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RESEARCH ARTICLE

Irrigation Scheduling Based on Evapotranspiration of Tomato (*Solanumm Lycopersicum*) Using Atmometer in The Upland Rolling Production Area

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Abstract

Objective: The goal is to provide the right amount of water to the crop, at the right time, to meet the crop's needs. It was conducted to estimate evapotranspiration using atmometers for irrigation scheduling that may be highly beneficial in soil water balance, water allocation and budgeting, irrigation management, and improving crop yield and production for greater income. **Methods**: This study was conducted at the Organic Agricultural Research and Development Innovation Center at the Bataan Peninsula State University – Abucay Campus, Bangkal, Abucay, Bataan, Philippines (North 14°44'28" East 120°27'04"). The effects of using different evapotranspiration estimation methods on the timing and amounts of water application were then evaluated by using a computed irrigation scheduling model. **Findings:** The atmometer (ET_{o-A}) and Penman-Monteith (ET_{o-PM}) values were statistically analyzed using linear regression (y=0.8573x + 1.586), coefficients of determination (R^2 = 0.7236), root mean – squared error (RMSD = 0.73), mean bias error (MBE = 0.03), and the t-statistics (significant at 5% level). The study revealed that the ETo-A data strongly correlated with the ETo-PM data. Using an atmometer for scheduling irrigation on tomatoes would have resulted in an equally similar distribution of irrigation events, more water would have been provided throughout the season compared to using ETo-PM data. **Novelty :** The calibrated evapotranspiration data from the atmometer may guide appropriate irrigation depth and schedule for tomatoes. By aligning irrigation intervals with other crops' water requirements, farmers can optimize water usage, minimize water stress, and achieve higher crop yields.

Keywords: Atmometer; Bataan Philippines; Evapotranspiration; Tomato; Penman-Montheith Equation

1 Introduction

Upland farmers choose to produce tomatoes as it is one of the main ingredients in every dish and is considered as one of the most economic crops in the Philippines, and when it is off-season, its market value increases. Tomato production needs enough water, however, due to an insufficient supply of water in the upland, the consumptive use of tomatoes should be estimated especially during off-season production.

Evapotranspiration is the simultaneous process of soil water evaporation and plant transpiration transferring water to the atmosphere. Evapotranspiration is a crucial component of the soil water balance, as it determines the water usage efficiency[(1)]. Given the limited availability of water resources in upland areas, water management is critical for crops. In this environment, water resource sustainability is a top priority, necessitating irrigation management based on an accurate evaluation of evapotranspiration needs[(2)]. The FAO Penman-Monteith is an alternative for direct measurements of evapotranspiration, it uses meteorological data to estimate evapotranspiration (ET). Reference evapotranspiration (ET_o) is the evaporation from a hypothetical crop surface, also it is an important parameter in hydrological, agricultural, and environmental studies. Accurate estimation of reference evapotranspiration helps to improve water management and increase water productivity and efficiency.

The goal is to provide the right amount of water to the crop, at the right time, to meet the crop's needs. One of the crucial components of irrigation delivery is irrigation scheduling, which allows for the control of irrigation delivery time and volume to farmland[(3)]. Estimating evapotranspiration using an atmometer for irrigation scheduling will play an important role in the potential yields of crops as evapotranspiration is significant in the soil water balance components. In water allocation, irrigation management, analyzing the effects of changing land use on water production, environmental evaluation, and development of the best management practices to safeguard surface and groundwater quantity and quality, accurate evapotranspiration determination is critical.

This study aimed to estimate the evapotranspiration of tomatoes using an atmometer for irrigation scheduling. The cost of an Atmometer is cheaper than that of a complete weather station, and the ease of installation[(4)]. With the proper irrigation scheduling and knowledge about evapotranspiration, the use of irrigation to increase tomato production and profit will be met. With good irrigation scheduling, even if it is off-season for a crop, a sustainable high production is possible to meet. This can also result in water-use efficiency, and favorable income for the farmers.

