Estimation of Crop Coefficient and Response of Tomato (lycopersicon esculentum mill.) To deficit irrigation

Christy, Salvacion N.
College of Engineering and Food Science, Central Bicol State University of Agriculture

Luyun Jr., Roger A.
College of Engineering and Agro-industrial Technology, University of the Philippines-Los Baños

Lampayan, Rubenito M.
College of Engineering and Agro-industrial Technology, University of the Philippines-Los Baños

https://doi.org/10.5109/7395633

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 11, pp.987-992, 2025-10-30. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：

Estimation of Crop Coefficient and Response of Tomato (lycopersicon esculentum mill.) To deficit irrigation

Salvacion N. Christy [1], Roger A. Luyun, Jr.[2], Rubenito M. Lampayan [3]
[1]College of Engineering and Food Science, Central Bicol State University of Agriculture, [2] College of Engineering and Agro-industrial Technology, University of the Philippines-Los Baños, [3]College of Engineering and Agro-industrial Technology, University of the Philippines-Los Baños
salvacion.christy@cbsua.edu.ph

Abstract: *A study to estimate the crop coefficient (Kc) of tomato and evaluate its response to water stress by application of deficit irrigation was carried out at Los Baños, Laguna, Philippines, from October 2020 – January 2021. "Rosanna" tomato, grown inside a greenhouse, was subjected to a pot experiment with three irrigation treatments. Treatments were T1 (100%), T2 (66%), and T3 (33%) of its pot capacity, replicated three times and laid out in a completely randomized design. Readings from the atmometer calibrated with the Penman-Monteith equation and actual evapotranspiration were used to compute the Kc. Results revealed that the crop coefficient of tomato varies from 0.32–0.91 for each phenological stage. Results of the study on the response of tomato to deficit irrigation revealed that water deficit significantly affects its physiological and yield parameters. Tomatoes subjected to deficit irrigation experienced a 60% reduction in the number of fruits; however, they recorded the highest irrigation water use efficiency.*

Keywords: Evapotranspiration1; *Lycopersicum esculentum* Mill2; crop coefficient; deficit irrigation; atmometer

1. INTRODUCTION

Tomato (*Lycopersicum esculentum* Miller) is one of the most popular vegetables grown either in an outdoor field or inside greenhouses. In many parts of the world, tomato is produced under irrigation because this plant is known to be highly afflicted when it comes to water stress. In crop production, irrigated crops have the potential to provide higher yields than rainfed agriculture but water requirements under this practice are much higher [1].

Estimates vary, but approximately 70% of the world's freshwater withdrawals are used for agriculture, primarily for crop production, and are considered the primary factor behind the increasing global scarcity of freshwater [2]. This water allocation is used for irrigating lands which contribute to around 40% of the world's produce [3].

The continuous population growth increases the food demand and together with numerous environmental directives place unprecedented pressure on the land and water resources of our planet. By 2050, it is estimated to have the global water demand for agriculture to increase by a further 19% due to irrigational needs [4]. When water is a limiting factor for agricultural production under the "drier and warmer" scenario, the constraint of the availability of water supply should be considered in identifying the irrigation schemes to be practiced. One option is to use deficit irrigation (DI), which is a technique that aims to increase the water use efficiency of a crop by eliminating irrigations that have little impact on yield [5]. Another significant factor in crop production under irrigated agriculture is the quantification of crop water requirements. Crop water requirements may also be estimated through the actual crop evapotranspiration (ETc) which is determined by multiplying the reference evapotranspiration (ET_0) by the crop coefficient (Kc). The crop coefficient adjusts the reference ET_0 to obtain the crop evapotranspiration (ETc) which is tantamount to the water needed by the crop [6].

To effectively use this procedure, there should be accurate local ET_0 values throughout the growing season. Different empirical methods have been developed for estimating ET_0, one of which is the Penman-Monteith equation, which is the most accurate and widely used [7]. However, this equation is computed using climatological data from a weather station and is valid only for local conditions. Furthermore, many areas do not have nearby weather stations. An alternative is the use of an atmometer, a simple, inexpensive instrument that provides a visual interpretation of ET_0 [8].

