e-GRO Edible Alert

Chieri Kubota
kubota.10@osu.edu

Volume 10 Number 5 May 2025

# Dish Evaporation - A simple tool to assess crop transpiration demand in your facility





*Measurement of crop water use (transpiration) is not a trivial task, as it is affected by many different environmental factors. We have developed a simple tool that growers can use to assess crop transpiration demand via direct measurement of water evaporation rate. The specific procedures are for applications in indoor vertical farms but can be also applied to greenhouses with some modifications.*

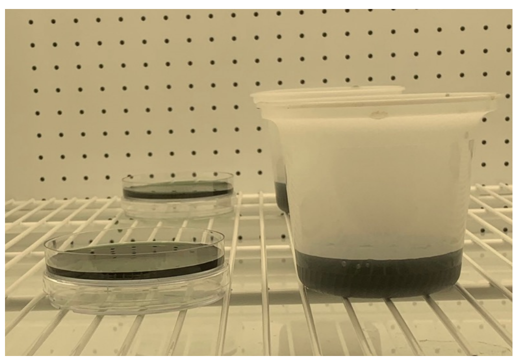

Figure 1. Petri-dishes and deep dishes filled with black-colored water for measuring water evaporation rates under electric lighting (Photo credit: Gio Papio).

Crop transpiration is an important physiological activity of plants, yet practical tools for direct measurements of plant transpiration rates are limited. Several environmental factors affect transpiration rates, including irradiances (both short- and long-wave radiation), air current speed, and humidity (vapor pressure deficit, VPD). This makes it difficult to understand actual potential transpiration of the crop. Plant scientists developed transpiration models to estimate crop transpiration rates from environmental conditions. However, they are not practical especially when the resource and/or space is limited, as models require installing additional environmental sensors (anemometer, net radiometer, etc.). As a low-cost approach applied outdoors, large metal pans holding water are widely accepted predictors of potential (maximum) evapotranspiration rates. Similar in shape, but smaller in size, conventional plastic petri dishes (10 cm in diameter) are found to be a useful low-cost tool to directly measure evaporation rates as water loss over time (Ciolkosz and Albright, 2000; Papio, 2021). The small size of petri dishes is particularly suitable for indoor applications with a small head space over the plant canopy (Papio, 2021). While this approach does not identify the actual transpiration rates, the values (evaporation rates) are useful to understand evaporative demand of the microclimate, which should highly be correlated with crop potential transpiration. Namely, high transpiration rates are expected when the evaporation demand is high.

**Applications in indoor vertical farms and growth chambers with electric lighting.**

Understanding crop transpiration rate is important in managing tipburn of lettuce, an environmental, physiological disorder due to the limited calcium availability in the fast-growing shoot tip. While methodology of measuring crop transpiration rate is limited, the petri dish tool we developed can help to evaluate the plant growing microenvironment relative to the potential risk to induce tipburn. Lettuce tipburn incidence increases when plants are grown under conditions that enhance the overall growth rates but limit transpiration rate.

**Applications in the greenhouse.**

Although the first use of petri dish evaporation was examined in greenhouse (Ciolkosz and Albright, 2000), we think that larger containers may be more suitable for greenhouse applications. The small size of petri dish may make the measurement too sensitive to the fluctuating environmental conditions. Additionally, more infrequent measurements (e.g., daily assessment instead of hourly) may be necessary to minimize the impact of temporary non-uniformity. Once daily rates of evaporation (or daily evaporation integral, DEI) are obtained, they may be directly compared with daily light integral (DLI) to understand the potential tipburn risk. This is because daily transpiration rate and DLI essentially represent the potential supply and demand of calcium of fast-growing plants, respectively.

**Standard measurement protocols.**

Materials and preparation: For applications under electric lighting such as LEDs, this protocol calls for black dye solution instead of tap water. Without black dye, water does not absorb photosynthetic active radiation (PAR) emitted by electric lights and the dish evaporation rates do not respond to changes in light intensity, a significant factor driving evaporation and transpiration. Food-grade black dye has nearly 100% absorptance between 400 through about 650 nm wavelength, when measured using a spectrophotometer (Papio, 2021). By adding black dye to water, measured evaporation rates responded significantly to different light intensities (PPFD) in indoor environment. For applications outdoors or in greenhouses without supplemental lighting, black dye is not necessary as evaporation rates are correlated with solar radiation as water absorbs infrared portion of radiation.