The main objective of this study was to estimate the evapotranspiration of tomatoes using atmometer for irrigation scheduling. The evapotranspiration rate of tomatoes in the upland rolling production area using an atmometer was also determined. Evapotranspiration using the Penman-Monteith equation was calculated. The data gathered using an atmometer and the data computed using the Penman-Monteith equation in tomato production were differentiated. Irrigation scheduling for tomato production was estimated using the calibrated equation.

This study was limited in estimating the evapotranspiration rate using an atmometer of a tomato in an upland rolling production area. The seed variety used is Diamante Max F1 with a germination rate of 85%. The seedlings were transplanted 3 to 4 weeks after it was sown in a seedling tray with garden soil.

2 Methodology

The atmometer was installed in the area and the tomatoes seedlings were transplanted to establish the crop production area. First, atmometer data were monitored and used to identify the actual evapotranspiration rate of tomato. Second, the obtained meteorological data were used to calculate the computed ET rate with the Penman-Monteith equation. Third, the ETo from the atmometer and the Penman-Monteith equation were used to get the calibrated evapotranspiration rate of the tomato. Lastly, irrigation scheduling for tomatoes was estimated using the calibrated ET rate.

2.1 Materials and Equipment

After the production area was prepared using a shovel and grab hoe, tomato seedlings were transplanted at 60 cm per plant in a triangular pattern. Dripper and water hose were laid in the area together with an atmometer for the monitoring of evapotranspiration. Tomato growth was monitored using measuring tape and steel tape during the vegetation stage.

2.2 Site Selection

The study was conducted and located in Bataan Peninsula State University - Abucay Campus – Organic Production Area, Bangkal, Abucay, Bataan (North 14°44'28" East 120°27'04") at around 450 – 500 masl (Figure 1).

Fig 1. Satellite view of study area via Google Map

2.3 Crop Establishment

- **Seedling Preparation.** Locally available seedling trays were used with a dimension of 533.4 mm x 279.4 mm x 44.45 mm; 38.1 mm top diameter; and 25.4 mm bottom diameter. Each hole was filled with an equal amount of garden soil. One seed was sown in each hole and then covered with thin garden soil. The trays were placed in an elevated space with natural ventilation.
- **Transplanting.** Tomato seedlings were transplanted to the production area with rice hull as organic mulch of the area 3 to 4 weeks after sowing (3 - 4 weeks old). The most suitable for transplanting are seedlings with 3 to 5 true leaves and measuring 150 to 250 mm tall. The seedlings were watered immediately after transplanting. To avoid shock to the seedlings, the transplanting was done early in the morning when the sun did not directly hit the field. The seedlings were planted in a 120 m^2 rolling production area. The growing plant was supported with poles in the development and fruiting stage.
- **Irrigation Preparation and Management.** The drip irrigation method was applied for the experimental crop. The irrigation of the crops depends on the identified evapotranspiration rate. Reading of atmometer was used in determining the evapotranspiration rate of the crop.

2.4 Data Gathering

The data were gathered from October 2022 to March 2023, meteorological data and atmometer data were used.

- **Meteorological data:** The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) Synoptic weather station located inside the Bataan Peninsula State University – Abucay Campus, Bangkal, Abucay, Bataan (North 14°44' East 120°27') was the source of the meteorological data used in the study. The daily data were requested at the end of every month and were used to compute the estimated evapotranspiration with the FAO Penman-Monteith equation.
- **Atmometer data:** One commercial atmometer (ETgage) was installed within the enclosure (Figure 2), attached on the vertical wooden post with the top of the ceramic plate 1.0 m above the ground following the manufacturers' guidelines. The instrument was provided with the cover (No. 54 – canvass cover for crops) for estimating evapotranspiration. The instrument was prepared with distilled water and was checked for correct operation a week before the start of the field evaluation. Measurements from the atmometer were taken daily at 8 a.m. from October 5, 2022, to March 5, 2023. The study period was off-season chosen to match the duration when ET rates exceed rainfall and when supplemental irrigation is needed. The evaporated water from the atmometer was calculated as the difference between the observed water levels on a consecutive days' basis for irrigation depth.
- **Growth parameters:** Plant height was measured from the base part up to the tip of the largest leaves. Measuring tape or steel tape was used to measure the experimental plant. This was done during the 7, 14, 21, and 30 days after transplant.

