



Crop Water Requirements of Early and Late-Season Tomato (*Lycopersicon esculentum*) in Umudike Area of Abia State, Southeastern Nigeria

Abstract

Water requirements of tomato planted in the Umudike area of Abia State, Southeastern Nigeria was estimated based on a 11-year meteorological data of the National Root Crop Research Institute, Umudike, using Penman's equation. Results obtained showed that seasonal crop evapotranspiration (ET_{crop}) of tomato planted on 1 March and harvested in July (early season) was 387.10 mm, whereas that sown on 1 August and harvested in December (late season) was 353.31 mm. The results indicated that water requirement for early season tomato was higher than the late season tomato. Supplementary irrigation requirements were estimated at 11.52 mm during the initial growth stage of early-season tomato and 126.49 mm during the productive and maturity stages of late-season tomato. It is therefore recommended that the early season planting be done at a time when crop water requirements of the initial growth stage and reproductive and maturity stages of tomato in Umudike can be met by effective rainfall for economic reasons. However, provision for supplementary irrigation should be made during November and December for late-season tomato production.

Keywords: Crop Water Requirement, Penman's equation, Season, Tomato, Evapotranspiration.

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Introduction

Crop growth periods and their water requirements vary with climatic conditions of an area. Irrigation scheduling is dependent on the moisture needs of the crop, timing and the amount of available water to the crop. The irrigation needs are also dependent on the amount of available moisture unable to be supplied by rainfall, particularly under rain fed conditions, and therefore represents the amount of water needed to make up the deficit between crop water requirement and effective rainfall (Allen

et al., 1998; Ouda *et al.*, 2015). Broner and Schneekloth (2003) reported that water requirements of crops depend mainly on environmental conditions. Adequate moisture is however necessary for good crop establishment, growth, yields and quality (Machado *et al.*, 2022).

Tomato (*Lycopersicon esculentum*) is known to originate in the Western Southone normal spaceand Central America (Encyclopaedia Britannica, 2018), but its cultivation and use as a crop may have originated with the Indian people of

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Mexico (Cage, 2005) and now it is widely grown in one normal space most climatic zones of the world. The word 'tomato' comes from the Nahuatl word *tomatl* meaning 'the swelling fruit' (Merriam-Webster, n.d.; Online Etymology Dictionary, n.d.). It is one of the most important vegetable plants in the world (Kimura and Sinha, 2008), and widely used as food and research material. The red edible fruits are a good source of antioxidant Lycopene which has many health benefits (Petre, 2018) and thus an important constituent of the daily one normal space diets of most Nigerians (Ubi and Osodeke, 2009). Tomato has interesting features such as fleshy one normal space fruit, a sympodial shoot, and compound leaves (Kimura and Sinha, 2008).

Nigeria produces about 3.78 million metric tons of tomato annually, with about 60% produced in the northern regions of the country (NAERLS, 2025). Although the crop is predominantly and commercially grown in the northern region of the country, its production also occurs in the southern part, but on a smaller scale. The lower level of production in the southern region may be associated with factors such as high rainfall, high relative humidity, and other agro-climatic and production constraints (Ubi and Osodeke, 2009). The crop requires well-drained and fertile soil with pH range of 5.8 – 6.8. Tomato has a relatively shallow root system, with more than 70% of effective roots usually found

in the upper 2 cm of the soil depth. Its water requirement varies with climatic conditions, crop species, growth stage and soil water availability (Allen *et al.*, 1998; Negash *et al.*, 2024).

Water shortage during early flowering and yield formation in tomato reduces the number of fruits, fruit size and yield (Raemackers, 2001; Sivakumar and Srividhya, 2016). Thus adequate water and nutrient supply to tomato is very important at the early flowering and yield formation stages. This is because about 90% by weight of the plant tissues are made up of water (Ridge, 1991; Hou *et al.*, 2020), indicating that drought conditions can significantly reduce plant growth and yield (Sivakumar and Srividhya, 2016).

The primary constraint for high yields in crops such as tomato during the late season period is soil moisture deficit (Nangare *et al.*, 2016). Inadequate soil moisture can adversely affect plant growth, yield and water productivity, making appropriate irrigation management important for maintaining adequate soil moisture, particularly in late season (Nangare *et al.*, 2016; Mahmoud and Fayad, 2022; Mukherjee *et al.*, 2023). To cope with moisture deficit of this season, irrigation is needed to meet the deficit requirement that cannot be met by effective rainfall (Du and Kang, 2011; Nangare *et al.*, 2016). This suggests that crop water demand must be met through water supplied by rainfall, irrigation and soil-water storage within the root zone to

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satisfy evapotranspiration requirements and prevent water stress (Allen *et al.*, 1998; DeJonge *et al.*, 2024).

