

Chapter **20**

Non-destructive Measurement of Seed Moisture



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Summary

Measuring the relative humidity of the air in equilibrium with seed samples is a reliable, non-destructive alternative to gravimetric moisture content determination. The equilibrium relative humidity (eRH) of seeds is directly related to seed water activity and water potential. Equilibration time and sample size are particular concerns for the routine measurement of conservation collections of diverse species. This paper describes experiments that investigated these factors using a hygrometer that is used routinely at the Millennium Seed Bank. Recommendations based on these experiments are provided. Measuring seed moisture status in the field is also discussed and alternative, including low-cost, approaches are briefly reviewed.

Introduction

Because of the impact of moisture content on seed longevity, reliable monitoring of seed moisture status is important at a number of stages in the handling and processing of seed collections. For example, understanding the moisture status of seeds at the point of collection, in relation to the prevailing ambient conditions, will help to inform post-harvest handling decisions (Probert, 2003 – Chapter 19). Routine monitoring of seed moisture status at the seed bank is especially important to confirm that seeds are properly dry prior to storage but earlier monitoring can also provide vital information. Periodic monitoring of seed moisture status during drying for example, could be important for seeds with complicated covering structures that could restrict or prevent drying. Accurate determination of seed moisture status is also pivotal to many research applications. For studies of desiccation-sensitive seed, it is important to know the average moisture status of seed samples drawn for the measurement of viability during different drying treatments. Similarly, for seed longevity studies, accurate measurement of the moisture status of seeds during ageing treatments is critical.

Gravimetric seed moisture content determination, involving oven drying at temperatures above 100°C (ISTA, 1985), remains the most common method employed. However, this method has one serious drawback in that it is destructive and wastes valuable seeds. This is highlighted in seed banks for wild plant species where individual collections tend to be smaller than those in crop seed banks.

Non-destructive methods for measuring seed moisture status rely on the fact that all seeds are hygroscopic and thus will tend to absorb or desorb moisture depending on the relative humidity of the surrounding atmosphere. When seeds are at equilibrium with the air, the relative humidity of the air (which can be mathematically converted to water potential) will be directly related to the water potential of the seed. At equilibrium, the relationship between the moisture content of seeds and the relative humidity of the air at a given temperature is described by a characteristic reverse sigmoid 'isotherm' (see Probert, 2003 – Chapter 19). The accurate measurement of the relative humidity of the air above seed samples therefore offers a non-destructive alternative for measuring seed moisture status that can be related, if required, to seed moisture content by reference to isotherms.

There are a variety of instruments available designed for measuring the relative humidity of gases, including air, or the moisture status of hygroscopic materials such as seeds. Only dew point hygrometers provide a direct measure of a psychrometric parameter of the air at equilibrium, the dew point temperature (see Probert, 2003 – Chapter 19). Others tend to rely on the physical or chemical change in a substance which is directly related to a change in humidity against a calibrated standard. Such instruments include hygrometric, capacitance and resistive sensors. Modern digital hygrometers operate with software that calculates the required output units from psychrometric principles. Thus displays in relative humidity (% RH); water activity (a_w); water potential (MPa); and dew point temperature (°C) are common. Instruments with sample chambers designed for seeds or other hygroscopic materials tend to measure equilibrium relative humidity (eRH), or water activity (identical to eRH but expressed on a decimal % basis i.e., on a scale from 0 to 1).

It is beyond the scope of this chapter to provide a comprehensive review of the full range of measuring instruments available (for further details see HMSO, 1996). Rather, the chapter provides an overview of a selection of instruments that were trialled by the Millennium Seed Bank Project for non-destructive seed moisture testing and describes experiments that focused on two important practical considerations: equilibration time and sample size.

Quoting the manufacturers name and specifications of the instruments tested does not constitute an official endorsement by the Royal Botanic Gardens, Kew.

Materials and Methods

Instruments supplied by Rotronic instruments uk ltd., fitted with two types of humidity sensor: hygrolyt¹ and hygromer, were used in the experiments described below.

1. Sensors Used in Experiments

1.1. Rotronic hygrolyt

The hygrolyt sensor is based on the electrical impedance of a hygroscopic liquid electrolyte. As the liquid absorbs or desorbs water, the electrical impedance changes in proportion to changes in relative humidity.

The hygrolyt sensor was enclosed within a WA-40 measuring station which in turn was connected to the BTRS1 display unit. Accuracy $\pm 2\%$ RH.

1.2. Rotronic hygromer

The hygromer sensor is based on the dielectric properties of a polymer. In this case, the capacitance of the polymer changes in proportion to relative humidity, as water is absorbed or desorbed from the air.

The hygromer sensor was enclosed in a AWVC-DIO² water activity station which was connected to a HygroPalm AW1 measuring instrument held in a PD1 docking station. Accuracy, $\pm 1.5\%$ RH.

Both of the above measuring systems allowed datalogging of measurements using dedicated software.

2. Equilibration Time

When a sample of seeds is placed into the sample chamber of a hygrometer, the time taken for the sensor to reach equilibrium will depend on how quickly the seeds absorb or desorb water molecules as the relative humidity of the sample chamber atmosphere attains equilibrium with the seeds. This time will depend on a number of factors including:

- temperature;
- the water potential difference between the seeds and the air at the start of the test;
- whether the seeds need to absorb or desorb water; and
- seed properties such as the permeability of the covering structures.