Against this background, a study that employs an alternative method of estimating evapotranspiration, like an atmometer, was carried out. As water becomes increasingly scarce, irrigation strategy that utilizes water efficiently are of utmost importance; therefore, a study on the response of tomato to deficit irrigation was also covered by this study.

2. MATERIALS AND METHODS

2.1 Experimental Site and Set-up

The study was conducted inside a greenhouse situated at the organic farm of Binhing Pamana, Pili Drive, University of the Philippines-Los Baños (UPLB), Laguna at 14°9'49.86" N latitude, 121°15'3.42" E longitude and an altitude of 23.77 m above mean sea level. Los Baños falls under Type I climate which has two pronounced seasons, dry during November to April and wet for the rest of the year. In 2020, the site has an annual rainfall of 2,712 mm. The hottest month is May with an average maximum temperature of 34.4oC and the coldest month is February with an average minimum temperature of 21.8 °C (NAS-UPLB Data, 2020). The study used commercial garden soil that was classified as sandy loam. The physical properties of the soil used in the study is shown in Table 1.

Table 1. Physical Properties of Soil

BULK DENSITY (g/cc)	PARTICLE SIZE DISTRIBUTION (%)			SOIL MOISTURE (%)	
	Clay	Silt	Sand	Field Capacity	Permanent Wilting Point
1.13	12.51	20.93	66.56	15.17	6.47

The "Rosanna" variety tomato was used as the experimental crop in the study the seeds of which were acquired from the Institute of Plant Breeding (IPB), UPLB. The experiment was conducted inside a greenhouse through a pot experiment. Four-week-old tomato seedlings were transplanted into the experimental pots that were made of high-density polyethylene plastic utility pails with a dimension of 35 cm in height and diameter. A total of nine pots were laid out in a completely randomized design (CRD) with three levels of irrigation treatments and three replicates. The irrigation treatments were Treatment 1 (T1) irrigated with 100% of its pot capacity (PC), T2 with 66% PC, and T3 with 33% PC. The moisture content of the soil was monitored through the installed EC-5 soil moisture probe positioned at approximately 5cm from the plant, calibrated through the gravimetric method. The Water Advisory for Irrigation Scheduling System (WAISS) was used as the soil moisture sensor setup in the study. WAISS is a technology developed at UPLB through Project SARAI or Smarter Approaches to Reinvigorate Agriculture as an Industry in the Philippines. Daily reading from the soil moisture sensor was the basis of the volume for irrigation, which followed the moisture level of the irrigation treatments. The experimental setup is shown in Figure 1.

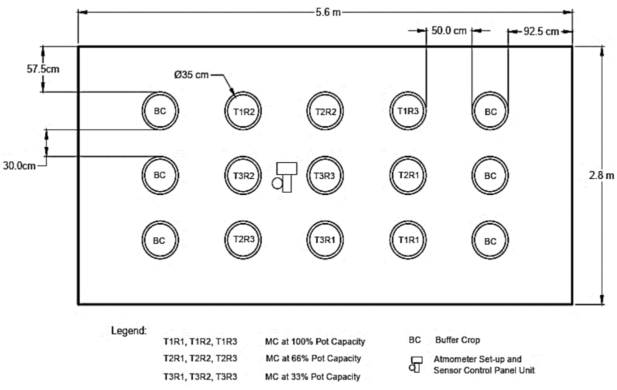

Fig. 1. The experimental layout in Completely Randomized Design (CRD).

The same experimental setup was used for the calculation of crop coefficient. Using only the tomatoes irrigated at 100% of pot capacity (T1). An atmometer was also installed inside the greenhouse for the measurement of reference evapotranspiration.

2.2 Local Climatological Data

Standard climatological records of sunshine duration, air temperature, humidity, and wind speed were obtained from the National Agromet Station at the University of the Philippines (NAS - UPLB).