2.5 FAO Penman-Monteith method

The FAO Penman-Monteith equation was used to calculate the evapotranspiration rate of tomatoes using the gathered meteorological data.

$$ET_o = \frac{0.408\triangle(R_n - G) + \gamma \frac{900}{T_{mean+273}} u_2(es - ea)}{\triangle + \gamma(1 + 0.34u_2)} \quad (1)$$

Where:

ET_o = Reference evapotranspiration, mm/day.
R_n = Net radiation at the crop surface, MJ-m^{-2}-day^{-1}.
G = Soil heat flux density, MJ-m^{-2}-day^{-1}.
T_{mean} = Mean daily air temperature at 2-meter height, °C.
u_2 = Wind speed at 2-meter height, m-s^{-1}
es = Mean saturation vapour pressure, kPa.
ea = Mean actual vapour pressure, kPa.
es – ea = Vapour pressure deficit, kPa.
Δ = Slope vapour pressure curve, kPa-°C^{-1}.
γ = Psychrometric constant, kPa-°C^{-1}.

2.6 Irrigation scheduling

Evapotranspiration (ET_c) is the biggest subtraction from the water balance equation. The ET_c changes throughout the growing season due to weather variations and crop development. With irrigation scheduling, you can plan when and how much water to apply to maintain healthy plant growth during the growing season. It's an essential daily management practice for a farm manager growing irrigated crops.

2.7 Statistical Analysis

The ET_o data readings from the atmometer (ET_{o-A}) were compared against FAO Penman-Monteith (ET_{o-PM}) using daily meteorological data from the weather station. The comparison between ET_{o-A} and ET_{o-PM} values was conducted on a 10-day basis through the growing season of the tomato. Statistical analysis using linear regression, coefficients of determination (R^2), root-mean-squared error (RMSD), mean bias error (MBE), sensitivity analysis, and the t-test were used to test the statistical significance of the ET_{o-A} data. For error analysis, the following statistics were used:

$$RMSD = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\gamma_i - \chi_i)^2} \quad (2)$$

$$MBE = \frac{\sum_{i=1}^{n}|(\gamma_i - \chi_i)|}{n} \quad (3)$$

Where:

RMSD = Root mean square deviation
MBE = Mean bias error
n = Number of daily observations
Xav = Average values of estimated ET_o, mm/day
χ_i= ET_o calculating value by using equations in the ith day, mm/day, and
γ_i= ET_o measured by the atmometer in the ith day, mm/day

The RMSD provides information on the short-term performance of the atmometer by allowing comparisons of the actual difference between the computed ET_{o-PM} and ET_{o-A} values. The smaller the RMSE value, the better the atmometer performance. The MBE provides information on the long-term performance of the atmometer. A positive value gives the average amount of overestimation in the estimated ET_{o-A} values and vice versa. The smaller the absolute value, the better the atmometer performance. The RMSD and MBE statistical indicators must be used in conjunction; if used in isolation, they may not be adequate indicators of the atmometers' performance.

3 Results and Discussion

Evapotranspiration (ET) is a key component of the water cycle in agriculture, and it refers to the loss of water through both plant transpiration and soil evaporation. The accurate estimation of ET is essential for water management in agricultural systems, particularly in regions where water resources are limited. The estimation of evapotranspiration plays an important role in determining the crop's growth and productivity, it is also critical for improving water-use efficiency and reducing water stress in crop production. With this, the study aimed to use an atmometer in estimating the evapotranspiration rate of tomatoes for irrigation scheduling in the upland rolling production area.

The study was conducted for 150 days as multiple factors, including temperature, humidity, wind speed, and sunshine hours influenced evapotranspiration rates.

3.1 Evapotranspiration Rate of Tomato

One commercial atmometer (ET Gage Evapotranspiration Simulator, #54 canvass cover) was installed and used to measure the evapotranspiration rate of tomatoes which was taken daily at 8:00 in the morning (Figure 2). The individual readings taken from the atmometer (ET_{gage}) daily were determined by the difference between water levels on consecutive days.

