigation just to serve as palliative and minimize the hydric stress and not to give to plants the optimum watering for growth. In this case, this irrigation would not have the ambition to provide the full irrigation. The fertigations may however be the great advantage to provide even in irrigation of smaller volumes the necessary nutrients to the crop demands and at least ensure adequate nutrition during the months in which the irrigation is used. The cost of irrigation equipment to supply low volumes per day is cheap as well as the use of energy is less, but the ideal for maximum productivity and get the best benefit/cost would be full irigation.

30. The so-called new theory of "Double-Relativity" for fertigation. What would be this theory?



First a very special thanks to Einstein for his first original relativity approach, that served as the inspiration for this new theory of double-relativity for fertigation, that start as one exercise or joke, but at the end of the way, it is very logic for people that wants challenges for interpretation.

For explain this new theory, we will also use the format of a sequence of premises.

Premises for interpretations of nutrients in soil solution with the "Double-Relativity" comparison between the same nutrient after at least 2 samples collections and one interval time between them and its contribution to the EC:

Premise 1. There is no absolute value in plant nutrition.

Premise 2. Identify the total salinity in soil solution measured by the EC - electrical conductivity in mS/cm, which is similar to unit of the international system dS/m;

Premise 3. Consider the relationship for each measurement of EC = 1 mS/cm, represents 10 equivalents of cations and others 10 equivalents of anions, keeping this proportionality... EC = 2 mS/cm represents 20 equivalents of cations and other 20 equivalents of anions, and so on, till EC ~7.0 mS/cm.

Premise 4. The main cations that form the ionic cocktail in soil solution are K^+, Ca^{++}, Mg^{++}, NH_4^+, $H^+{}_3O$ (hydronium), and the micros Fe^{++}, Mn^{++}, Zn^{++}, Cu^{++}.

Premise 5. The main anions that form the ionic cocktail in soil solution are Cl^-, NO_3^-, SO_4^{--}, SO_3^-, PO_4^{---}, HPO_4^{--}, OH^-, HCO_3^-, and the micros $B_4O_7^{--}$ e MoO_4^{--}.

Premise 6. Exemplifying with Potassium which has molecular weight 39 as a monovalent cation, its equivalent is equal to its own molecular weight, and each equivalent contributes in solution to the total EC with 0.1 mS/cm, so if the soil solution EC is of 2.5 mS/cm and K^+ contributes with 10 equivalents, this mean that the other 15 equivalents in the soil solution cocktail must be composed by other cations. The concentration of K^+ in ppm in the nutritive soil solution in this example that contain 10 equivalents will be 10 x 39 = 390 ppm (parts per million) of K^+ and its contribution in the total salinity would be of 1 mS/cm within the 2.5 mS/cm the whole cocktail of cations. In parallel, this same nutritive soil solution with EC = 2.5 mS/cm must contain also other 25 equivalents of anions. The sum of all equivalents of cations + anions in this example is 50 equivalents.

Premise 7. The concentration of K^+ in soil solution is presented in ppm or mg/L or mg/Kg and all these units are similar. Let's consider that 1 Equivalent of K^+ = 39 ppm K^+ and contributes in the total salinity of the soil solution with EC = 0.1 mS/cm. Being proportional, 2 equivalents of K^+ will be 2 x 39 ppm = 78 ppm of K^+ and the salinity caused by K^+ contributes on EC with 0.2 mS/cm.

Premise 8. Example with one bi-valent cation like Calcium Ca^{++} which has molecular weight 40, but being bi-valent charged, its equivalent is 40/2 = 20. Therefore each 20 ppm Ca^{++} in the soil solution contributes with 0.1 mS/cm on the EC. If we identify for example in a soil solution analysis 80 ppm of Ca^{++}, we can conclude that the EC has 0.4 mS/cm originated from cationic ion.

Premise 9. Returning to the K^+ concentration, free in the soil solution is the 100% K^+ only in hydroponics and in extremely sandy soils. However, in soils with any clay content and presence of organic matter, there are many pitfalls and traps to capture K^+ and hinder partially its availability to the soil solution, where the roots can obtain partially some nutrients. That's the big difference between soil solution analysis and traditional soil analysis. In soil solution appears only the K^+ available to the roots at that moment without considering the K^+ immobilized. This concept is valid for all cations and for phosphates.

Premise 10. The traditional soil analysis brings to us absolute information of the K^+ in the soil sample handled in the laboratory with efficient extraction methods to obtain K^+ total in the soil, even if not available to the roots at natural status. This sole and absolute information has been used to serve as the basis of quantitative fertilization recommendations in many no irrigated crops. Many farmers perform these analyses with low frequency of only once every 1 or 2 years and during these periods so many variations occur naturally.

Premise 11. An example with the Nitrate anion NO_3^-, whose molecular weight is N = 14, + 3 Oxygens x 16 = 48, then the total will be 14 + 48 = 62. As a monovalent ion, nitrate has its molecular weight divided by 1 forming its equivalent equal to the molecular weight of 62. So, we say that 62 ppm of nitrate in soil solution contributes to total salinity EC with 0.1 mS/cm. Twice the 62 would be 124 ppm or 2 equivalents of nitrate and their contribution to the EC would be 0.2 mS/cm and so on in linear proportionality. This proportionality is true until EC ~ 7.0 mS/cm, but at higher salinity > 7.0 mS/cm, the solution became saturated and no longer linear.

Premise 12. The use of Soil Solution Extractors (SSE) tubes bring a dynamic option, easy and quick that suggests a new interpretation for a nutrition management that runs away from absolute values and creates a Double-Relativity in sequences of comparisons to itself individual nutrient and this nutrient contribution within the EC. So, we no longer have absolute references how many ppm of K^+ would be ideal in every stage of cultivation, but rather how many ppm of K^+ would be ideal for different levels of EC in every stage of cultivation.

Premise 13. Soil solution collection in weekly intervals, or bi-weekly, or when it is convenient, because it is easy and fast, can serve to identify trends for relative comparisons of current collection against the previous collection and check how many ppm of each relevant nutrient are available at that time of collection in the soil solution to the roots and which DELTA (Δ) in relation to previous collection. Similar to compare the EC between 2 sequences of soil solution collection samples and the contribution of each relevant nutrient to EC actual x previous sample. The comparison is first relative of the specific nutrient level against itself; the second comparison is relative of this nutrient contribution to total salinity EC, and identifies for every two sequence of samples the Δ. This is a Double-Relativity.

Premise 14. For the method of soil solution extractors, tolerance of +/-1 equivalent in accuracy of the measurements is very reasonable for the level of farmer; and up to +/-0.5 equivalent of tolerance for the level of researcher.

Premise 15. The practical variations ranges for the nutrient levels in soil solution in the fields are much greater than 1 equivalent of the suggested tolerance the degree of accuracy of colorimetric kits with rapid tests for various nutrients such as K^+, Ca^{++}, Mg^{++}, NH_4^+ for the main cations and Cl^-, NO_3^-, SO_4^{--}, HPO_4^{--} among the anions. This variation would be sufficient for this purpose and enough to identify the trends of the DELTA (Δ) in two or more successive collections and use to support decisions of nutritional management of doses to be applied in the fields. Therefore, rapid or colorimetric digital portable kits serve that purpose within a reasonable tolerance. More accurate tests are much more expensive and time consuming, but without any practical advantage for use by farmers.

