Monitoring nutrient balance, pH & EC in the root zone

Introduction

One of the benefits of using Next Generation Grodan® substrates is that the composition of the nutrient solution in the root zone is under your total control. This is because stone wool is inert and does not interact with individual nutrients during the cultivation cycle. However the uptake of particular nutrients varies constantly with plant growth and fruit load and therefore the nutrient balance, pH and EC in the root zone is also constantly changing. A regular analysis of this solution in combination with daily monitoring of EC and pH allows you to exercise complete control over crop nutrition and plant development. This will not only help avoid serious mistakes (plant & fruit quality) but will also enable you to grow with more precision, optimizing the input of water and fertilizer and minimizing unnecessary flushing of drain water to the environment.

Nutrient analysis in the root zone

To ensure regular growth and fruit quality it is important to maintain the correct balance between individual elements, particularly potassium to calcium (K^+:Ca^{2+}) and potassium to nitrogen (K^+:NO_3^-), however the root zone is a dynamic environment which is been continually modified by the development of the crop. A regular analysis of the nutrient solution will ensure that correct and timely adjustments to the drip solution can be made in order to achieve the desired slab target levels. It is advisable to do this on an weekly basis.

Taking a sample is easy, but it is a task that must be performed correctly to secure a representative sample. For an analysis at least 250 ml of solution is required. Sample flasks should be clean and completely filled with solution to exclude air. For an analysis of the slab solution use a syringe to extract samples from 20 different slabs from within the irrigation or crop zone. Take an equal number from under and between the blocks taking care not to sample too close to the drain hole.

Impact of pH

The pH of a solution is a measure of how acidic or alkaline it is pH plays an important role as it influences the availability of nutrients (Figure 1). Generally micro nutrients iron (Fe^{3+}) manganese (Mn^{3+}) and zinc (Zn^{2+}) become less available as the pH is increased from 6,5 to 7,5 so it is always advisable to supply these in chelated form.

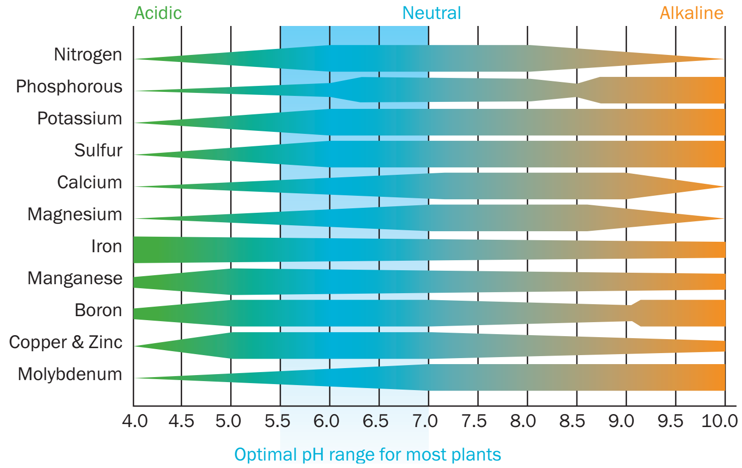


Figure 1: Effect of pH level on the availability of different nutrients.

At high pH levels phosphate ($H_2PO_4^-$) will also precipitate as insoluble calcium phosphate (Figure 2), making $H_2PO_4^-$ unavailable to the crop as well as blocking the irrigation drippers (Picture 1).

A balanced uptake of each of the nutrient elements is only possible if the pH in the root zone is within the range 5,5 to 6,5 (Figure 1). The target pH for the drip solution on Next Generation Grodan® substrate should be 5,5 to 5,8. Never reduce the pH of the drip solution below 5,0 at these levels there is a danger that the acidic solution will breakdown the stone wool fibres causing the slabs to collapse

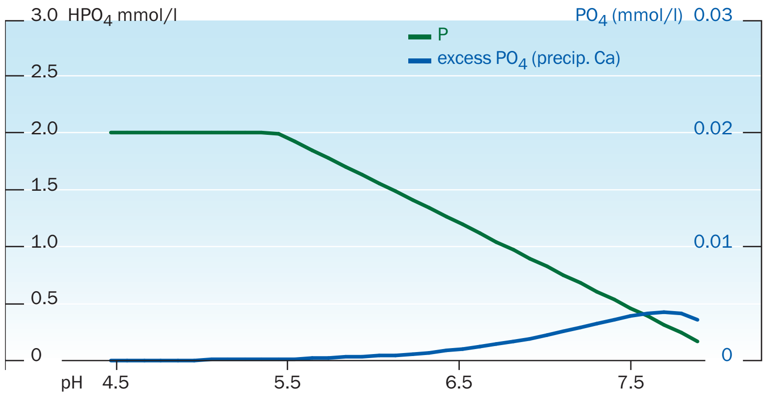
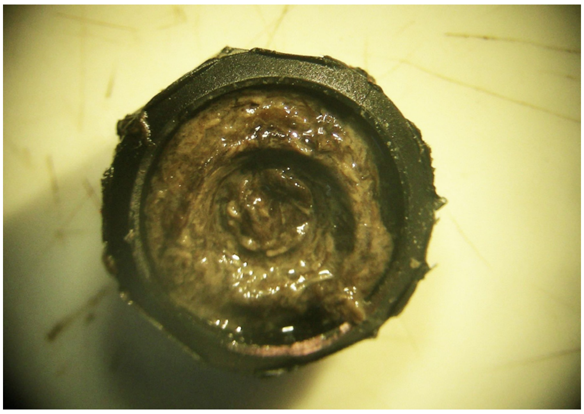