¹ The hygrolyt sensor was phased out in 2002.

² The AWVC-DIO was superseded by the AW-DIO in 2002 and is no longer available.

For routine monitoring of seed bank collections, the possibility of differences in the rate of equilibration of different species is of particular interest. In a preliminary investigation, seed samples of 17 wild plant species, representing eight families, were tested using two Rotronic AWVC-DIOs. Collections were selected to represent seeds with wide variation in seed size and structure. For example, 1,000 seed weights varied from 1,400 g (*Elephantorrhiza elephantina* Skeels) to 7.7 g (*Aristolochia bracteolata* Lam.) and species with known physical dormancy (impermeable seed coats) such as *Adenocarpus decorticans* Boiss. were included. A consistent volume of seeds (50 cm³) was used for all measurements. All collections had been previously dried at 10% RH and 18°C. All measurements were carried out in an air-conditioned laboratory at 21°C. For 11 collections, two separate tests were conducted at different times when the laboratory RH differed.

3. Sample Size and Measurement Accuracy

As a general rule, the sample chambers of water activity hygrometers should be filled to their maximum volume with seeds to achieve the most accurate measurements. This is because the sample (seeds) will need to lose (desorb) or gain (absorb) moisture from the sample chamber atmosphere before equilibrium is reached. Consequently, there will be a change in the water activity of the sample depending on the amount of water lost or gained. This change is negligible when large seed samples are measured with minimum air space. Collections of seeds of wild plant species are often small in volume simply because the seeds themselves are small. Consequently, it may not be possible to completely fill the sample chamber.

Recognising the importance of minimal airspace for maximum accuracy, a series of solid, stainless steel inserts were manufactured. These were designed to reduce the volume of airspace within a 72 cm³ Rotronic WA-40 measuring station sample chamber. Three such inserts reduced the sample chamber volume to 28, 13 and 2.8 cm³ respectively.

The eRH of samples of moist (80% eRH) seeds of *Ranunculus sceleratus* L. was then recorded using the WA-40 measuring station and hygrolyt sensor with the four sample chambers (72, 28, 13 and 2.8 cm³) approximately filled to nine different levels (100, 80, 60, 40, 20, 16, 12, 8 and 4% filled). The eRH values recorded for the 100% filled chambers were taken as the most accurate value in each case and results were expressed as the deviance in eRH from that value. Although manufacturers aim to minimise the air space within the sensor head, a residual volume of air is inevitable. The hygrolyt sensor used in this experiment had approximately 3.3 cm³ of residual air space. Taking this air space into account, the actual percentage of the total air space occupied by seeds for the four chambers is indicated in Table 20.1. Also shown is the corresponding weight of seeds used in each case.

Table 20.1 Correction of sample chamber filling values to take account of 3.3 cm³ residual air space in hygolyt sensor head

% of chamber volume occupied	% of total air space and corresponding weight in g (in brackets) occupied by sample for each chamber			
	72 cm ³	28 cm ³	13 cm ³	2.8 cm ³
100	96 (31.9)	89 (10.3)	80 (5.2)	46 (0.78)
80	76 (25.5)	72 (8.2)	64 (4.2)	37 (0.62)
60	57 (19.2)	54 (6.2)	48 (3.1)	28 (0.47)
40	38 (12.8)	36 (4.1)	32 (2.1)	18 (0.31)
20	19 (6.4)	18 (2.1)	16 (1.04)	9 (0.14)
16	15 (5.1)	14 (1.6)	13 (0.83)	7 (0.11)
12	11 (3.8)	11 (1.2)	10 (0.63)	6 (0.08)
8	8 (2.6)	7 (0.8)	6 (0.42)	4 (0.05)
4	4 (1.3)	4 (0.4)	3 (0.21)	2 (0.03)

For each combination of sample chamber and fill, the hygrometer was allowed to equilibrate and the end point eRH noted. All measurements were made at 21°C.

Results and Discussion

1. Equilibration Time

In this experiment, measurements were datalogged at 15 second intervals. For each test, results were plotted as decline in sensor reading (% RH) against time, where the decline in RH represented the rate of absorption of water molecules by the seeds until the sensor, and hence the chamber atmosphere and the seeds, reached equilibrium. The equilibration time was recorded as the time elapsed from the start when sensor readings began to oscillate. In most cases, the RH at this time point (end RH) was the lowest attained. The time elapsed when the sensor was 1% RH higher than the end RH was also recorded.

