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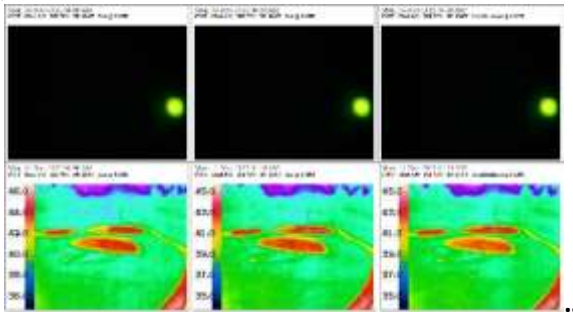
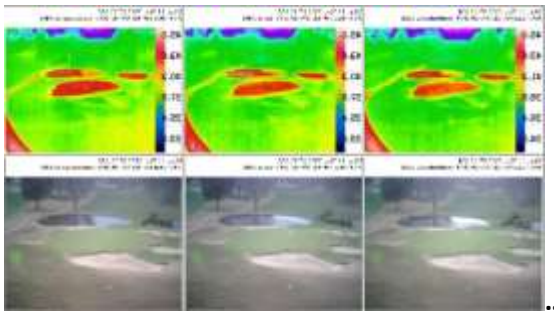
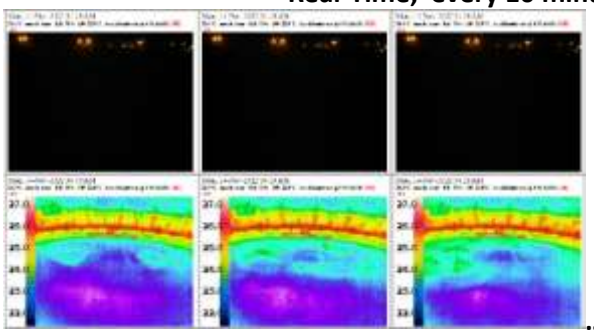
November 2022

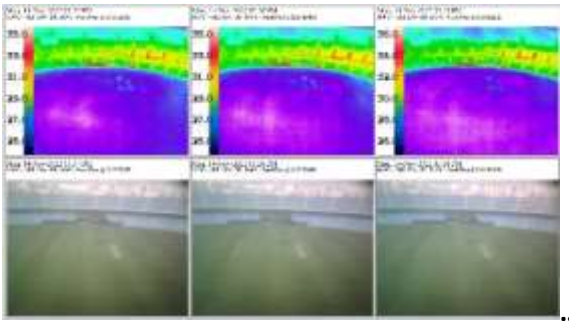
With an EYAS and/or a Hawk-Eye™ System it is possible to measure canopy temperature and color remotely and persistently from digital imagery of a subject plot, and pair the image data with air temperature, dew point, solar radiation.





Real-Time, every 10 minutes, Night & Day, 24/7/365





We use the canopy temperature, air temperature, and dew point measurements to autonomously assess plant stress and infer water status. This is known as the Canopy Temperature Index (CTI), and also known as the Stress Index (SI).

Stress Index (SI)

Stress and Water Status indicator

The Hawk-Eye™ System Canopy Temperature Index (CTI), or Stress Index (SI), is an empirically derived version of the Crop Water Stress Index (CWSI)[1]. The classic method of exploiting the CWSI uses parameterized expressions of the TLL and TUL that are not seasonally referenced for the entire stand/crop and a crop coefficient is used to estimate the water status. We use frequent (every 10 minutes) canopy temperature, air temperature, and dew point temperature to inform the index and establish the TLL and TUL on a daily basis rather than rely on any parameterizations.

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[1] EYAS and Hawk-Eye™ Systems exploit the findings of Jackson RD, Idso SB, Reginato RJ, Pinter PJJ. 1981, describing canopy temperature as a crop water stress indicator, and the form of an equation outlined by J. Miguel Costa, Olga M. Grant, M. Manuela Chaves, 2013, in Thermography to Explore Plant–Environment Interactions, equation (5) on page 3.
This equation is known as a Crop Water Stress Index (CWSI).

(CWSI) = (Tm − TLL)/(TUL − TLL)

Tm = canopy temperature - air temperature [Ta]
TLL = canopy temperature - air temperature as the non-stressed condition
TUL = hottest canopy temperature - air temperature as the stressed condition

Thus, CTI or SI = (Tm – TLL)/(TUL – TLL)

Tm = canopy temperature - (air temperature [Ta] + dew point depression [Ta-Tdew point] times .2; measured at every image data capture time

TLL = {non-stressed condition} = early daylight canopy temperature - air temperature; running average over several days*

TUL = {stressed condition} = hottest canopy temperatures - air temperature; running average over several days*

- **The running average of the five past days of lower (TUL) and upper (TUL) measurements gives good results after 3 days but needs 4-5 days for best results.**

ItriCorp's Daily Stress Index is available 10 minutes after sunset and can be reported via internet, e-mail, and to mobile devices by SMS text.

Turf Grass Guidance:

We've found that in cool season turfgrass when the Daily SI ranges between .3 and .5 the plant is doing well for water and its health. Above .6, it is stressed, and irrigation may be needed, but also consider if a disease is impacting the plant or if an abiotic stress, such as insects or traffic is the cause. If the SI is below .2, don't irrigate and investigate to see if there have been recent rain and/or overcast skies for several days. Consider if long term drainage is be needed to relieve persistently low Daily Stress in a location where too much water is frequently available. In warm season turfgrass when the Daily SI ranges between .4 and .6 the plant is doing well for water and its health. Above .7, it is stressed, and irrigation may be needed.

