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Estimating an Actual Transpiration for Mango Trees Using the Energy Balance Model.

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Abstract: Actual Crop water requirement is an essential factor to irrigate plant and get a highest water use. Moreover, using energy balance model helps to determine an actual transpiration. Thus, this work Utilized energy model to estimate an actual transpiration for Mango tree and compare this value with crop Evapotranspiration (ETc) which calculated by CropWat specially during period (March, April and May 2020). Further; produce a simple model to estimate an actual transpiration depending on solar radiation (SR), Vapour pressure deficit (VPD) and canopy temperature (T_c). Data represent that there is a strong relationship between ETc calculated and T_{actual} (R^2= 0.92 & E = 0.83 & RMSE = 54%) for Mango. the Solar Radiation increase by increasing the day of year (DOY) which obtained a highest value (350 watt.m^{-2}) during the period (DOI=148-152).however, the lowest value for SR was recorded (263.8watt. m^{-2}) at (DOY = 60-70). Moreover, T_{actual} recorded a lowest value by (4.3mm.day^{-1}) with SR (236.8 watt.m^{-2}) but the highest value (7.3883mm.day^{-1}) for T_{actual} was obtained after SR recorded (338.9 watt.m^{-2}). Further, T_{actual} decreased to (3.8 mm.day^{-1}) when VPD decreased to (0.98 KPa). On the other hand, after (T_c-T_a) got a negative value (-0.2 C°) the T_{actual} acquired a highest value with average (7.88 mm.day^{-1}) but, in contrary with high positive value (0.26 C°) the T_{actual} recorded a low value by (3.8 mm.day^{-1}). Finally; using the mathematical model help to estimating an actual transpiration related to solar radiation, VPD and canopy temperature. T_{actual} = 0.020241* (SR) + 0.016462*(VPD) - 4.99*(T_c-T_a) + 0.07 Where, Solar Radiation (watt.m^{-2}), vapour pressure deficit (KPa), air and Canopy temperature (C°).

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1. Introduction

Optimization of consumptive and beneficial water use in agriculture is a key issue to maximize irrigation efficiency (Burt et al., 1997), especially considering the scarcity of water resources. Accurate assessment of crop evapotranspiration (ET) is essential for the optimization of irrigation water use, although its estimation is challenging, especially in tree crops, considering the wide range of ground cover and tree density patterns (Testi et al., 2004). The average evapotranspiration from wide area can be roughly estimated by using some meteorological data (Penman,1948 & Monteith. 1980).

Crop Evapotranspiration (ETc) is often estimated using the reference Penman-Monteith (PM) evapotranspiration (ET_o), (Allen et al. 1998), and corrected by a crop-specific coefficient Kc (Lakso, 2003). Due to various approximations and assumptions in the determination of Kc, ETc estimations can be inaccurate (Auzmendi et al. 2011). To eliminate the need for using a crop coefficient, some researchers have related the transpiration of trees to the field measurements of daily or midday radiation interception (Girona et al. 2011). In addition, transpiration from a tree is strongly influenced not only by the meteorological conditions but also by many other factors, such as tree type, age of trees and leaves, soil type, saturation of soil and so on. Furthermore, Mango trees considered medium-sized with comparatively high water requirements are usually irrigated by surface or drip irrigation methods and their water consumption varies based on many factors, including climate and soil. However, these relationships are empirical and site-specific data are most often required (Pereira et al. 2006).

Evapotranspiration is influenced by transpiration of plant and evaporation of soil. Solar radiation, air temperature, wind speed, and relative air humidity are the key factors influencing transpiration (Jhajharia et al., 2012). Up to a certain saturation point, photosynthesis increases with increasing irradiance. Depending on photosynthesis type and plant species, there are various differences in saturation points depending on air temperature and global radiation. The longer and higher radiation is available, the longer the plant can open its stomata and the gas exchange can take place. For photosynthesis to occur, a certain minimum temperature must be present. Generally, with the exception of specially adapted plants, the minimum temperature is around 0°C. The higher the temperature rises, and provided that no other processes act as limiting factors, the more productive photosynthesis becomes. The evaporation chill caused by the transpiration of the plant can keep the temperature of the leaves up to 15 ºC below the ambient air temperature (Weiler et al., 2008). The humidity of the atmosphere also plays a significant role in transpiration.

Notable, Transpiration reduces canopy temperature and cools down air temperature of vegetated urban areas (Bowler et al., 2010; Konarska et al., 2016a) and of their surroundings (Leuzinger et al., 2010; Rahman et al., 2017a). In particular, Rahman et al. (2017) showed up to 3.5 °C air temperature reduction at the center of a tree canopy compared to the outside. The transpiration of trees is controlled by stomatal conductance, net radiation, and an air vapour pressure deficit (Dragoni et al. 2005). In addition, to responding to environmental factors such as solar radiation and vapour pressure deficit (Lakso, 2003), the stomatal conductance of leaves reacts to changes in crop loads (Palmer et al., 1997). On other hand, infrared thermometry can provide an operational tool to derive tree transpiration remotely over large areas, which is of foremost importance for management purposes and to assess the within-orchard spatial variability of the water status.

Canopy temperature (T_c) has attracted much attention in recent decades as a means to estimate crop water status. Since the discovery of the relation between canopy temperature and heat dissipation from plant transpiration in the early 60s (Gates, 1964), researchers have developed a series of indices derived from (T_c) to evaluate water status, such as the Crop Water Stress Index (CWSI, Jackson et al., 1981) or the Apparent Thermal Inertia (ATI, Tramutoli et al., 2000). Further; there are three variables plant canopy temperature (T_c), air temperature (T_a) and atmospheric vapour pressure deficiency (VPD) have much influence on water used by plants (Braunworth , 1989). (Gardner and Shock, 1989) suggested that AVPD in the range of 1-6 kPa is necessary to define a baseline that could be used in many locations.