Tomato requires an adequate supply of water for optimum production (Raemackers, 2001; Sivakumar and Srividhya, 2016). Therefore, determining crop water requirements and the response of tomato to soil moisture availability at different growth stages in both seasons cannot be essential for efficient water management and optimum production. This will help in the development of suitable water management practices for optimal tomato production in Umudike areas of Abia State, Southeastern Nigeria. The information generated from this study will also provide a basis for planning irrigation schedules and improving the efficient use of available water during early and late season tomato production. The objectives of the study were to determine the crop water requirements and the irrigation need of tomato for early and late season production cycles.

Materials and Methods

The study was conducted at the Michael Okpara University of Agriculture, Umudike, which lies between latitude 05° 29'N and longitude 07° 33'E (Chukwu, 1999) in the humid forest zone of Nigeria and has an altitude of 122 m above sea level. The area has an annual rainfall range of 1900 mm to 2200 mm which is bimodally distributed and peaks in July and September (Iren and Osodeke, 2006). The soil of Umudike is sandy clay loam

(coarse textured) and classified as an Ultisol (Njoku *et al.*, 2001).

Crop water requirement

Crop water requirement is the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climatic region, when adequate soil water is maintained by rainfall and / or irrigation so that plant growth and yield are not limited (Hess, 2005). The crop water requirement of early and late season tomato in Umudike areas of Abia State was estimated with 2009 to 2019 meteorological data collected from the meteorological station of the National Root Crop Research Institute, Umudike, typical of the study area (Table 1). The meteorological data contains monthly rainfall, relative humidity (maximum and minimum), mean temperature, sunshine and wind speed over an 11-year period. The data was analyzed to obtain the reference crop evapotranspiration (ET_o), crop coefficient (K_c), crop evapotranspiration (ET_{crop}), and irrigation water requirement (IR).

A total growth duration of 135 days (Phene, 1989) for each cropping period was disaggregated into 30, 40, 40 and 25 days, representing the initial, crop development, mid-season and harvest stages respectively (Adelama and Simons, 1980; Quinn, 2000) for this study. The crop was assumed to have been sown within the recommended periods for the early and late season cultivation of tomato in the tropics (Thompson, 1996). The early season tomato was assumed to

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have been planted on the 1st of March and harvested on the 14th of July, while the late season cropping was assumed to have been planted on the 1st of August and harvested on the 14th of December. The estimation of crop evapotranspiration involved three stages; Reference or potential evapotranspiration (ET_o), crop coefficient (K_c) and crop evapotranspiration (ET_{crop}).

Estimation of reference evapotranspiration

Reference crop evapotranspiration (ET_o) is defined as the rate of evaporation of an extended surface of 8 to 15cm tall green grass cover actively growing completely shading the ground and not short of water (Doorenbos *et al.*, 1986). It therefore indicates the atmospheric evaporative demand and its potential effect on crop water use. Thus reference crop evapotranspiration was calculated based on Penman's equation given as:

$$ET_o = C [W + R_n + (1 - W) \times f(u) \times (e_a - e_d)] \quad (1)$$

Where;

$e_a - e_d$ = vapor pressure deficit (the difference between saturation vapor pressure (e_a) at the mean temperature of that location and actual vapor pressure (e_d).

$$e_d = e_a \times RH / 100; \quad (2)$$

e_a = saturation vapour pressure at the mean air temperature of the location; and

RH = relative humidity (%).

$$f(u) \text{ (wind function)} = 0.27 (1 + [U/100]), \quad (3)$$

U = wind speed in km/day measured at 2m height.

$$R_n \text{ (total net radiation in mm/day)} = 0.75 R_s - R_{nl} \quad (4)$$

Where R_s is incoming short wave radiation in mm/day.

$$R_s \text{ can be obtained as } (0.25 + 0.5n/N) R_a. \quad (5)$$

R_a is extra-terrestrial radiation in mm/day, n = mean actual sunshine duration in hr/day and N = maximum possible sunshine duration in hr/day; R_{nl} is a long wave radiation in mm/day and is a one normal spacefunction of temperature (F_t), a function of actual vapor pressure ($F(e_d)$) and sunshine duration $F(n/N)$

or

$$R_{nl} = (F_t) \times (F(e_d)) \times F(n/N). \quad (6)$$

W = temperature and altitude dependent wilting factor.