Evidence is presented in Table 20.2 that final equilibration times vary considerably between species. However, these differences must be interpreted with caution because in those collections which were tested twice, there was often a considerable difference in the equilibration time between tests which could not be explained by differences in the start and end point RH values. The time taken for the sensor RH to fall to 1% of the final value was less variable and remarkably quick. Across the 17 collections tested, the *average* time taken to reach this point was just 14.2 min with only one collection,

Combretum apiculatum Sond. taking longer than 30 min. Although there was no correlation between time to reach 1% RH of end value and parameters such as seed size or weight of seeds tested, the results suggest that equilibration time might be related to aspects of seed structure and this is under further investigation. For example, it is noteworthy that all three collections of Combretaceae (complicated winged fruits) were slow to equilibrate. The two other species that were notably slow to reach 1% RH of the end value were *Triumfetta rhomboidea* Jacq. and *A. decorticans*. Although in both cases there is evidence from germination tests that seeds possess impermeable seed coats, we cannot conclude that seeds possessing physical dormancy are inherently slow to equilibrate since seeds of *Amblygonocarpus androngensis* (Welw. ex Oliv.) Exell & Torre and *E. elephantina* (both *Fabaceae*) were amongst the fastest tested. Despite this, we strongly advise caution in the conduct of eRH measurements on seeds known to possess impermeable seed coats. Although not thoroughly tested, we believe that in some cases such seeds may possess relatively porous outer covering structures with good water holding properties. In such cases it is possible that the outer layers of the seed will not be in equilibrium with the internal tissues. The absorption and desorption of water from these outer layers could give credible, but false, RH measurements for the whole seeds. As a precaution, it is thus recommended that seeds with physical dormancy are cut open or crushed immediately prior to testing. To avoid the possible gain or loss of water from the seeds, it is extremely important that such treatments are carried out swiftly. Preliminary tests in our laboratory with commercial seedlots of field and dwarf beans showed that coarsely ground samples reached equilibrium 50% quicker than intact seeds. The obvious disadvantage of such treatments is that the seeds are effectively destroyed and thus such tests cannot be considered 'non-destructive'.

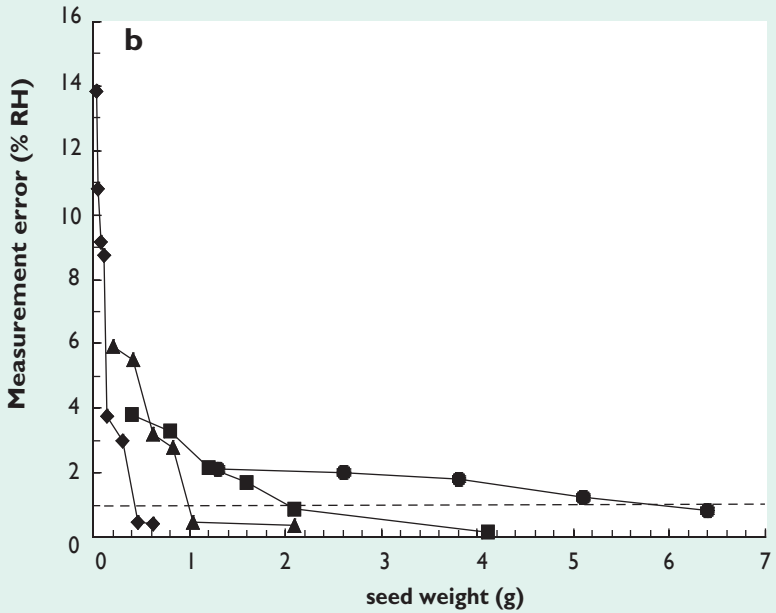
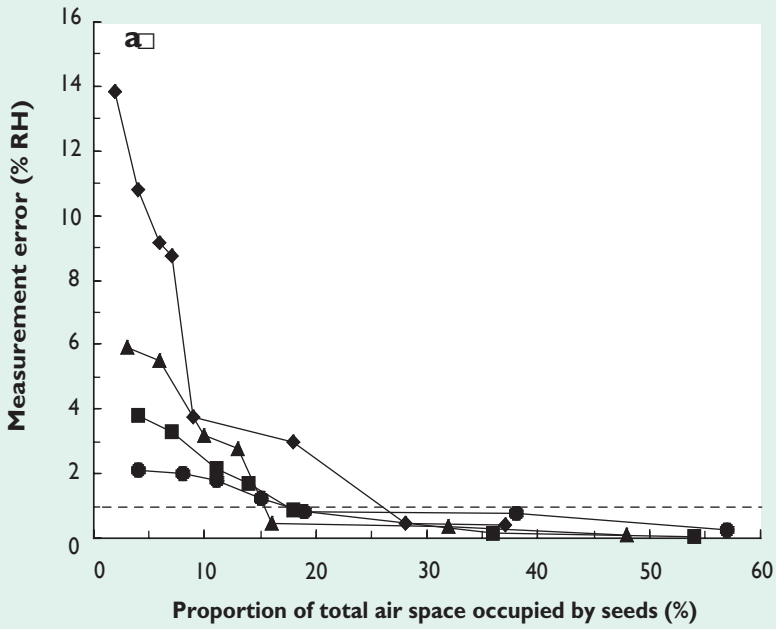
2. Sample Size and Measurement Accuracy

As expected, the accuracy of measurements was strongly dependent on the quantity of seed material relative to the total air space within the sample chamber and sensor head. When the 72, 28 and 13 cm³ sample chambers were used, provided that the seed sample occupied more than 20% of the total space, readings were within 1% RH of the most accurate value. When the smallest sample chamber (2.8 cm³) was used, the seed sample needed to occupy closer to 30% of the total space for the same accuracy (Figure 20.1a).

An accurate measurement of eRH will be possible when the amount of water to be lost or gained from a seed sample, to equilibrate with the air in the residual space, is insignificant in relation to the total amount of water present in the seeds. Accepting that the water holding capacity of seeds is related to seed composition (at a given eRH an equivalent weight of oily seeds will hold less water than non-oily seeds), the amount of seed tissue needed for an accurate eRH measurement is more likely to depend on weight rather than volume. An equivalent volume of heavy seeds will contain far more water than light seeds.