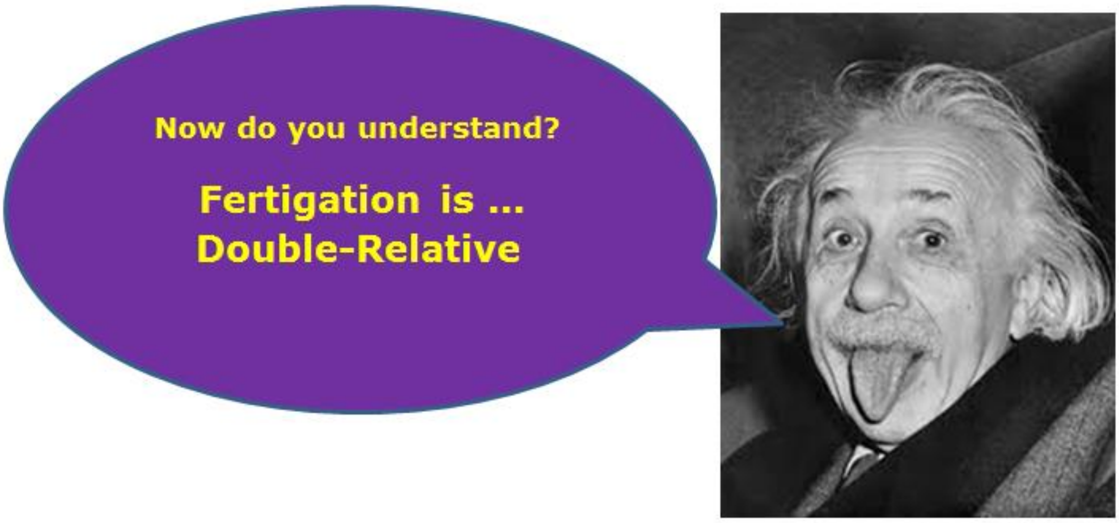
Premise 16. Use of soil solution extractors in irrigated crops x dryland crops. Use in irrigated crops it is routine for many farmers, who can make the corrections via fertigation dosages; However, dryland crops have some tricks for using this method. The soil solution extractors tubes need to suck the soil solution under vacuum and put those vacuum tubes with the aid of a syringe 60 ml normally, only when the soil is wet and it occurs after a rain or we have to simulate watering manually with a bucket of water around the extractor tubes and so proceed with the vacuum in the tubes. No vacuum is possible in dry soil or with low humidity.

Premise 17. Example for potato crop. The collecting of soil solution at the week before would identify the EC = 2.0 mS/cm indicating the total salinity level in the solution. Considering the concentration of Calcium in the EC identified as 100 ppm. We know that 1 equivalent of Ca^{++} is 20 ppm, calcium in the EC's contribution would be of 0.5 mS/cm of total 2.0 mS/cm which is an excellent concentration during the filling phase of the tubers within the total salinity, and Calcium participates with 25% of the cations. However, the following week, after a possible rain, which caused a dilution and partial leaching of the soil solution, the total CE reduced to 1.0 mS/cm and calcium concentration within that EC identified as only 60 ppm, and then it lost 40 ppm of Calcium, and certainly other nutrients that make up the total EC. In percentage, the calcium got 3 equivalents (3 x 20 = 60 ppm) in a total of 10 equivalents of cations with the EC = 1 mS/cm, which implies a ratio of 30% of the EC would be the contribution of Calcium between the cations. The interpretation is that in general the soil solution lost part of all nutrients and in absolute numbers also of Calcium, however the concentration in the soil solution Calcium became more concentrated. If we wish to make a complement via fertigation with various nutrients to replenish the EC lost and get again EC = 2.0 mS/cm, we have to apply the "Golden Rule of Fertigation" which is:

Premise 18. If we wish to restore the Calcium concentration of 60 ppm to 100 ppm using the Golden Rule of Fertigation, and choose the source of Calcium as Calcium Nitrate that has the guarantees percentage of 15-00-00 + 19Ca, and to facilitate the round count of 19Ca content, let's consider only for this account of Calcium as 20 instead 19 in this example. We know that 100 g of this fertilizer in each m^3 of irrigation will contribute with 20 ppm of Calcium and if we wish to provide via 40 ppm of Calcium fertigation, by proportionality we should apply 200 g of Calcium Nitrate per m^3 of irrigation. If the volume of water to be applied is of (example) 300 m^3 of irrigation and each m^3 receive 200g of fertilizer will be applied 60 kg of this fertilizer and the Calcium complement will increase the concentration within the soil solution. In this case, the same fertilizer would supply also 30 ppm of N, since we have 15 N in the formula guarantee. Then for every 100g / m^3 represents 15 ppm, and for the 200 g / m^3 will be 15 x 2 = 30 ppm N. If we would like to complement with more Nitrogen, together with other fertilizer like urea 45% N and apply 100 g/m^3 of this fertilizer for the same volume of 300 m^3 would be 30 kg of Urea to that Fertigation the sum of N would be the previous 30 ppm originated from Calcium Nitrate + 45 ppm from Urea and totaling 75 ppm of N.

Premise 19. The EC of the soil solution is considered within the physiological range for the main cultivated plants between 1.5 to 4.0 mS/cm. When the EC < 1.5 mS/cm is a strong indicator that the soil solution is too much diluted and plants will be starving. When the EC = 4.0 mS/cm is borderline and is a clear indicative of excessive fertilizer (salts) applied. We know that for every unit of EC in the soil solution tension increases negatively in ATM -0.3 hindering the absorption by the roots. EC between 5 and 7 mS/cm inhibits the solution absorption by the roots and will force the closing of stomata for much of the daylight by decreasing the capacity of photosynthesis. When the EC > 7 mS/cm the reverse phenomenon can occur forcing the water loses by the plant to the soil and the plant gets dehydrated entering wilt and collapse.

Premise 20. The evolution of our knowledge of agricultural chemistry opens a broad path to best practice recommendations avoiding the use for fertigation the "cake recipes" in required ready doses and belittle the management capacity of farmers and their agronomists to decide the best compatible settings for fertigation handlings. The practice of fertigation is an unparalleled tool for optimizing nutrition of irrigated crops and it all starts with qualification and training of field teams to provide the best benefit/cost ratio... After all everything is... with permission of Einstein… doubly-relative...



31. Can we fight against nematodes via fertigation?

Note this new technology called Aqua4D that is a Swiss technology that emits electromagnetic radiation as the water passes into the tube and then goes to normal pipe that will lead to irrigation water to the field.

This tube acts very similar to a microwave which emits electromagnetic radiation at a specific wavelength that is enough to break the hydrogen bonds between the water molecules, temporarily eliminating the surface tension of water for about 2 to 3 days. The water is denser, i.e. greater amount of water molecules on the same volume and this causes the water to be much more efficient to dissolve salts and thus also facilitates the roots to absorb the soil solution. The water molecule forms dense clusters temporary.

It can be with individual tube for small areas, or modular as pictured for more volumes.

The energy expenditure is to trigger the electromagnetism of 1 tube is similar to a 60W lamp. Its action must be continuous as long as the irrigation time.