Figure 2: Effect of pH on P availability and precipitation of Calcium Phosphate
Source: Groen Agro Control, NL

During cultivation the pH in the root zone will fluctuate (Figure 3). For example with a greater uptake of negatively charged ions (anions) such as NO_3^-, in response to strong vegetative growth the pH will increase (become more alkaline). With a greater uptake of positively charged ions (cations) such as K^+ in response to a high fruit load the pH will decrease (become more acidic). To regulate pH it is important to maintain the correct balance between ammonium-N and nitrate-N (NH_4^+-N and NO_3^--N), however the managed changes of pH in the substrate should not be too large. For this reason pH should to be measured on a daily basis by doing so trends can be followed by plotting results on a graph and you can react in time by making informed adjustments to the drip pH, or by adding or removing NH_4^+-N from subsequent nutrient mixes.



Picture 1: Blocked irrigation emitter due to precipitation of calcium phosphate.
Source: Groen Agro Control, NL.

Taking a sample is easy, but it is a task that must be performed correctly to secure a representative sample to avoid making the wrong conclusions. Simply extract a small quantity of solution from 20 slabs using a syringe, don't mix the samples but measure the pH of each slab individually below and between the blocks. Please note drain samples should not be used to determine pH.

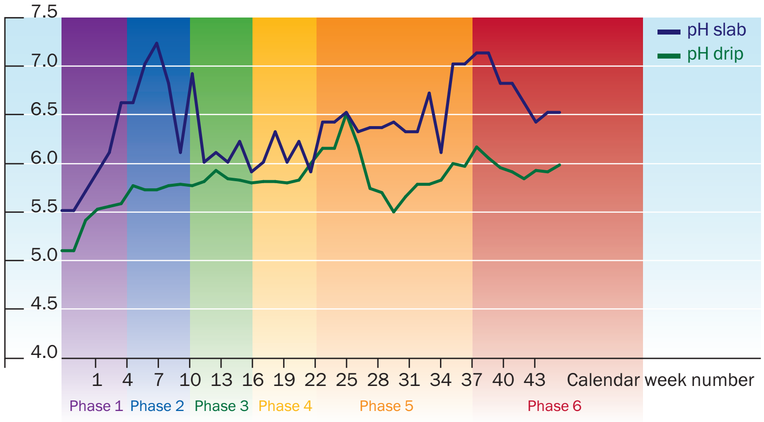


Figure 3: Reaction of drip and slab pH during the cultivation cycle of a tomato crop in Netherlands.

Tips for accurate pH measuring

- Calibrate the pH meter regularly using standard solutions.
- Check the battery status, low batteries in portable pH meters are often a cause of error.
- Always replace the probe into de-ionized water when not in use.
- Store portable meters in a cool dry place, do not leave them in the glasshouse.

Below are some tips and actions to take if the pH of the root zone environment needs adjusting.

The main **reasons for a high pH** in the root zone:

- High pH of irrigation water (>5,5).
- Strong vegetative plant growth.

Actions to **correct a high pH** in the root zone:

- Decrease the pH of feed solution to 5,2 - 5,3.
- Increase or add NH_4^+-N to the drip solution i.e. 0,7-1,75 mMol l^{-1} (10-24 ppm). However for beef tomatoes use a maximum 1,0 mMol l^{-1} (14 ppm) NH_4^+-N in the drip solution.
- When you add NH_4^+-N always increase the amount of Fe^{3+} (+20%) as a precautionary measure. If the pH moves >6,0 Fe^{3+} deficiencies can appear rapidly. It would be good practice to use a chelated form of Fe^{3+} with better pH stability, EDTA (pH 3,0-6,0) is most commonly used. However at higher pH levels other chelates such as Fe-DTPA or Fe-EDDHA should be considered.
- Increase the length of irrigation cycles and lower their frequency.
- Steer the crop more generatively i.e. increase the fruit load.

The main reason **for a low pH** in the root zone:

- Low pH of the irrigation water <5,3.
- Incorrect composition of nutrient solution i.e. too much ammonium nitrate or ammonium phosphate.
- Generative plant growth.

Actions to **correct a low pH** in the root zone:

- Increase the pH of the nutrient solution to maximum 6,0.
- Decrease the amount of NH_4^+-N in the irrigation water i.e. <0,7 mMol l^{-1} (<10 ppm).
- Decrease the length of irrigation cycles and increase the frequency.
- Steer the crop in a vegetative direction i.e. decrease the fruit load.

