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pH and EC Meters - Tools for Substrate Analysis

Todd J. Cavins, James L. Gibson, Brian E. Whipker, and William C. Fonteno
Commercial Floriculture Extension & Research

Introduction

Every greenhouse grower should own a pH and electrical conductivity (EC) meter. These meters are important substrate analysis tools. Why? Because immediate decisions can be made about a crop's nutritional status based on the substrate pH and EC values. A pH and EC meter must be easy to use and provide growers with accurate values without the risk of failure. Currently, there are over 20 companies and hundreds of pH and EC meters available. This article compares the attributes and provides insight of several available pH and EC meters (Table 1).

The NCSU floriculture research group has promoted the PourThru technique for nutritional monitoring of floricultural crops for the past 3 years. During presentations and workshops, we were introduced to a large array of meters that growers were using to measure pH and EC. We have been overwhelmed by the number of growers who desire additional information about meters. This past year, at the Southeast Greenhouse Conference and Trade Show and at the Ohio Florist Association Short Course, a survey was conducted during the PourThru workshops and the information gathered is presented here. The survey listed several meters commonly advertised in greenhouse supply catalogs or trade publications and asked if growers could highlight the pros or cons about the meters they use (Table 2).

pH and EC Meter Principles

By definition, pH is the negative log of the hydrogen ion concentration of a substrate solution or a measure of acidity or basicity of a solution. The more hydrogen ions within the solution, the lower (more acidic) the pH value will be and vice versa. How does a pH meter accurately provide you with the value? Modern meters have a single probe which contains two types of electrodes. One electrode (measurement cell) determines the hydrogen ion activity, while the reference electrode offers constant voltage output. As the probe is submersed into an aqueous solution, electrical current passes from the reference electrode into the measurement cell, then along a silver/silver chloride wire to the meter. The pH value (in millivolts) displayed is the difference between the measurement cell and the electrical current produced by the reference electrode.

An EC meter measures the concentration all soluble salts dissolved in a solution, but does not determine which salts are present at specific concentrations. The passage of an electric current through a solution is measured via a probe with two metal prongs one centimeter apart. Electrical current flows between the two prongs, the higher the EC, the easier it is for electrical current to move through the solution, thus a higher EC value.

Electrical conductivity is measured in millisiemens per centimeter (mS/cm) or millimhos per centimeter (mmhos/cm). Some EC meters or combination pH/EC meters express salt concentration

Table 1. Comparisons of selected pH and electrical conductivity (EC) meters.

Brand	Model	pH range	EC range	Resolution	Accuracy	Power Supply	Calibration Points	Replaceable Probe	ATC[1]	Price ($)
Cole-Parmer (pH bench-top)	MX-59003-20	0.00-14.00	N/A	0.01	± 0.01	AC/ (8) AA	2		Yes	315.00
Cole-Parmer (EC bench-top)	MX-19950-00	N/A	0-19.99 mS	0.01 mS	± 0.01%	AC (8) AA	1		Yes	450.00
Cole-Parmer (pH pen)	MX-59000-20	-1.0-15.0	N/A	0.1	± 0.1	(3) 1.4 V		Yes		63.50
Cole-Parmer (EC pen)	MX-19800-30	N/A	0-19.90 mS	0.1 mS	± 2%	(4) 1.4 V		Yes		55.50
Cole-Parmer (Combo portable)	MX-19825-00	0-14.00	0-19.99 mS	0.01 (pH) 0.01(mS)	± 0.01 (pH) ± 1% (mS)	(4) AAA	3 (pH) 1 (mS)	Yes	Yes	450.00
Hanna (pH pen)	pHep+ HI98108	0.0-0.14	N/A	0.1	± 0.1	(4) 1.4 V	2	Yes		39.50
Hanna (EC pen)	DiST 4 HI98304	N/A	0-19.99 mS	0.01 mS	± 2%	(4) 1.4 V	1	Yes		39.50
Hanna (Combo portable)	HI9811	0.0-14.0	0.0-6.00 mS	0.1 0.01 mS	± 0.02 (pH) ± 2% (mS)	(1) 9 V	1 (pH) 1 (mS)	Yes	Yes	169.00
Horiba (pH pen)	Cardy Twin	0.0-14.0	N/A	0.1	± 0.1	(2) 3 V	2	Yes	Yes	249.00
Horiba (EC pen)	Cardy Twin	N/A	0.0-19.0 mS	0.01 mS	± 2%	(2) 3 V	1	Yes	Yes	294.00
IQ (pH pen)	IQ120	2.0-12.0	N/A	0.1	± 0.1	(2) 3 V	1	Yes	Yes	99.00
Milwakee (pH pen)	pH41	0.0-14.0	N/A	0.1	± 0.1	(4) 1.4 V	2	Yes		62.00
Milwakee (EC pen)	C62	N/A	0.0-19.99 mS	0.01 mS	± 2%	(4) 1.4 V	1	Yes		54.00
Milwakee (Combo portable)	SM802	0.0-14.0	0.0-6.0 mS	0.1 0.01 mS	± 0.20(pH) ± 2% (mS)	(1) 9 V	1	Yes	Yes	199.00
Myron (Combo portable)	AG6/pH	2.0-12.0	0.0-5.0 mS	N/A	± 0.2 0(pH) ± 2% (mS)	(2) 9 V	2 (pH) 1 (mS)	Yes	Yes	369.00

[1] Automatic Temperature Compensation

in total dissolved solids (TDS). This is expressed as parts per million (ppm), which is mS/cm multiplied by 640 or 700. This and other conversion values are listed in Table 3.