C = adjustment factor for the ratio of wind speed of wind speed in the day over wind speed at night for RH maximum and R_s .

Estimation of crop coefficient (K_c)

The crop coefficient (K_c) value varies with crop, development stage of the crop, and to some extent with wind speed and humidity. For most crops, the K_c value increases from a low value at time of crop

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emergence to a maximum value during the period when the crop reaches full development, and declines as crop matures (Doorenbos *et al.*, 1986).

Crop coefficients (Kc) of 0.45, 0.75, 1.05 and 0.8 (Doorenbos *et al.*, 1986), were used for the initial, crop development, mid-season and late season growth stages of tomato respectively.

The Kc value at each of the growth stages was converted to monthly Kc value as follows;

$$\text{Kc/Month} = \frac{\text{Kc growth stage} \times \text{N}}{30} \quad (7)$$

Where N = number of days growth stage lasted.

Crop evapotranspiration (ET_{crop})

Crop evapotranspiration (ET_{crop}) refers to conditions when water is adequate for unrestricted growth and development (Allen *et al.*, 1998), *i.e.*, when soil water is not limited. It is also referred to as water requirements in mm/day or mm/period. Crop evapotranspiration (ET_m or ET_{crop}) was determined as:

$$\text{ET crop} = \text{ET}_o \times \text{Kc} \quad (8)$$

Crop evapotranspiration (ET_{crop}/month) was obtained as the product of the monthly mean ET_o in mm/day and the Kc for the crop over each 30-day period. Seasonal ET crop values were calculated by summing the monthly values.

Irrigation water requirement (IR)

Irrigation water requirement IR was calculated as the difference between ET_{crop} and Effective one normal space Rainfall (ER) (Brouwer and Herbloem, 1986).

Effective Rainfall (ER) was calculated using the formulae;

$$\text{ER} = 0.8R - 25, \text{ if } R > 75\text{mm / month.} \quad (9)$$

Or

$$\text{ER} = 0.6R - 10, \text{ if } R < 75\text{mm / month.} \quad (10)$$

Where

R = monthly rainfall (mm).

When actual evapotranspiration (ET_a) is less than the maximum evapotranspiration (ET_m), there is moisture deficit signifying the need for irrigation.

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Table 1: Meteorological data of Umudike from 2009 to 2019

Months	Total Rainfall (mm)	Relative Humidity (%)			Mean T °C	Sunshine Hours	Wind speed (U)	Mean U (day)	Mean U (night)	Uday/night	ETo mm/day	ETo mm/month
	(mm)	max	min	mean			Km/hr	(m/sec)	(m/sec)	(m/sec)		
Jan.	9.10	58.30	36.70	47.50	27.00	4.80	669.60	3.40	2.00	1.70	3.58	110.98
Feb.	44.50	69.80	30.20	50.00	28.60	4.70	643.20	3.40	2.00	1.70	3.84	111.36
Mar.	86.60	76.75	46.25	61.50	28.70	4.20	736.80	3.40	2.00	1.70	4.00	124.00
Apr.	192.40	80.10	56.90	68.50	28.20	4.60	736.80	3.40	2.00	1.70	3.92	117.60
May	248.30	81.60	72.40	77.00	27.70	5.00	638.40	3.40	2.00	1.70	3.79	113.70
June	325.40	85.00	66.00	75.50	26.70	4.00	669.40	3.40	2.00	1.70	3.42	102.60
July	306.70	86.50	65.50	78.00	26.80	2.60	586.40	3.40	2.00	1.70	3.10	96.10
Aug.	346.70	84.75	74.25	79.50	25.60	2.60	849.60	3.40	2.00	1.70	2.85	88.35
Sept.	322.30	85.20	70.80	78.00	25.80	2.70	688.80	3.40	2.00	1.70	3.15	94.50
Oct.	273.30	83.14	65.86	74.50	26.60	3.70	566.40	3.40	2.00	1.70	3.42	106.02
Nov.	54.80	80.50	57.50	69.00	27.00	4.50	564.00	3.40	2.00	1.70	3.53	105.90
Dec.	4.30	72.50	45.50	59.00	26.80	5.30	626.40	3.40	2.00	1.70	3.42	106.02
Total	2214.40	943.79	687.86	818.00	325.50	48.70	7971.80	40.80	24.00	20.40	40.02	1277.13
Mean	184.53	78.65	57.32	66.17	27.13	4.06	664.32	3.40	2.00	1.70	3.50	106.43