Table 20.2 Equilibration times for different species when measuring the eRH of dry seeds

Species (family)	Start RH	End RH	Time (mins)	Time (mins) to 1% RH of end
<i>Prekia tetragona</i> (Aizoaceae)	31.6	15.2	95	22
	48.7	19.6	53	14
<i>Hymenogyne conica</i> (Aizoaceae)	30.5	13.4	63	8
	47.5	18.5	21	5
<i>Aristolochia bracteolata</i> (Aristolochiaceae)	31.5	13	39	3
	46.9	14.2	57	5
<i>Citrullus rehmii</i> (Cucurbitaceae)	30.9	11.9	13	3
	45.3	13.5	46	21
<i>Acanthosicyos naudinianus</i> (Cucurbitaceae)	32.2	18.8	16	4
<i>Cucumis prophetarum</i> (Cucurbitaceae)	29.9	14.7	35	7
<i>Combretum apiculatum</i> (Combretaceae)	50	19.1	105	43
<i>Combretum psidioides</i> (Combretaceae)	48	18.5	60	30
<i>Guiera senegalensis</i> (Combretaceae)	48	15.3	90	23
<i>Grewia androyensis</i> (Tiliaceae)	29.6	14.7	5	1
	46.8	15.9	55	14
<i>Grewia andramparo</i> (Tiliaceae)	29.2	11.8	70	7
	45.1	14.2	26	6
<i>Triumfetta rhomboidea</i> (Tiliaceae)	30	13.1	80	24
<i>Adenocarpus decorticans</i> (Fabaceae)	31.1	17.6	98	22
	45.1	23	56	38
<i>Amblygonocarpus androngensis</i> (Fabaceae)	30	13.2	8	3
	43.8	17.6	13	3
<i>Elephantorrhiza elephantina</i> (Fabaceae)	29.1	16.2	8	4
	45.5	21.9	13	4
<i>Balanites aegyptica</i> (Balanitaceae)	30.5	14.5	16	4
	48.4	14.3	83	24
<i>Ricinus communis</i> (Euphorbiaceae)	28.8	12.8	6	2
	45.6	14.5	40	5



The minimum weight of seeds giving a measurement within 1% RH of the most accurate value varied depending on the sample chamber used, ranging from about 0.5 g for the 2.8 cm³ chamber to about 6 g for the 72 cm³ chamber (Figure 20.1b). These minimum seed weights gave a near-linear relationship when plotted against total air space (Figure 20.2) confirming the considerable value of reducing sample chamber size for small seed samples. Interestingly, when the speed of equilibration was compared across the four chambers each filled to 100% with the same seed, equilibrium was attained fastest when the smallest chamber was used and was progressively slower as the chamber size increased. Although not studied directly, the likely explanation is the increasing time required for water molecules to diffuse into the air space between seeds as sample size increases. Whilst this observation seems to favour the choice of the smallest sample chamber for routine measurements, we argue against this for two reasons.

1. The residual air space above small sample chambers will be a significant proportion of the total air space thus increasing the risk of measurement error when there is a large difference in moisture status between the sample and the sample chamber atmosphere.
2. Measurement error increases more steeply with decreasing sample size, the smaller the sample chamber (Figure 20.1). Thus although complete filling of small sample chambers should give accurate measurements there is a greater risk of error if the chamber is not filled, compared to larger chambers.

Ideally, the largest sample chamber that can be completely filled with the seeds that are available should be chosen. When sample size is limiting, the following rule of thumb based on the data presented in (Figure 20.2) is recommended. A sample chamber should be selected such that the weight of seeds to be measured in grams is at least 10% of the total air space in cm³. For example, for a 70 cm³ sample chamber, the weight of seeds should be at least 7 g.

Figure 20.1

The effect of sample size expressed as a proportion of total air space occupied (a) or sample weight (b) on the accuracy of eRH measurements using different sized sample chambers. Sample chamber volume was reduced by stainless steel inserts placed inside a 72 cm³ chamber. Sample chambers: 72 cm³ (●), 28 cm³ (■), 13 cm³ (▲), 2.8 cm³ (◆). Moist (~80% eRH) *Ranunculus sceleratus* seeds were tested using a Rotronic WA-40 measuring station. The broken horizontal lines denotes the minimum sample volume (a) or weight (b) giving readings within 1% RH of the most accurate value.

