# Chapter 22: General recommendations for the use of instruments

**Julian Pietragalla and Alistair Pask**

## 1. Correct use of instruments

Instructions may vary according to the make and model of your instrument. Refer the instrument user manual for specific information (modes, measurement, data download etc.), further details and clarification.

| Do: | Do not: |
|---|---|
| Do ensure that the operator is familiar with each instrument, functionality, correct approach to take data, and expected readings before going into the field – it is worth receiving advice and training from an experienced user and reading the user guide. | Do not use an instrument before it has equilibrated with ambient temperature and relative humidity (RH) as this may affect the calibration and data. Take the instrument out of its protective case and turn on at least 10 minutes before starting use. |
| Do take measurements consistently – this is very important. In particular, ensure that the instrument is calibrated correctly before (and sometimes again during) use. Keep a careful eye on the data during measurement to guard against erroneous data, and large variations within a plot. | Do not leave an instrument in direct sunlight/heat before use as this can affect calibration and may cause incorrect readings (especially for instruments with black cases). When reading air temperature and RH, stand with your back to the sun so as not to expose the instrument to direct sun during measurements. |
| Do maintain batteries of correct type, size and polarity. Recharge batteries fully before use (note that this may require overnight charging). Take spare batteries to the field to ensure that measurements are not interrupted. | Do not operate an instrument outside specified temperature and RH range for the instrument, as measurements taken may be incorrect (check the user guide for specifications). Excess heat and moisture/RH may cause permanent damage (note that instruments are typically not water resistant). |
| Do ensure to take the whole repetition with the same instrument. If more than one instrument is available, cross-compare between instruments to check that they are giving similar data. | Do not discard instruments after use. Remember to clean the instrument, return it to its protective case, and to the equipment store room. It is important that each instrument is stored clean, dry, dust-free and in the correct protective case. |
| Do always make data easy to interpret/process at a later date. For example, when taking readings with a data logger which records only basic information, at the end of each section take two blank readings without a sample in the sensor chamber as an 'end marker'. | Do not discard malfunctioning instruments when anomalies or problems have been noted during equipment use. Repairs and/or recalibrations to instruments may be required which may involve returning the instrument to the factory/specialist. This could take weeks or months. |

## 2. Drying of samples

It is important that samples are dried to absolute dry weight (DW), i.e., 0% moisture. The DW refers to the sample weight reached after drying in a well ventilated/forced-draft oven (Figure 22.1A) at 60-75°C until constant weight (typically for at least 48h) (see Table 22.1).

When drying samples:

- Do not mix fresh samples with dry samples.
- Organize sampling to optimize use of the oven, and of oven space.
- Use a non-draft oven for drying open container samples (e.g., soil moisture samples; Figure 22.1B).

Set dryer temperature and time depending on the type of sample, estimated moisture content and capacity of the dryer:

**Table 22.1. General drying temperatures and times for dry weight determination. Note that drying time may differ according oven drying capacity.**

| Material | Temperature (°C) | Time (hours) |
|---|---|---|
| Relative leaf water content | 60-75 | 24 |
| Grain moisture* | 60-75 | 24-48 |
| Biomass (maturity) | 60-75 | 48 |
| Root biomass | 60-75 | 48 |
| Biomass (emergence to grain-filling) | 60-75 | 48-72 |
| Soil moisture (gravimetric) | 105 | 48 |

* Note that seed which potentially may be used for future trials should not be oven dried, as drying seed at temperatures >40°C and/or for long periods of time reduces their viability.

Notes for drying samples for nutrient and/or metabolite analysis:

- Dry biomass samples at 60-75°C for N, P, K and water soluble carbohydrate determination.
- High drying temperatures >90°C for long periods may affect the nutrient content. Some specific metabolites analyses (e.g., enzymes, proteins etc.) require freeze drying of samples or heat drying at a precise temperature and duration. Ensure to check the specific procedural requirements of the laboratory.



**Figure 22.1. Drying ovens: (A) large capacity forced-draft oven; and, (B) small capacity non-draft oven (suitable for drying open container samples; e.g., soil moisture samples).**

## 3. Accurate weighing of samples

It is essential that accurate weights are recorded for sampled material. Poor weighing technique and/or incorrect use of the balance will cause significant data errors: either consistent (e.g., due to not removing the bag 'TARE' weight) or random (e.g., due to irregularly cooled oven dried samples).