The great curiosity is that the areas irrigated with Aqua4D system of electromagnetism had strong reduction of nematodes attacks and several attempts to give explanations to justify the action mechanism against nematodes suggest disoriented them in soil, while it helps the antagonistic microbial flora, etc. It is not clear how it works, but it is a fact that the nematodes decreased dramatically in these irrigated areas after receive irrigation with this electromagnetic mechanism.

The roots efficiency to uptake soil solution at more density water is also a fact compared against normal water not treated by this electromagnetism tool.

32. Fertilizer injection in the system must be made before or after the filter.

The normal place for fertigation injection would be after the filters considering the use of fertilizers 100% soluble in good purity quality.

We know that in the market for fertilizers, however, there are also some fertilizers not so pure with some dirty impurities. It would be prudent to filter the solution before inject them to the irrigation pipes. In addition, there is the misuse of some soil fertilizers that should not be used via fertigation, but some farmers insist on trying to dissolve them even partially to inject them and these are of low efficiency and risk of clogging of emitters of drippers and sprinklers.

33. Any news in the market of soluble fertilizers?

PeKacid - 00-60-20 is a 2.2 pH buffer based on purified Phosphoric Acid (food grade) that is dried to be the unique powder phosphoric acid and fully soluble and stabilized by mix with MKP (00-52-34) which provides the pH buffering and keeps the product in dry powder while stored. Its solubility is 680 g/L. Its salinity at 1 g/L gives the EC = 1.4 mS/cm which is well below the liquid phosphoric acid that has the EC = 2.2 mS/cm. The process of drying out the phosphoric acid and the end product is patented by ICL Fertilizers. PeKacid is also widely used as a raw material in NPK formulations to acidify and serves to maintain the irrigation system cleaned in regular applications. It is suggested at least 5 kg per week per hectare.

PeKacid due to acidic pH and your composition be of PK that have high mobility in the phloem, has been also used as a foliar fertilizer tolerated by plants that enjoy it as nutrients in addition to the effect of pH against a wide range of pests and diseases that are sensitive to very acidic pH sprayed.

PeKacid presented as a fully soluble and clean powder very acid PK fertilizer with 00-60-20 and buffer pH 2.2 as the unique and most effective acid PK in the market.

PeKacid foliar – Use and Patent for phytosanitary effect called "pH shock treatment".

PeKacid foliar is one of the sources of my patent for use of foliar fertilizers of extremes pH, always PK-based, i.e. very acid or very alkaline, but always PK. due to acidic pH and your composition and be PK that have high mobility in the phloem, PeKacid was the acid version and has been used with dual purpose as nutrients since the plants tolerate acidity and neutralize internally in the plant metabolism and immediately after leaf absorption the P and K are translocated via phloem to different sink organs of the plant and evading the leaves with low risk of burning or leaf toxicity. The effect of pH solution sprayed against a range of pests and diseases that are sensitive to very acidic pH by contact action while the leaves are wet. The action is effective while the solution stays in contact with the pests and pathogens. This effect disappears after solution evaporate because the pH occurs only at liquid stage. There is also the alkaline pH of the PK version ~11 and which also have plant protection action in which there are inhibitions by contact action with strong inhibition of many pests and diseases sensitive to alkaline pH while the plants tolerate this pH level just because the source is PK is easily neutralized internal and then translocated in plants.

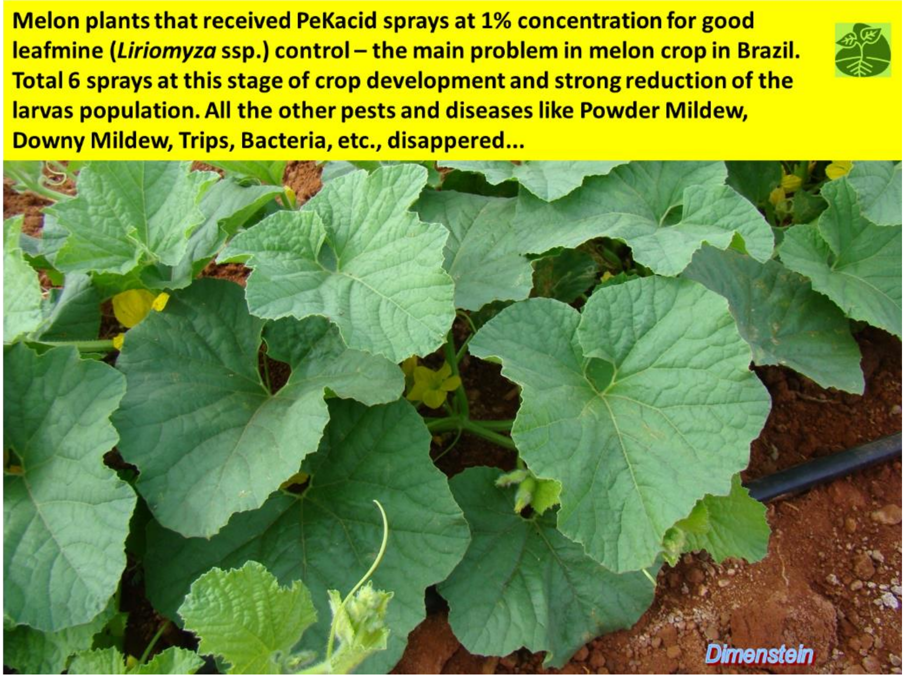
The link to access details of the patent by Luiz Dimenstein in US Patent & Trademark Office, the use of soluble fertilizers or PK-based liquids of pH extremes via foliar for reduction of various pests and diseases by contact action for pests and pathogens susceptible to extreme pH while the plants are tolerated because they are mobile in the phloem and neutralized into the plants by the internal homeostasis of plants:

http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PG01&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.html&r=1&f=G&l=50&s1=%2220130130896%22.PGNR.&OS=DN/20130130896&RS=DN/20130130896

Control with high infestation of leaf mine and powder mildew

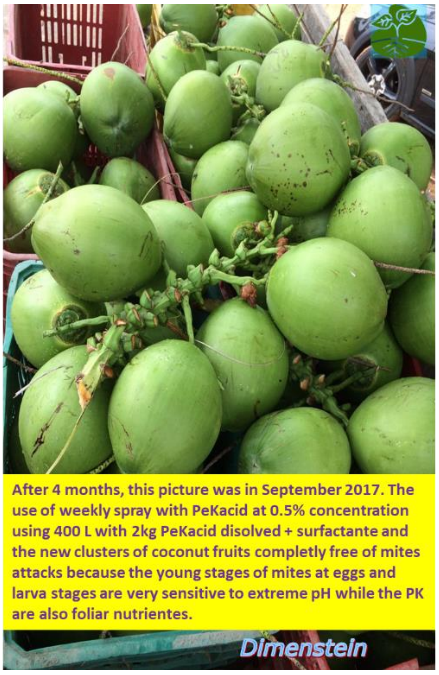
Treated with sprays of PeKacid at 1% concentration at weekly intervals during 20 weeks keep plants free of all attacks of pests and diseases by contact

Control area with larvas of leafmine (*Liriomyza* ssp.) in spite of insecticides application



