Moisture Content Measurement of Bark and Sphagnum Moss Using ECH2O Sensor for the Production of *Phalaenopsis*

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Abstract

Two types of moisture ratio sensors (ECH_2O-5, ECH_2O-10, Decagon Device, Inc., USA) measuring dielectric constant of materials were used in this study. The converting equations provided from manufacturer are for soil only. Totally, 3 sizes of barks (Orchiata, Besgrow, NZ) and 3 sources (New Zealand, Chile and China) of sphagnum moss were investigated. Besides equations derived, several conclusions are as follows: 1. ECH_2O-5 is less sensitive to EC compare with ECH_2O-10. 2. Different sources of sphagnum moss required different converting equations. Moss from China contains more foreign materials thus leading to higher EC values. 3. When using sphagnum moss as growth media, the way growers filled the pot affects sensor readings. Certain standard operating procedures (SOPs) need to be established regarding pot filling operation. 4. In terms of water holding capability, moss from Chile is better than moss from NZ and moss from China performed poorly. 5. Usage of bark with pre-submerge or not affects sensor readings for large particle (Orchiata no.5) barks and has little effect on Orchiata no. 8.

Keywords: *Phalaenopsis*, Moisture ratio, Bark, Sphagnum moss, Loadcell

1. Introduction

Orchid business is booming worldwide especially for *Phalaenopsis*. Growers expand so fast that skillful watering workers are lacking leading to poor quality products. The focus of this study is to establish quantitative means in understanding moisture ratio of growth media to facilitate this fast growing orchid production industry.

2. Equipment and methods

2.1 Moisture ratio sensor

There are many methods available in measuring moisture content of grow media, including: gravimetric technique, hygrometric technique, tensiometric technique, nuclear technique and electromagnetic technique, etc. Among electromagnetic technique, there are resistive sensors, capacitive sensors, time-domain-reflectometry (TDR) sensors.

As shown in Fig. 1, sensors used in this study are ECH_2O-5 and ECH_2O-10 (Decagon Device, Corp., USA) measuring moisture ratio based on dielectric constant measurement. Measurement time is

10 ms and resolution is 0.1%. Power requirement is 2 VDC at 2 mA or 5 VDC at 7 mA and the output is 10 to 40 % of the excitation voltage.

The dielectric constant εr is defined as the ratio:

$$\varepsilon_r = \varepsilon_s / \varepsilon_o = \varepsilon_s / (8.85 \times 10^{-12} F/m) = \varepsilon_s \quad \times 1.13 \times 10^{11}$$

where,

ε_s : the static permittivity of the material in question,

ε_o : the vacuum permittivity. This permittivity of free space is derived from Maxwell's equations and is equals the ratio D/E in vacuum, where D is the electric flux density and E is the electric field intensity.

In vacuum (free space), the permittivity ε_s is just ε_o, so the dielectric constant is unity. In air and water, dielectric constant εr is 1.0005 and 80, respectively.

Fig. 1　Moisture ratio sensor (a) ECH_2O-5 (b) ECH_2O-10

(Adapted from http://www.decagon.com/echo/)

The manufacturing company provides converting equations to convert signal outputs to volumetric moisture ratio. However, they are for soil only. Users need to develop their own equations for other growth media. The accuracy of ECH_2O-10 is in ±4 %, and ECH_2O-5 using a high frequency, accuracy improved to ± 3 %. The excitation voltage of 2.5 V is used throughout this study.

2.2 Experimental setup

As shown in Fig.2 is the simulated air-inflated double-Poly greenhouse equipped with artificial light source (HID lamp) providing 300 W/m^2 radiations continuously. Growth media (sphagnum moss or bark) were placed in container and placed on top of a load cell. The output signals of load cell were converted to digital signals through RI 1203, locally made converter, and recorded using PC. The output signals of moisture ratio sensors were recorded using 21X data logger (Campbell Scientific Corp., USA).