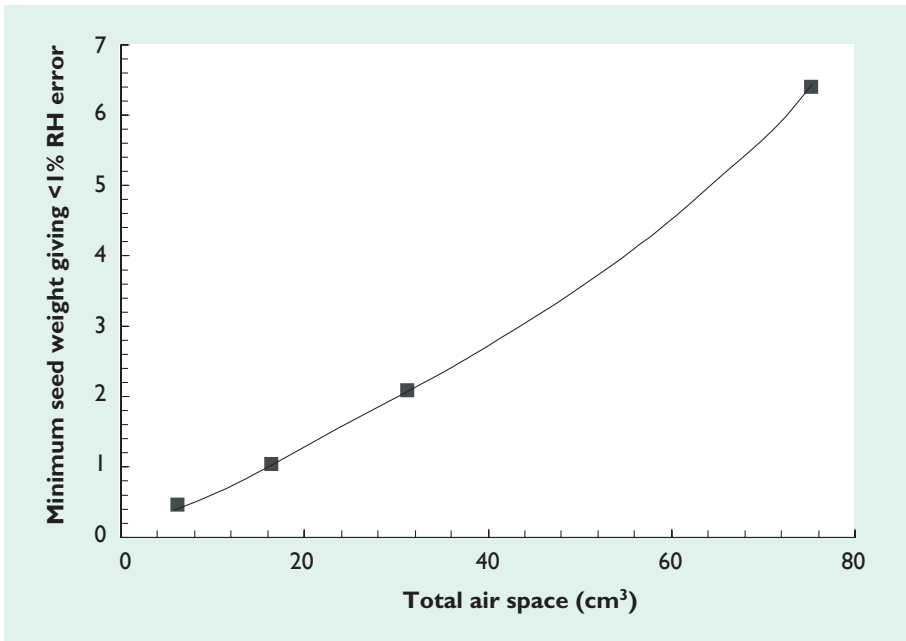


Figure 20.2 The relationship between the minimum seed sample weight giving <1% RH error in the eRH measurement, and total air space within the hygrometer sample chamber and sensor head, when moist (~80% eRH) *Ranunculus sceleratus* seeds were tested using a Rotronic WA-40 measuring station.

Other Important Practical Issues

1. Measuring Non-equilibrated Samples

When an individual seed is in the process of drying, or moisture absorption, there will be a water potential gradient between the centre of the seed and its surface. The same will be true for a multi-layered batch of seeds where there will be a water potential gradient between the middle of the batch and the outside layers. This situation will arise in studies of seed storage behaviour. When seed samples are being tested for viability in response to desiccation treatments, samples are usually withdrawn at stages during a drying treatment when the surface layers of the seed will be drier than the interior. When measuring the eRH or water activity of such seeds, it is extremely important that ample time is given for the seeds to attain equilibrium inside the

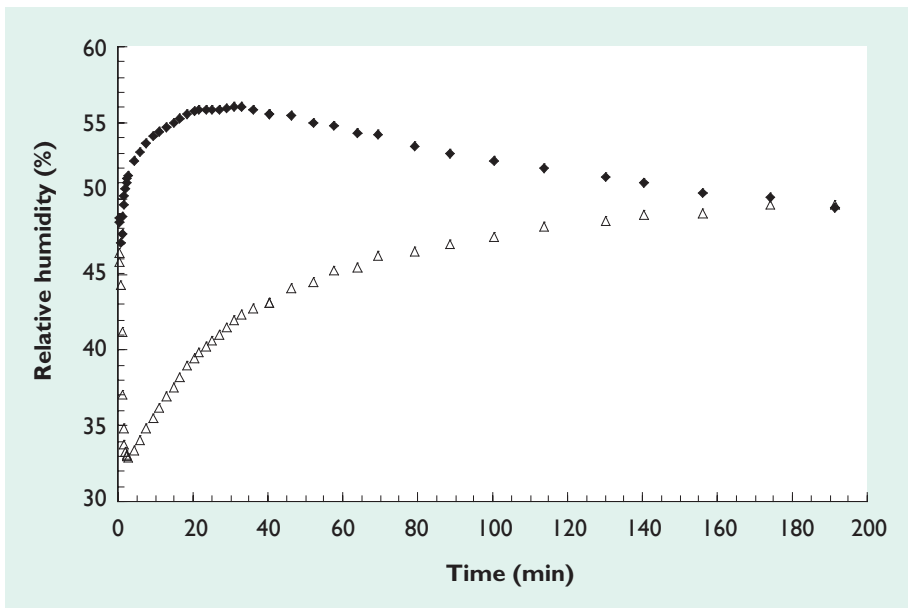


Figure 20.3 Equilibrium relative humidity measurement of non-equilibrated seed samples. Wheat seeds previously equilibrated to 46% eRH were divided and placed for 24 h at 80% (◆) and 10% (△) RH prior to measurement using a Rotronic AWVC-DIO.

hygrometer sample chamber. It is strongly recommended that measurements are datalogged, if possible, or at least that values are periodically checked and noted so that a time to equilibrium graph can be plotted.

Figure 20.3 shows measurement data for two non-equilibrated samples of wheat seeds. These samples, drawn from a single batch of seeds at equilibrium with laboratory conditions, had been placed for one day at either high or low humidity. Consequently when tested, the surface layers of the seeds in each case were either wetter or drier than the internal tissues. Of particular concern, is the data for the seeds that had been in a moist atmosphere. The data clearly show apparent equilibrium over the period 20–35 min followed by a steady decline as the drier internal tissues of the seeds begin to reabsorb water from the sample chamber atmosphere.