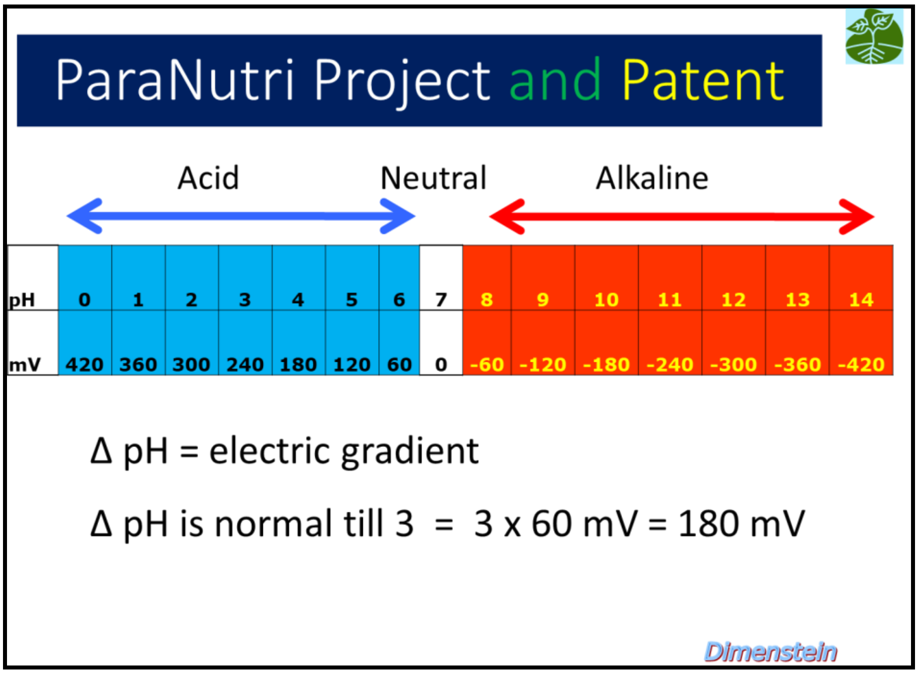
Melon plants that received PeKacid sprays at 1% concentration for good leafmine (*Liriomyza* ssp.) control – the main problem in melon crop in Brazil. Total 6 sprays at this stage of crop development and strong reduction of the larvas population. All the other pests and diseases like Powder Mildew, Downy Mildew, Trips, Bacteria, etc., disappered...


Picture from August 2017 with Strong mites attack in Bahia, Brazil


After 4 months, this picture was in September 2017. The use of weekly spray with PeKacid at 0.5% concentration using 400 L with 2kg PeKacid disolved + surfactante and the new clusters of coconut fruits completly free of mites attacks because the young stages of mites at eggs and larva stages are very sensitive to extreme pH while the PK are also foliar nutrientes.

The effectiveness of the contact action depends on use of an abundant volume spray of extreme pH solution bathing the pathogens and pests at nice cover by contact. Insects and mites are more sensitive to pH extremes in the young stages of egg and larva. Many fungi and bacteria have strong inhibition by pH extreme action and always with PK as product source for mobility in the phloem and also serve as nutrients for plants as a parallel effect and that's why it is at the same time plant nutrients and get some pests and diseases reduction.

This project of "pH Shock Treatment" with soluble fertilizers PK had the original name of "ParaNutri Project" and we used for the acidic effect the PeKacid because it has stable buffer acid pH, while for the alkaline versions we tested 4 different combinations of PK that technically are all excellent, however the version acid is cheaper. So, PK applications sequences are very versatile with good results using sequences of acid after acid sprays, or alkaline after alkaline, and also the alternate acid – alkaline sprays sequences. All options were effective in reducing many pests and diseases. There is no systemic effect because the extreme pH effect is restricted only by contact of the spray solution against the pests and diseases.



ParaNutri Project and Patent

Acid Neutral Alkaline

pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
mV	420	360	300	240	180	120	60	0	-60	-120	-180	-240	-300	-360	-420

Δ pH = electric gradient

Δ pH is normal till 3 = 3 x 60 mV = 180 mV

The pH scale runs from 0 to 14, but it measures voltage and we use MilliVolts (mV). We get voltage zero only at pH 7. For each pH unit deceasing into the acid scale is equivalent of about 60 milliVolts (mV) in round numbers. The tolerance of biological membranes is up to 180 mV as the called DELTA - ΔpH, i.e. the difference in pH in the cytoplasm of the cell of the pathogen, or the eggs or larvae of the insect or mite. If it is washed with a solution of extreme pH that causes a ΔpH > 3 will generate an electrical gradient > 180 mV and this is the limit the integrity of biological membranes that would pass for disruption or plasmolysis. We know that the internal pH in the cytoplasm of most cells is ~7.2 and applications < 3 pH solutions for acid version proved to be effective. For alkaline with a pH > 10.5 version also worked very well. All biology needs a driving force that promotes pH differences between the membranes of many organelles and cytoplasm, forming Δ always < 3 pH units and metabolism works with normal ion streams.

AcidNPK – for fertigation with acid NPK and for use together with herbicides - Developed a new family of fertilizers acid that is 100% soluble fertilizer and contain PeKacid inside providing the total or partial as the Phosphates source of these blends' formulations, with pH range usually between 3 - 3.5 for use in fertigation with hard and alkaline water. It is also the ideal pH with buffer for use together with herbicides. Several other tailor-made formulas can be prepared with this conception and optional accept addition of some additives like biostimulants to get enriched acid fertilizers.

Examples of some **AcidNPK** formulas:

24-04-24
06-06-46
10-10-40
34-14-04
25-15-15

Magnesium Nitrate - pure version (11-00-00+9,3Mg) is the traditional soluble fertilizer obtained from the reaction of Nitric Acid with Magnesium Carbonate eliminating Carbonic Acid eliminated as a byproduct. The liquid Magnesium Nitrate is then heated up to 400°C to eliminate most water content and the concentrated solution is dropped on a cold mat to crystallize and form the grains.

Traditional pure white Magnesium Nitrate grains like lentils format and known as greener promoter because it supplies to leaves the main nutrients components of the chlorophyll nucleus with N and Mg, considering the high plant mobility for both nutrients in the xylem and phloem.

Enriched Magnesium Nitrate + Micronutrients or + RNA* -

(10-00-00+9Mg + Micros or + RNA*) During the production process of this fertilizer, before the moment of crystallize the $Mg(NO_3)_2$ to get the grain, the original solution can get some additions to get a complex product enriched. So, it is possible to add a strong Micronutrients cocktail with 6 elements (Mn, Zn, Cu and Fe as chelates of EDTA, and anions B and Mo as salts) or other additives.