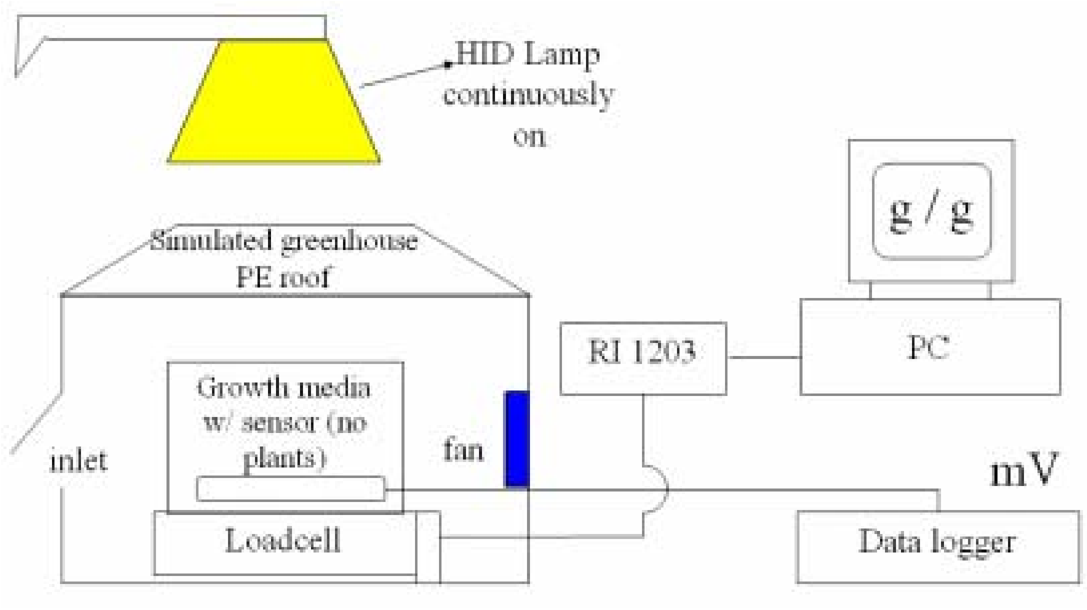

Fig. 2 Experimental setup

2.3 Materials

Growing plants in poor quality media is often expensive as management costs increase while plant quality decreases. Both sphagnum moss and bark are quite popular in Taiwan for orchid growers. Mainly 3 sources of sphagnum moss throughout all growers of Taiwan are from New Zealand, Chile and China.

Bark is a good media for growing orchids as well. However, there are many different types of bark with different physical and chemical properties. Barks used in Taiwan are mainly from New Zealand. *Pinus radiate* is a fast growing conifer grown widely in New Zealand in man made forests for the timber industry. The bark from these trees is usually 20-50 mm thick and formed in a large nugget shape. Three sizes of orchiata barks (no. 5, 8 and 9) were investigated. Particle size of grade no. 5, 8 and 9 are 9-12 mm, 3-6 mm and 6-9 mm, respectively. No. 8 is the smallest and no. 8 and 9 are suggested grades for *Phalaenopsis* by the manufacturer.

Aged bark is different from waste bark from landfill dumps or compost bark. Aging allows only the outside of the bark particle to break down leading to water and nutrient holding capability and inside remains solid in structure leading to long lasting lifespan. Bark is generally acidic because of various chemical compounds in its structure. Orchiata is pH adjusted with Dolomite to increase the pH thus, pre-submerge of the barks before use is not suggested by the manufacturers.

3. Results and Discussion

3.1 Barks

Fig. 3 shows variations of gravimetric moisture ratio over time for 3 sizes of Orchiata bark with or without pre-submerge overnight. Before measurement starts, all pots were irrigated with 500 ml of tap water per pot and wait for drained out. As shown in Fig. 3, treatment of pre-submerge has great difference for large particle (size no.5) and has least effect on the smallest particle (size no.8). Due to the least amount of water holding capability, most of the growers using barks will pre-submerge the materials before use discard the suggestions from the bark manufacturing company.