To prepare the black solution, approximately one milli-liter of black food dye (e.g. McCormick Black Food Color) is mixed into one liter of water. This is approximately one teaspoon of dye in one gallon of water. In addition, you will need plastic petri dishes (10 cm diameter) and a good digital balance with a resolution of 0.01 gram. Additionally, you will need deep plastic containers of a similar diameter (10 cm diameter, ~10 cm height) if you are interested in assessing the relative magnitude of evaporation driven by vertical air currents compared with horizontal air currents (Figure 1). Applying vertical air currents is the most effective in tipburn management (Ertle and Kubota, 2025) as it effectively enhances the transpiration rate of leaves around the shoot tip.

Measurement:

1) Dispense a uniform volume (depth) of black solution among petri dishes (and food containers). We typically add 20 mL solution to a petri dish and 100 mL solution to a deep container.

2) Place a petri dish and a deep container side by side in a selected location where you wish to assess evaporative demand of the microclimate.

3) Leave them uncovered in the location for at least 30 min.

4) Measure the whole weight (grams) of petri dish and container, one by one, to find starting weight. Record the weight and time. Move dishes and containers carefully to avoid spilling solution.

5) Repeat measurements every 30-60 min for 2-3 times to obtain an average.

Data analysis:

1) Plug your measurements (grams) into the following calculations (Table 1) to find evaporated water grams per hour. Table 1 further coverts the value to evaporation rates per square meter per hour using the area of petri dish (5 cm x 5 cm x 3.14 = 78.5 $cm^2$ = 0.00785 $m^2$).

2) Petri-dish evaporation rates at 180 grams $m^{-2}$ $h^{-1}$ (10 mol $H_2O$ $m^{-2}$ $h^{-1}$) or lower indicate that the specific microclimate has a very low evaporation (transpiration) demand. In contrast, petri-dish evaporation rates at 360 grams $m^{-2}$ $h^{-1}$ (20 mol $H_2O$ $m^{-2}$ $h^{-1}$) or higher indicate relatively high evapotranspiration demand (Table 2).

Implementations in tipburn assessment:

When lettuce crops are grown under environments with relatively low evaporation demand, there is a potential risk of tipburn, especially if the environment is optimal for enhancing crop biomass production (growth) (e.g., high PPFD, optimal temperature, and high $CO_2$). Growers need to improve the crop growing environmental conditions so that evaporation demand can be increased by, for example, increasing daytime VPD and/or airflow around the plant shoot tips. Deep container evaporation is a useful indicator for vertical airflow, because it responds to vertical airflow more sensitively than to horizontal airflow. Under vertical airflow, evaporation rates of petri dish and deep dish become similar.

**Table 1.** An example calculation of evaporation rate from total weight of dish containing water measured over 30 min interval. Petri-dish diameter and sureface area are 10 mm and 0.00785 $m^2$.

| Starting weight (grams) (A) | Ending weight (grams) (B) | Time interval in min (time between two measurements) (C) | Petri dish area ($m^2$) | Water evaporation rate (grams $m^{-2}$ $h^{-1}$) $(A - B) \div \frac{C}{60} \div 0.00785$ |
|---|---|---|---|---|
| 26.5 g | 23.0 g | 30 min | 0.00785 $m^2$ | $(26.5 - 23.0) \div \frac{30}{60} \div 0.00785 =$ 222.9 g $m^{-2}$ $h^{-1}$ |

However, these two values also become similarly small values when airflow is limited for all directions.

The evaporation rate measured in this procedure can be referred to as 'reference evaporation rate'. Actual transpiration rates from leaves are many times smaller than this reference evaporation rate due to the stomatal and non-stomatal resistances to water loss. Therefore, this procedure is suitable for comparing microclimate conditions of different systems or times (e.g., seasons).

Ciolkosz and Albright (2000) suggested that as large as 20 mm per day evaporation (20,000 grams or 20 liter per $m^2$ per day) was a minimum reference evaporation rate preventing tipburn under a DLI (daily light integral) of 17 mol $m^{-2}$ $d^{-1}$. This value is several times larger than those we obtained in growth rooms and chambers. Therefore, this may support our anecdotal observations of higher tipburn incidences in indoor vertical farm environments than in greenhouse (or outdoor fields). More research is needed for a wide range of possible applications of this low-cost tool, not only for tipburn control but also for other aspects of water management in crop production, such as irrigation control.

