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Estimation of consumptive water use for Watermelon in Auchi, Nigeria

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Abstract. *This study aims to estimate the consumptive water use (CWU) for watermelon production in Auchi, Edo State, Nigeria. The research was conducted over a period of eight months (March–October) and used data collected from the watermelon field at the Demonstration and Research Farm of Auchi Polytechnic, Auchi. The result of the experiment revealed the estimation of CWU and watermelon water requirements (CWR) of 175.9 mm and 195 mm for the 62-day (August to October) vegetation stage of watermelon, with a CROPWAT projected harvest on November 20, 2022. The finding also revealed that the mean annual consumptive water use for watermelon production was 520.7 mm. The mean seasonal water use for watermelon production was higher in the dry season (March to June, 488.7mm) than in the wet season (July to October, 390.6mm). However, based on this harvest date, the model predicted irrigation requirements of 23.1 mm and 59.4 mm in October and November. Additionally, this study offers proof that management strategies for water use efficiency and irrigation scheduling can dramatically lower water losses and boost efficiency. The findings of this study can be applied to the Auchi region's water management decision-making procedures as well as to help watermelon farmers reduce their water consumption levels while maintaining output.*

Keywords: *Crop water use, Watermelon production, CROPWAT, Watermelon, Auchi.*

1. Introduction

Watermelon, (Citrullus lanatus) is cultivated throughout the tropics and subtropics and has a worldwide distribution [1]. Its world production had expanded from 2.917 to 3.7 million ha in the period from 1999 to 2003 [2]. In Nigeria, though there are no official figures recorded for its production, the crop has a wide distribution as a garden crop, while as a commercial vegetable production; its cultivation is confined to the drier savanna region of Nigeria [3]. It is a crop with high economic value and is grown and traded for export. Most as well drained-soils, clayey or sandy, can be used to produce the crop. Its fruit has a moisture content of about 92% and sometimes serves as a source of water for human consumption [4]. Despite high water content, its seasonal water requirement is between 400 and 600 mm under tropical climates [4]. It is of much importance to assess the effects of water consumptive use, water stress and mulch on production, yield and quality of certain crops both at the experimental level as well as to farm level and integrate new knowledge with the traditional farmers' knowledge through participating, research and extension [4]. Accurate knowledge of the impact of reduced water supply on yield and quality is required to define appropriate strategies to optimize crop production and economic benefits, while maintaining environmental requirements. Many studies were reported on the irrigation of watermelon [5]. The available information shows that fruit yield response to water is usually highest when watermelon is adequately irrigated.

Scarce water resources and growing competition for water reduce its availability for irrigated agriculture. Achieving high water use efficiency is a primary challenge in irrigated agriculture, irrigation practices and techniques aimed at maximizing crop production with minimum water utilization are fast evolving, and there is a need for evaluation of these practices before adoption, which include the employment of techniques and practices that deliver a more accurate water supply to crops [4]. Studies are needed to increase the efficient use of the available water. A regulated irrigation system with mulching is one among many practices that are fast gaining ground, and it appears a very promising option at achieving the goal of more crops per unit volume of water, if properly adopted. The development of new irrigation scheduling and identifying the sensitive crop growth stage to water consumptive use is one way to enhance crop productivity with less water [7]. This study is designed to estimate water melon crop water use using CROPWAT software and establish the relationship between crop water use and growth parameters.

2. Materials and methods

2.1. Study area

A field experiment was carried out at the mini Teaching and Demonstration Farm located in between the E-Learning Centre and Alumni Drawing Studio at Campus-One, Auchi Polytechnic at latitude 7.04°N and longitude 6.27°E. Auchi is classified as a savanna with an average mean temperature and precipitation of 28.5oC and 1201.3 mm.

February is the driest period with an average air temperature of 29.5°C, whereas the Months of July and September indicate a low mean temperature of 26.6°C and 27.8°C respectively. The watermelon was planted on sandy loamy soil on 3rd August 2022 at a planting depth of 2.5 cm and 75% of the plant germinated after eight days of planting over a plot area of 5m * 5m. A spacing of 15 cm x 15 cm was adopted with a plant density of 8000 per acre on the average. Plate 1 a – e shows some of the field activities.