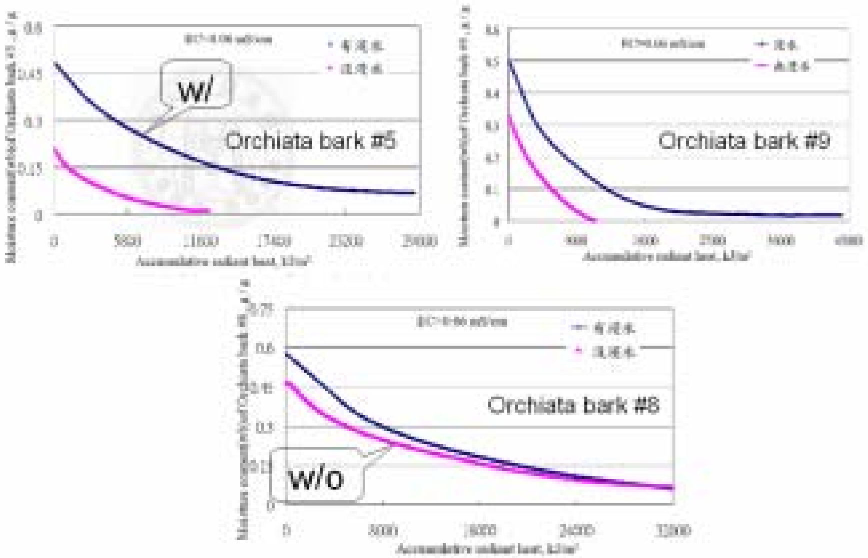

Fig. 3. Variations of gravimetric moisture ratio over time of 3 sizes of Orchiata bark with or without pre-submerge overnight treatment before use.

Table 1 shows converting equations for measuring gravimetric dry basis and wet basis moisture ratio of three sizes of Orchiata barks using ECH$_2$O-10 for measurement. Barks were pre-submerge overnight before use.

Table 1. Converting equations for measuring gravimetric dry basis and wet basis moisture ratio of three sizes of Orchiata barks using ECH$_2$O-10 for measurement.

Bark no.		Eqs.*	R^2
5	db	y = 0.0094x – 2.5492	0.8941
	wb	y = 0.0049x – 1.3258	0.8715
8	db	y = 0.0075x – 2.0518	0.8906
	wb	y = 0.0032x – 0.8758	0.8792
9	db	y = 0.0086x – 2.4096	0.9580
	wb	y = 0.0044x – 1.2168	0.9565

* y: g/g, x: mV;   Barks were pre-submerge overnight before use

3.2 Compactness of sphagnum moss potting

As shown in Fig. 4, loosely filled pot has less mV outputs (ECH$_2$O-10 sensor) and holding less amount of water. To fill the pots compact or loose affects not only the sensor outputs but also the amount of water holding in the beginning and during the evaporative process. It is not practical to derive equations for different compactness of pots, thus, the compactness of the pots filled with sphagnum moss need to be defined before any equations derived to be used.