Note that all balances are sensitive to changes in the environment, and that laboratory balances (both precision and analytical) are more sensitive than field scales (i.e., battery powered bench balance or spring mechanical scale). Follow manufacturer's instructions for installation, and:

- Keep level (use inbuilt spirit level).
- Keep on a stable, non-vibrating surface (e.g., a concrete plinth).
- Avoid areas near heaters, ovens or air conditioners.
- Avoid direct sun and air flows.
- Avoid sharing power circuits with high consumption items (e.g., a microwave oven).

It is essential to select the type of balance according to the capacity and resolution demanded (Table 22.2; Figure 22.2). It is often observed that samples are weighed on inappropriate balances (e.g., weighing stems from the partitioning of 20 culms on a large precision balance rather than a small precision balance).

When weighing samples:

- Do not weigh hot samples direct from the oven –allow time for sample to cool to room temperature before weighing– to avoid incorrect readings and/or causing damage to the balance.

**Table 22.2. Recommendations for the type of balance and minimum resolution required for the determination of sample weight of various sample types.**

| Sample | Typical weight (g) | Type of balance | Minimum resolution (g) |
|---|---|---|---|
| 2 $m^2$ plot grain weight FW | >1000 | Industrial/retail bench | 5 |
| 2 $m^2$ plot biomass FW | >1000 | Industrial/retail bench | 5 |
| 100 culm sub-sample FW | 500 | Large precision | 1 |
| 100 culm sub-sample DW | 200 | Medium precision | 1 |
| Sub-sample grain weight | 50 | Small precision | 0.1 |
| Soil moisture (of 100 g) | 30 | Small precision | 0.1 |
| 20 culm stem biomass DW | 20 | Small precision | 0.01 |
| 200 grain FW and DW | 10 | Small precision | 0.01 |
| Leaf samples for RWC | <2 | Semi-analytical | 0.001 |
| Root biomass (of 100g) | <2 | Semi-analytical | 0.001 |

Where: FW = fresh weight; DW = dry weight; RWC = relative water content.

- Do not allow time for samples to absorb moisture after oven drying. Once dried, samples tend towards ambient humidity over time (this may be from hours to days depending on the RH and type of sample).
- Samples for precision weighing may be kept in a desiccator after drying (only appropriate for small quantities).
- Distribute the weight of the sample evenly across the balance plate.
- For small samples (<20 g), carefully empty the sample from the container (i.e., the bag, envelope etc.) into a specific weighing container (and remember to subtract the container weight from the total weight).
- For samples >20 g, keep the sample in its container to avoid losses (and remember to TARE the container weight).

**Removing the container weight by using a 'TARE':**
When weighing samples in containers (e.g., a bag, envelope, tube etc.), remember to first 'TARE' this weight so that the weight of this container is deducted from the gross weight to give the sample weight. This is typically appropriate for samples >20 g.

To do this:

- Select an empty container which is otherwise identical to that of the samples (i.e., from the same box/packet, with the same ventilation holes/staples if any, etc.).
- Dry the empty container in the oven next to samples (for the same drying time).
- Before weighing samples, place this empty container on the balance and press 'RE-ZERO'/'TARE'.
- The balance should show zero with the empty container on the balance plate, or a negative value when the empty container is removed (and the plate is empty).
- Note that individual container weights may vary slightly. Ensure to select a good, representative TARE container.

An alternative to using a TARE container is to: (i) subtract the average DW weight of the containers (use 10+ empty containers to do this); or (ii) to weigh individual containers (as for the aluminum pots in the determination of soil moisture content, this volume, Chapter 17).

## 4. Typical ranges and units

It is recommended to keep all measurements in the same unit system; typically on the decimal scale (Tables 22.3 and 22.4).