2.3 Reference Evapotranspiration

The reference evapotranspiration was measured from the commercial atmometer (ETgage brand). The atmometer was calibrated with the Penman-Monteith equation for accuracy. The equation is written as:

$$ET_o = \frac{0.408\,\Delta\,(R_n - G) + \gamma\,[900/\,(T_{mean} + 273)]\,u_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,u_2\,)} \quad (1)$$

ET_0 = reference evapotranspiration (mm day^{-1}); Rn= net radiation at the crop surface (MJ m^{-2} day^{-1}); G = soil heat flux density (MJ m^{-2} day^{-1}); T = air temperature at 2 m high (°C); u_2 = wind speed at 2 m high (m s^{-1}); es = saturation vapor pressure (kPa); e_a = actual vapor pressure (kPa); e_s-e_a = saturation vapor - pressure deficit (kPa); Δ=slope vapor-pressure curve (kPa $°C^{-1}$); and γ = psychrometric constant (kPa $°C^{-1}$)

Under greenhouse conditions, wind speed approximately equals zero, therefore, equation 1 was modified as suggested by Singh, et al., 2016 [9]:

$$ET_o = \frac{0.408\,\Delta\,(R_n - G)}{\Delta + \gamma} \quad (2)$$

2.4 Actual Crop Evapotranspiration

The actual crop evapotranspiration was determined by weighing the individual pots where the crop is planted. Weighing was done daily with a digital platform weighing scale. The difference between the weights of the pot before and after irrigation was recorded as the measurement of the daily ETc. The depth of ETc was calculated using the equation

$$ETc = \frac{(W_i - W_f)}{\rho A}\,x\,1000 \quad (3)$$

ETc=crop evapotranspiration (mm); $(W_i - W_f)$ = difference of the weight of pots before and after the irrigation (kg); ρ=density of water (1000 kg/m^3); A = area of the pot (m^2).

2.5 Crop Coefficient

Crop coefficient was computed using the equation:

$$K_c = \frac{ET_c}{ET_o} \quad (4)$$

2.6 Crop Parameters

The response of the tomato plant to the irrigation treatments was evaluated through the effect on growth, physiological, and yield parameters of the plant. The height of the tomato plant was measured from the base of the plant to the top of the main plant stem with a meter stick. The stem diameter was measure at the base of the stem of the tomato plant by a digital caliper. A leaf porometer was used to measure the stomatal conductance of the tomato leaves. To have an even representation of the whole plant leaf system, three leaf samples found at the apex, middle, and base of the plant were measured at every data collection. The absolute growth rate (AGR) of the tomato was determined following the equation suggested by Hunt [10].

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

$W_2 - W_1$ is the difference between the weights (g) of the pots wherein the tomatoes were planted; and $t_2 - t_1$ is the time interval (day) for the data gathering. AGR is expressed as fresh weight per day (g/day) since the tomato samples were limited, the destructive method to obtain dry weight of the tomato is not ideal.
The determination of the percentage of flowers aborted was through the formula given below:

$$Flower\ Abortion\ rate = \frac{Total\ number\ of\ flowers - Number\ of\ fruits}{Total\ number\ of\ flowers}\ x\ 100$$

Yield measurements were done by recording the number of fruits per plant, fruit weight, and diameter of tomatoes at mature stage. Three fruits per replicate for each treatment were selected. For the fruit weight, each fruit sample was weighed using an electronic weighing balance. The fruit diameter was measured using a digital caliper. The measurement of fruit diameter was done on the traverse section of the fruit.

2.7 Statistical Analysis

Comparison between the measured evapotranspiration from the atmometer ($ET_{0\text{-}A}$) and the calculated ET using Penman-Monteith ($ET_{0\text{-}PM}$) was made on a daily average basis using simple regression analysis. Statistical analysis using regression, coefficients of determination (R^2), root-mean-squared error (RMSE), and t-test were used to test the statistical significance of the $ET_{0\text{-}A}$ data.
The data collected for the effects of deficit irrigation on the tomato plants were subjected to Analysis of Variance (ANOVA) using Statistical Tool for Agricultural Research (STAR) software [13]. To further analyze the differences among the treatments, Least Significant Difference (LSD) at P-value ≤ 0.05 was carried out.