Fig 2. The experimental site at harvest stage of tomato

Figure 3 shows the decadal evapotranspiration rate of tomatoes which ranges from 2.9 mm to 7.6 mm during the growing period of 150 days with a mean average of 5.17 mm. On February, specifically, the 120th day, the ET_o rise to 7.6 mm, with linear regression analysis, the relative humidity and air temperature showed negative correlations with a coefficient of determination (R^2) of 0.68 and 0.23 respectively, indicating an inverse relationship with ET_{o-A} while the sunshine duration and wind speed exhibit positive correlations with R^2 of 0.19 and 0.10 respectively, suggesting a direct relationship with ET_{o-A}. This result agreed with the study at Vengurle station wherein the relative humidity appears to be the most influential factor in determining the ET_{o-A}, followed by air temperature, sunshine duration, and wind speed[5]. Figure 4 shows the relationship of climatic parameters to the evapotranspiration from the atmometer.

3.2 FAO Penman-Monteith Evapotranspiration

The FAO Penman-Monteith equation (Equation (1)) was used to calculate the 10-day sum evapotranspiration rate of tomatoes using the gathered meteorological data from the Bataan Synoptic Weather Station – Abucay, Bataan.

The computed decadal evapotranspiration rate of tomato using Penman-Monteith equation was shown in Figure 5 and it ranges from 3 mm to 7 mm, with a total value of 90.35 mm and mean average of 6.02 mm. Similarly, on February, specifically, the 120th day, the ET_o rise to 7.98 mm, with linear regression analysis, the relative humidity and air temperature showed negative correlations with a coefficient of determination (R^2) of 0.74 and 0.45 respectively, indicating an inverse relationship with ET_{o-A} (Figure 6) while the sunshine duration and wind speed exhibit positive correlations with R^2 of 0.08 and 0.28 respectively, suggesting a direct relationship with ET_{o-A}. This result also agreed with the study at Vengurle.

The observed data from the atmometer and computed data from the Penman-Monteith equation were differentiated in terms of values. The computed values from PM were higher compared to the observed values from the atmometer. The total value of ET_{o-A} was 77.6 mm while the Penman-Monteith was 90.35 mm.