**Table 22.3. Useful units of measurement.**

| Multiple | Area / length | Weight |
|---|---|---|
| 1,000,000 | - | Ton (t) |
| 10,000 | Hectare (ha) | - |
| 1,000 | - | Kilogram (kg) |
| 1 | Meter (m / $m^2$) | Gram (g) |
| 0.01 | Centimeter (cm) | - |
| 0.001 | Millimeter (mm) | Milligram (mg) |

**Table 22.4. Typical units of data expression.**

| Sample | Measured as | Expressed as |
|---|---|---|
| Grain yield and biomass weights | g $plot^{-1}$ | g $m^{-2}$ or t $ha^{-1}$ |
| Dry weight of culms and crop components (e.g. leaf lamina, leaf sheath, stem) | g per 20 culm sub-sample | g $m^{-2}$ or g $culm^{-1}$ |
| Root biomass | g g $soil^{-1}$ | g $cm^3$ $soil^{-1}$ |

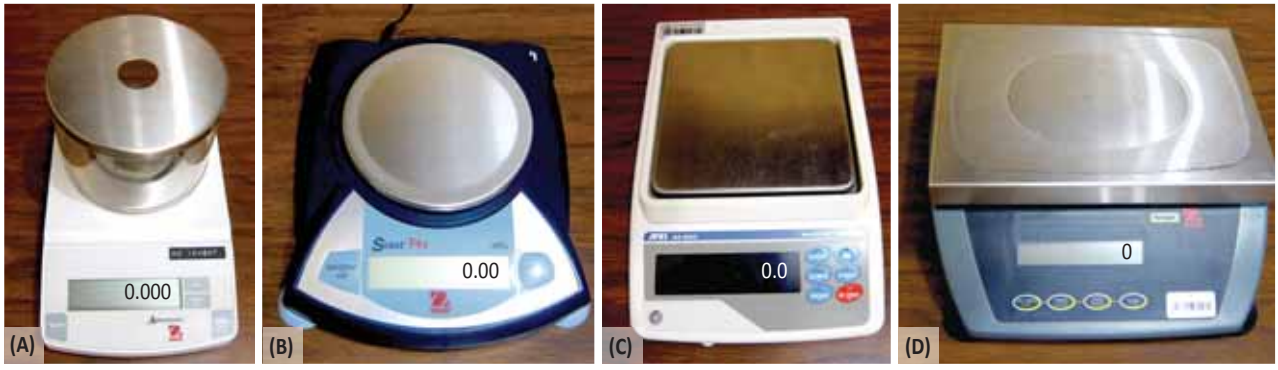


**Figure 22.2. Types of balances for physiological measurements, showing: (A) semi-analytical (3 d.p.); (B) small precision (2 d.p.); (C) medium/large precision (1 d.p.); and, (D) Industrial/retail bench balances (0 d.p.).**

## 5. Suggestions on models of instruments

Reference to specific instruments is made in most chapters. The mention of trade names and commercial products are for information purposes only, and do not imply endorsement by CIMMYT. Prices quoted serve as a guideline – and will vary according to accessories, functionalities, taxes and customs fees. Table 22.5 provides details of suggested models of instruments.