ETo = Reference crop evapotranspiration, Max= maximum, Min = Minimum, T °C = Temperature in degree centigrade, U=wind speed

Table 2: Calculated monthly crop coefficient and maximum evapotranspiration for early and late season tomato

Months	ETo / month (mm)	Kc/month
Early season tomato		
March	124.00	0.45
April	117.60	0.75
May	113.70	0.95
June	102.60	0.97

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July	96.10	0.37
Late season tomato		
August	88.35	0.45
September	94.50	0.75
October	106.02	0.95
November	105.90	0.97
December	106.02	0.37

Table 3: Estimation of Crop evapotranspiration (ET_{crop}), Effective rainfall (ER) and Irrigation requirements of Tomato

Months	Crop evapotranspiration (ET _{crop}) (mm)	Effective rainfall (ER) (mm)	ER- ET _{crop}	Irrigation water requirement (IR)
Early season tomato				
March	55.80	44.28	-11.52	11.52
April	88.20	128.92	40.72	0.00
May	108.02	173.64	65.63	0.00
June	99.52	235.32	135.80	0.00
July	35.56	220.36	184.80	0.00
Seasonal values	387.10	802.52	415.43	11.52
Late season tomato				
August	39.76	252.36	212.60	0.00
September	70.88	232.84	161.96	0.00
October	100.72	193.64	92.92	0.00
November	102.72	22.88	-79.84	79.84
December	39.23	-7.42	-46.65	46.65
Seasonal values	353.31	694.32	340.99	126.49

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Results and Discussion

The meteorological data of Umudike from 2009 to 2019 is presented in Table 1. The table shows that rainfall amounts (346.70mm), mean relative humidity (79.50%) and wind speed (849.60 km/hr) were highest in the month of August while mean temperature (25.60 °C) was lowest in the same month. The month of December recorded the lowest rainfall amount with 4.30mm only.

The daily reference crop evapotranspiration ETo varied from 2.85 to 4.00 mm/day with a mean of 3.50 mm/day while the monthly ETo varied from 88.35 to 124.00 mm/month with a mean of 106.43 mm/month. Reference crop evaporation (ETo) values were generally higher during the drier months of January to April, with the highest value recorded in March (124.00 mm), but lower in the wetter months of July and August. with the lowest value observed in August (88.35 mm). Similar results in which ETo values were higher in drier months of January to April but lower in the wetter months of July and August have been reported by many researchers (Chukwu, 1999; Chukwu and Igbokwe, 2001; Iren and Osodeke, 2006). Higher rainfall is expected to confer higher relative humidity on the environment, this will automatically lower the air temperature (Singh and Dhillon, 2004) resulting in the lower ETo of the wetter months.

The calculated monthly crop coefficient (Kc /month) values for the early season

and late season tomato from the initial, crop development, mid and late season stages are presented in Table 2. The Kc values were the same for both seasons. However, the Kc values increased from low values at time of crop emergence to maximum values when the crop reaches full development and thereafter declines when the crop matures. This result corroborated the report of Iren and Osodeke (2006), Ubi and Osodeke (2009), and Akinwutimi (2015) who all had similar observation of Kc values according to the growth stages. Highest Kc values were recorded in the months of May and June (0.95 and 0.97) for early season and October and November (0.95 and 0.97) for the late season tomato. These months coincided with the productive and maturity stages of growth in tomato and are reportedly the most active growth stages (Doorenbos *et al.*, 1986; Phene, 1989; Thompson, 1996; Quinn, 2000).

Table 3. shows the crop evapotranspiration (ET_{crop}), effective rainfall (ER), and irrigation water requirement of early and late season tomato production in Umudike area. Crop evapotranspiration for early season was 387.10 mm while that of the late season was 353.31 mm. The calculated seasonal effective rainfall was 802.52 and 694.32 mm for early- and late-season tomato, respectively. In the early season cultivation, the calculated effective rainfall was higher than the water requirement of tomato in the months of

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April to July, indicating that there is no need for irrigation in these months. However, in the month of March, Table 3 showed a lower ER than ET_{crop}, suggesting a need for supplementary irrigation in this month. The irrigation water requirement in the month of March was 11.52mm. Adebola *et al.* (2017) reported similar results where supplementary irrigation for tomato production was needed in the month of March. With regards to the late season production phase, effective rainfall was lower than the water requirement of the crop in the months of November and December. Thus, the need for supplementary irrigation in these months. The irrigation water requirements for tomato in the months of November and December were 79.84 and 46.65 respectively.