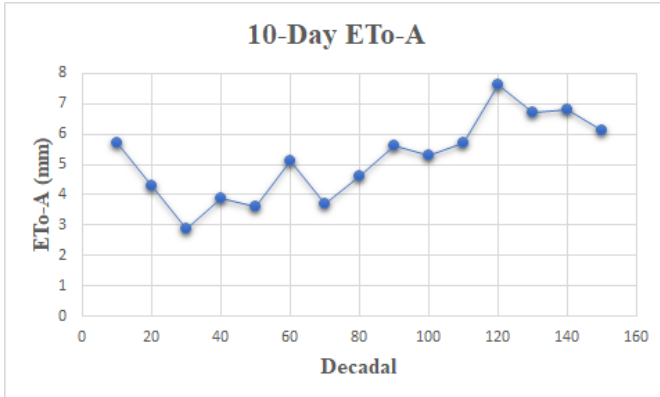

Fig 3. Decadal evapotranspiration rate using Atmometer

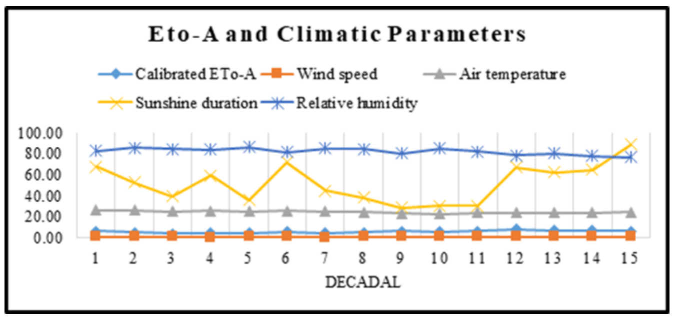

Fig 4. Climatic parameters during study period

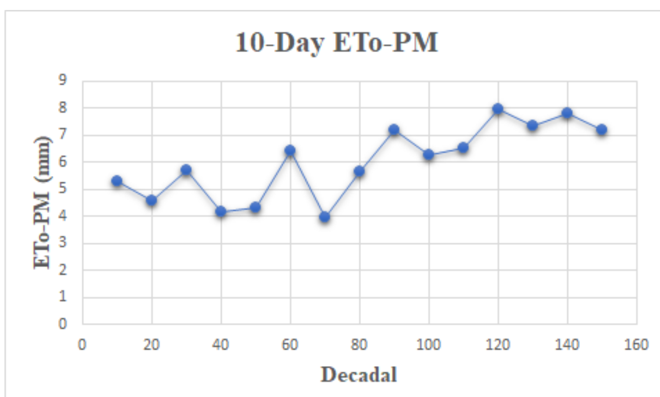

Fig 5. Calculated Decadal evapotranspiration rate using Penman-Monteith equation

With the use of Statistical Tool for Agricultural Research (STAR), the atmometer (ET_{o-A}) and Penman-Monteith (ET_{o-PM}) values were analyzed, graphed, and interpreted. The mean and standard error (SE) of the decadal values of the atmometer (ET_{o-A}) and the computed evapotranspiration using the Penman-Monteith equation (ET_{o-PM}) from the synoptic weather station and it also compares the performance of the ET_{o-A} against the ET_{o-PM} data. The standard error indicates that there could be more variability in ET_{o-A} estimates than in ET_{o-PM}, it is important to note that a higher standard error may be influenced by various factors such as the precision of the measurement of the instrument by various factors such as an atmometer was located nearby or beside buildings and other obstructions. Atmometers (ET_{o-A}) have a low positive MBE of 0.03 mm per day which indicates a small but systematic underestimation in ET_o compared to the ET_{o-PM}. The high RMSD value reflected a significant overestimation in ET_o of Penman-Monteith compared to the Atmometer whereas MBE was low due to atmometer precision. In addition, the statistics indicated that the atmometer method (ET_{o-A}) and the Penman-Monteith method (ET_{o-PM}) have different mean values and exhibit significant differences based on the t-statistic which is in contrast with the prior study. However, the MBE is very small, suggesting a negligible bias between the two methods. The RMSE provides an overall measure of the difference, indicating a typical difference of 0.73 mm $d^{-1°}$ between the two methods. According to the data, the Penman-Monteith (ET_{o-PM}) generates higher mean ET values than the atmometer (ET_{o-A}). The statistical analysis indicates that the difference in means is significant, suggesting that the Penman-Monteith method estimates ET more accurately. It is worth noting, however, that the atmometer has a lower standard error, implying partially higher precision.

The linear regression for the decadal correlations between the ET_{o-A} and the ET_{o-PM} were well correlated, with the coefficient of determination (R^2) of 0.7236. This suggests a moderate positive relationship between the atmometer and the Penman-Monteith method over this time frame. However, the daily compared values showed a distant correlation, with R^2 values of 0.0568. Therefore, the daily values show a much weaker and less consistent relationship between the two variables compared to the decadal correlations, wherein daily ET_{o-A} values were the ones that are well correlated with ET_{o-PM}. With this analysis, the atmometer and the Penman-Monteith method have a stronger and more predictable relationship when observed over a longer time frame (10 days) rather than daily. The correlation of Penman-Monteith and Atmometer applied to tomato was different from other crops using the lysimeter method[6] in estimating evapotranspiration.