Crop water stress index (CWSI), derived from canopy-air temperature differences (T_c - T_a) versus the air vapour pressure deficit (AVPD), was found to be a promising tool for quantifying crop water stress (Idso and Reginato, 1982).Vapour Pressure Deficit dictates how efficiently a plant might balance its internal energy with that of the wider environment. Ben-Asher et al. (1989) used infrared thermometry to estimate aerodynamic and canopy resistance required for the computation of transpiration from a Penman ET equation. However the no homogeneity of the tree canopies poses a big challenge in the use of infrared thermometry and modelling of the transpiration process.

Thus, the main objective of this study was to develop a methodological approach to face the issue of quantifying an actual transpiration from the energy budget of a single mango leaf similar to that of the big leaf approach. In addition, the relationships among transpiration with vapour pressure deficit and Canopy-air temperature.

2. Material and Methods

Study was carried out at farm located Ismailia governorate. The study site, established on three months March, April and May (2020), (30° 37' 10.91"N - 32° 16'1.33"E). The site was in an arid area with a Mediterranean climate at about 47 m above sea level. The meteorological data recorded at the local meteorological weather station of average climatic parameters are provided in [table (1)] for temperature, relative humidity, wind speed and solar radiation which calculated from (Allen et al., 1998).

Table 1. Climatic characteristics at Ismailia governorate (2020).

DOI	Tem. max	Tem min.	Hum.	Prc.	Wind (2m)	dew point	Solar radiation
	°C	°C	%	mm/m	m/s	°C	watt / m
61-70	24.23	9.74	60.49	0.28	3.67	6.46	236.83
71-81	21.89	10.23	67.96	7.10	4.69	8.64	255.38
82-92	25.83	11.01	55.66	0.04	4.09	7.23	274.70
93-103	24.86	11.82	58.31	0.79	3.53	8.11	293.00
104-114	27.56	12.81	60.05	28.04	4.16	9.81	309.55
115-125	26.72	13.61	62.89	69.95	3.62	11.05	323.86
126-137	29.13	14.58	60.63	0.27	3.67	11.68	335.67
138-148	35.08	19.07	47.16	0.01	3.87	11.96	344.93
149-152	27.51	14.59	59.34	0.00	4.14	10.94	350.49

Prc. = Precipitation; *Tmp. min*/*max* = minimum/maximum temperature; *hum.* = relative humidity; *Sun shine* = Sun shine as percentage of day length; *Wind* (*2m*) = wind speed at 2m.

Mango trees were spaced (4 m row spacing) × (3 m tree spacing) and irrigated by a pressure compensated drip irrigation system with total water emitters 32 Lph (4 drippers/tree each dripper 8 Lph). The transpiration of Mango trees was estimated from four trees which irrigated with an accurate water requirement using a crop Evapotranspiration.

Fig.1. Leaf of Mango tree with mean average dimension (4.0 Cm).

Crop Evapotranspiration model

Crop Evapotranspiration calculated related to the (Richard et al., 1998) "Irrigation and Drainage Paper #56: Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements." Further; Using an average Reference Evapotranspiration (ETo) and the Crop coefficients (Kc) for Mango tree by the following equations.

$$ETc = ETo * KC \quad (1)$$

Where:

ETc	Crop Evapotranspiration, (mm. day^{-1}).
ETo	Reference Evapotranspiration,(mm.day^{-1}).
Kc	Crop coefficients. For mango during three months = (1.10)

Actual transpiration model (T_{actual})

Transpiration, like direct evaporation, depends on the energy supply, vapour pressure gradient and wind. Hence, radiation, air temperature, air humidity and wind terms should be considered when assessing transpiration (Allen et al., 1998). The energy balance model for a single mango leaf under steady-state conditions can be expressed as (Campbell and Norman 1998).

$$Rn - G - \lambda ET - H = 0 \quad (2)$$

Where:

Rn	=	Net radiation (watt . m^{-2})
H	=	Sensible heat (watt . m^{-2})
λET	=	Latent heat flux (watt . m^{-2})

Sensible heat (H) can be calculated related to the following equation (Campbell and Norman 1998.)

$$H = g_H C_p \Delta T_m \quad (3)$$

Where:

C_P	=	Heat capacity of air (29.17 J · mol^{-1} · C^{-1})
ΔT_m	=	Measured canopy and air temperature difference ($\Delta Tm = Tc - Ta$);
Tc	=	Leaf temperature (°C)
Ta	=	Air temperature (°C)
g_H	=	Boundary layer conductance to heat (mol.m^{-2}.s^{-1})

Moreover, boundary layer conductance to heat is gH = 2gHf (Blonquist et al. ,2009),where, (gHf) is The boundary layer conductance of air to heat for laminar forced convection which calculated using the subsequent empirical formula [Eq. (4)] as per (Campbell and Norman 1998).

$$g_{Hf} = (1.4) * (0.135)\sqrt{\frac{U}{d}} \quad (4)$$

Where:

U	=	Wind speed (at 2-m high above the ground) (m.s^{-1}).
d	=	Characteristic dimension defined as 0.72 times the leaf width (width of mango leaf = 4 cm, measured in the field).