Conclusion

Results showed that supplementary irrigation will be needed during the initial growth stage in the early season cultivation phase of tomato planted in 1 March in Umudike area. In the late season phase, supplementary irrigation will be necessary during the productive and maturity (most active) growth stages.

The findings also showed that the seasonal crop water requirement of tomato was higher during the early season than during the late season in the study area.

It is therefore recommended that the early season planting be done at a time

when crop water requirements of the initial growth stage and reproductive and maturity stages of tomato in Umudike can be met by effective rainfall for economic reasons. However, provision should be made for supplementary irrigation in the months of November and December.

References

- Adelama, B. O., and Simons, J. A. (1980). An evaluation of some tomato varieties for yield and disease tolerance in southwestern Nigeria. *Nigerian Journal of Agricultural Science*, 2, 29–34.
- Adebola, A. A., Badajo, A. A., Opafola, O. T., Bada, B. S., and Nkleshita, F. C. (2017). Estimation of water requirement of selected field crops in the southwest and southeast Nigeria. *Journal of Agriculture and Sustainability*, 10(2), 172–186.
- Akinwutimi, A. L. (2015). Estimation of water requirements of early and late season maize in Umudike, southeastern Nigeria, using Penman's equation. *Journal of Soil Science and Environmental Management*, 6(2), 24–28.
- Allen, R. G., Pereira, L. S., Raes, D., and Smith, M. (1998). *Crop evapotranspiration: Guidelines for computing crop water requirements* (FAO Irrigation and Drainage Paper No. 56). Food and Agriculture Organization of the United Nations.
- Brouwer, G., and Herbloem, M. (1986). *Irrigation water needs* (Irrigation Water Management Training Manual No. 3). Food and Agriculture Organization of the United Nations.
- Broner, I., and Schneekloth, J. (2003). *Seasonal water needs and opportunities for limited irrigation for Colorado crops*. Colorado State University Extension.

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"Crop Water Requirements of Early and Late-Season Tomato (Lycopersicon esculentum) in Umudike Area of Abia State, Southeastern Nigeria

- Cage. (2005). Tomato History. Available at www.tomato-cages.com/tomato-history.html.
- Chukwu, G. O. (1999). Estimation of water requirements of soybean and groundnut in southeastern Nigeria. *Nigerian Journal of Sustainable Agriculture and Environment*, 1, 150-154.
- Chukwu, G. O., and Igbokwe, M. C. (2001). Modeled water requirement of potato (*Solanum tuberosum* L.) on Jos Plateau, Nigeria. *Nigerian Agricultural Journal*, 32, 12-18.
- DeJonge, K. C., Thorp, K. R., Brekel, J., Pokoski, T., and Trout, T. J. (2024). Customizing pyfao56 for evapotranspiration estimation and irrigation scheduling at the Limited Irrigation Research Farm (LIRF), Greeley, Colorado. *Agricultural Water Management*, 299, 108891. <https://doi.org/10.1016/j.agwat.2024.108891>
- Doorenbos, J., Kassam, A. H., Bentvelsen, C. L. M., Branscheid, V., Plusjé, J. M. G. A., Smith, M., Uittenbogaard, G. O., and van der Wal, H. K. (1986). *Yield response to water* (FAO Irrigation and Drainage Paper No. 33). Food and Agriculture Organization of the United Nations.
- Du, T. S., and Kang, S. Z. (2011). Efficient water-saving irrigation theory based on the response of water and fruit quality for improving quality of economic crops. *Journal of Hydraulic Engineering*, 42(2), 245-252.
- Encyclopaedia Britannica. (2018). *Tomato*. Encyclopaedia Britannica. <https://www.britannica.com/plant/tomato>
- Hess, T. (2005). *Crop water requirements*. WCA infoNET. <http://silsoe.cranfield.ac.uk/iwe/dailyet.htm>
- Hou, X., Zhang, W., Du, T., Kang, S., and Davies, W. J. (2020). Responses of water accumulation and solute metabolism in tomato fruit to water scarcity and implications for main fruit quality variables. *Journal of Experimental Botany*, 71(4), 1249-1264. doi:10.1093/jxb/erz526
- Iren, O. B., and Osodeke, V. E. (2006). Estimation of water requirements of early and late season pepper (*Capsicum annum*) in Umudike, southeastern Nigeria. *Global Journal of Agricultural Sciences*, 5(2), 95-99.
- Kimura, S. and Sinha, N. (2008). Tomato (*Solanum lycopersicum*): A Model Fruit-Bearing Crop. Available at <http://cshprotocols.cshlp.org/content/2008/11/pdb.emo105.short>.
- Machado, J., Fernandes, A. P. G., Fernandes, T. R., Heuvelink, E., Vasconcelos, M. W., and Carvalho, S. M. P. (2022). Drought and nitrogen stress effects and tolerance mechanisms in tomato: A review. In V. Kumar, A. K. Srivastava, & P. Suprasanna (Eds.), *Plant nutrition and food security in the era of climate change* (pp. 315-359). Elsevier. <https://doi.org/10.1016/B978-0-12-822916-3.00014-7>
- Mahmoud, M. A. A., and Fayad, A. M. (2022). The effect of deficit irrigation, partial root drying and mulching on tomato yield, and water and energy saving. *Irrigation and Drainage*. <https://doi.org/10.1002/ird.2666>
- Merriam-Webster. (n.d.). *Tomato*. In *Merriam-Webster.com dictionary*. Retrieved May 13, 2023. from <https://www.merriam-webster.com/dictionary/tomato>
- Mukherjee, S., Dash, P. K., Das, D., and Das, S. (2023). Growth, yield and water productivity of tomato as influenced by deficit irrigation water management. *Environmental Processes*, 10, Article 10. <https://doi.org/10.1007/s40710-023-00624-z>