3. RESULTS

3.1 Calibration of the Atmometer

The comparison of ET_0 values from the atmometer ($ET_{0\text{-}A}$) and those computed using the FAO Penman-Monteith ($ET_{0\text{-}A}$) is shown in Figure 2.

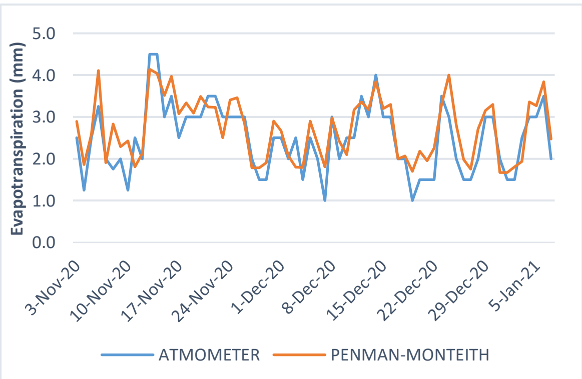

Fig. 2. Measurement of $ET_{0\text{-}A}$ (mm) compared to $ET_{0\text{-}PM}$ (mm) during the growing season of the tomatoes.

The simple linear regression analysis established the relationship between $ET_{0\text{-}PM}$ and $ET_{0\text{-}A}$ with the generated equation:

$$ET0 - PM\ =\ 0.7792\ ET0 - A\ +\ 0.7831$$

This equation was found significant at an F value equal to 176.07, significant at the P-value of 0.000. The R^2 was 0.7334 and the calculated RMSE was 0.3825. The values of $ET_{0\text{-}PM}$ and $ET_{0\text{-}A}$ are also found to have a positive correlation, as shown in the scatter plot in Figure 3.

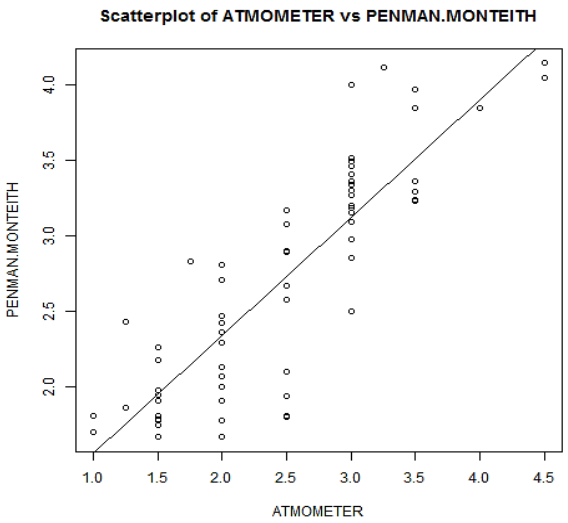

Fig. 3. Correlation of $ET_{0\text{-}PM}$ computed using the Penman-Monteith equation to the $ET_{0\text{-}A}$ from the atmometer.

3.2 Crop Coefficient of Tomato

The computed crop coefficients of tomato for each phenological stage were tabulated in Table 2. The growing season of tomato for the determination of crop coefficient was categorized into three phenological stages. The Vegetative-reproductive period is from the day of transplanting to the first bloom of its flower, which lasts for 35 days. In this stage, the cumulative ETc was 7.40 mm and the ET0 was 23.41 mm, generating a Kc of 0.32. The next stage was Reproductive fructification, which covers flowering to the development of fruits that runs for 25 days and has a Kc of 0.91. The last stage is the period of maturation and picking of mature fruits with a Kc of 0.68.

Table 2. Crop Coefficient of the Tomato Plants.