2. Sample Temperature

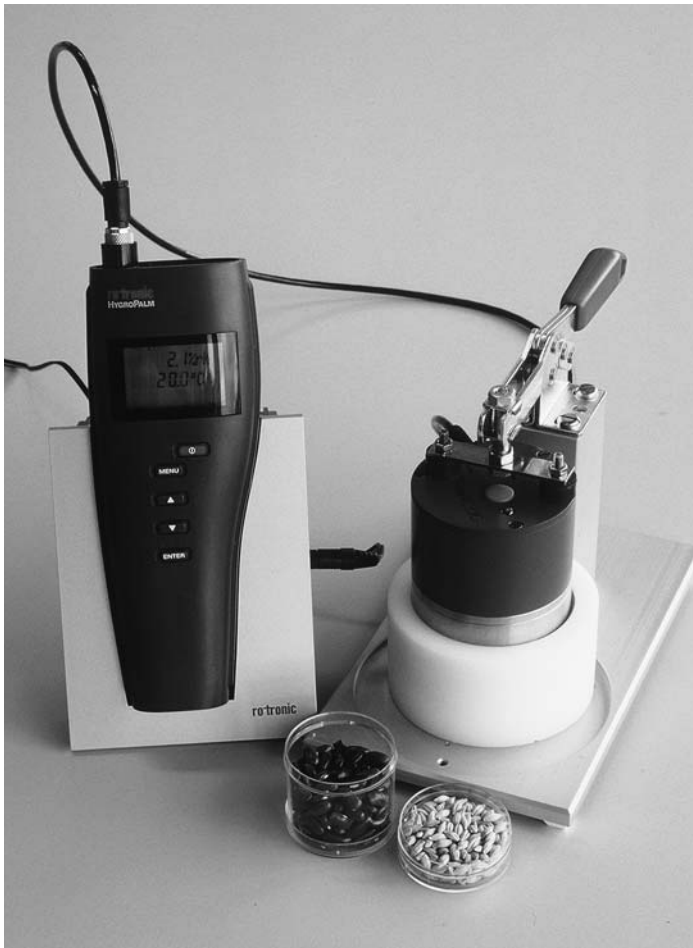
We know from moisture sorption isotherms that equilibrium values are temperature dependent (see Probert, 2003 – Chapter 19). Consequently, if there is a discrepancy between the temperature of the seeds to be measured and the temperature of the hygrometer sample chamber, an incorrect value

could be recorded. Such a situation could arise for example, if a water activity hygrometer was being used to check the moisture status of collections held in a seed bank. Usually such measurements would be performed at room (or dry room) temperature. If the seed collection to be tested had not fully equilibrated to the temperature of the room, and was significantly colder, then an inaccurate value could be recorded. This inaccuracy could be higher or lower than the correct value depending on how quickly the seeds were transferred to the sample chamber, and on the ambient RH. For example, if very cold seeds were exposed to the open air, even for a couple of minutes, there is a significant risk that water molecules would be absorbed onto the surface of the seeds by condensation. This (additional) water would be quickly lost to the sample chamber atmosphere during measurement giving an inaccurate high reading.

Thus it is strongly recommended that if seed samples are to be measured at a temperature different from that where they have been held, that ample time is allowed for the sample to equilibrate to the measuring temperature before the container is opened and the sample is transferred to the hygrometer sample chamber.

Box 20.1 Practical guideline for routine, laboratory monitoring of seed moisture status

- Choose a suitable sample chamber size to minimise the total headspace above the seed sample.
- The weight of sample in g must not be less than 10% of the volume of the total headspace in cm³.
- If the seeds are known to possess impermeable seed coats (presence of physical dormancy), the seeds should be cut, coarsely ground or crushed immediately before placing into sample chamber.
- The temperature of the seed sample must be fully equilibrated to the sample chamber temperature before starting the measurement.
- Remember that the human body is constantly leaking water vapour through the skin and breath. Minimise direct handling of seeds, avoid touching the inside surfaces of the sample chamber and avoid breathing on an exposed sensor.
- Manufacturer's claims for equilibration time should be treated with caution. We recommend allowing at least 30 min for accurate measurements of seeds that are at a stable moisture status and substantially longer if the internal and external tissues of the seeds are thought not to be in equilibrium.
- Wherever possible, measurements should be datalogged and final equilibration time should be interpreted from graphical data.

**Figure 20.4**

Battery or mains operated Rotronic HygroPalm water activity monitor with docking station and AWVC DIO (replaced by AW DIO) sensor with clamp.

3. Measuring Seed Moisture Outside the Laboratory

Elsewhere in this book (Probert, 2003 – Chapter 19; Hay and Smith, 2003 – Chapter 6), evidence is presented that the moisture status of seeds at the point of collection can be surprisingly high and not in equilibrium with the ambient RH. Whilst some understanding of expected RH and temperature from meteorological records can be useful for planning purposes, there are compelling arguments for being able to measure both ambient RH and seed eRH at the time of harvest. Such information will guide post-harvest handling decisions (Probert, 2003 – Chapter 19).