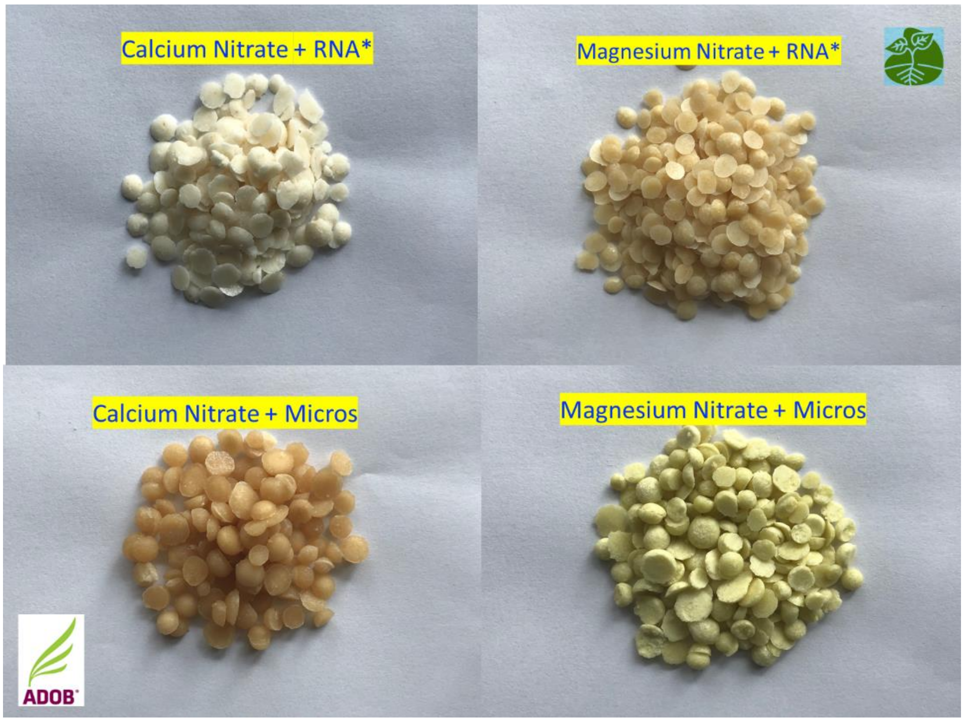
During the production process of Magnesium Nitrate, the key moment is the stage of the concentrated solution just before drop it on the cold mat to crystallize is the moment to add the complementary solution with a Micronutrients cocktail or a soluble polypeptide that is precursor of a new chelate called IDHA and the idea is use the enriched Magnesium Nitrate with this specific soluble polypeptide and after use this fertilizer for fertigation the polypeptide will form into the irrigated wet soil this new IDHA chelate that will attract several cations immobilized by the clays in the soil and then release them to roots absorption. We decide then to call this additive polypeptide with the acronym RNA*, but it doesn’t mean the Ribonucleic Acid, but in this specific case it means *“**R**elease **N**utrient **A**dditive”. The same IDHA chelate is the unique biodegradable chelate in the market and it decomposes in soil within 30 days and it is already commercial for the main cations like the other chelates in the market. IDHA is produced by ADOB from Poland. See the picture with the format of microcrystals of this new chelate fully soluble and biodegradable and the called RNA* will form the chelate in the soil to release the cations that this IDHA can get from the clays in the soil to roots uptakes. The preliminary trials show increase of the treated areas with the main cations in the dry matter between 25% to 40% compared against the control without the RNA*, but maintained the same nutrient levels applied. So, the RNA* will form in the soil the chelate IDHA to release several nutrients to the roots uptake and will increase the efficiency by fertigation.

The curiosity was that the RNA* also caused release of Phosphorus that increased in the dry matter by about 20%, in spite of phosphate be anions. We still have no explanation for the influence of this chelation for phosphates because it is known that chelates are active only for cations, the research in the future will try to explain this case.

Enriched Calcium Nitrate + Micronutrients or + RNA* -

Calcium Nitrate production process is quite similar to the Magnesium Nitrate described before. Both fertilizers can be enriched by Micronutrients or by RNA*

See pictures of the 4 new versions of enriched fertilizers in this family:



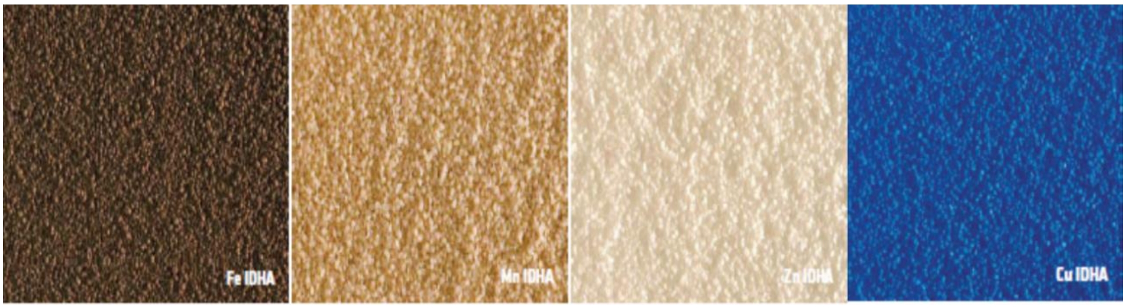
For foliar sprays for fruits and vegetables the dose can be between 0.5% to 1% and the volume per hectare between 400 to 1.000 Liters.

For grains, cereals, cotton, sugar cane, the tendency is use low volumes per hectare and then the fertilizer concentration can increase to be between 3% to 6% of the volume.

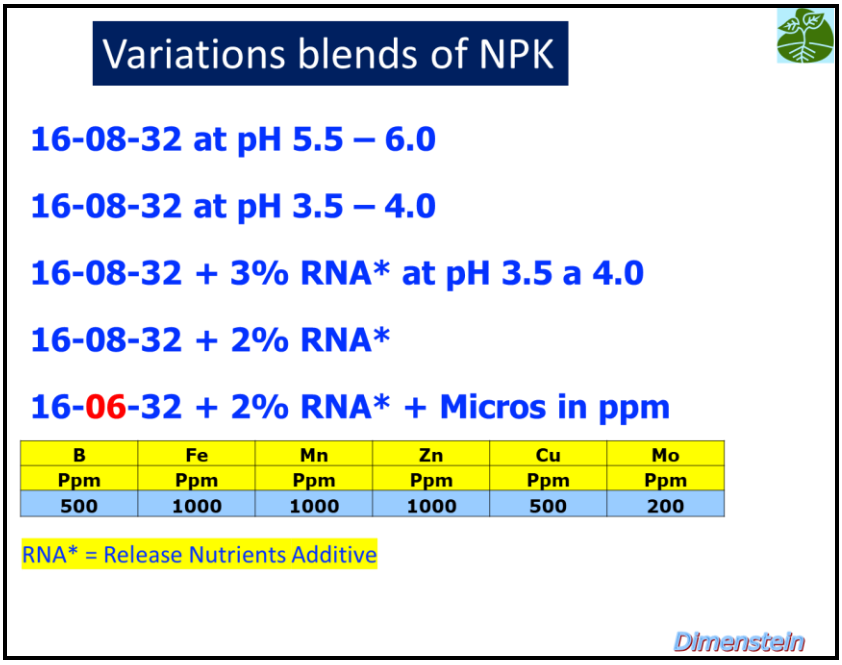
Important always add a surfactant.

For fertigation use the rates can be adjusted using the fast test kits suggested before. One example of dose is for example use 300g of Magnesium Nitrate per m^3 of irrigation and 500g/m^3 of Calcium Nitrate. If today the irrigation volume per hectare would be for instance 40m^3, then the Magnesium Nitrate 300g x 40m^3 = 12 kg. for the example above for Calcium Nitrate would be 500g x 40m^3 = 20 kg to apply per hectare with that irrigation volume. Later, based on the next result of the fast test kit, we can adjust the doses.

If these fertilizers would be the enriched versions described before, then the nutritional advantages to supply Micronutrients and the additive that could help to release some immobilized nutrients in the soil.