Figure 1. is a good summary of how our System charts the trend of the stress and how it can be used:

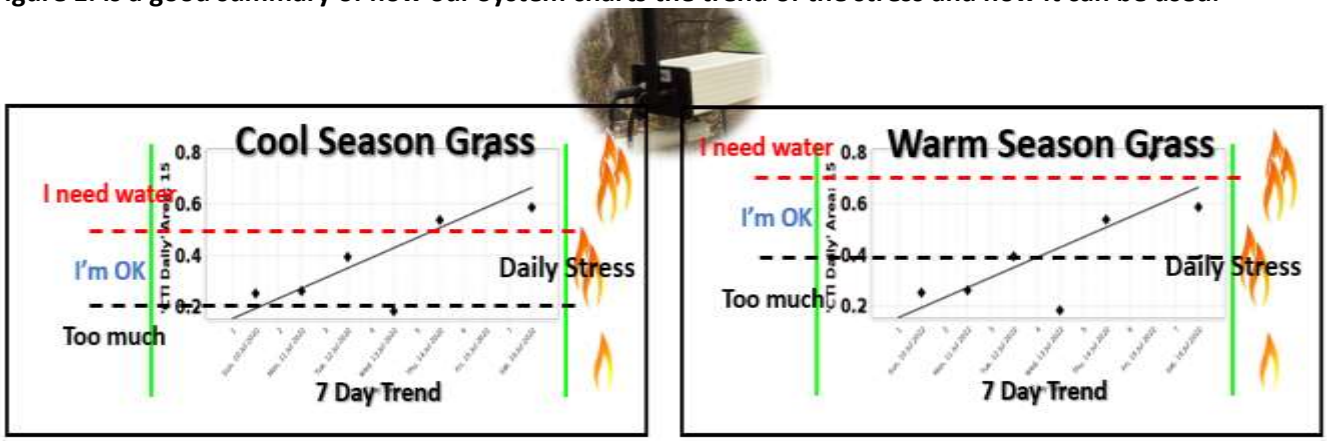

Figure 1. Seven Day Summary of Daily Stress.

Applying Irrigation:

When the Daily Stress Index, aka Irrigation Index, crosses the plant's threshold (reported at sunset) that day, irrigation is applied in a predetermined amount. The amount is a constant (i.e. the same amount all season) that is specific to the location and it is based on a typical amount of irrigation that might be applied.
In cases when the Index exceeds the plant's threshold, the 'prescribed' amount may be conveyed as "add one turn" to the usual sprinkler timing. In other cases, it may be a specific value such as "irrigate 0.1 inches".

In cases when the Index is below the plant's threshold, it is recommended that irrigation is not applied.

Daily Index measurements continue every day. The next day the SI Irrigation Index crosses the threshold the water is applied or withheld again according to the 'prescription'.
Figure 2. plots the Daily SI of two areas on a bermuda grass sport field over a 7 day period:

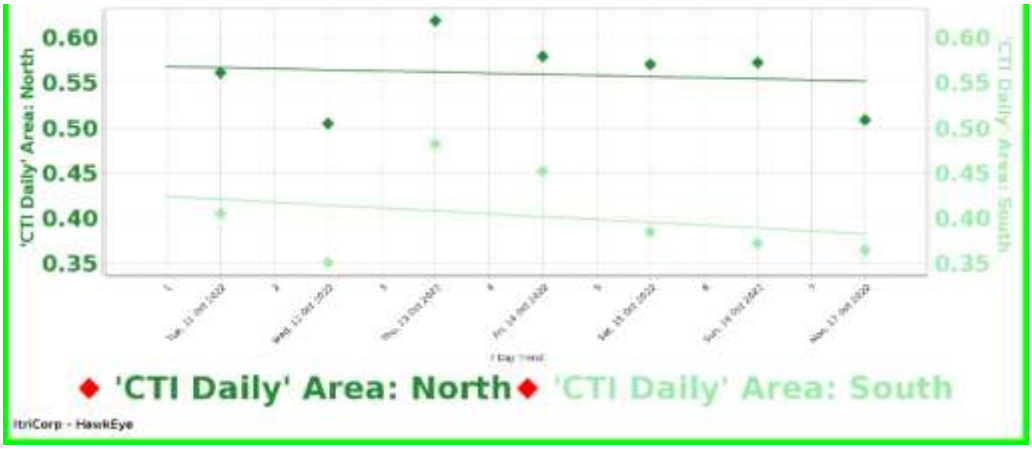

Figure 2. Seven Days Sports Field Daily Stress. North is full sun; South is shaded most of the day.

The north end of the field is irrigated according to the groundskeeper normal schedule. Except on Thursday evening when the SI exceeded 0.6. and an extra turn was needed.

<u>Nighttime Recovery from Stress</u>:
Measuring Stress 24/7/365 has the benefit of seeing/measuring the relief from stress when it is nighttime. Lack of water and solar radiation are the greatest abiotic stressors that a plant encounters. Sunlight is necessary for photosynthesis but if water isn't available in the leaves to enable the processes of photosynthesis and transpiration to expel sufficient water vapor to cool the canopy, the sun would burn up the plant.
Figure 3. plots the Nightly Stress Index of the same two areas on the sport field.

Figure 3. Seven Nights Sports Field Stress Recovery. North is full sun during day; South is shaded.

Notice the relief measured overnight Thursday-Friday and reported Friday morning at sunrise.

Measuring nighttime recovery is a new aspect of our system. How to use it in the irrigation prescription is under consideration.