



East African Journal of Forestry & Agroforestry

ejfa.eanso.org

Volume 5, Issue 1, 2022

Print ISSN: 2707-4315 | Online ISSN: 2707-4323

Title DOI: <https://doi.org/10.37284/2707-4323>

EANSO

EAST AFRICAN
NATURE &
SCIENCE
ORGANIZATION

Original Article

Review of Plant Water Status Measurement Techniques

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Article DOI: <https://doi.org/10.37284/eajfa.5.1.850>

Date Published: ABSTRACT

20 September 2022

Keywords:

*Dry Method, Leaf Temperature,
Pressure Chamber, Plant Leaf Welt,
Water Content, Thermocouple
Psychrometer,
Transpiration, Stem Diameter,
Stomata Conductance.*

The growth of the plant largely depends on the available water and soil. Soil supports the plant in mechanical ways and acts as a nutrient reservoir for its growth. Not only for plants but also for all living things, water plays a significant role in the life process. For a tree grower, knowing the relationship and techniques of measurement of plant, soil, and water help to improve their management system as well as the efficiency of crop production in a given area. Besides, it helps to know the relative water status of planted tree species. Therefore, this paper provides general information about seven plant water status measurements.

APA CITATION

Asmare, M. T. (2022). Review of Plant Water Status Measurement Techniques *East African Journal of Forestry and Agroforestry*, 5(1), 213-221. <https://doi.org/10.37284/eajfa.5.1.850>

CHICAGO CITATION

Asmare, Melkamu Terefe. 2022. "Review of Plant Water Status Measurement Techniques". *East African Journal of Forestry and Agroforestry* 5 (1), 213-221. <https://doi.org/10.37284/eajfa.5.1.850>

HARVARD CITATION

Asmare, M. T. (2022), "Review of Plant Water Status Measurement Techniques", *East African Journal of Forestry and Agroforestry*, 5(1), pp. 213-221. doi: 10.37284/eajfa.5.1.850.

IEEE CITATION

M. T., Asmare, "Review of Plant Water Status Measurement Techniques", *EAJFA*, vol. 5, no. 1, pp. 213-221, Sep. 2022.

MLA CITATION

Asmare, Melkamu Terefe "Review of Plant Water Status Measurement Techniques". *East African Journal of Forestry and Agroforestry*, Vol. 5, no. 1, Sep. 2022, pp. 213-221, doi:10.37284/eajfa.5.1.850

INTRODUCTION

Water is crucial in plants as a component, a solvent, a reactant in a variety of chemical processes, and in maintaining turgidity. Water binds to proteins, cell walls, and other hydrophilic surfaces, which has a significant impact on plant physiological function. Several components vital for cells as well as their surroundings influence cellular water potential. These substances are the end product of the interactions between the solute, pressure, solids (matrix), and gravity. The influence of gravity is minimal (Blum, 2011). The amount of water in a plant, or its water content, is most likely the most often used measure for measuring plant water status. However, measuring the amount of water in plant tissue is impracticable since it cannot be compared to measurements taken from other plants or different tissue on the same plant. So that, a standard point of reference is necessary; frequently, a turgid weight (the maximum amount of water the tissue can hold) serves as this point of reference. By first getting the fresh weight or field weight of plant tissue (either leaf discs or complete leaves), and then measuring its turgid weight after equilibration, relative water content (RWC) can be easily established (floating tissue on water or placing it in a moist chamber on water-saturated polyurethane foam for a prescribed period of time). To obtain a constant weight and RWC, the identical tissue is oven-dried.

Avoiding oven drying the tissue and computing RWC directly from the ratio of fresh weight to turgid weight may be feasible if it is thought that there are little variations in turgid weight and dry weight between sample intervals.

RWC is without a doubt one of the most widely used markers of plant water status, even though

it may be difficult to get precise turgid weight measurements. The water content is displayed in relation to the tissue's maximum water-holding capacity using a simple computation that can be immediately applied in the field (100% RWC = no plant water deficit). The goal of this review is paper is therefore, provide a compile information and appreciate the basic ideas, procedures, advantages, and constraints of plant water status measurement systems.

PRINCIPLES AND TECHNIQUES OF PLANT WATER STATUS MEASUREMENT

Biophysically-Based Measurement Technique

Methods that directly assess how plants physiologically respond to water availability can be much more sensitive and accurate than indirect methods such as measuring soil moisture (Parry, 2014).