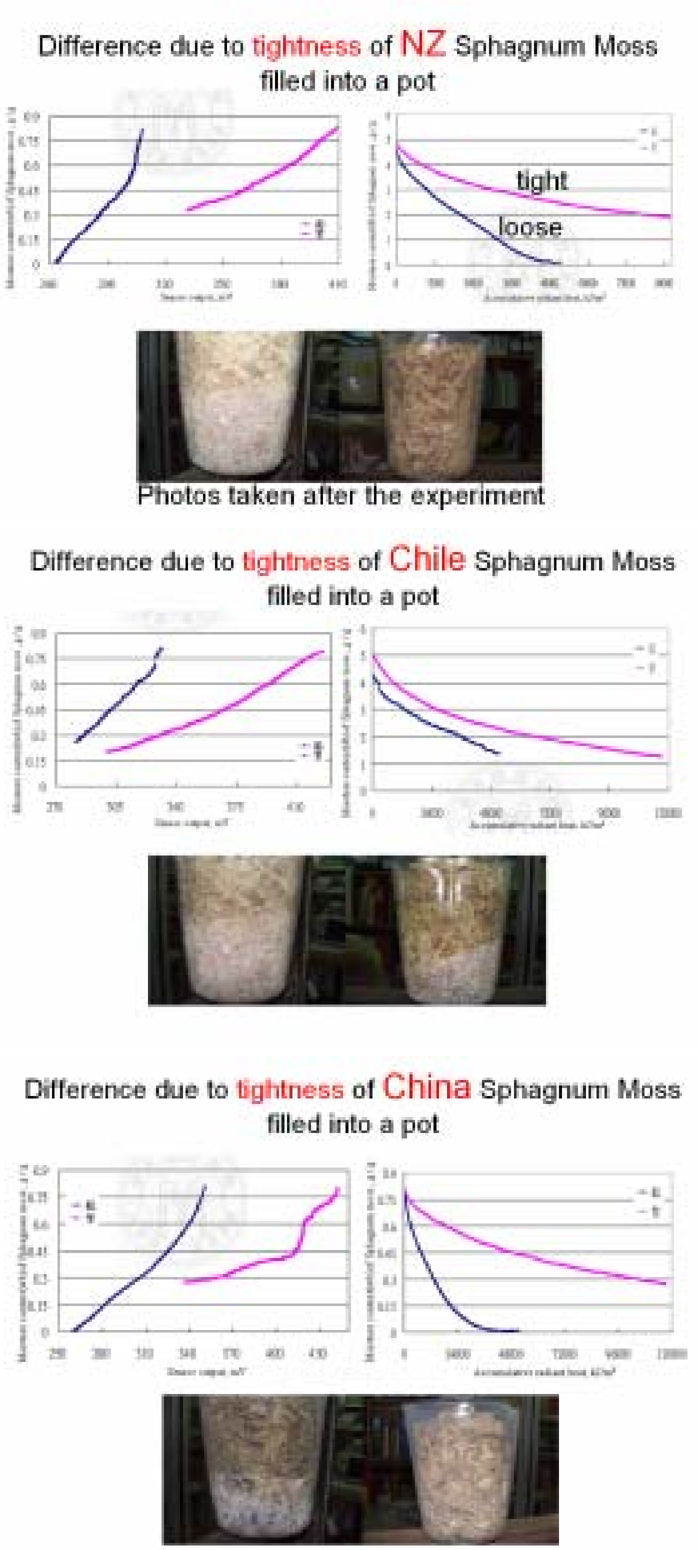

Fig. 4 Compactness of pot filling affects sensor outputs using ECH2O-10 on Sphagnum moss from (a) New Zealand (b) Chile (c) China and photos taken at the end of experiment (left: compactly filled, right: loosely filled)

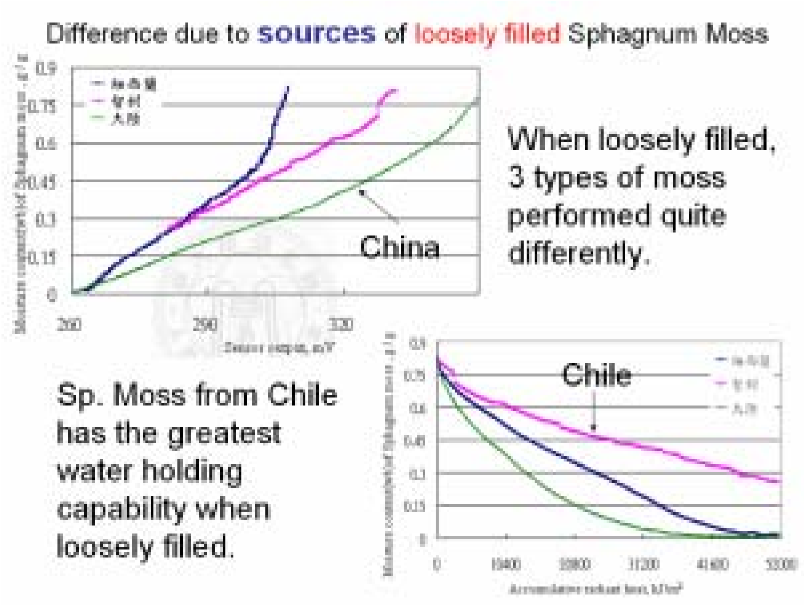

Fig. 5 Differences of moisture content of loosely filled sphagnum moss from different sources

As shown in Fig. 5, converting equations of sphagnum moss are quite different among different sources making the equations difficult to use. At same mV level of sensor output, moss from China contains least amount of water due to its high EC values of raw material itself. Fig.5 also shows the moss from Chile has the best water holding capability and moss from China perform poorly.