PHENOLOGICAL STAGE	DAYS	ETc (mm)	ET0 (mm)	Kc
Vegetative	35	7.40	23.41	0.32
Fruiting	25	60.10	66.32	0.91
Maturation	10	18.63	27.31	0.68

*Means with the same letter(s) within a column are not significantly different at P ≤ 0.05 by LSD

3.3 Response of Tomato to Deficit Irrigation

3.3.1 Agronomic Parameters

The results of the analysis of variance among the average values of plant height and stem diameter revealed that there was no significant difference in these parameters. However, T1 has the highest plant height and stem diameter. Plants applied with an irrigation level of 33% of pot capacity (T3) are relatively stunted (lower plant height) compared with plants receiving 100% and 66% of pot capacity (Table 3). While deficit irrigation does not seem to affect the stem diameter of tomato plants, as evident in Table 4.
The absolute growth rate (AGR) of the tomato plants was determined to further analyze the effect of the irrigation treatments (Figure 4). Tomatoes irrigated with T1 have the highest AGR of 0.10 g/day attained at 49 DAT, whereas the lowest AGR was observed in T3 at 64 DAT

with a value of -0.03g/day. Analysis of variance, however, revealed that there was no significant difference among the average values of irrigation treatments.

Table 3. Effects of irrigation treatments to plant height (cm) of tomato.

Treatment	Days After Transplanting						
	24	33	38	47	52	59	64
T1	54.7a	70.7a	83.3a	88.0a	90.3a	90.0a	91.0a
T2	55.2a	74.0a	86.7a	87.0a	88.7a	89.7a	90.0a
T3	56.0a	73.0a	78.3a	76.5a	77.0a	77.0a	76.3a

*Means with the same letter(s) within a column are not significantly different at P ≤ 0.05 by LSD

Table 4. Effects of irrigation treatments to stem diameter (mm) of tomato.

Treatment	Days After Transplanting						
	24	33	38	47	52	59	64
T1	7.0a	7.6a	8.6a	9.6a	11.6a	12.2a	12.3a
T2	6.7a	7.5a	8.8a	9.7a	9.8a	10.4a	10.6a
T3	7.1a	8.3a	9.2a	9.5a	10.2a	10.7a	10.5a

*Means with the same letter(s) within a column are not significantly different at P ≤ 0.05 by LSD

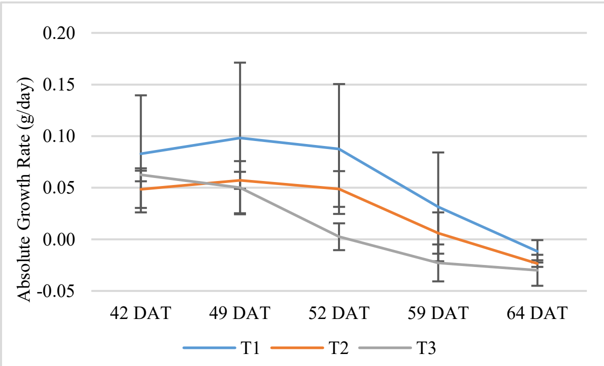

Fig. 4. Absolute growth rate (g/L) of the tomato plants.

3.3.2 Physiological Parameters

The graph presenting the relationship of evapotranspiration to the stomatal conductance of tomato as affected by water deficit is shown in Figure 5.

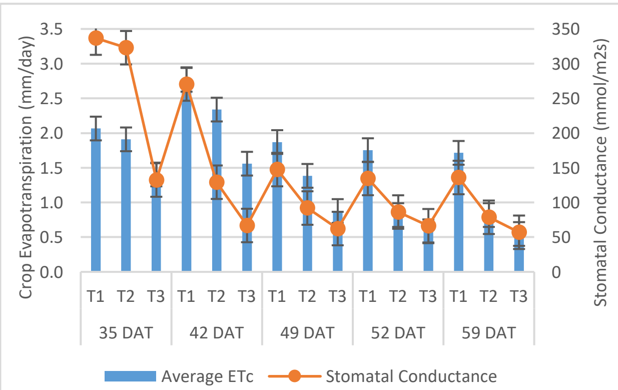

Fig. 5. The relationship of stomatal conductance (mmol/m^{2}s) to the crop evapotranspiration rate (mm/day).

The analysis of variance indicates that there were significant differences among the average values of both parameters when subjected to deficit irrigation.