Reorganizing Eq. (2) to solve for E (= T) then the equation well be:

$$T_{actual} = 86400 * \frac{R_n - gHCp\Delta Tm}{\lambda} \quad (5)$$

Where:

T_{actual}	=	Actual transpiration (mm. day^{-1})
86400	=	Factor for converting (Kg.m^{-2}.s^{-1}) to (mm.day^{-1}).
R_n	=	Net radiation (Mj.m^{-2}.day^{-1}).
λ	=	22.6 *10^5 (J. Kg) (heat needed to evaporate 1 kg of water)

After that calculate R_n using a normally standard weather parameters as R_{si} (solar irradiation) (watt.m^{-2}), Ta (air temperature, C^o), wind speed and relative humidity. (Allen et al., 1998) proposed the following equation for calculating the daily net radiation:

$$R_n = (1-\propto) * R_{si} - \left[a_c\left(\frac{R_{si}}{R_{so}}\right) + b_c\right](a_1 + b_1 e_d^{0.5})\sigma(\frac{T_m^4 - T_n^4}{2}) \quad (6)$$

Where:

∝	=	Soil surface albedo (sand wet 0.09 & sand dry 0.18) (Van Wijk and Scholte Ubing,1963)
σ	=	Stefan -Boltzmann constant (5.67 * 10^{-8}) (watt .m^{-2}. K^{-4})
R_{si}	=	Solar irradiation (watt.m^{-2}).
$\frac{R_{si}}{R_{so}}$	=	Relative short-wave radiation, which is used to express the cloudiness of the Atmosphere. When the sky is cloudier, its value is smaller. It

		varies in the range from 0.33 (dense cloud Cover) to 1 (clear sky) (Allen et al., 1998). As an average (0.66).
T_m-T_n	=	Maximum and minimum temperature (ºC).
a_c & b_c	=	Cloud factor 1.35 & -0.35
a_l & b_l	=	Emissivity factors 0.35 & -0.14
e_d	=	Actual vapour pressure (kPa)

Besides, e_d is calculated from the mean daily dew point temperature T_d (ºC):

$$e_d = 0.611\exp\left(\frac{17.27T_d}{T_d + 237.3}\right) \quad (7)$$

After that R_{so} solar radiation is expressed in equation (8)

$$R_{so} = (0.75 + 0.00002EL_{msi})R_{sa} \quad (8)$$

Where:

EL_{msi}	=	Elevation (m) above the mean sea level.
R_{sa}	=	Extraterrestrial solar radiation (Mj. m^{-2}.day^{-1}).

, where R_{sa} can be calculated by (Evett et al., 2011):

$$R_{sa} = \left[\frac{24(60)}{\pi}\right] G_{SC} d_r (\cos\emptyset \cos\delta \sin\omega_s + \omega_s \sin\emptyset \sin\delta) \quad (9)$$

$$d_r = 1 + 0.033\cos\left(\frac{2\pi J}{365}\right) \quad (10)$$

$$\omega_s = \cos^{-1}(-\tan\emptyset \tan\delta) \quad (11)$$

$$\delta = 0.409\sin\left(\frac{2\pi}{365}J - 1.39\right) \quad (12)$$

Where:

$24(60)/\pi$	=	Inverse angle of rotation in daily
G_{sc}	=	Solar constant (0.08202 MJ. M^{-2} min^{-1})
d_r	=	Inverse relative distance Earth-Sun
J	=	Day of year
ω_s	=	sunset time angle (rad)
Ø	=	Latitude(rad)
δ	=	solar declination (rad)

Vapour Pressure Deficit (VPD)

The VPD metric consists of air temperature, leaf temperature, and relative humidity which measured in Kilopascals. (Richard et al., 2015) To Get VPD, need to subtract an actual vapour pressure of the air (VP_{air}) from the saturated vapour pressure (VP_{sat})

$$VPD = VP_{sat} - VP_{air} \quad (13)$$

To get (VP_{sat}) , need to know the temperature of the saturated environment, in this case, the leaf of the plant by using an infrared temperature gun.(UNI-T UT300C, which is an infrared thermometer that is specially designed for surface temperature measurements within the range from -20 ºC to 400 ºC). The leaf temperature was recorded throughout the day starting at 10 am until 2.00 pm .The formula for VPsat (in Kilopascals kPa) is:

$$VP_{sat} = \frac{610.7 * 10^{\left(\frac{7.5T}{237.3+T}\right)}}{1000} \quad (14)$$

Where T is leaf Temperature in Celsius (C°).

To get (VP_{air}), need to know the temperature and humidity of the air,. The formula for VP_{air} (in Kilopascals kPa) is:

$$VP_{air} = \frac{610.7 * 10^{\left(\frac{7.5T}{237.3+T}\right)}}{1000} * \frac{RH}{100} \quad (15)$$

Where:

T = Air Temperature in Celsius (C°) .
RH = Relative humidity (%).

Statistical model

The coefficient of determination (R^2), root mean square error (RMSE), and model efficiency (E) were used as the error statistics to evaluate both calibration and validation results. These statistical indices were used to compare measured and simulated values. Model performance was assessed using E (Nash and Sutcliffe, 1970) as follows:

(16)

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(S_i - O_i)^2}{n}} \quad (17)$$

Where:

Si = Predicted data,and

Oi = Observed data, and

Ōi = Mean value of Oi, and

N = Number of observation.