3.3 Comparison of two sensors

When fertigation is conducted, the EC value of the water is much higher than regular tap water. Will this influence sensor readings is the question of interests. Fig.6 shows sensor output if irrigated with tap water (EC=0.06 mS/cm) or water with fertilizer (Peters 20-20-20 x 500, EC=2.21 mS/cm). As shown in Fig. 6, at the same level of sensor output voltage, the moisture ratio of sphagnum moss irrigated with lower EC water is higher. Three sources of sphagnum moss show same tendency.

Table 2 shows 6 equations for the calculation of dry basis gravimetric moisture ratio (in g/g) of compactly filled sphagnum moss from 2 types of sensor output mV signals. Sphagnum moss used by Taiwan growers are mostly imported from New Zealand, Chile and China.

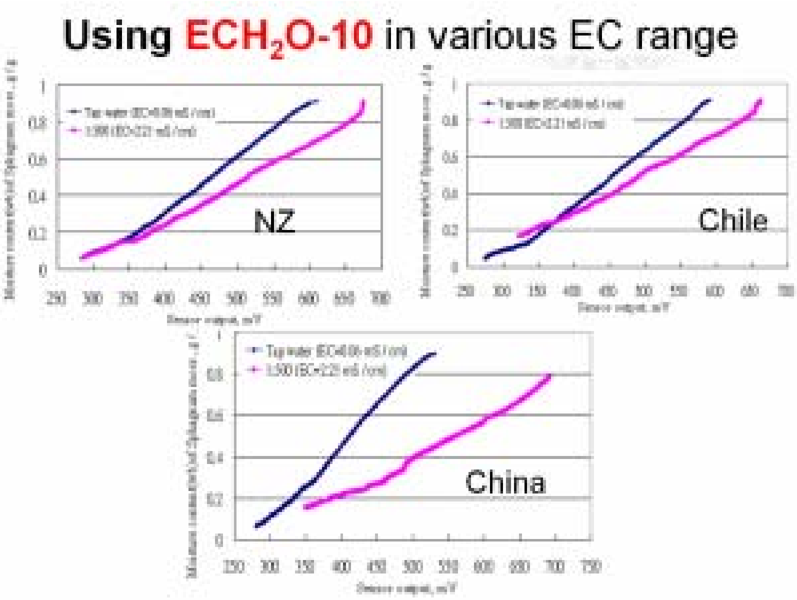

Fig. 6 Effects of EC values of irrigating water on the ECH_2O-10 moisture sensor output

Table 2 Equations derived for dry basis moisture ratio of compactly filled sphagnum moss

Source of Sphagnum moss	Type of sensor	Equations	R^2
New Zealand	ECH2O-10	Y = 0.024 X – 6.4422	0.9292
Chile	ECH2O-10	Y = 0.0248 X – 6.4717	0.9618
China	ECH2O-10	Y = 0.018 X – 4.2573	0.8037
New Zealand	ECH2O-5	Y = 0.0299 X – 6.2301	0.9331
Chile	ECH2O-5	Y = 0.0257 X – 5.7949	0.9083
China	ECH2O-5	Y = 0.024 X – 4.6515	0.9312

Note: Y in g/g and X in mV

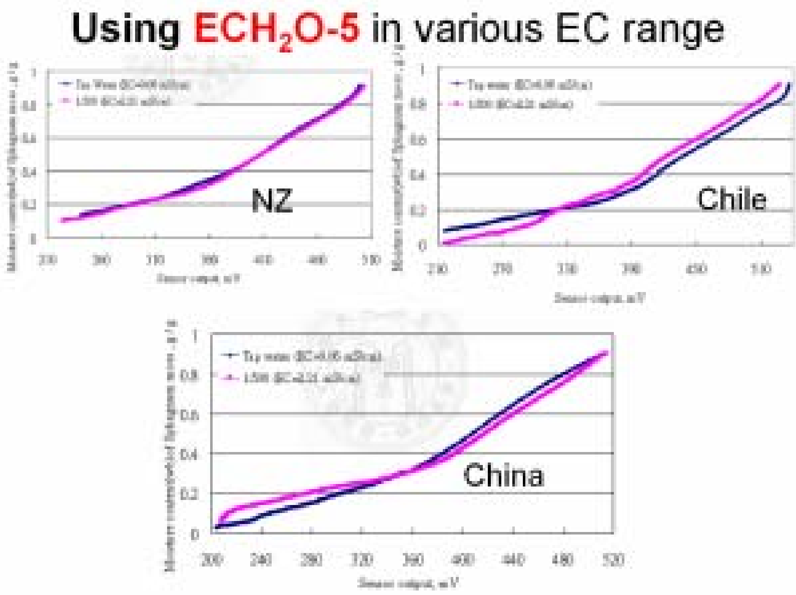

Fig. 7 ECH_2O-5 moisture sensor is suitable for measuring water content with wide range of EC values