T1, which has the highest stomatal conductance, is significantly different from T2 and T3. While T2 and T3 are not significantly different from each other.

The highest evapotranspiration rate was observed on T1, which has an average value of 2mm/day throughout its growing season. The lowest evapotranspiration rate was recorded on T3, which is equal to an average value of 0.99 mm/day.

3.3.3 Yield Parameters

The measurement of various yield parameters during the conduct of the study is shown in Table 5. The ANOVA indicates that there were significant differences among the yield parameters of the tomato.

Table 5. Yield parameters measured during the study.

Treatment	Flower Abortion Rate (%)	Number of Fruits Per Plant	Fruit Diameter (cm)	Weight of Fruit (g)
T1	38.91a	11.0a	26.47a	13.33a
T2	79.87b	4.0b	23.70b	8.78b
T3	76.09b	3.3b	19.74c	4.67c

*Means with the same letter(s) within a column are not significantly different at P ≤ 0.05 by LSD

T1, with the lowest flower abortion rate of 38.9% is significantly different from T2 and T3. While the abortion rates of T2 and T3 are not significantly different from each other, with values of 79.87% and 76.09%, respectively.

Tomato plants irrigated under T1 yield the greatest number of fruits per plant, with an average number of 11 per plant, which significantly differs from T2 and T3. Tomatoes irrigated under T2 and T3 are not significantly different from each other, having an average number of 4.0 and 3.33 fruits per plant, respectively.

The largest fruit diameter was recorded under T1, which measures an average diameter of 26.47mm. T2 was the second largest with an average diameter of 23.70mm, and the smallest was measured under T3 with an average of 19.74mm in stem diameter.

The highest fruit weight was recorded under T1, which had an average of 13.33g per fruit. The lowest fruit weight was observed in T3, which only weighs an average of 4.67g per fruit.

3.4 Irrigation Water Use Efficiency

The analysis of variance shows that deficit irrigation has a significant effect on the IWUE of tomato plants. Table 6 shows that T3 achieved the highest IWUE with 36.07 g/L and the lowest IWUE was exhibited by T1 with 12.35 g/L. Both T1 and T2 are significantly different from T3, but not from each other.

Table 6. Irrigation Water Use Efficiency

TREATMENT	Fruit Weight (g)	Water Consumed (L)	WUE (g/L)
T1	84.2	6.8	12.4b
T2	29.1	2.1	14.0b
T3	21.0	0.6	36.1a

*Means with the same letter(s) within a column are not significantly different at P ≤ 0.05 by LSD

4. DISCUSSIONS

4.1 Discussions on Crop Coefficient

The estimated Kc values are lower than those proposed in FAO 56 by Allen et al. [6] for tomato (*Lycopersicon esculentum* L.) grown under field conditions with values of 1.15 and 0.70-0.90 for middle and late growing stage, respectively. A similar result of the computed Kc values was observed with those found by Harel et al. [14] in a study conducted in Israel, grown under net house conditions. The Kc reported in their study were 0.47 during blooming and initial fruit set and 0.81 for fruit pick, which are slightly higher than those from this study. But the Kc values in the fruit development stage were almost the same, with a Kc of 0.90.

The effects of the crop characteristics are incorporated into the crop coefficient. The difference in climatic conditions and the growth rate of the crops and their characteristics explained the variability of Kc values. The study of crop water requirement carried out for many years proved the variability in both measured Kc and ETc values at different temporal scales – growing season, daily, and monthly [15].

4.2 Discussions on the Effects of DI to Tomato

The study revealed that there is no significant difference in the agronomic parameters of tomato. However, it can be observed that plants under T3 that experienced severe water stress have smaller plant height and stem diameter measurements. Results from this study are similar to those found by Jiang et al. [16] and Chand et al. [11] where plant height and stem diameter of water-stressed plants were smaller than the equivalent components in the well-watered plants. Therefore, a lower rate of AGR was observed in the severely stressed plants. Many researchers believed that the first reaction of the plants to severe drought is the closure of stomata to prevent water loss through transpiration [17]. With this, transpiration rate gradually decreases because plants under water deficit open their stomata lesser or even remain closed to reduce transpirational water losses, thus reducing stomatal conductance [18].