Principles

Energy balance and biophysical concepts have long been used to quantify the stomata conductance of individual leaves. Using 1) regular measures of the weather, 2) accurate measures of the canopy's average temperature, plus 3) an understanding that canopy structure, the same biophysical method can be applied to plant communities. Here we use a model of the two-source energy balance constructed to calculate stomata conductance (SC) in crops grown in rows with randomly distributed leaves. The two-source model separates the soil and canopy heat sources and takes into account the unique characteristic of row vegetation. The placement of plants in rows affects the separation of heat sources in the soil and canopy, as well as the penetration of wind and

radiation into the canopy. Soil and canopy temperatures must be measured or estimated for a two-source energy balance model.

Advantage

- Availability of a larger sample area and the possibility of automating measurements in real time
- It provides accurate comparisons over a wide range of environmental conditions.

Disadvantage

- By the time wilting becomes apparent; the impact on potential production can be severe because it is not an early indicator that a plant is facing a water deficiency.
- Sensitivity to environmental factors, stomata aperture, and other regulatory processes.
- More accurate meteorological data are required, especially for radiation interception and canopy energy balance.

Pressure Chamber Measurement Technique

The following are the principles, techniques, benefits, and drawbacks of it:

Principles

In this process, it is anticipated that the pressure required to push water from the leaves in to xylem and out to the cut surface will be almost equivalent to the water content initially present in the cells. (Gavriil, 2004; Bruce, 1987; Hinckley *et al.*, 2022).

Usually, a metal cylinder, usually cylindrical, with an opening in the lid makes up the pressure chamber. The rubber seal used to close this opening allows plant leaves' petioles to pass

through. The source of compressed air or gas is linked to the pressure-resistant chamber. A regulator regulates the flow of gas into the chamber. Water travels to the system of soil, plants, and atmosphere as a result of changes in water's free energy content in different areas of the system (Gavriil, 2004). The water column of a plant is constantly tensed. The tension in the xylem of the leaf petiole is released when a leaf is removed from the plant, and sap then withdraws again from incision site and flows into the blade. the moment a leaf is inserted as well as the chamber is crushed, the water potential of the leaf is raised by the amount of pressure supplied until the water potential is zero at the equilibrium pressure (the pressure required to force the sap to the surface of the cut end of the petiole). The original leaf water potential and balance pressure added together have no value. The initial leaf water potential is therefore equal to the balance pressure's inverse. A plant experiences more stress the higher the negative water potential. It is thought that the osmotic pressure in the xylem is negligible.

The needed pressure is the balancing pressure. This indicates that the balancing pressure is equal (but in the opposite sign) to the xylem's water potential.

Water potential readings collected soon before sunrise (predawn water potentials) are frequently an excellent indicator of the soil's water potential. This assumes that the water potential of the tree's tissues has reached balance with the soil's water potential throughout night, when tree is not transpiring.

Water potential readings recorded during the day when the tree is transpiring provide an indicator of the tree's level of water stress.

Procedures

- Remove a leaf or other plant part from the specimen plant, or decapitate the entire plant above the root collar (for young seedlings) that is exposed to the specified climatic conditions, soil moisture content, and associated soil media.
- Peeled back Phloem and bark (if using a conifer or hardwood stem) far enough to allow the twig to be inserted into the rubber gland
- Apply silicone grease to the gland to provide a good seal between the stem and the rubber.
- Place the chamber top on top of the chamber body.
- Securely close the bleed-off and metering valves and gradually apply continuous pressure from the storage cylinder to the chamber.
- At atmospheric pressure, observations are conducted the severed petiole or stem jutting from the chamber.
- Increase the pressure in the chamber until liquid water emerges from the clipped petiole or stem.
- Take the balancing pressure gauge reading when water shows up at the cut end of the twig or leaf petiole.
- Take note of the observed positive pressure (provided to the pressure chamber) required to drive liquid water from the leaf or stem. This is the amount of negative pressure held by the leaf or stem when it was linked to the plant.
- After that, close the metering valve and

evacuate the system via the bleed-off valve.

- When working with little twigs, leaf petioles, or pine needles, a dissecting scope mounted atop the device is useful. A 10X magnification is usually sufficient for larger stuff.