When E and R^2 approaching one, and a RMSE near zero this indicate that the model performance were improved.The simple regression models with predictor variables $X_1; \ldots\ldots ;X_p$can be describe by equation (18).

$$y = B_0 + B_1X_1 + \ldots\ldots\ldots\ldots + B_pX_p + k \qquad (18)$$

Where:

Variable y, called a response or dependent variable, depends on another variables $X_{(1..p)}$ which is called the independent or predictor variable (also called the regress or variable), B_0 is intercept, $B_{1\text{-}P}$ is the slope parameters and the variability of the error (k) is constant for all values of the repressor.

3. Result and Discussion

Actual transpiration and solar radiation.

During season, the regionally determined crop coefficients for converting Kc to ETc were nearly 1.0 with a peak of 1.1 (Karimi et al. 2013). This is a time when, under arid and semiarid conditions, the actual transpiration of well-watered mango trees is expected to be close to the alfalfa reference ET (Allan et al. 1998). In addition, canopy temperature measurements early in the season are associated with high uncertainties due to incomplete canopy growth. Therefore, a midseason and late-season time period Therefore, a midseason and late-season time period was useful to measuring, but midseason was the focus especially on 61 to 152 day of year for mango.

Fig. 2(A) illustrate that the Solar Radiation increase by increasing the day of year (DOY) which obtained a highest value (350 watt/m^2) during the period (148-152 DOY).however, the lowest value for SR was recorded(263.8watt/m^2) at (DOY = 60-70). Generally, solar radiation increase dynamics during first half of the year and after that decrease dynamics to create al lowest value at the end of the year. Thus, the (DOY) between 60 to 152 was consider a significant period which plant consuming a lot of water especially for mango.

Moreover, an actual transpiration T_{actual} for mango tree increased by increased SR fig.2 (B). For instance, the T_{actual} recorded a lowest value by (4.3mm.day^{-1}) with SR (236.8 watt.m^{-2}) however the highest value (7.3883mm.day^{-1}) for T_{actual} was obtained after SR recorded (338.9 watt.m^{-2}).

Cleary, after SR excessed by (102.1watt.m-2) the T_{actual} value augmentation by (3.6mm.day^{-1}), comparing with value at the first period (DOY 60-70). Transpiration is mainly driven by net radiation (Lakso 2003) and is reduced drastically in response to low solar radiation levels (Wanjura and Upchurch 1997). In addition, the linear regression between T_{actual} and SR [day of year DOY= 60-152] yielded slope, intercept, and R2 of 0.0342, - 4.4093, and 0.885, respectively. T_{actual} can predict using the flowing equation depending on solar radiation.

$$T_{actual} = 0.0342(SR) - 4.4093 \qquad (19)$$

Where ,

T_{actual} = Actual transpiration (mm.day^{-1})

SR = Solar Radiation (watt.m^{-2})

Actual transpiration and vapour pressure deficit (VPD).

Vapour pressure deficit (VPD) has been widely recognized as the evaporative driving force for water transport, the potential to reduce plant water consumption and improve water productivity by regulating VPD (Zhang et al., 2017). As shown on fig.3. (A). Data represented that there are a liner relation between VPD and solar radiation (SR). Moreover; VPD recorded a highest value (2.4 KPa) when (SR) obtained (347.6 watt.m^{-2}). Otherwise, the lowest value for VPD was (0.9 KPa) when (SR) was (254.49 watt.m^{-2}). Thus, the linear regression analysis between VPD and (SR) yielded (7.88 mm.day^{-1}) but, in contrary with high positive value (0.26 C°) the T_{actual} recorded a low value by (3.8 mm.day^{-1}).

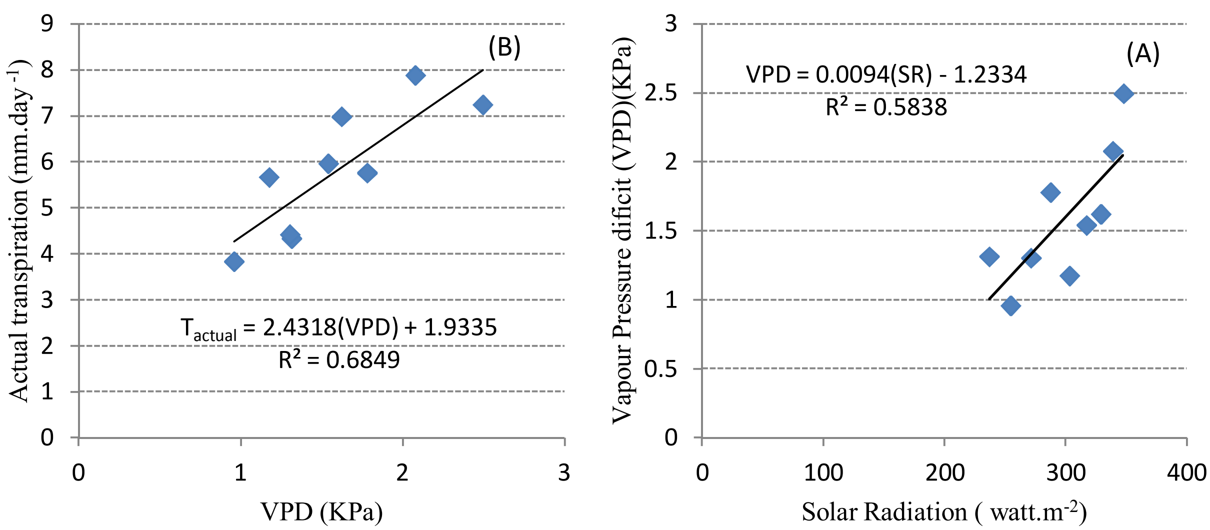

Fig.2. Relation between Solar radiation and actual transpiration for Mango during the day of year.