3.4 Converting from volumetric moisture ratio to gravimetric moisture ratio

Equations derived mentioned above are good for converting sensor output voltage (in mV) to gravimetric moisture ratio (in g/g). However, most frequent unit used for moisture ratio is in volumetric basis, that in m^3/m^3. The converting equation between two ratios is as follows:

MRv = MRg * BK

Where, MRv: Dry basis volumetric moisture ratio (m^3/m^3)

MRg: Dry basis gravimetric moisture ratio (g/g)

BK: Bulk density (g/cm^3)

Bulk densities of the growth media of interests were listed in Table 3. As shown in the last column, how the sphagnum moss was filled can make a great difference thus leading one to realize that certain standard operating procedures (SOPs) need to be setup for workers to guide the filling/potting operation. Table 3 shows that the amount of sphagnum moss used can be double when compactly filled compare with loosely filled.

Table 3 Bulk density of growth media measured (g/cm^3)

Orchiata bark	Bulk density	Source of Sphagnum moss	Filled	Bulk density
No. 5	0.2656	New Zealand	Loose	0.1434
			Compact	0.2879
No. 8	0.28499	Chile	Loose	0.1362
			Compact	0.3024
No. 9	0.33752	China	Loose	0.1368
			Compact	0.2481

4. Conclusion

Equations to convert sensor outputs to gravimetric moisture ratio and volumetric moisture ratio were derived for 3 sources of sphagnum moss and 3 particle sizes of Orchiata bark. All equations derived were integrated into a software program written in VB.Net. Users can select proper equation for different analog input port based on the type of the sensor and the growth media under use. As shown in Fig.8, all raw data and converted data can be stored in Access (Microsoft) database allow for later process or display trends in real time.

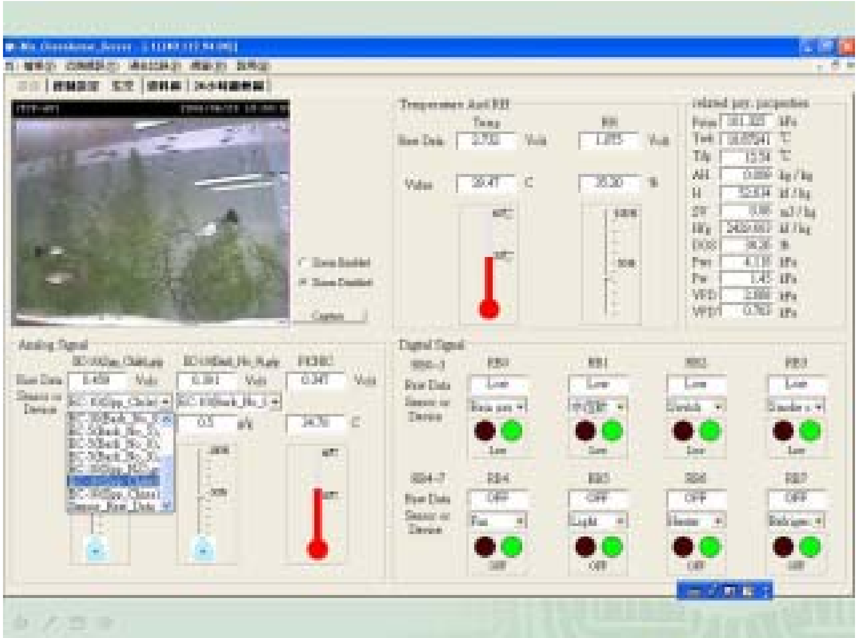

Fig. 8. User interface of the software containing equations derived

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