2.2. Estimation of Consumptive Water Use of Water Melon

Phocaides [7] mentioned that the consumptive water use of crop is the quantity of water used by the vegetative growth of a given area in transpiration or building of plant tissue and that evaporated from the soil or intercepted precipitation on the area in any specific time. It is expressed in water depth per unit of time (consumptive use or evapotranspiration). This study applied CROPWAT AND AQUACROP to estimate consumptive water use(CWU) and some other parameters. Hence, the inbuilt mechanism of the selected process-based models estimates the (CWU) as shown in equation 1-4:

$$CWU = ET_0 * K_c * K_s \quad (1)$$

At initial growth phase

$$CWU = ET_{0i} * K_{ci} * K_{si} \quad (2)$$

At developmental growth phase

$$CWU = ET_{0d} * K_{cd} * K_{sd} \quad (3)$$

At maturity growth phase

$$CWU = ET_{0m} * K_{cm} * K_{sm} \quad (4)$$

where:

ETo is reference evapotranspiration (mm/day)
Kc is the crop coefficient
Ks is the crop stress factor
i, d and m are the initial, developmental and maturity of watermelon growth

Figure 1. Map of Edo State showing the study area
Source: https://www.owogram.com/edo-state/

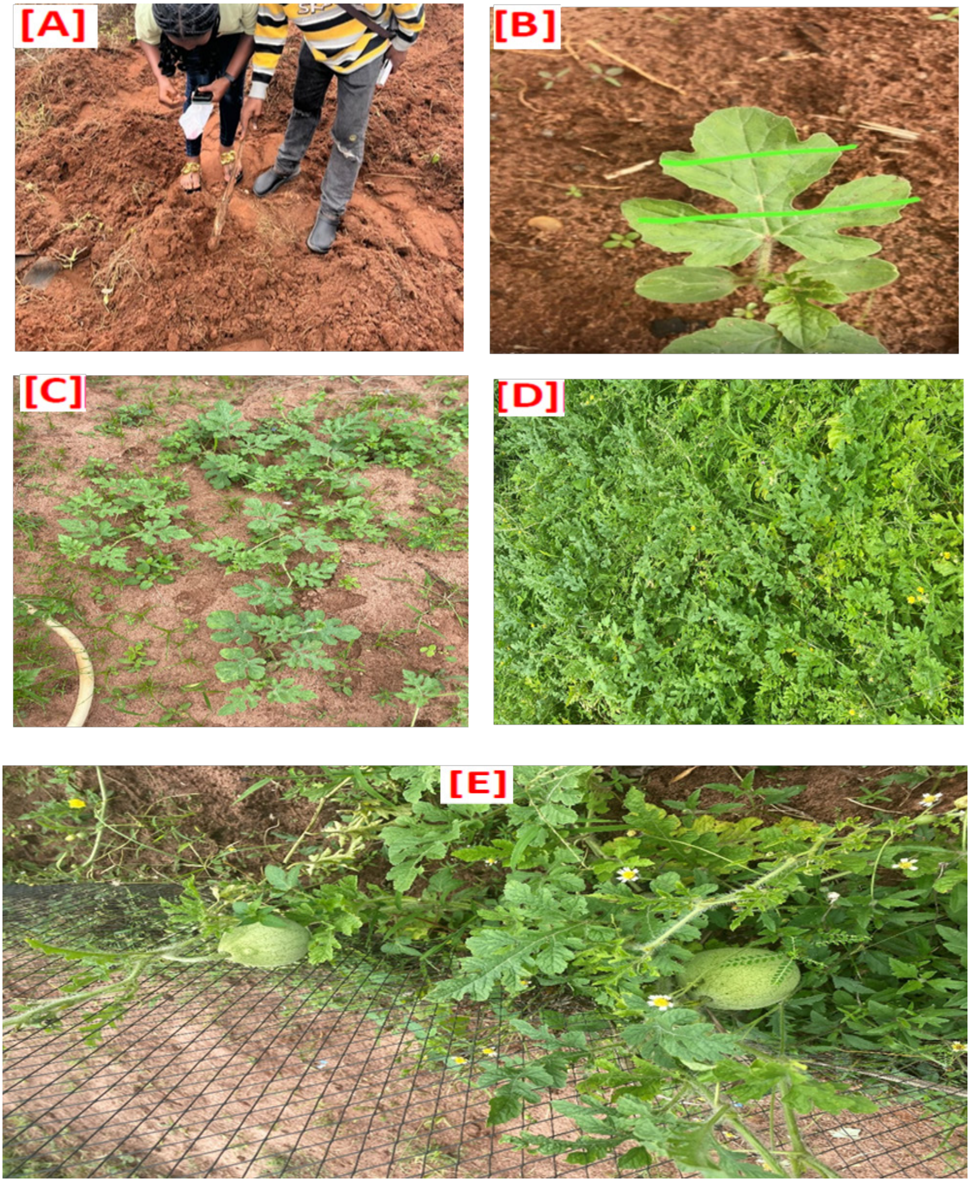

Plate 1. Field cultivation and planting of water melon (a), growth of watermelon at fourteen days (14) after planting (b) growth of watermelon at forty-five (45) days after planting (c) growth of watermelon at seventy days after planting (d and e).

2.3. CROPWAT Model

FAO's CROPWAT 8.0 model is a computer program used in estimating and modelling crop water requirements, irrigation requirements and consumptive water use of different crops based on soil- climate-crop data [8]. The program allows the development of irrigation schedule for different management conditions and the calculation of scheme water supply for different areas under different crops. The CROPWAT model was selected based on its ability to simulate the impact of various climate change scenarios on the consumptive use of water. The consumptive water use of watermelon was estimated using the inbuilt CROPWAT mechanism. Table 1 shows the input and output parameters of the CROPWAT model for simulating the consumptive water use of watermelon.