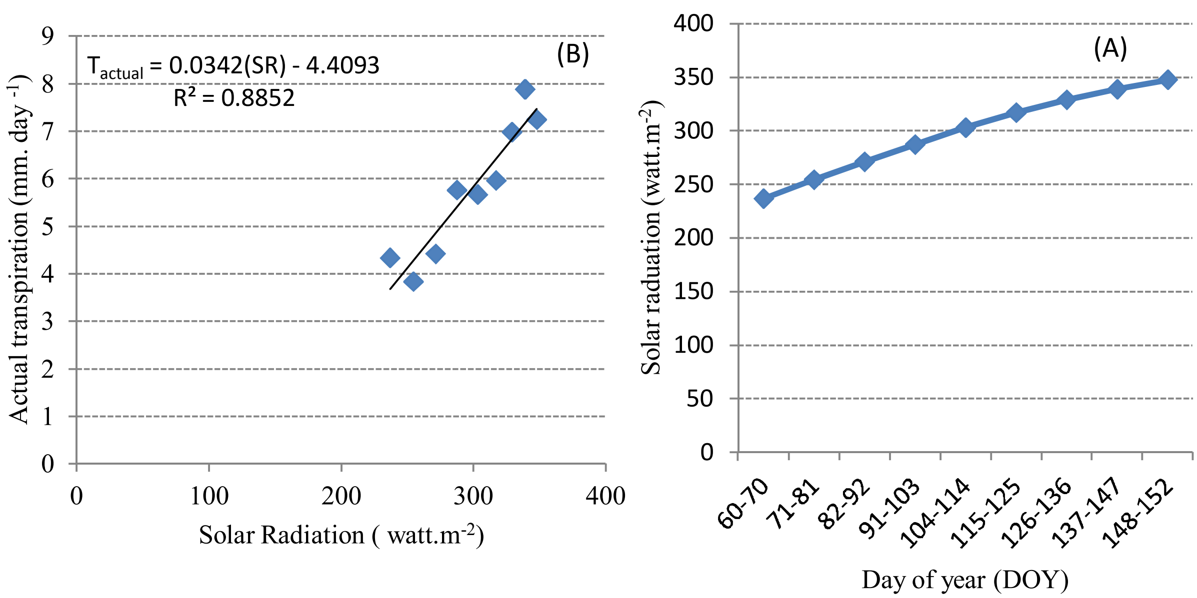

Fig.3. Relation between vapour pressure deficit (VPD) and actual transpiration for Mango

Determination coefficients of (0.58) with slope and intercept was (0.0094) and (-1.2334).

On the other hand, actual transpiration T_{actual} increased dynamically by increased VPD Fig.1. (B). For instance, after VPD increased (from 1.6 to 2.0 KPa) the T_{actual} increased from (6.98 to 7.88 mm.day^{-1}). Further, T_{actual} decreased to (3.8 mm.day^{-1}) when VPD decreased to (0.98 KPa). Cleary, the VPD increases, Evapotranspiration also increases as the air has an increased capacity to hold water vapour, creating a larger potential gradient across the leaf-air and soil-air boundaries (Garratt, 1992). Positive relationship between T_{actual} and VPD can explained on the flowing formula.

$$T_{actual} = 2.4318(VPD) - 1.9335 \qquad (20)$$

Where,

T_{actual}	=	Actual transpiration (mm.day^{-1})
VPD	=	vapour pressure deficit (KPa)

Actual transpiration and Canopy temperature.

Infrared thermometry could be a useful technique for monitoring stomatal conductance in fruit trees at high temporal frequencies(Jones, 2004). Fig.4. showed that there is a significant inverse relation between canopy and air temperature with actual transpiration T_{actual}. For instance, when (T_c-T_a) got a negative value (-0.2 C°) the T_{actual} acquired a highest value with average

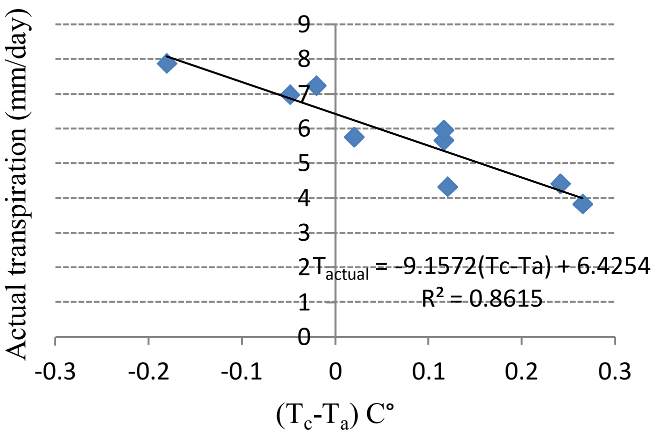

Fig.4. Relation between Canopy temperature (Tc) and actual transpiration for Mango.

Meaning, that the canopy temperature with negative value this reflect that there is a more transpiration accomplished and with positive value refers to less transpiration acquired by plant. May this related to as the VPD increased, the full potential of evapotranspiration was utilized and the plants cooled down resulting in a negative value for $T_c - T_a$ (Nielsen, 1990). In addition, measurements of trees using infrared thermometers, (Glenn et al. ,1989) showed that canopy and air temperature difference was related to the air vapour pressure deficit, a parameter also reflected in stomatal responses to water stress. Infrared thermal imagery was also found effective in timely determination of plant water stress in apple and peach orchards (Giuliani et al., 2001), olive orchards (Sepulcre-Canto et al., 2006).