Advantage:

- It is a well-known reference approach; it is especially beneficial when evaluating stem water potential (SWP) with bagged leaves or suckers.
- It is the quickest and most straightforward method for figuring out leaf water potential.
- When combined with consistent sampling and measuring processes, it provides trustworthy information on the water condition of an urban tree.

Disadvantage

- It is slow and labour intensive (thus expensive, especially for predawn measurements); it is unsuited for automation.
- It is vulnerable to a variety of potential sources of procedural errors, including seal damage to vascular tissues, rate of pressurization, relative amounts of tissue inside vs outside the chamber, elapsed time following sample excision, and moisture loss from the sample during sealing and pressurization.
- Limit its usefulness for woody plants in the field.

Stem Diameter Change Measurement technique (Bruce 1987; Parry, 2014)

Principle and Measurement Techniques

It is done based on the biological premise that this occurs as water leaves living cells and into the stream of transpiration, the cells contract. This reduction in cell size results a tiny but discernible drop in stem diameter. The Ceres instrument measures this change using the pressure transducer and strain gauges. Electrical resistance raises when stress increases within the strain gauges, delivering data on sensitive changes in stem diameter. This equipment is connected to a microprocessor and a logging unit. The Helix detector and related testing units are based on cohesion theory, where water molecules confined because of the strong, attractive forces that occur between water molecules in microscopic capillaries, they can survive very low negative pressure potentials. molecules. As a result, when moisture in the plant is exposed to a water potential gradient, the water-conducting components experience a micro contraction, the magnitude of which is proportional to the stress level. The concepts are not new, but the technology for monitoring minute variations in stem diameter has advance recently.

Advantage

- Portable enough to record data in the field
- Accurate and reliable

Disadvantage

- It requires skilled manpower.
- Not easily automated

Leaf Temperature Changes Techniques

Measuring leaf temperature can predict relative variations in moisture stress amongst plants. This technique is very useful for developing irrigation schedules for landscaping plants in urban and suburban settings (Bruce, 1987; Parry, 2014; Menoux-Boyer, Y et al., 1983).

Principles and Measurement Techniques

As Bruce (1987); Parry (2014), Said and cited in their works, it is employed as a principle by different professionals through the following assumption.

According to energy balance calculations, if transpiration reduces but when the latent heat exchange between the plant and the atmosphere decreases and the radiation flux and wind structure remain essentially constant, the leaf temperature will increase. As a result, a careful analysis of temperature differences across plants, particularly between those that receive adequate water and others, may reveal differences in transpiration and, consequently, in the level of water that plants are receiving.

The leaf position to incident solar radiation creates variation in temperature. As a result, a leaf that is straight to the sun's rays will be significantly hotter than one that is either completely in the shade or has a broad angle of incidence. The difference in leaf and air temperature has previously been utilized by researchers to estimate relative water stress in order to get around this sampling problem. But micrometeorological research has shown that leaf and air temperatures are not always related. When compared to the ambient air, leaves are frequently warmer during the day than at night. Recent developments in infrared thermometry

have solved many of these sample-related problems, and measuring leaf temperature may eventually prove to be a very effective method for assessing the relative water condition of urban trees.

Advantage

- It is used to determine the relative water states of urban tree (Menoux-Boyer, Y et al., 1983).

Disadvantage

- Difficulty in obtaining uniform samples (Menoux-Boyer, Y et al., 1983).

Using a Thermocouple Psychrometer to Measure Water Potential

Thermocouple psychrometry is a technique that determines the water potential of a sample's liquid phase from measurements in the sample's vapour. The term "water potential" refers to how active the water is in a plant system when compared to water in a reference condition, and is therefore probably the most accurate indicator of the water status of plants that is currently available. In recent years, psychrometers have gained popularity, and commercial equipment for measuring water potential in the field is now available. In a nutshell, evaluations are taken by keeping track of the equilibrium relative humidity in a small, sealed room with the sample and reference thermocouples. (Bruce 1987; Gavriil, 2004)