Table 1. The input and output of the CROPWAT model

Dataset	Input Parameters	Output Parameters
Climatic data	Rainfall	Solar radiation
	Minimum temperature	Reference evapotranspiration
	Maximum temperature	Crop water requirement
Crop datasets	Sowing data	Actual crop evapotranspiration
	Crop description (phenology)	
	Crop coefficient (K_c)	
Soil	Soil texture	Soil moisture deficit
	Available moisture	Estimated yield reduction
	Infiltration rate	

Source: Nyatuame et al., 2013

2.4. Measurement of Phenological Parameters of Watermelon

The control of weeds on the plot where watermelon was planted was achieved through the combination of manual and chemical operations. The phenological growth was evaluated by measuring the plant height from the soil surface to the emergence point of the youngest leaf, counting the number of living leaves, measuring the length and width of the youngest fully developed leaf.

2.5. Data Analysis

The relationship of plant phenological parameters such as plant height, leaf breadth, and number of leaf emergences was evaluated using statistical metrics such as mean, median, variance, regression coefficient, and T-test of SPSS software.

3. Results and Discussion

3.1. Calibration meteorological variables

The climatic variables such as rainfall, minimum temperature (Tmin), relative humidity (RH), wind speed (WS), maximum temperature (Tmax), and evaporation rate (EVR) were measured during the 76-day field experimentation of watermelon (Citrullus vulgaris, cv. Crimson Sweet). Mean temperature (Tmean oc) and effective rainfall (EffRain) were calculated using the empirical relationship between Tmin, Tmax, and CLIM module in CROPWAT software, as shown in the CROPWAT interface window. The results in Figure 2 show the lowest and highest relative humidity of 63% and 90%, respectively, were recorded on 08/07/2022 and 03/09/2022. However, the RH fluctuated throughout the period of experimentation.

The coefficient of determination R^2 = 0.016 demonstrated no link between the relative humidity and the watermelon growing duration (days) (Figure 2). Therefore, it could be determined that higher RH values corresponded to the period of high rainfall intensity and duration. This supports the finding of [2], which revealed that