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"Crop Water Requirements of Early and Late-Season Tomato (Lycopersicon esculentum) in Umudike Area of Abia State, Southeastern Nigeria

- NAERLS. (2025). *Agricultural performance survey of 2023 wet season in Nigeria*. Federal Ministry of Agriculture and Food Security; National Agricultural Extension and Research Liaison Services. Available at https://naerls.gov.ng/wp-content/uploads/2025/04/Agricultural-Performance-Survey-of-2023-Wet-Season-in-Nigeria.pdf?utm_source=chatgpt.com
- Nangare, D. D., Singh, Y., Kumar, P. S., and Minhas, P. S. (2016). Growth, fruit yield and quality of tomato (*Lycopersicon esculentum* Mill.) as affected by deficit irrigation regulated on phenological basis. *Agricultural Water Management*, 171, 73–79.
- Negash, T. W., Tefera, A. T., Bikila, G. A., Bizuneh, K. T., Awulachew, T. W., and Dinku, A. G. (2024). Determination of evapotranspiration and crop coefficient for tomato by using non-weighing lysimeter in semiarid region. *Air, Soil and Water Research*, 17. <https://doi.org/10.1177/11786221241291313>
- Njoku, J. C., Okpara, D. A., and Asiegbu, J. E. (2001). Growth and yield responses of sweet potato to organic nitrogen and potassium in a tropical Ultisol. *Nigerian Agricultural Journal*, 32, 30–41.
- Online Etymology Dictionary (No date). Available at www.etymonline.com/search?q=tomato.
- Ouda, S., Tahany, N., and Khalad, A. E. (2015). Water requirement for wheat and maize under climate change in North Nile Delta. *Spanish Journal of Agricultural Research*, 13(1).
- Petre, A. (2018). *Lycopene: Health benefits and top food sources*. Available at <https://www.healthline.com/nutrition/lycopene>.
- Phene, C. J. (1989). Water management of tomato in the tropics. In *Tomato and pepper production in the tropics* (pp. 308–322). Asian Vegetable Research and Development Center.
- Quinn. (2000). *Factors affecting the production of tomato for the processing industry during different seasons in the northern states of Nigeria* (Master's thesis, Ahmadu Bello University).
- Raemackers, R. H. (2001). Crop production is tropical Africa directorate general for international cooperation DAK Belgium 1540p.
- Ridge, I. (1991). *Physiology*. Hodder and Stoughton.
- Singh, J., and Dhillon, S. (2004). *Agricultural geography* (3rd ed.). Tata McGraw-Hill Publishing Company.
- Sivakumar, R., and Srividhya, S. (2016). Impact of drought on flowering, yield and quality parameters in diverse genotypes of tomato (*Solanum lycopersicum* L.). *Advances in Horticultural Science*, 30(1), 3–11.
- Thompson, A. K. (1996). *Post-harvest technology of fruit and vegetables*. Blackwell Science.
- Ubi, W., and Osodeke, V. E. (2009). Estimation of water requirement of early and late season tomato (*Lycopersicon esculentum* Mill.) in Calabar, southeastern Nigeria. *Global Journal of Agricultural Sciences*, 8(1), 115–118.

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