A comparison between the values observed ET_{o-A} and the computed ET_{o-PM} during the growing period of tomato is shown in Figure 6. The atmometer closely matched ET_{o-PM}, and by the end of the season, the discrepancies amounted to only a single irrigation. The maximum value computed ET_{o-PM} was 7.98 mm, recorded on day 120, whereas the maximum value for ET_{o-A} is 7.6 mm, also recorded on day 120 while the minimum value for ET_{o-PM} was 3.94 mm, recorded on day 70, whereas the minimum value for ET_{o-A} is 2.9 mm, recorded on day 30. However, during the first 50 days, from the 6th of October to the 23rd of November, it was observed that the atmometer diverged significantly from ET_{o-PM} but then reestablished its slightly consistent trend. This is explained by some very high temperatures recorded during that period when daily maximum temperatures reached 25°C to 31°C. The ET_{o-PM} values during this period were 4.14 to 5.69 mm $d^{-1°}$, but the atmometer values during that period were 2.9 to 5.7 mm $d^{-1°}$. This would agree with the study[7] that it is important to first calibrate the atmometer readings (ET_{o-A}) against equivalent Penman-Monteith (ET_{o-PM}) data for a season using a local meteorological station or weather station before using it for irrigation scheduling on-farm. This would address any potential measurement error inherent in the instrument. Once the discrepancies have been identified, an adjustment factor could be applied to the atmometer values to offer a more accurate ET_o estimation.

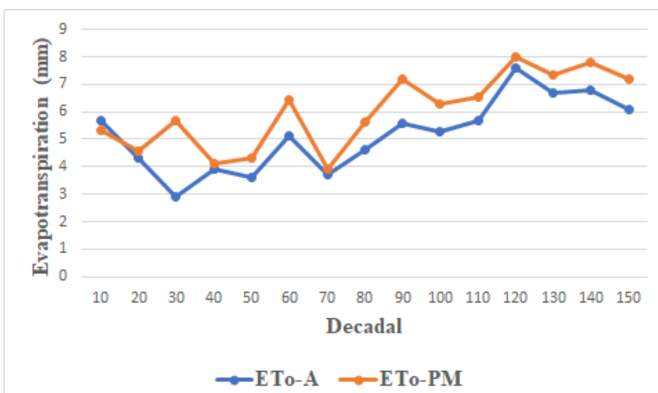

Fig 6. Evapotranspiration observed from atmometer (ETo-A) and computed from Penman-Monteith (ETo-PM)

3.3 Calibration of Atmometer

The raw data from the atmometer and the computed data using the Penman-Monteith equation were plotted to generate an equation to calibrate the ET_o of Penman-Monteith (Figure 7). Subsequently, the calibrated ET_{o-PM} were plotted with ET_{o-A} to get the calibrated model. The atmometer data was the independent variable (x) while the computed evapotranspiration was the dependent variable (y). In the production areas where distant synoptic station located, the generated equation was used using the Atmometer as dependent variable for Penman-Monteith. With this, the equation generated was

$$y = 0.8573x + 1.586 \quad (4)$$

The mean 10-day sum data from the atmometer and the computed evapotranspiration during the growing period of the experimental crop. The correlation coefficient of 0.8506 indicates a strong positive linear relationship between the ET_{o-A} and ET_{o-PM}. In addition, Figure 7 shows that with linear regression analysis, R^2 is calculated to be 0.7236 which indicates that 72.36% of the variance in ET_{o-PM} can be explained by ET_{o-A} using the linear regression equation.

The cumulative values of calibrated ET_{o-A} and calibrated ET_{o-PM} were 90.35 mm and 101.29 mm respectively and with statistical error analysis RSMD and MBE were found to be 0.0045 mm d^{-1}° mm and 0.04 mm d^{-1}°. This result showed that the atmometer was not statistically different from ET_{o-PM}. Low values of both RMSD and MBE, indicate that the ET_{o-PM} closely matched the ET_{o-A} without any significant bias. This suggests that the calibration equation model (Figure 7) was accurate and reliable in estimating the evapotranspiration.