Many modern, water activity hygrometers, including those described in this chapter (see also Figure 20.4) and other dedicated instruments are designed to operate by battery as well as mains power and can therefore be used in the

field. The sensor head can be exposed to the air (not attached to the sample chamber) to give measurements of ambient RH and temperature, and samples of seeds at the point of collection can be loaded into an appropriately sized sample chamber for measurement of seed eRH. There are however, some important practical considerations if meaningful results are to be obtained:

1. It is very important to be aware of the considerable spread of seed/fruit maturity that may be present in any collection being made. Thus unless the collection is deliberately going to be split into distinct maturity classes for different post-harvest handling, care should be taken that samples for eRH measurement are representative of the bulk.
2. If the eRH measurements are being made to inform the post-harvest handling of collections, it is important that measurements are made on the components that will make up the bulk collection. Thus it would be wrong to remove seeds from partly opened fruits if the bulk collection is not going to be treated in the same way. If on the other hand it is planned to clean the seeds from their surrounding fruit structures immediately after harvest, then eRH measurements should be made on extracted seeds.
3. If the eRH measurements are intended to provide information on the water status of seeds at the point of dispersal, then the above recommendations obviously do not apply. Rather, it will be very important that only fully ripe seeds that fall naturally from the parent plant should be measured. In this case, relatively small amounts of contaminating unripe seeds or 'green' fruit tissue could give a false high reading.
4. Prior to, and during measurements, it is extremely important that the hygrometer is kept in the shade to avoid solar gain by the sample chamber and sensor. Artificially high temperatures will give seed eRH values that are too high and ambient RH values that are too low. The sample chamber should not be held during measurement.

Other Non-destructive Methods

1. Dew Point Hygrometers

In theory, dew point hygrometers should offer the most accurate means of measuring the eRH or water activity of seed samples because they rely on the direct measurement of a psychrometric parameter (dew point temperature of the air inside the sample chamber) rather than a parameter that correlates with relative humidity.

The general working principle of dew point hygrometers is based on a high quality mirror which is cooled by an attached thermo-electric Peltier heat pump. A light source directed at the surface of the mirror as it is cooled is analysed by an optical sensor. As the mirror temperature reaches the dew point temperature of the atmosphere surrounding the mirror (in the sample chamber), water droplets or frost condenses on the surface of the mirror and this is detected by the optical sensor. The exact temperature of the mirror surface when condensation forms is measured (dew point temperature) and the sample temperature (or air temperature of the sample chamber) is measured simultaneously. As explained in the previous chapter (Probert, 2003 – Chapter 19), if two psychrometric parameters are known, in this case dew point temperature and dry bulb (sample) temperature, then any one of the remaining psychrometric parameters can be calculated or read from a psychrometric chart. Modern dew point hygrometers are usually programmed to display relative humidity, water activity or water potential which are calculated from the measured dew point and sample temperatures.

As with other methods of determining the eRH or water activity of seed samples, accurate measurement of the sample temperature is critical. The main potential problem of using dew point hygrometers is the possibility that the cold mirror surface could influence the air temperature of the sample chamber and thus the temperature of the seed sample. Positioning of the temperature sensor is therefore critical. Difficulty in overcoming this technical problem when using a dew point hygrometer originally designed for measuring gas streams but modified for seed samples, is the main reason why the Millennium Seed Bank Project (MSBP) has focused on hygrometers based on impedance or capacitance sensors.

Recently however, a dew point hygrometer specifically designed for measuring the water activity of hygroscopic materials (Figure 20.5) has been trialled. It is possible that instruments of this type will prove to be more accurate and will therefore be the preferred option for routine laboratory monitoring of seed collections in the future.

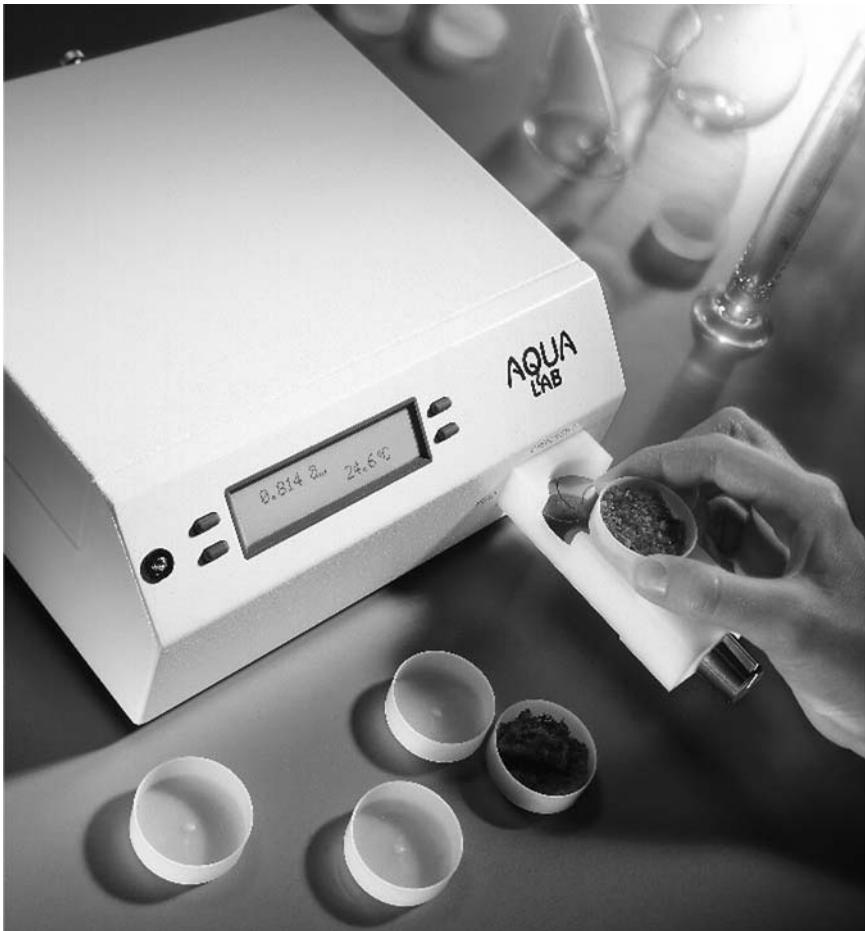


Figure 20.5 Modern dew point hygrometer (Labcell AquaLab) designed to measure water activity of hygroscopic samples such as seeds.