Finally, the flowing model helps to describe this relation between (T_c-T_a) and T_{actual}.

$$T_{actual} = -9.1572(T_c - T_a) + 6.4254 \qquad (21)$$

Where,

T_{actual} = Actual transpiration (mm.day^{-1}).
T_c = Canopy temperature (C°).
T_a = air temperature (C°).

Assessment model of actual transpiration with crop Evapotranspiration.

As shown at (fig.5). The data indicated that there is a strong relationship between ETc calculated and T_{actual} (R^2= 0.92 & E = 0.83 & RMSE = 54%) for Mango. Noticeable; that the higher R^2 and E values and the lower RMSE values indicated a good model performance. In addition; T_{actual} a highest value by (7.88 mm.day^{-1}) during (DOI=137-147). However, during (DOI= 71-81) T_{actual} obtained a lowest value by (3.8488 mm.day^{-1}).

The transpiration of mango trees was controlled by stomata regulations reflected in a lowered or elevated canopy temperature. T_{actual} was demonstrates a normal trend influenced by weather conditions such as temperature, and humidity similar to the trends in (Jensen *et al*., 1990). Cleary, Transpiration rates were higher during the dry season than during the wet season. This result was contrary to expectations given the extended seasonal drought, and the decline in leaf stomatal conductance and predawn leaf water potential observed in many species within the area (Fordyce et al. 1997). Finally, these results suggest that the liner model is useful for predicting T_{actual} for mango depending on ETc using flowing equation:

$$T_{actual} = 1.1445(ETc) - 1.2672 \qquad (22)$$

Where:

T_{actual} = Actual transpiration (mm.day^{-1}).
T_{actual} = Crop Evapotranspiration (mm.day^{-1}).

Occasionally; a model is a schematic representation of the conception of a system or an act of mimicry or a set of equations, which represents the behaviour of a system (Murthy, 2003). Thus; there is a significant response between (T_{actual}) and three variable canopy temperature (T_c) , Vapour Pressure Deficit (VPD) and solar radiation (SR) with R2 more than 0.9. (Equation 23). This can used to determine an actual transpiration for mango.

$$T_{actual} = 0.020241*(SR) + 0.016462*(VPD) - 4.99*(Tc-Ta) + 0.07 \quad (23)$$

Where,

T_{actual}	=	Actual transpiration (mm.day^{-1}).
SR	=	Solar Radiation (watt.m^{-2})
VPD	=	vapour pressure deficit (KPa)
T_c	=	Canopy temperature (C^o).
T_a	=	Air temperature (C^o).

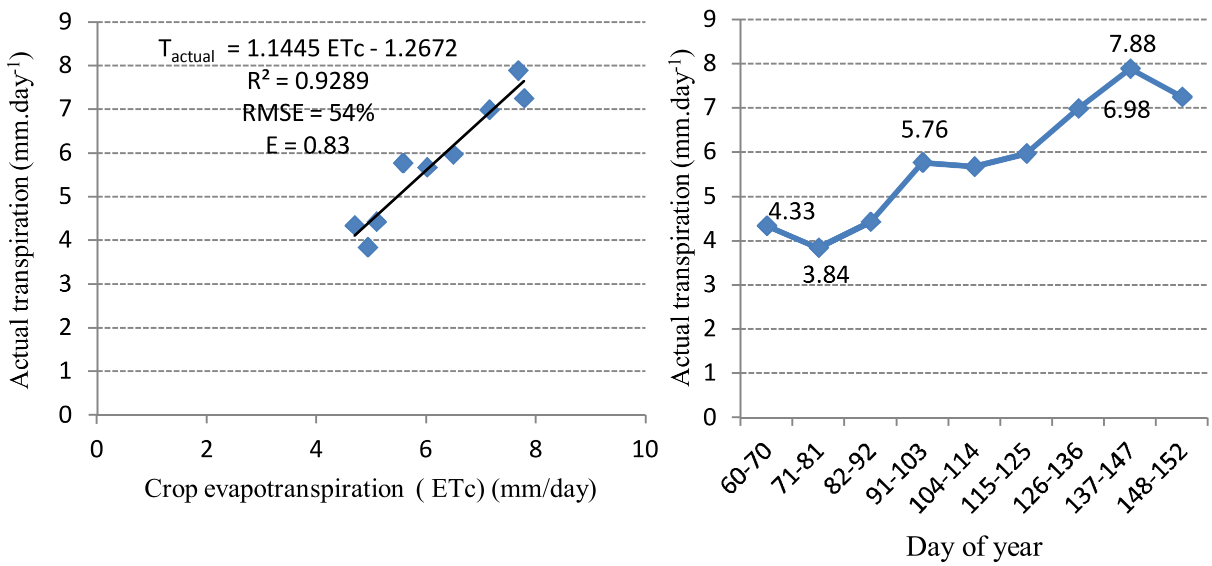

Fig.5. Actual transpiration and crop Evapotranspiration during day of year for Mango.