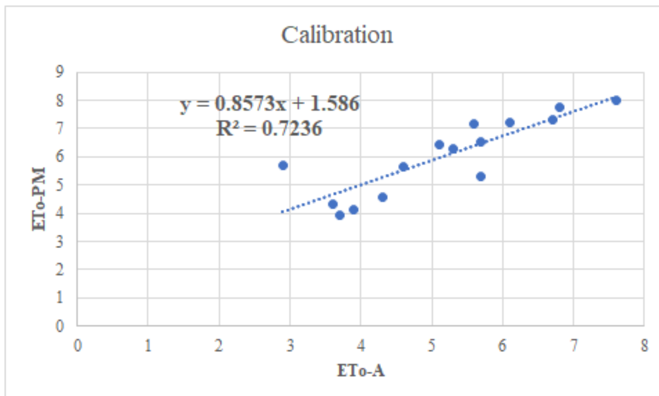

Fig 7. Calibration equation model generated from raw atmometer values (ETo-A) and computed Penman-Monteith values (ETo-PM)

3.4 Irrigation Scheduling for Tomato

Table 1 shows the irrigation scheduling for tomatoes using the calibrated evapotranspiration values from the atmometer. The soil type used in this study is Antipolo Clay. The calibrated ET_{o-A} ranges from 40 to 81 mm. The crop coefficient (Kc) values were obtained from the irrigation scheduling chapter of the FAO handbook[(8) (9)]. The crop evapotranspiration (ETc) ranges from 18 to 93 mm for the whole growing period of tomato with a total crop water requirement of 771.49 mm and the computed readily available water (RAW) were as follows: initial stage (48) for 30 days, development stage (64) for 40 days, mid-season (72) for 50 days, and late stage (80) for 30 days. The irrigation interval from the initial to development stage ranges from 2-3 days, while from the mid-season stage to the late stage, it is constantly a 1-day interval[(10)]. The irrigation interval is influenced by factors such as crop water requirement, available soil water, depletion threshold, and crop stage. It is important to consider these factors collectively to determine an appropriate irrigation interval that meets the crop's water requirements and avoids excessive water stress or wastage instead of soil moisture content[(11)]. Table 1 also shows that the irrigation interval varies across different crop stages and days, it can be observed that the irrigation interval is influenced mainly by the crop evapotranspiration[(12)]. As for the initial stage, day 30 resulted in an interval of 3 days, this is due to the low crop evapotranspiration with a value of 18.32 mm, while on the development stage, day 60 resulted in interval of 1 day due to the high crop evapotranspiration with a value of 44.70 mm. Shorter intervals indicate higher water demand, while longer intervals suggest lower water demand.

Table 1. Irrigation scheduling for tomato using ET_{o-A}

Day	Crop Stage	Calibrated ET_{o-A}	Kc (FAO)	ETc	RAW	Interval (days)
10		64.75	0.45	29.14	48	2
20	Initial	52.74	0.45	23.73	48	2
30		40.72	0.45	18.32	48	3
40		49.30	0.75	36.98	64	2
50	Crop development	46.73	0.75	35.05	64	2
60		59.60	0.75	44.70	64	1
70		47.59	0.75	35.69	64	2

Continued on next page

Table 1 continued

80		55.31	1.15	63.61	72	1
90		63.90	1.15	73.48	72	1
100	Mid-season	61.32	1.15	70.52	72	1
110		64.75	1.15	74.47	72	1
120		81.06	1.15	93.22	72	1
130		73.34	0.8	58.67	80	1
140	Late	74.20	0.8	59.36	80	1
150		68.19	0.8	54.55	80	1

Figure 8 shows the relationship of the calibrated ET_{o-A} to the crop's water requirement (ETc) of tomatoes for different crop stages. In the initial crop stage (Day 10-30), the calibrated ET_{o-A} is 158.21, while the crop ET (ETc) is 71.20 which indicates that during this stage, the crop's water requirement (ETc) is lower than the reference evapotranspiration (ET_{o-A}). During the crop development stage (Day 40-70), the calibrated ET_{o-A} increases to 203.23, while the crop ET (ETc) also increases to 152.42. The increase in both values suggests that the crop's water requirement is closer to the reference evapotranspiration during this stage. In the mid-season stage (Day 80-120), a significant increase in both the calibrated ET_{o-A} and crop ET (ETc) as the calibrated ET_{o-A} rises to 326.35, indicating higher water demand due to evapotranspiration, while the crop ET (ETc) increases even more substantially to 375.30, this suggests that the crop is actively transpiring and requires more water for optimal growth during this stage. In the late stage (Day 130-150), a decrease in both the calibrated ET_{o-A} and crop ET (ETc) was observed. The calibrated ET_{o-A} drops to 215.72, indicating a lower water requirement due to reduced evapotranspiration, while the crop ET (ETc) also decreases to 172.58, this decline suggests that the crop's water needs decrease as it approaches maturity.