2. Inexpensive Options

Work by the MSBP has shown that acceptable estimates of seed eRH can be obtained from a range of less expensive hygrometers designed for other purposes.

2.1. Probe type hygrometers

Meteorological (probe-type) hygrometers can be used to measure seed eRH provided that the sensor has an air-tight seal at its probe end and that the sensor itself can be located into a suitable 'sample chamber' also through an air tight seal (Figure 20.6).

Box 20.2 General tips on maintenance and calibration

- Hygrometers must be kept clean and any seals should be periodically checked to ensure that moisture cannot migrate into or out from the sample chamber during measurement.
- Sample chambers should be cleaned with deionised water and or alcohol and then carefully dried. Some manufacturers supply sample pots to prevent contamination of the sample chamber.
- Sensors (including cooled mirrors) must be checked regularly and kept free of contamination. Always follow the manufacturer's recommendations for cleaning.
- Regular calibration is essential to maintain accuracy. As a rule, multi-point calibrations using certified standards is recommended. However, in order to monitor long-term sensor behaviour (drift), it is generally not advisable to adjust the sensor following calibration. Rather, a correction factor based on the calibration should be applied to measurements.



Figure 20.6 Miniature datalogger (Gemini Tinytag Plus) inserted inside jar of seeds (left). Handheld probe-type hygrometer (Testo Hygrotest 6400, no longer available) adapted for insertion into seed container to measure eRH.

2.2. Self contained dataloggers

In theory, miniature RH/temperature dataloggers could be used to record the eRH of seed samples inside sealed containers (Figure 20.6). Potentially, such measurements could have important practical application, for example, in monitoring the behaviour of seed collections as seed containers are moved from ambient to sub-zero temperatures and back again. However, our experience shows that unless large containers, virtually filled with seeds are used, false readings can occur because of slight moisture leakage from the datalogger.

Dataloggers however have considerable potential for monitoring the moisture status of seed collections in transit. Located amongst the seeds inside a single cloth bag or amongst a number of collections boxed up for shipment, dataloggers can provide important clues to explain the final quality of collections arriving at a seed bank.

2.3. Low cost mechanical and electronic hygrometers

Mechanical and small electronic hygrometers can be purchased for under \$50 US (Figure 20.7). Although generally much less accurate, these instruments could be used to roughly determine the moisture status of seeds. Such instruments placed amongst seed collections during a collecting mission could be used to indicate whether certain collections needed to be dried further. The instruments could also be used to check that ambient conditions were suitable for drying, and subsequently to confirm that drying had occurred.

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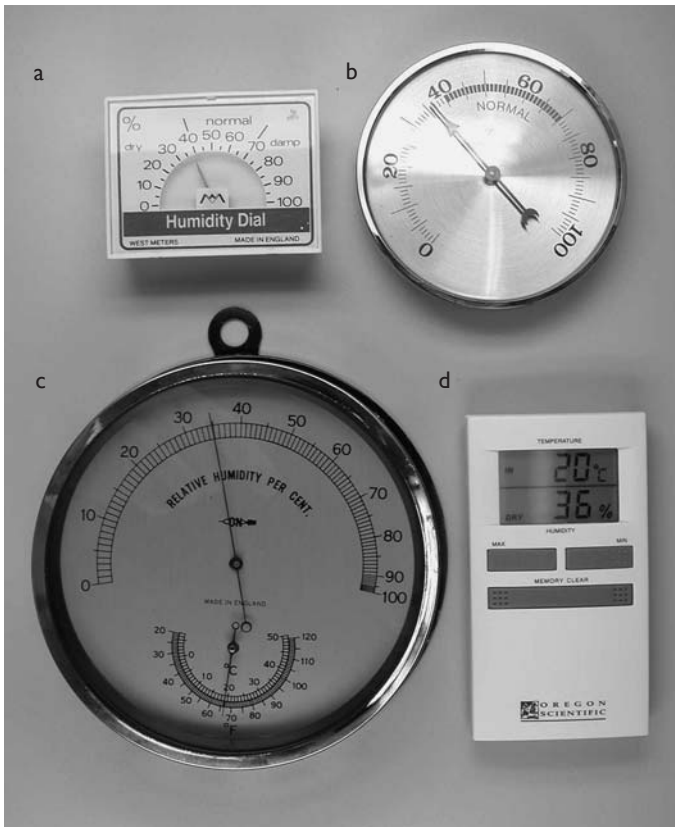


Figure 20.7 A selection of low-cost hygrometers. a. West Meters humidity dial; b. Pocket Hygrometer (Fisher Scientific); c. Hair Hygrometer (Fisher Scientific) (all mechanical). d. Oregon Scientific Thermo Hygrometer (electronic).

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