Principles

The psychrometer works on the premise that a solution's or a tissue's water potential determines how much water vapour is produced over it (Gavriil, 2004). The vapour pressure (relative humidity) of the air in the chamber

equalizes with the water potential of the sample when a sample of plant material is placed in a vapour-tight chamber. Water potential of an enclosed volume of air can be calculated by determining its vapour pressure. The Kelvin equation (ANDRASKI and SCANLON 2002) describes the theoretical relationship between the liquid phase's water potential and the vapour phase's relative humidity:

$$\Psi = \text{energy/volume} = (RT/V_w) \ln(p/p_o)$$

Where: Ψ is the molar volume of water ($1.8 \cdot 10^{-5} \text{ m}^3 \text{ mol}^{-1}$), is the water potential (sum of matric and osmotic potential, MPa), R is the universal gas constant ($8.314 \cdot 10^{-6} \text{ MJ mol}^{-1} \text{ K}^{-1}$), T is the temperature (K), and p/p_o is relative humidity expressed as a fraction where p is the actual vapour pressure of air in equilibrium with the liquid phase (MPa) and p_o.

Advantage

- It avoids the need for precise temperature control by employing thermocouple transducers and makes the devices that are more suitable for field use.
- Valuable, thermodynamically based measures of water status; can be automated.
- They are capable of detecting minute temperature variations over extremely wide temperature ranges.

Disadvantage

- It needs a too long time for equilibration
- The majority of leaf tissue from woody plants is bulky generates heat of respiration;
- The passage of water vapor is impeded by extensively cutinized tree leaves; and

- Requires sophisticated equipment as well as professional man power

Computer modelling of transpiration's reflection of plant water status

The moisture loss from individual tree crowns is modelled using computers. This method may have useful applications for tree maintenance difficulties, especially in creating irrigation strategies for landscape plantings, according to a study using two species of maple (Bruce, 1987; Running, 1984).

Principles

This methodology is done on the principle that water consumption can be predicted use a local evapotranspiration a reference point (ET₀) and an ETZ multiplier for effectiveness (K_c) that the reference value is changed to a given plant. During the growing season, the K_c values change to account for fluctuations in irrigation frequency, crown size, and crop physiology. The following equation is used to produce daily estimates of evapotranspiration (ETC):

$$ETC = ET_0 \times K_c$$

Their model calculates transpirational water loss (E) as $R_{net} - H - CE =$, where R_{net} is the incident radiation's net flux density, and H is convectional. energy loss, C is conductional energy loss, and = the latent heat of vaporization of water.

$$R_{net} - H - CE = E$$

Advantage

- Used to provide irrigation management information for field crop
- Adaptable for use with other vegetation

- It functions best for trees that are experiencing quite minor soil moisture stress.

Disadvantage

- It could not function best for model trees that are under high levels of soil moisture.

Leaf Water Potential measurement by dry method (Knipling, 1967)

Procedures Used

- Immerse leaf tissue samples in a cascade of graded solutions with substantial water potential enclosed in hypodermic. The water potential of leaves is thought the difference between the leaf sample solutions that the samples absorb and lose water.
- Determine a direction of movements of water between leaf samples absorbing water and samples losing water in the solution.
- Lightly colour each test solution was mixed with a powdered colour, like methyl orange or methylene blue.
- Using medicine droppers, matching members of a parallel series of neutral control solutions, into their centres.
- Determine if these are falling or rising.
- Determine whether or not water exchange occurs

Principles

This method works by assuming that the modest amount of dye employed in the solution has no major effect on their densities. The accuracy of measurement using the dye technique determines how much the water

potential increase varies between test solutions. One to five bar increments are frequently the only rational options in order to have a viable number of solutions (typically 6 to 10) encircling an unknown leaf water potential. Sucrose or mannitol should be used to make test solutions. When sucrose is utilized, the commercial (trade) kind is appropriate.

Advantage

- It is simple and does not require any complicated or expensive equipment.

Disadvantage

- Values observed after a brief immersion appear to be the water being absorbed by the leaf surfaces (Knipling, 1967).
- Within the first few minutes of immersion, water is extracted from the solutions, increasing their density before osmotic water exchange.
- As a result, Drip patterns from test solutions that are less potent than those for the leaf then inserted into the control solutions; the patterns are reversed.

CONCLUSION

Generally, a plant's water potential is measured in different ways such as - pressure chamber, change in stem diameter, change in leaf Temperature, thermocouple psychrometer, computer modelling of transpiration, dry method, and canopy temperature biophysically. Of those listed techniques, the most known methods are pressure chambers and thermocouple psychrometers. The pressure equilibration or pressure bomb technique is best option for evaluating the water potential of field planted species. Unlike chambers pressure

method, the thermocouple psychrometer is suitable for automation and reduces the cost of labour.

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