The result of the analysis on the yield parameters of the tomato of this study concurs with what Sibomana et al. [19] have stated, that the highest flower abortion increased in severely stressed plants. It could be because as the water stress increases, the number of ovules per floret decreases. A model was generated by Ganeva et al. [20] correlating flower abortion to the degree of water stress. The model demonstrated that 71% of flower abortion was due to water stress, and over 60% of the flowers in well-watered plants formed fruits, while in reduced irrigation plants the number of flowers that failed to form fruits increased.

With regards to the quantity of fruit, this study was in agreement with the research of Nuruddin et al. [21], which revealed that water stress throughout the growing season significantly reduced the number of yield and fruit size. According to Tamirneh [22], deficit irrigation with 50% of the crop water requirement reduces the tomato yield significantly. Therefore, the marketable yield obtained from less irrigated tomato plants is lower than irrigated with full irrigation.

Although deficit irrigation applied under T3 resulted in high WUE, an enormous yield reduction of about 60% of the total fruit yield was recorded in this treatment as well. Bogale [23] reported that the higher WUE corresponds to a yield reduction.

5. CONCLUSION

The results of the study suggest that with proper operation and careful reading, an atmometer can give ET_0 estimates that are close to those obtained using the Penman-Monteith equation. The computation crop coefficient of the tomato for each phenological stage resulted in a lower value than other published Kc values. The results analysis of the various parameters of the tomato plants subjected to deficit irrigation revealed that as the level of water deficit increases, the detrimental effect on the parameters of tomatoes also increases. A possibility of obtaining a higher irrigation water use efficiency for DI greenhouse-grown tomato with lesser effect on the yield is to apply lower water stress than used in this study.

Acknowledgements

This study would not be possible without the financial support from the Department of Science and Technology – Science Education Institute (DOST–SEI), through the Engineering Research and Development for Technology (ERDT) scholarship grant.

Statement on Conflict of Interest

The authors declare no conflicts of interest.

6. REFERENCES

[1] FOOD AND AGRICULTURE ORGANIZATION [FAO]. 2002. Crops and drops: making the best use of water for agriculture. Rome, Italy Retrieved from http://www.fao.org/3/Y3918E/y3918e10.htm

[2] FAO. 2003. World agriculture: towards 2015/2030 an FAO perspective. London, UK. Earthscan Publications Ltd.

[3] FAO. 2011. The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Food and Agriculture Organization of the United Nations, Rome and Earthscan, London

[4] INTERNATIONAL ASSESSMENT OF AGRICULTURAL KNOWLEDGE, SCIENCE AND TECHNOLOGY FOR DEVELOPMENT (IAASTD). (2016). Agriculture at a crossroads. IAASTD findings and recommendations for future farming. Vol. 320. 31

[5] KIRDA, C., R. KANBER. (1999). Water, no longer a plentiful resource, should be used sparingly in irrigated agriculture. In: C. Kirda, P. Moutonnet, C. Hera & D.R. Nielsen, eds. Crop yield response to deficit irrigation, Dordrecht, The Netherlands, Kluwer Academic Publishers

[6] ALLEN, R.G., L.S. PEREIRA, D. RAES. M. SMITH (1998). Evapotranspiration and Crop Water Requirements; Irrigation and Drainage Paper No. 56; FAO: Rome

[7] DIOP L., A. BODIANA, D. DIALLO. (2015) Use of atmometers to estimate reference evapotranspiration in Arkansas. African Journal of Agricultural Research. pp. 4376-4383. DOI: 10.5897/AJAR2015.10332

[8] GAVILÁN, P. and F. CASTILLO-LLANQUE (2009) Estimating reference evapotranspiration with atmometers in a semiarid environment. Agricultural Water Management. Vol. 96, Issue 3. 465-472. Doi: https://doi.org/10.1016/j.agwat.2008.09.011