**Table 22.5. Suggested models of instruments (websites accessed August 2011).**

| Instrument | Brand | Model/s | Measurement level | Website |
|---|---|---|---|---|
| Ceptometer | Delta-T Devices | SunScan System, and SS1 | Canopy | http://www.delta-t.co.uk/ |
| | Decagon Devices | AccuPAR LP-80 | Canopy | http://www.decagon.com/ |
| Chlorophyll fluorometer | Opti-Sciences | OS1-FL, and OS-30p | Leaf | http://www.optisci.com/ |
| | Qubit Systems | Z990 FluorPen | Leaf | http://www.qubitsystems.com/ |
| | WALZ | PAM-2500, MINI-PAM | Leaf | http://www.walz.com/ |
| | Hansatech Intruments | FMS 2, Pocket-PEA | Leaf | http://www.hansatech-instruments.com/ |
| Chlorophyll meter | Minolta | SPAD 502 Plus | Leaf | http://www.specmeters.com/ |
| | Field Scout | CM 1000 | Canopy | http://www.specmeters.com/ |
| | Opti-Sciences | CCM-200 | Leaf | http://www.optisci.com/ |
| | Hansatech Intruments | CL-01 | Leaf | http://www.hansatech-instruments.com/ |
| | Apogee | CCM-200 | Leaf | http://www.apogeeinstruments.com/ |
| | FT Green, LLC | At Leaf | Leaf | http://www.atleaf.com/ |
| | Qubit Systems | Z955 Nitrogen Pen | Leaf | http://www.qubitsystems.com/ |
| Infrared thermometer | Sixth Sense | LT300 | Canopy | http://www.instrumart.com/ |
| | Mikron | MI-N14 | Canopy | http://www.mikroninfrared.com/ |
| | Extech | 42540 | Canopy | http://www.extech.com/instruments/ |
| Leaf area meter | Licor | LI-3100C, and LI-3000C | Leaf | http://www.licor.com/ |
| | CID Bio-Science | CI-202, and CI-203 | Leaf | http://www.cid-inc.com/ |
| | Delta-T Devices | WinDIAS 3 | Leaf | http://www.delta-t.co.uk/ |
| Leaf porometer | Delta-T Devices | AP4 | Leaf | http://www.delta-t.co.uk/ |
| | Decagon Devices | SC-1 | Leaf | http://www.decagon.com/ |
| Normalized difference vegetation index (NDVI) Sensor | NTech Industries | GreenSeeker Hand Held | Canopy | http://www.greenseeker.com/ |
| | Holland Scientific | Crop Circle Handheld | Canopy | http://www.hollandscientific.com/ |
| | Field Scout | CM 1000 NDVI | Canopy | http://www.specmeters.com/ |
| | Qubit Systems | Z950 NDVI | Leaf | http://www.qubitsystems.com/ |
| Photosynthesis system | LI-COR | 6400-XT | Leaf/plant | http://www.licor.com/ |
| | PP Systems | CIRAS-2 | Leaf/plant | http://www.ppsystems.com/ |
| | CID Bio-Science | CI-340 | Leaf | http://www.cid-inc.com/ |
| | WALZ | GFS-3000 | Leaf | http://www.walz.com/ |
| | ADC | LCpro-SD | Leaf | http://www.adc.co.uk/ |
| Plot combine | Wintersteiger | Classic | Plot | http://www.wintersteiger.com/ |
| | Almaco | PMC 20, SPC 20 | Plot | http://www.almaco.com/ |
| Sample mill (Grinder) | UDY Corporation | Cyclone | Grain/biomass | http://www.udyone.com/ |
| | IKA | MF 10.1 | Grain/biomass | http://www.ika.net/ |
| | FOSS | Cyclotec 1093 | Grain/biomass | http://www.foss.dk/ |
| | Thomas Wiley | Model 4, and Mini | Grain/biomass | http://www.thomassci.com/ |
| Scholander pressure chamber | Soil moisture Equipment Corp. | 3000 Series, and 3005 Series | Leaf | http://www.soilmoisture.com/ |
| | Skye | SKPM 1405/50 | Leaf | http://www.skyeinstruments.com/ |
| | PMS Instrument Company | Model 600 | Leaf | http://www.pmsinstrument.com/ |
| Seed counter (automatic) | Seedburo | 801 Count-A-Pak | Grain | http://www.seedburo.com/ |
| | Pfeuffer | CONTADOR | Grain | http://www.pfeuffer.com/ |
| Seed counter (manual) | Seedburo | Placement Trays | Grain sample | http://www.seedburo.com/ |
| Soil corer set (electric percussion hammer) | Eijkelkamp Agrisearch Equipment | Percussion drilling set with light electrical percussion hammer | Soil/root | http://www.eijkelkamp.com/ |
| Soil corer (tractor mounted) | Giddings Soil Sampling Co | #15 | Soil/root | http://www.soilsample.com/ |
| Spectrometer | Spectral Evolution | PSR-2500 | Canopy/leaf | http://www.spectralevolution.com/ |
| | Ocean Optics | JAZ | Canopy/leaf | http://www.oceanoptics.com/ |
| | PP-Systems | UniSpec SC, and UniSpec DC | Canopy/leaf | http://www.ppsystems.com/ |
| | CID Bio-Science | CI-700 (leaf clip ready) | Leaf | http://www.cid-inc.com/ |
| Spectroradiometer | ASD Inc | FieldSpec 3, AgriSpec, and HandHeld 2 | Canopy/leaf | http://www.asdi.com/ |
| | Spectral Evolution | PSR-2500, and PSR-1100 | Canopy/leaf | http://www.spectralevolution.com/ |
| Thresher | Almaco | SBT and LPT | Plot/bundle sample | http://www.almaco.com/ |
| Vapor pressure osmometer | EliTech Group - Wescor | VAPRO 5600 | Tissue sap | http://www.wescor.com/ |