Conclusion

The simultaneous assessment of actual transpiration T_{actual} for mango tree has a lot of relations between different weather characteristics. For instance , data represent that the Solar Radiation increase by increasing the day of year (DOY) which obtained a highest value (350 watt.m^{-2}) during the period (148-152 DOY).however, the lowest value for SR was recorded (263.8watt.m^{-2}) at (DOY = 60-70). T_{actual} recorded a lowest value by (4.3mm.day^{-1}) with SR (236.8 watt.m^{-2}) however the highest value (7.3883mm.day^{-1}) for T_{actual} was obtained after SR recorded (338.9 watt.m^{-2}). Actual transpiration T_{actual} increased dynamically by increased VPD. (B). For instance, after VPD increased (from 1.6 to 2.0 KPa) the T_{actual} increased from (6.98 to 7.88 mm.day^{-1}). Further, T_{actual} decreased to (3.8 mm.day^{-1}) when VPD decreased to (0.98 KPa). On the other hand, after (T_c-T_a) got a negative value (-0.2 C°) the T_{actual} acquired a highest value with average (7.88 mm.day^{-1}) but, in contrary with high positive value (0.26 C°) the T_{actual} recorded a low value by (3.8 mm.day^{-1}). Meaning, that the canopy temperature with negative value this reflect that there is a more transpiration accomplished and with positive value refers to less transpiration acquired by plant. Notable, there is a strong relationship between ETc calculated by CropWat and T_{actual} (R^2= 0.92 & E = 0.83 & RMSE = 54%) for Mango. Finally; using the mathematical model help to estimating an actual transpiration related to solar radiation and VPD and canopy temperature. T_{actual} = 0.020241* (SR) + 0.016462*(VPD) - 4.99*(T_c-T_a) + 0.07 Where, Solar Radiation (watt.m^{-2}), vapour pressure deficit (KPa), air and Canopy temperature (C^o).

References

1. **Allen, R.G., Smith, M., Raes, D., Pereira, L.S. 1998**. Crop evapotranspiration, guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No.56. Rome, Italy

2. **Auzmendi, I., Mata, M., Lopez, G., Girona, J., and Marsal, J. (2011).** “Intercepted radiation by apple canopy can be used as a basis for irrigation scheduling.” Agr. Water Manage., 98(5), 886–892.
3. **Ben-Asher, J., Meek, D. W., Hutmacher, R. B., and Phene, C. J. (1989).** “A computational approach to assess transpiration from aerodynamic and canopy resistance.” Agron. J., 81(5), 776–781.
4. **Blonquist, J. M., Jr., Norman, J. M., Bugbee, B. (2009).** “Automated measurement of canopy stomatal conductance based on infrared temperature.” Agr. Forest. Meteorol., 149(11), 1931–1945.
5. **Bowler, D.E., Buyung-Ali, L., Knight, T.M., Pullin, A.S., 2010**. Urban greening to cool towns and cities: a systematic review of the empirical evidence. Landsc. Urban Plan. 97, 147–155.
6. **Braunworth Jr., W.S. 1989.** The possible use of the crop water stress index as an indicator of Evapotranspiration deficits and yield reductions in sweet corn. J. Am. Soc. Hort. Sci. 114, 542-546.
7. **Burt, C.M., Clemmens, A.J., Strelkoff, T.S., Solomon, K.H., Bliesner, R.D., Hardy, L.A., Howell, T.A., Members, A.S.C.E., Eisenhauer, D.E., 1997.** Irrigation performance measures: efficiency and uniformity. J. Irrig. Drain. Eng. 123 (6), 423–442.
8. **Campbell, G. S., and Norman, J. M. (1998).** An introduction to environmental biophysics, Springer, New York.
9. **Dragoni, D., Lakso, A., and Piccioni, R. (2005).** “Transpiration of apple trees in a humid climate using heat pulse sap flow gauges calibrated with whole-canopy gas exchange chambers.” Agr. For. Meteorol., 130(1–2), 85–94.
10. **Evett SR, Prueger JH, Tolk JA. (2011).** Water and energy balances in the soil-plant-atmosphere continuum. In: Huang PM, Li Y, Sumner ME, editors. Handbook of soil sciences: properties and processes. 2nd ed. Boca Raton, Florida, USA: CRC Press; 6-1-6-44.
11. **Fordyce, I.R., G.A. Duff and D. Eamus. 1997.** The water relations of Allosyncarpia ternata at contrasting sites in the monsoonal tropics of northern Australia. Aust. J. Bot. 45:259--274.
12. **Gardner, B.R., Shock, C.C. 1989.** Interpreting the crop water stress index. ASAE, 89, 2642.
13. **Garratt, J.R. 1992.** The Atmospheric Boundary Layer. Cambridge University Press. Cambridge, UK.
14. **Gates, D., 1964.** Leaf temperature and transpiration. Agron. J. 56, 273–277.
15. **Girona, J., del Campo, J., Mata, M., Lopez, G., and Marsal, J. (2011).** “A comparative study of apple and pear tree water consumption measured with two weighing lysimeters.” Irrig. Sci., 29(1), 55–63.
16. **Giuliani, R., Magnanini, E., Flore, J.A., 2001**. Potential use of infrared thermometry for the detection of water deficit in apple and peach orchards. In: Palmer, J.W., Wunsche, J.N. (Eds.), Proc. 7rd Intern. Sympos. Orch.&Plant Syst, ISHS. Acta Hort. 557, 399–405.
17. **Glenn, D.M., Worthington, J.W., Welker, W.V., McFarland, M.J., 1989.** Estimation of peach tree water use using infrared thermometry. J. Am. Soc. Hort. Sci. 114, 737–741.
18. **Idso, S.B., Reginato, R.J. 1982.** Soil and atmosphere-induced plant water stress in cotton as inferred from foliage temperatures. Water Resour. Res. 18, 1143-1148.
19. **Jackson, R., Idso, S., Reginato, R., Pinter, P.J., 1981.** Canopy temperature as a crop water stress indicator. Water Resour. Res. 17, 1133–1138.
20. **Jensen, M.E, Burman, R.D. and Allen, R.G. (Eds.). (1990).** Evapotranspiration and irrigation water requirements. ASCE, 332 pp.
21. **Jhajharia, D.; Dinpashoh, Y.; Kahya, E.; Singh, V.P.; Fakheri-Fard, A.2012.** Trends in reference evapotranspiration in the humid region of northeast India. Hydrol. Process. 26, 421–435.
22. **Jones, H.G., 2004.** Irrigation scheduling: advantages and pitfalls of plant-based methods. J. Exp. Bot. 55, 2427–2436.
23. **Karimi, T., Peters, R. T., and Stockle, C. O. (2013).** “Revising crop coefficient for Washington state.” Proc., ASABE Annual Int. Meeting, American Society of Agricultural and Biological Engineers, St. Joseph,MI.
24. **Konarska, J., Uddling, J., Holmer, B., Lutz, M., Lindberg, F., Pleije, H., Thorsson, S., 2016a**. Transpiration of urban trees and its cooling effect in a high latitude city. Int. J. Biometeorol. 60, 159–172. https://doi.org/10.1007/s00484-015-1014-x.
25. **Lakso, A. N. (2003).** In Apples: Botany, production and uses, water relations of apples, D. C. Ferree and I. J. Warrington, eds.,