[9] SINGH V.K., K.N. TIWARI, D.T. SANTOSH (2016) Estimation of crop coefficient and water requirement of dutch roses (*Rosa hybrida*) under greenhouse and open field conditions. Irrigation Drainage System Engineering 5: 169. doi: 10.4172/2168-9768.1000169

[10] HUNT, R. (2003). Growth analysis, individual plants. Encyclopedia of Applied Plant Sciences. Thomas, B., Murphy, D., Murray, B. (eds). Academic Press. London. p.579-583

[11] CHAND, J., G. HEWA, A. HASSANLI, B. MYERS. (2020). Evaluation of deficit irrigation and water quality on production and water productivity of tomato in greenhouse. Agriculture 10, 297. doi:10.3390/agriculture10070297

[12] AGBNA, G.H., DONGLI, S., ZHIPENG, L., ELSHAIKH, N.A., GUANGCHENG, S., and TIMM, L.C. (2017). Effects of deficit irrigation and biochar addition on the growth, yield, and quality of tomato. Scientia Horticulturae. 222, 90–101

[13] STAR, version 2.0.1 2014. Biometrics and Breeding Informatics, PBGB Division, International Rice Research Institute, Los Baños, Laguna

[14] HAREL D, M. SOFER, M. BRONER, D. ZOHAR, S. GANTZ. (2014) Growth-stage-specific kc of greenhouse tomato plants grown in semi-arid Mediterranean region. Journal of Agricultural Science. Vol. 6(11). doi:10.5539/jas.v6n11p132

[15] LAZZARA, P., & G. RANA. (2010). The crop coefficient (Kc) values of the major crops grown under Mediterranean climate. Mediterranean Dialogue on Integrated Water Management, FP6 INCO-MED Funded Project

[16] JIANG, X., Y. ZHAO, R. WANG, S. ZHAO. (2019). Modeling the relationship of tomato yield parameters with deficit irrigation at different growth stages. HortScience. Vol.54, 1492–1500.

[17] PIRASTEH-ANOSHEH, H., A. SAED-MOUCHESHI, H. PAKNIYAT, M. PESSARAKLI (2016). Stomatal responses to drought stress. in water stress and crop plants: a sustainable approach. USA. Ahmad, P., Ed.; John Wiley & Sons, Ltd.

[18] MANZONI, S., V. GIULIA, G. KATU, P. A. FAY, W. POLLEY, S. PALMROTH, A. PORPORATO. (2011). Optimizing stomatal conductance for maximum carbon gain under water stress: a meta-analysis across plant functional types and climates. Functional Ecology 25: 456–467

[19] SIBOMANA, I.C., J. N. AGUYOH, A. M. OPIYO. (2013). Water stress affects growth and yield of container grown tomato (Lycopersiconesculentum Mill) plants. Global Journal of Bio-Science and technology, Vol.2 (4) 2013: 461-466

[20] GANEVA, D., S. GROZEVA, G. PEVICHAROVA. (2019). Effect of reduced irrigation on flowering, fruit set and yield of indeterminate tomato. International Journal of Recent Technology and Engineering (IJRTE). 932-936. DOI:10.35940/ijrte.B1185.07-82S419.

NURUDDIN, M. M., C. A. MADRAMOOTOO, G.T. DOODS. (2003) Effects of water stress at different growth stages on greenhouse tomato yield and quality. HortScience: a publication of the American Society forHorticultural Science 38(7):1389-1393 DOI: 10.21273/HORTSCI.38.7.1389

[22] TAMIRNEH K. (2018). Evaluation of tomato response to deficit irrigation at Humbo Woreda, Ethiopia. International Journal of Research - Granthaalayah, 6(8), 57-68. https://doi.org/10.5281/zenodo.1403803

[23] BOGALE, A., NAGLE, M., LATIF, S., AGUILA, M., and MÜLLER, J. (2016). Regulated deficit irrigation and partial root-zone drying irrigation impact bioactive compounds and antioxidant activity in two select tomato cultivars. Scientia Horticulturae. 213, 115–124