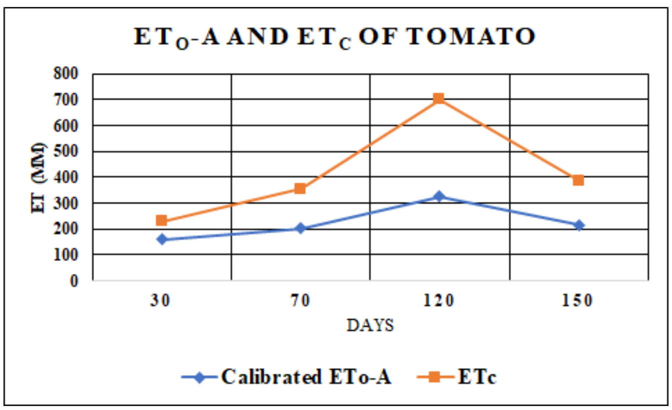

Fig 8. Relationship of calibrated ET_{o-A} and crop ET (ETc) of tomato for different crop stages

This result showed that as the crop progresses from the initial to the mid-season stage, its water demand increases significantly, demonstrating active growth and transpiration. However, in the late stage, the water requirement decreases as the crop approaches maturity. Understanding these relationships can help in managing irrigation and ensuring optimal water supply for different crop stages. Also, the result of this study agreed with the study wherein higher crop evapotranspiration values may suggest a higher water demand from the crop, which could lead to a shorter irrigation interval to ensure an adequate water supply for crop development stages. Penman-Monteith is generally estimated based on climatic data and crop development stage at any location, condition, and place. Atmometer data was based on a specific time, condition, location, and place regardless of the development stage.

3.5 Growth Parameters

Plant height (Table 2) was measured from the base part up to the tip of the largest leaves. Measuring tape or steel tape was used to measure the experimental plant. This was done weekly for every month. Table 2 shows that using the Atmometer in production, the growth parameters were improved compared to the study of Solis et al.[13]. It shows that the calibrated Penman-Monteith Method using an atmometer was a better basis for the irrigation of crops compared with other methods[14] of estimating the evapotranspiration of tomatoes for irrigation scheduling for crop production.

Table 2. Plant height during the growing period

Day	Average Plant Height (cm)	Day	Average Plant Height (cm)
13-Oct-22	20.3	24-Dec-22	102.7
20-Oct-22	29.8	31-Dec-22	114.3
27-Oct-22	33.2	07-Jan-23	121.9
05-Nov-22	38.7	14-Jan-23	138.7
12-Nov-22	41.4	21-Jan-23	161.8
19-Nov-22	48.1	28-Jan-23	172.3
26-Nov-22	55.4	04-Feb-23	176.7
03-Dec-22	69.1	11-Feb-23	179.9
10-Dec-22	72.9	18-Feb-23	183.5
17-Dec-22	87.3	25-Feb-23	187.7
		04-Mar-23	190.3

4 Conclusion

The Penman-Monteith equation was found to estimate ET more accurately on average in conjunction with other climatic parameters. The atmometer can still provide valuable information when properly calibrated from Penman-Monteith that could be used for irrigation scheduling. The calibrated evapotranspiration data from the atmometer, may guide appropriate irrigation scheduling for tomatoes. By aligning irrigation intervals with crop water requirements, farmers can optimize water usage, minimize water stress, and achieve higher crop yields. The use of atmometer precision on irrigation schedules has been assessed using tomato as a reference crop and can be used for other important irrigated crops, including short-season shallow-rooting crops such as lettuces and protected soft fruit, as long as the atmometer was calibrated and used in open production area since it was not effective in controlled environment specifically in unventilated conditions[(15)].

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