Commonwealth Agricultural Bureaux, Wallingford, U.K., 167–195.
26. **Leuzinger, S., Vogt, R., Körner, C., 2010.** Tree surface temperature in an urban environment. Agric. For. Meteorol. 150 (1), 56–62.
27. **Monteith J. L. (1980).** the development and extension of Penman's evaporation formula, in Application of Soil Physics, ed. By D. Hillel, Academic Press, Orlando, Fla., pp. 247-253.
28. **Nash, J. E. and J. V. Sutcliffe (1970).** River flow forecasting through conceptual models part I — A discussion of principles, Journal of Hydrology, 10 (3), 282–290.
29. **Nielsen, D.C. 1990**. Scheduling irrigations for soybeans with the Crop Water Stress Index (CWSI). Field Crops Res. 23: 103–116. doi.org/10.1016/0378-4290(90)90106-L
30. **Palmer, J. W., Giuliani, R., and Adams, H. M. (1997).** "Effect of crop load on fruiting and leaf photosynthesis of 'Braeburn'/M.26 apple trees." Tree Physiol., 17(11), 741–746.
31. **Penman, H. L. (1948).** Natural evaporation from open water, bear soil and grass. Proc. R. Soc. London, Ser. A, 120-146
32. **Pereira, A. R., Green, S. R., and Villa Nova, N. A. (2006).** "Penman- Monteith reference evapotranspiration adapted to estimate irrigated tree transpiration." Agr. Water Manage., 83(1–2), 153–161.
33. **Rahman, M.A., Moser, A., Rötzer, T., Pauleit, S., 2017.** Within canopy temperature differences and cooling ability of Tilia cordata trees grown in urban conditions. Build.Environ. 114, 118–128.
34. **Rahman, M.A., Moser, A., Rötzer, T., Pauleit, S., 2017a.** Microclimatic differences and their influence on transpirational cooling of Tilia cordata in two contrasting street canyons in Munich, Germany. Agric. For. Meteorol. 232, 443–456.
35. **Richard Seager, Allison Hooks, A.Park Williams, Benjamin Cook , Jennifer Nakamura and Naomi Henderson 2015.** Climatology, variability and trends in United States vapor pressure deficit, an important fire-related meteorological quantity. Journal of Applied Meteorology and Climatology. 54, 1121-1141. https://doi.org/10.1175/JAMC-D-14-0321.1
36. **Richard, G. A. ; Luis S. P., Dirk Raes and Martin Smith. 1998.** Crop evapotranspiration - Guidelines for computing crop water requirements. FAO irrigation and drainage Paper No.56. FAO, Rome, Italy:pp 90-139.
37. **Sepulcre-Canto, G., Zarco-Tejada, P.J., Jimenez-Munoz, J.C., Sobrino, J.A., de Miguel, E., Villalobos, F.J., 2006.** Detection of water stress in an olive orchard with thermal remote sensing imagery. Agric. Forest Meteorol. 136, 31–44.
38. **Testi, L., Villalobos, F.J., Orgaz, F., 2004.** Evapotranspiration of a young irrigated olive orchard in southern Spain. Agric. For. Meteorol. 121 (1–2), 1–18.
39. **Tramutoli, V., Claps, P., Marella, M., Pergola, N., Pietrapertosa, C., Sileo, C., 2000.** Hydrological implications of remotely sensed thermal inertia 267. IAHS-AISH .Publication, pp. 207–211
40. **Van Wijk WR, Scholte Ubing DW. Radiation. In: Van Wijk WR, editor.1963**. Physics of plant environment. Amsterdam, Netherlands: North-Holland Publishing Company; 1963. p. 62-101.
41. **Wanjura, D. F., and Upchurch, D. R. (1997).** "Accounting for humidity in canopy-temperature-controlled irrigation scheduling." Agr. Water Manage., 34(3), 217–231.
42. **Weiler, E.W.; Nover, L.; Nultsch, W. Allgemeine und Molekulare Botanik**, 1st ed.; Georg Thieme: Stuttgart, Germany, 2008; ISBN 3131476613.
43. **Zhang, D., Du, Q., Zhang, Z., Jiao, X., Song, X., Li, J. 2017**. Vapour pressure deficit control in relation to water transport and water productivity in greenhouse tomato production during summer. Sci. Rep. 7: 43461. doi.org/10.1038/srep43461

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