Extraction Technique

Most pH and EC meters are designed to measure aqueous solutions. Meters used to measure hydroponic solutions are ideal for measuring leachates with minimal debris from potting mixes. The PourThru technique extracts the substrate solution by displacement with very little debris. PourThru extractions can be measured immediately. The 2:1 method, where 2 parts water to 1 part substrate are mixed then measured after 30 to 45 minutes, is time consuming and debris from the mixture could damage the pH probe.

Calibration Solutions

pH and EC values are only as good as the last calibration and proper storage of the standards is important. Most pH meters require two pH calibration solutions of 7.0 and 4.0 (the range of most soilless substrates), and EC meters generally require one standard. If possible, use a calibration solution reported in mS/cm as most meters and analytical labs report values in mS/cm. However, converting values from ppm or µS/cm (Table 3) is relatively easy. Always store the meters and the solutions at room temperature. Avoid fluctuating temperatures and high humidity (do not store in the greenhouse). Throw away calibration solutions after use. The solutions should never be recycled back into the fresh solution container.

Electrode Care

Meters and probes are sensitive tools that need to be maintained properly. The pH electrode should be stored according to provided instructions. Most instructions recommend storing the probe in pH 7.0 standard calibration solution. However, some recommend tap water, but probes should never be stored in distilled or deionized water. With proper maintenance and care, electrodes should last for 2 or more years. However, all pH electrodes eventually fail because of constant ion exchange between the two electrodes on the probe. Avoid scratching the probe, because the electrode will not function properly.

Temperature

Why is temperature so important when taking measurements of the root substrate? At different temperatures, hydrogen ions move at different rates in solution. Thus, more or less hydrogen ions will be measured by the pH probe depending on the solution temperature. Changing the solution temperature takes time, therefore most meters have an automatic temperature compensation (ATC) function. This prevents timely mathematical conversions to adjust the solution pH when taken at various temperatures.

Power Source

Along with ATC functions, many meters have automatic shut-off functions. Some meters do not have this characteristic which can result in shortened battery life. Always keep fresh " back-up" batteries

Table 2. Grower survey results and comments on pH/EC meters and use.

Meter	% of Responses	Comments of Grower Survey Participants
Myron (Combination)	29	Comments included good reliability of the combination pH and EC meter. However, meter expense and calibration difficulty were noted as negative aspects.
Hanna pens (pH and EC)	20	Compliments on portability of the small pens were numerous. However, 2-point calibration (pH meter) as well as the short battery life was not desirable.
Horiba pens (pH and EC)	9	No comments provided.
Hanna portable (Combination)	5	Quick and easy calibration, easy battery replacement, and user friendly were all positive comments. The combination pH/EC probe was also well received.
Cole-Parmer pens (pH and EC)	5	Positive comments involved accuracy, ease of use, and mobility. Battery cost was listed as a negative aspect.
Cole-Parmer portable (Combination)	5	Lack of mobility and time consuming calibration were the major issues associated with this meter (as with all bench-tops).
Others	27	Comments mentioned included lack of instructions and units of EC not reported in mS/cm.

Survey was completed at the 2000 Southeast Greenhouse Conference and 2000 Ohio Florists' Association Short Course. Based on 87 surveys.

for the meter. Most pen-type meters run on watch batteries which can be quite costly and frustrating for growers if there is not an automatic shut-off function. Fresh batteries expedite calibration and acquiring pH and EC values.

Other Items for Substrate Analysis

- Wash bottle- Found in pharmacies (in the eye care section).
- Distilled water- Never use drinking water to rinse electrodes.
- 3 or 4 oz. cups for calibration and solution collections.
- Tissues (lint free)- Blot electrodes dry, do not swipe them as static electricity can alter the values.
- Pencil and Notepad- Always record values, PourThru plotting charts and guides are available at: www2.ncsu.edu:8010/unity/lockers/project/hortsublab/Charts%20and%20Guides.pdf.

Optional:

- Extra probe- In case of electrode failure
- Another meter- To check for consistency

Summary

Monitoring and managing the substrate pH and EC should be a high priority in floral and foliage crop production. Without operational information and properly functioning meters, on-site decisions about crop nutrition cannot be made confidently. Our goal is to promote a better understanding of pH/EC meter use and function. Hopefully this article can aide in selecting the meter which best fits your needs (Table 2). We would like to thank the growers who provided us with their comments on pH and EC meters. Additional information is contained at the NC State University Commercial Floriculture website: http://www.pourthruinfo.com.

Table 3. Conversion factors among electrical conductivity (EC) units.

From	To	Multiply by:
mmho/cm or mS/cm or dS/m	mho ^{x} 10^{-5} /cm	100
mho x 10^{-5} /cm	mmho/cm or mS/cm or dS/m	0.01
mmho/cm or mS/cm or dS/m	µmho or mho x 10^{-6} /cm	1000
µmho or mho x 10^{-6} /cm	mmho/cm or mS/cm or dS/m	0.001
mmho/cm or mS/cm or dS/m	ppm	670[1]
ppm	mmhos/cm or mS/cm or dS/m	0.0014925[1]
mho x 10^{-5} /cm	ppm	6.70[1]
ppm	mho ^{x} 10^{-5} /cm	0.14925[1]
µmho or mho x 10^{-6} /cm	ppm	0.670[1]
ppm	µmho or mho x 10^{-6} /cm	1.4925[1]

[1] Some labs report EC in the terms of ppm or convert EC to ppm. Although 670 is the basis used in this example, the conversion factor can vary from 640 to 700. This conversion factor is an average because of the variability in the type of fertilizer salts contributing to the EC of the substrate in each sample. This conversion should be considered a broad approximation. Expressing EC in terms of mS/cm or mmhos/cm is the preferred method.