Blends of NPK + Micronutrients + RNA* - This is a family of fertilizers and enriched with flexibility to be customized or the called tailor made, in accordance with orders to get the desired NPK, the pH level can be manipulated and adjusted according to the choices of raw materials for the blends, also optional to added a cocktail of Micronutrients chelates for the cations and salts for the anions, other additive option for enrich the blend formula is the new additive RNA*. All in the form of soluble powder soluble microcrystals. Another innovation for use in NPK blends is the source of N in the form of urea microcrystal instead of the squashed common urea because the version soluble microcrystals is dry and not hygroscopic avoiding the risk to turn the product wet while kept in storage and reduce the needs of anticaking use. See some examples of customized NPK with variations by raw materials, pH and additives:



Variations blends of NPK

16-08-32 at pH 5.5 – 6.0

16-08-32 at pH 3.5 – 4.0

16-08-32 + 3% RNA* at pH 3.5 a 4.0

16-08-32 + 2% RNA*

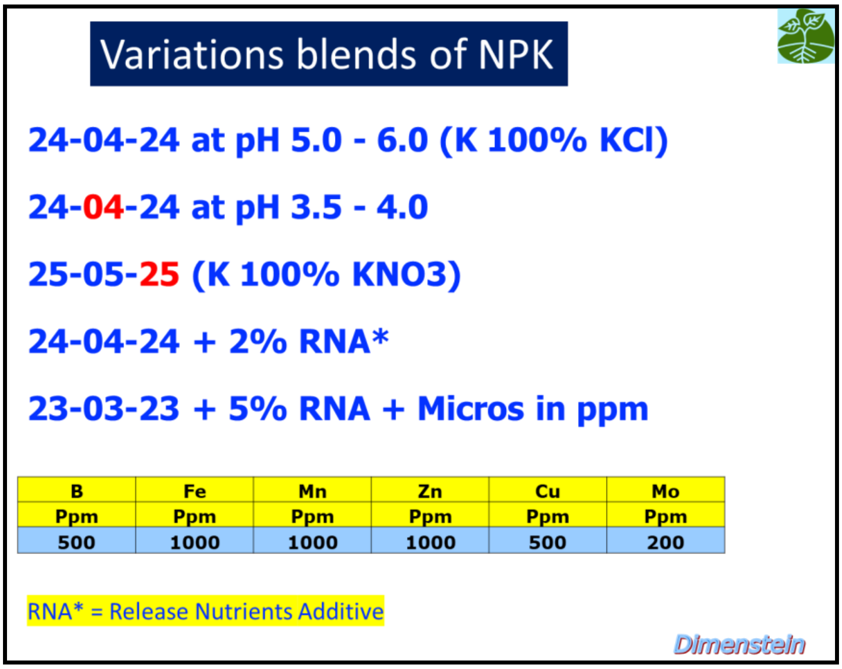
16-06-32 + 2% RNA* + Micros in ppm

B Ppm	Fe Ppm	Mn Ppm	Zn Ppm	Cu Ppm	Mo Ppm
500	1000	1000	1000	500	200

RNA* = Release Nutrients Additive

Dimenstein

Examples of variations with NPK formulas 16-08-32 or 16-06-32. The first version is the most popular with mixture of Urea microcrystal + MAP Purified + white KCl. The pH is between 5.5 and 6, gently acid. In the second version was changed the MAP purified by PeKacid and the pH of the formula reduced to a more acidic range between 3.5 to 4. In the third version, keeping the PeKacid as a source of phosphorus and pH more acidic, with addition of 3% of RNA* as additive enriching this formulation. As explained before the now called RNA* is Release Nutrient Additive based on a soluble polypeptide that is precursor of a new chelate called IDHA that will be formed in the soil after its application by fertigation together with the fertilizer of the formula. In the fourth version return the P source returned to be to MAP purified and it was complemented in this mixture with 2% of RNA*. On the last formulation presented here, we decide to sacrifice 2 units of P_2O_5 in the formula to open more space for use as additives 2% RNA* and also a cocktail of Micronutrients with B, Fe, Mn, Zn, Cu and Mo and whose concentrations can be adjusted on demand to get a tailor-made formulation.



Variations blends of NPK

24-04-24 at pH 5.0 - 6.0 (K 100% KCl)

24-04-24 at pH 3.5 - 4.0

25-05-25 (K 100% KNO3)

24-04-24 + 2% RNA*

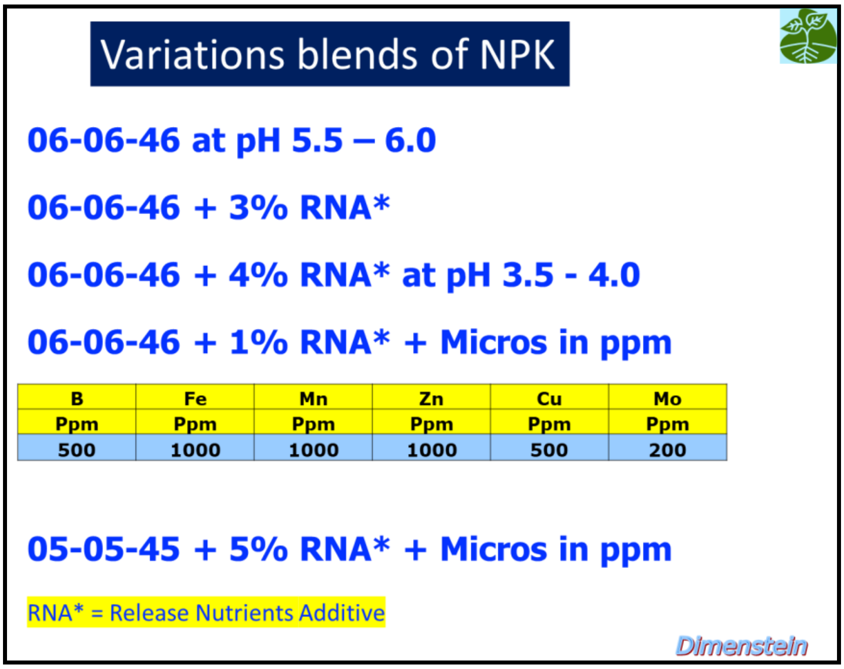
23-03-23 + 5% RNA + Micros in ppm

B	Fe	Mn	Zn	Cu	Mo
Ppm	Ppm	Ppm	Ppm	Ppm	Ppm
500	1000	1000	1000	500	200

RNA* = Release Nutrients Additive

Dimenstein

Examples of variations with NPK formulas 24-04-24 or 25-05-25 or 23-03-23. The first version is the most popular with mixture of Urea microcrystal + MAP Purified + white KCl. The pH was between 5 and 6 to be softly acid. In the second version was changed the MAP purified by PeKacid and the pH of the formula turned more acidic between 3.5 to 4. In the third version, the entire K was replaced from KCl for Potassium Nitrate and increased by 1 unit of each NPK content to get the guarantees of 25-05-25. In the fourth version returned to the use of urea microcrystal + MAP Purified + white KCl and fit in this blend 2% of RNA*. On fifth formulation version, we sacrificed 1 unit of each NPK content to get 23-03-23 and open space to add in 5% of RNA* + a cocktail of Micronutrients with B, Fe, Mn, Zn, Cu and Mo and whose concentrations can be adjusted on demand to get a tailor-made formulation as we already explained before.