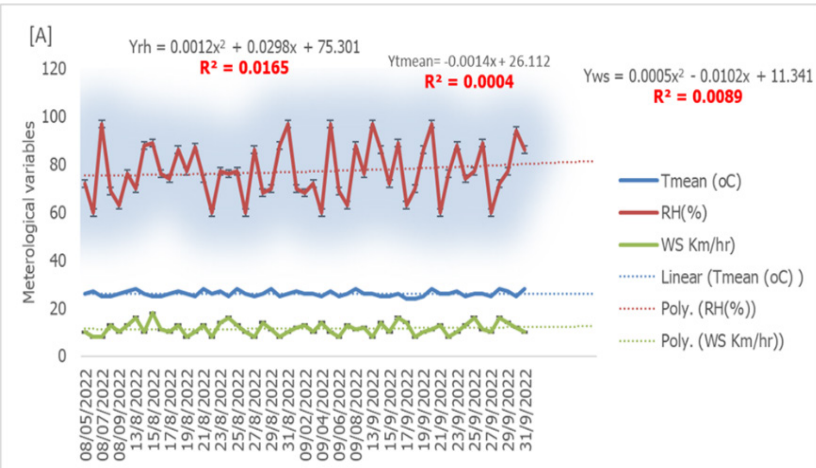

Figure 2. Relationship of meteorological variables

rainfall is anticipated when relative humidity and temperature are high, and minimal precipitation is anticipated when both of these factors are low. Figure 3 shows the rate of evaporation during the crop's growing cycle. The evaporation rate (EVR) changed from 0.1 cm to 0.3 cm.

The highest EVR of 3 cm/day was obtained on 08/06/2022 and 20/08/2022, respectively. The driver of the evaporation rate is not limited to temperature but includes sunshine hours, wind speed, and relative humidity. Poos and Varju (2020) revealed that evaporation is dependent on the properties of the materials and the conditions of the environment, such as air temperature, air humidity, air speed, and turbulence. Figure 4 presents the simulated effective rainfall at the study area (campus-one-Auchi Polytechnic, Auchi).

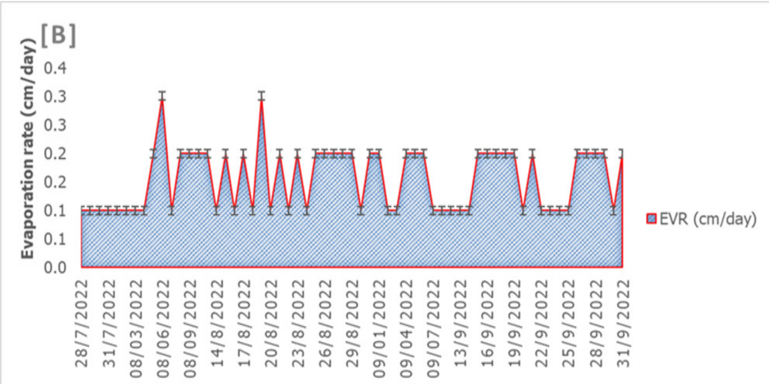

Figure 3. Evaporation rate

Monthly rain - untitled

Station: Campus 1-Auchi Poly   Eff. rain method: USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	2.5	2.5
February	15.2	14.8
March	43.2	40.2
April	83.8	72.6
May	124.5	99.7
June	162.5	120.3
July	185.4	130.4
August	200.7	136.3
September	213.4	140.5
October	137.2	107.1
November	30.5	29.0
December	5.1	5.1
Total	**1204.0**	**898.4**