***Acknowledgement.*** *This research was funded by USDA NIFA SCRI Grant (#2019-51181-30017). Special thanks to Gio Papio who conducted the research to design, develop, and validate the dish evaporation tool as part of his MS thesis submitted to the Ohio State University.*

**Table 2.** A guideline for transpiration demand assessed using dish evaporation rates measured by the petri-dish tool in an indoor vertical farm or growth chamber (after Papio, 2021)

| Dish evaporation rate (grams $m^{-2}$ $h^{-1}$) | Transpiration demand |
|---|---|
| Smaller than 180 | Low |
| 180 – 360 | Moderate |
| 360 or greater | High |

References:

Ciolkosz, D.E. and L.D. Albright. 2000. Use of small-scale evaporation pans for evaluation of whole plant evepotranspiration. Transactions of the ASAE. 43:415-420. https://doi.org/10.13031/2013.2720

Papio, G.A. 2021. Development of a new hydroponic management strategy and a tool to assess microclimate conditions in indoor leafy green production. A MS thesis, the Ohio State University. http://rave.ohiolink.edu/etdc/view?acc_num=osu1628780410728194

## e-GRO Alert

www.e-gro.org

### CONTRIBUTORS


**Dr. Nora Catlin**
Floriculture Specialist
Cornell Cooperative Extension
Suffolk County
nora.catlin@cornell.edu

**Dr. Chris Currey**
Assistant Professor of Floriculture
Iowa State University
ccurrey@iastate.edu

**Dr. Ryan Dickson**
Greenhouse Horticulture and
Controlled-Environment Agriculture
University of Arkansas
ryand@uark.edu

**Dan Gilrein**
Entomology Specialist
Cornell Cooperative Extension
Suffolk County
dog1@cornell.edu

**Dr. Chieri Kubota**
Controlled Environments Agriculture
The Ohio State University
kubota.10@osu.edu

**Heidi Lindberg**
Floriculture Extension Educator
Michigan State University
wolleage@anr.msu.edu

**Dr. Roberto Lopez**
Floriculture Extension & Research
Michigan State University
rglopez@msu.edu

**Dr. Neil Mattson**
Greenhouse Research & Extension
Cornell University
neil.mattson@cornell.edu

**Dr. W. Garrett Owen**
Sustainable Greenhouse & Nursery
Systems Extension & Research
The Ohio State University
owen.367@osu.edu

**Dr. Rosa E. Raudales**
Greenhouse Extension Specialist
University of Connecticut
rosa.raudales@uconn.edu

**Dr. Alicia Rihn**
Agricultural & Resource Economics
University of Tennessee-Knoxville
arihn@utk.edu

**Dr. Debalina Saha**
Horticulture Weed Science
Michigan State University
sahadeb2@msu.edu

**Dr. Beth Scheckelhoff**
Extension Educator - Greenhouse Systems
The Ohio State University
scheckelhoff.11@osu.edu

**Dr. Ariana Torres-Bravo**
Horticulture/ Ag. Economics
Purdue University
torres2@purdue.edu

**Dr. Brian Whipker**
Floriculture Extension & Research
NC State University
bwhipker@ncsu.edu

**Dr. Jean Williams-Woodward**
Extension Plant Pathologist
University of Wyoming
jwilwood@uwyo.edu




## Cooperating Universities

Cornell CALS College of Agriculture and Life Sciences

Cornell Cooperative Extension Suffolk County

UTIA Institute of Agriculture The University of Tennessee

Iowa State University

University of Wyoming

UCONN

U of A Division of Agriculture Research & Extension University of Arkansas System

Michigan State University

NC State University

Purdue University

The Ohio State University

## In cooperation with our local and state greenhouse organizations

Maumee Valley Growers Choose the Very Best.

Metro Detroit Flower Growers Association

NC Flower Power

Western Michigan Greenhouse Association

Connecticut Greenhouse Growers Association

Indiana Flower Growers Association

LIFGA

Cincinnati Flower Growers Association

Michigan Greenhouse Growers Council

NYSFI New York State Flower Industries, Inc.