Variations blends of NPK

06-06-46 at pH 5.5 – 6.0

06-06-46 + 3% RNA*

06-06-46 + 4% RNA* at pH 3.5 - 4.0

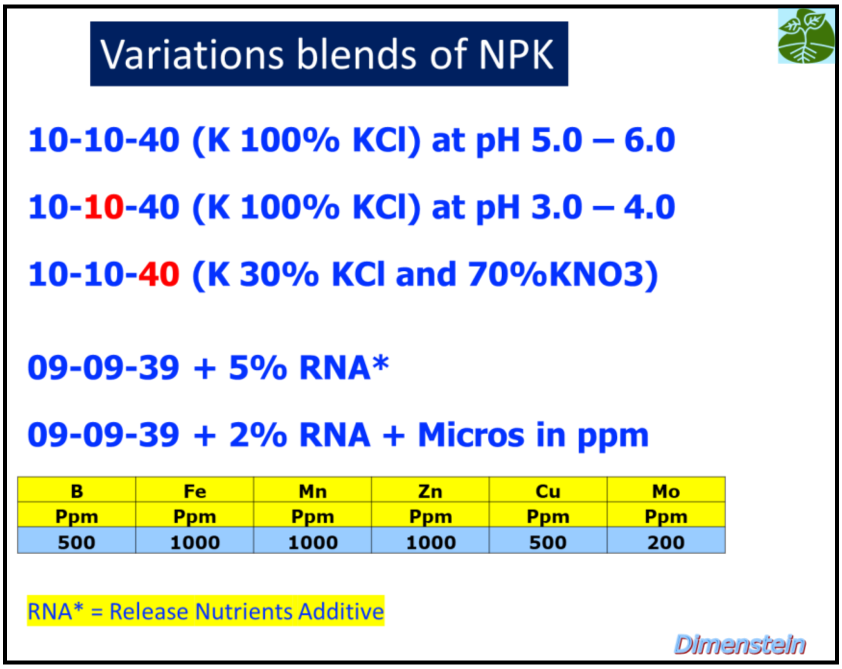
06-06-46 + 1% RNA* + Micros in ppm

B Ppm	Fe Ppm	Mn Ppm	Zn Ppm	Cu Ppm	Mo Ppm
500	1000	1000	1000	500	200

05-05-45 + 5% RNA* + Micros in ppm

RNA* = Release Nutrients Additive

Examples of variations with NPK formulas 06-06-46 or 05-05-45. The first version is the most popular with mixture of Urea microcrystal + MAP Purified + white KCl. The pH is between 5.5 and 6 gently acid. In the second version, it was possible to add 3% of RNA*. In the third version was changed the MAP purified by PeKacid and the pH of this formula was reduced to be more acidic between 3.5 to 4 and open space to add 4% of the additive RNA* as enriched formulation. In the fourth version we return to use MAP purified and added only 1% of RNA* + a cocktail of Micronutrients with B, Fe, Mn, Zn, Cu and Mo and whose concentrations can be adjusted on demand to get a tailor-made formulation. On the fifth version we sacrificed 1 unit of each nutrient in the 06-06-46 to form the nutrient guarantees of NPK of 05-05-45 and so we were able to add 5% of RNA* + the cocktail of micronutrients. In this case we have flexibility to play with additives that if instead of 5% RNA* could use less, i.e. 4% or 3% and could increase the micronutrients content in this mixture according to customization on demand.



Variations blends of NPK

10-10-40 (K 100% KCl) at pH 5.0 – 6.0

10-10-40 (K 100% KCl) at pH 3.0 – 4.0

10-10-40 (K 30% KCl and 70%KNO3)

09-09-39 + 5% RNA*

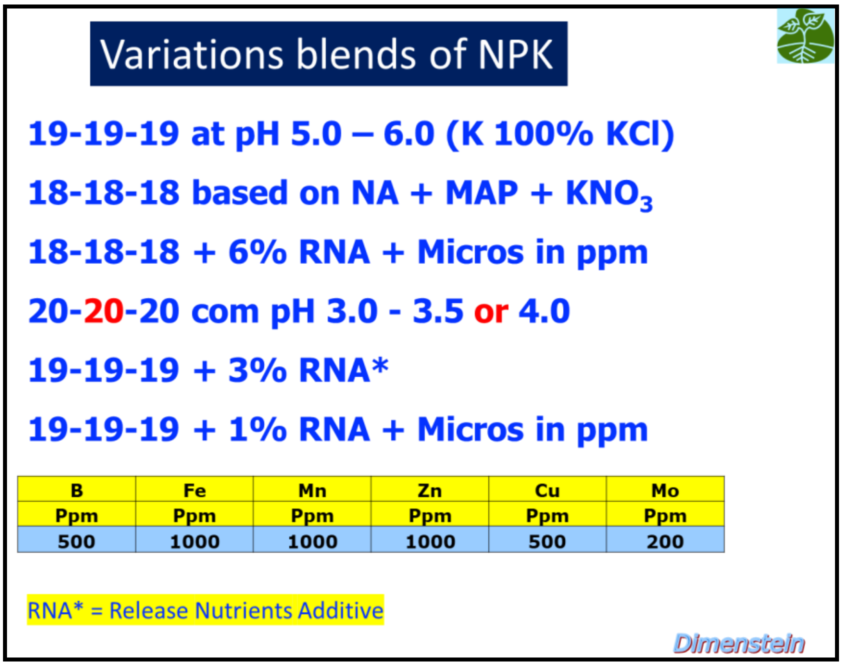
09-09-39 + 2% RNA + Micros in ppm

B	Fe	Mn	Zn	Cu	Mo
Ppm	Ppm	Ppm	Ppm	Ppm	Ppm
500	1000	1000	1000	500	200

RNA* = Release Nutrients Additive

Dimenstein

Examples of variations with NPK formulas 10-10-40 or 09-09-39. The first version is the most popular with mixture of Urea microcrystal + MAP Purified + white KCl. The pH was between 5 and 6 gently acid. In the second version it was changed the MAP purified by PeKacid and the pH of the formula turned more acidic between 3 to 4. In the third version the change was in the proportion of K sources where about 30% came from white KCl and the other 70% from Potassium Nitrate. This is to reduce partially the cost of the final blend and use chlorides at acceptable level of tolerance for some crops. The KNO_3 is about 4x more expensive than KCl and we can evaluate the partial use of the cheap source case by case according to the crop tolerance, original water quality used for fertigation, kind of soil, etc. So, this option is for crops sensitive to chloride. These adjustments are only examples that can be customized on a case by case basis. The fourth and fifth versions we sacrifice versions 1 unit of each NPK nutrient content, reducing from 10-10-40 to 09-09-39 and so we were able to add 5% RNA* or 2% RNA* + a cocktail of Micronutrients respectively.