Impact of EC

EC is a measure of the total salts concentration in the nutrient solution. EC is therefore a mixture of essential (e.g. NO_3^-, Fe^{3+}) and non-essential (e.g. Na^+, Cl^-, SO_4^{2-}) elements required for plant growth. EC is usually expressed in milliSiemens per linear centimeter (mS/cm) or microSiemens per linear cm (µS/cm) where 1 mS = 1000 µS. The higher the total salts concentration the higher the EC. As non-essential elements are not taken up by the plant they will accumulate in the root zone over time causing EC to increase. It is therefore important to undertake a regular nutrient analysis to determine the composition of solution.

On a daily basis EC can be used to influence plant development in line with incumbent weather conditions. For example when light levels are low it is possible to work with higher EC in the root zone to steer the plant in a generative direction. When light levels are high (>1500J/cm^2) a lower EC can be used to steer crop development in a more vegetative direction. EC can also affect yield and fruit quality; in general a high EC lowers production but increases quality, maintaining the right balance maximizes economic return to the company.

The managed changes of EC in the substrate should not be too large, for this reason EC should to be measured on a daily basis by doing so trends can be followed by plotting the results on a graph and you can react in time by making informed adjustments to the drip EC and irrigation strategy. A perfect tool for the monitoring the fluctuation in EC and stability of EC during the day in relation to WC and light levels is the WCM-continuous connected to the climate computer (Figure 4). Using this simple graphic you can zoom in to show in detail how EC reacts over 2 to 3 day period or zoom out to show the trend of EC development over 4 to 7 day period. Alternatively the hand operated WCM-control can supply these details both averages of WC and EC as well as logged recordings of a watering section over time

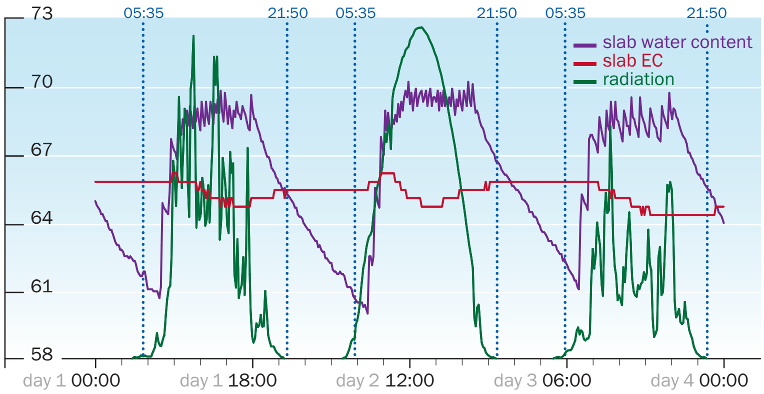


Figure 4: Graphic generated on the climate computer using information from the WCM showing stability of EC in relation the WC and radiation (Wm^2).

When monitoring with a portable EC meter sampling should take place in a number of slabs so that a meaningful and accurate assessment can be made. Simply extract a small quantity of solution from 20 slabs using a syringe, don't mix the samples but measure the EC of each slab individually. The best time to sample using this method is when the slabs have started to drain because this is when you want EC to be under control from the irrigation strategy.

In practice, the nutrient solution EC is normally applied in the range 2,5 to 3,5 mS/cm. The target values in the root zone should be 1,0 to 2,0 mS/cm higher. Greater variation from target is normally an indication that the irrigation strategy requires adjustment (Grodan 6phase advice).

Tips for accurate EC measuring

- Calibrate the EC meter regularly using standard solutions.
- Always take samples from a jar which is clean and preferably rinsed with de-ionized water.
- Always clean and the measuring flask after use by rinsing with de-ionized water.
- Store portable meters in a cool dry place, do not leave them in the glasshouse.

Below are some tips and actions to take if the EC of the root zone environment needs adjusting.

A **high root zone** EC (>5,5 mS/cm)
- Stimulates generative plant development.
- Develops plants with higher DM% and less risk of disease.
- Higher Brix values promoting better fruit quality.
- In combination with high transpiration by the crop creates a higher risk of fruit quality disorders such as blossom end rot (BER).

Actions to **correct an EC that is too high**:
- Reduce or remove Cl^- and SO_4^{2-} fertilizer from the drip solution.
- Reduce drip EC by maximum 0,5mS/cm and/or use a light reduction EC setting in the irrigation strategy.
- Ensure the irrigation strategy achieves drain on time and supplies correct ml/J throughout the day.

A **low root zone EC** (<2, 5 mS/cm)
- Stimulates vegetative plant development.
- Develops plants with low DM% and increased risk of soft growth and disease.
- Lower Brix values promoting lower fruit quality.

Actions to **correct an EC that is too low**:

- Add or increase Cl^- and SO_4^{2-} fertilizer in the feed mix.
- Increase drip EC by maximum 0,5mS/cm.
- Do not over supply irrigation water on dark days and be aware that the maximum rest time setting is not too short on dark days.

Summary

It is important to maintain a balanced nutrient composition in the slab solution and controlled and stable pH and EC to achieve the best results and best fruit quality. Monitoring these basic parameters should be obligatory for every grower. This will help not only help avoid serious mistakes (plant & fruit quality) but will also enable you to grow with more precision, optimizing input costs of water and fertilizer and minimizing unnecessary flushing.