Variations blends of NPK

19-19-19 at pH 5.0 – 6.0 (K 100% KCl)

18-18-18 based on NA + MAP + KNO_3

18-18-18 + 6% RNA + Micros in ppm

20-20-20 com pH 3.0 - 3.5 or 4.0

19-19-19 + 3% RNA*

19-19-19 + 1% RNA + Micros in ppm

B	Fe	Mn	Zn	Cu	Mo
Ppm	Ppm	Ppm	Ppm	Ppm	Ppm
500	1000	1000	1000	500	200

RNA* = Release Nutrients Additive

Examples of variations with NPK formulas 19-19-19 or 18-18-18 or 20-20-20. The first version is the most popular with mixture of Urea microcrystal + MAP Purified + white KCl. The pH was between 5 and 6 gently acid. In the second version were exchanged Urea by Ammonium Nitrate and White KCl by Potassium Nitrate, which are raw materials used typically for hydroponics and soilless options like substrates, avoiding use of urea and chlorides. For this case the nutrients guarantees are reduced to 18-18-18. In the third version we return to use the raw materials microcrystal Urea + MAP purified + white KCl and sacrifice also 1 unit of each 19-19-19 NPK to get 18-18-18 so we can add RNA* + a cocktail of micronutrients. In the fourth version exchanged MAP purified by PeKacid to acidify the formula between pH 3 to 4 and we were able to increase the guarantees of NPK for 20-20-20. In the fifth and sixth versions have 19-19-19 enriched with 3% of RNA* or 1% of RNA* + a cocktail of Micronutrients.

NPK with Polyphosphate + PeKacid with optional micronutrients + RNA* - was developed a new raw material based on Polyphosphate + PeKacid whose result has the pH gently acid ~6. Serves perfectly to form soluble NPK formulas with low phosphorous content because it will be more efficient and more available to the roots by having less adsorption on clay. Examples of NPK based on Polyphosphate + PeKacid as the P_2O_5 source:

These NPK will be of great contribution to increase the efficiency of absorption of Phosphate. These formulas can also be enriched with micronutrients and additives like RNA* similarly to that described previously. Polyphosphate should not be used individually or pure because it is very alkaline and at high pH in the soil solution the Phosphates are not available as nutrient for plants and for most Micronutrients (Fe, Mn, Cu, Zn and B) that become insoluble as well in alkaline medium. The combination with your PeKacid, however, brings two advantages, that in addition to getting the pH gently acid around pH 6, pass to be buffered by the presence of PeKacid inside the blend. The suitable then is to use NPK blends with low level of phosphate and this combination from Polyphosphate + PeKacid is the best option to get in soil high availability and efficiency.

05-05-50

35-05-10

15-05-35

23-10-23

34. Can we use Soil Solution Extractors (SSE) for no irrigated field crops?

Use of soil solution extractors in dryland crops x irrigated crops. The use in irrigated crops is already routines for many farmers, who can make the corrections via fertigation dosages; however, dryland crops have some tricks for using this method. The SSE need to suck the soil solution under vacuum and put those vacuum tubes with the aid of a syringe 60 ml, only when the soil is wet and that occurs after a rain or we have to simulate watering manually with a bucket of water around the SSE to do vacuum in these tubes. No vacuum is possible to do in dry soil or with low humidity. It is questionable what to do with the results of the analyses in the areas after get the samples and this is more for the curiosity and application of traditional fertilizers because for non-irrigated areas, but after some rain is possibly get samples to identify what is actually available to the plants in that area.

35. What are the features that make the drip irrigation system more efficient among all others irrigation systems?

If the drip irrigation was only to provide water while the fertilizers were applied to conventional mode for base and side dressing, there wouldn’t be a great advantage. However, the possibility of application of soluble fertilizers in small and frequent doses while maintaining the damp soil volume near the roots with salinity in acceptable concentrations without fluctuations typical of heavy fertilization followed by several irrigation water that cause dilutions and leaching. This would be like the "accordion effect" for the salinity caused by fertilizer, when the ideal is to keep the concentration of fertilizer salts with little variation. The best management would always we irrigate, it is also a fertigation together. However, it is common, due to lack of automation or by lack of planning, growers usually irrigate for example daily and fertigate once a week, or use other intervals.

The drip irrigation gives water savings and also fertilizers savings by use the application only for get fraction of reduced wet volume of soil rather than total area. It is without doubt the most efficiency irrigation method compared to every other irrigation system.

Fertigation can supply the nutrients demand for any crops according to the dose to handle and choose the source to get the pH range to optimize the availability of nutrients.

Drip allows in some subsurface irrigation crops, i.e. drip at 20 – 30 cm deep, more common for perennial or annual crops. Buried hoses have longer life for being protected from solar radiation at the surface and are mild temperatures. There are considerable water saving an estimated of up to 30%.

Surface or subsurface drip avoids wetting the leaves and fruits and reduce the attacks mainly of fungi and bacteria.

Dripping can be activating at any climate situation, winds, temperatures, and at any time of the day.

For non-flat topographies, there is the drip technology self-compensating and anti-drainage, which keeps the flow indicated by the manufacturer from the first to the last dripper along the lateral line of drip, independent of it is moving up or down the slope, and after shut down the runtime and the system stop pumping pressurized water hoses stop dripping, usually when the pressure is <0.4 ATM and stands within the water hoses without draining waiting the next watering turn. This technology is desirable in long sidelines when the flow is uniform along the whole line.

Summary of curriculum of the author:

Luiz Dimenstein -M. SC. Agr.- *Master Science of Agriculture* - Fertigation and plant nutrition specialist. Current consultant for intensive agriculture tools.

- Graduated in Agronomy by the ***Universidade Federal Rural de Pernambuco*** in 1985.
- Master of science in Agriculture, the ***Faculty of Agriculture of Rehovot, the Hebrew University of Jerusalem***, Israel, in 1990 and the Department of horticulture at ***Vulcani Center***, between 1988-1990.
- Seed companies agronomist in Israel for ***Zeraim Gedera*** and ***Hazera*** between 1991-1995.
- Agronomist invited by Ministry of Agriculture and Ministry of Foreign Affairs of Israel for technical support and courses abroad on agriculture, irrigation and **fertigation**, in 1995.
- Consultant in Brazil by the company ***Dimenstein Consultoria Eireli*** for **Fertigation management and intensive plant nutrition** to about 60 companies of irrigated crops diverse as tomato, melon, watermelon, asparagus, grapes, mango, potato, coconut, cotton, sugar cane, vegetables, coffee, citrus, etc., from 1996 and currently.
- Technical manager and R&D for ***Haifa chemical Brazil Ltda.*** between 1999-2004.
- International experience as a speaker in conferences and seminars about **Fertigation** in Mexico (Mexico City and Puerto Vallarta 2000 2002), USA (2001) and Orlando (2005), Israel (Tel Aviv 2000, 2008, 2009, 2011 and 2014, 2015, Haifa, 2003), Spain (Barcelona 2003),

Venezuela (Caracas 2004), Argentina (Mendoza, Tucuman and Buenos Aires 2011 and 2017), Peru (Lima 2011, 2014, 2016), Holland (Amsterdam 2015). And in Brazil about 60 lectures at regional and national events.

- Author of the patent of spray extreme pH solution based on PK fertilizers or very acid or very alkaline via foliar to reduce attacks of pests and diseases inhibited by contact action due the effect of pH against the pests and pathogens. (Submitted on 2009 and approved in 2013).
- Business and Development Manager for specialty fertilizers of **ICL Brazil ltda**., ICL Group - Israel Chemicals Ltd., between 2007 – 2017.
- Consultant for **ADOB** – Poland company that produce soluble fertilizers as chelates and soluble salts for foliar and fertigation. Since 2018 and currently.

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Fertigation Management
Golden Rule for Fertigation
Questions & Answers about Fertigation

Luiz Dimenstein

Method for dosage fertigation by concentration