Figure 4. Simulation of effective rainfall

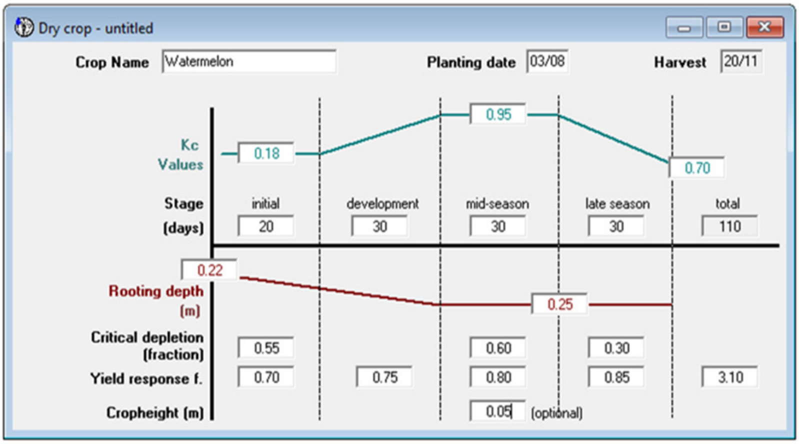

Figure 5. Simulation of watermelon growing cycle length

3.2. Estimation of Consumptive Water Use

A combination of reference evapotranspiration (ETo), crop coefficient (Kc), and crop stress factor is used to determine consumptive water usage or actual crop evapotranspiration (Ks) as described in equations 1-4. The CROPWAT interface is depicted in Figures 4 and 5, which is used to calculate the watermelon growing cycle, crop water requirements (CWR), effective rainfall (EffRain), and irrigation needs (Irr. Req). Table 2 presents the simulated outputs in the month of August which fell on the initial crop growth stage; CWR and CWU values of 28.8 mm and 23.0 mm were estimated, whereas EffRain and ETo of 128.5 and 103.3 were computed under a rainfed system (no irrigation applied) (Figure 4 and 5). However, the marginal difference of 5.3 between CWR and CWU could be explained by potential water stress that could develop during the water melon's early growth stage. Consequently, the crop was at a developmental stage by the end of September. In this period, the CWR and CWU climbed to 101.4 mm and 91.3 mm, respectively, but during mid-season (flowering and fruit-filling stages as shown in plate 1e), the CWU and CWR significantly reduced to 61.6 mm and 64.8 mm, respectively.

Table 2. Total number of consumptive water use, crop water requirements, irrigation applied, effective rainfall and seasonal evapotranspiration

Month	CWR (mm)	CWU (mm)	IA (mm)	EffRain (mm)	ETo	Ks
August	28.8	23.0	0.0	128.5	103.3	0.800
September	101.4	91.3	0.0	129.7	104.7	0.900
October	64.8	61.6	0.0	75.6	71.8	0.950
Total	**195.0**	**175.9**	**0.0**	**333.8**	**279.8**	

Crop Water Requirements

ETo station: Campus 1: Auchi Poly — Crop: Watermelon

Rain station: Campus 1-Auchi Poly — Planting date: 03/08

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Aug	1	Init	0.18	0.65	5.2	35.8	0.0
Aug	2	Init	0.18	0.66	6.6	45.5	0.0
Aug	3	Deve	0.28	1.03	11.4	45.9	0.0
Sep	1	Deve	0.55	1.96	19.6	47.5	0.0
Sep	2	Deve	0.81	2.82	28.2	48.6	0.0
Sep	3	Mid	0.95	3.35	33.5	44.3	0.0
Oct	1	Mid	0.95	3.38	33.8	40.8	0.0
Oct	2	Mid	0.95	3.41	34.1	37.8	0.0
Oct	3	Late	0.91	3.28	36.1	28.4	7.7
Nov	1	Late	0.82	2.98	29.8	16.6	13.2
Nov	2	Late	0.74	2.69	26.9	7.1	19.8
					265.4	**398.5**	**40.7**

Figure 6. Simulation of crop water requirements, effective rainfall and irrigation requirement

Throughout the 76-day growing cycle of the watermelon, the simulation result showed a total consumptive water consumption (CWU) of 175.9 mm and 195.0 mm for CWR. According to the simulationresults in Figure 4, the crop will be ready for harvest on November 20, 2022. However, it is anticipated that before it will be fully mature for harvest, the CWR and CWU of 130 mm and 125 mm, respectively, would be needed. It follows that effective rainfall in October and November will need to be supplemented by supplemental irrigation of 23.1 mm and 59.4 mm, as shown by the simulation in Figure 5 and Figure 6. Because of this, if precision irrigation is not used in October and November, crop water stress may grow and the watermelon CWU may subsequently decrease. The results are consistent with a study by [9], which revealed that 343 mm of crop water is needed for watermelon. The results are consistent with those of [10], who found that irrigation relieved water stress and decreased appropriately. Water stress then gradually increased to a maximum value right before the next irrigation application when the soil water in the crop root was depleted.

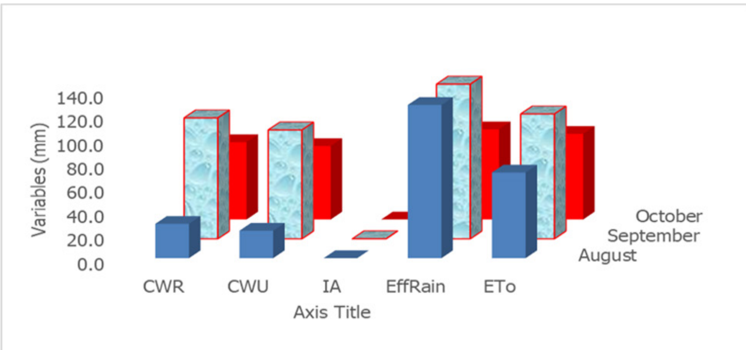

Figure 7. Calibration of consumptive water use (CWU)

3.3. Watermelon Phenological Development

The results are shown in Figure 7 and show how the length of the growing cycle affects the length and width of watermelon leaves. The LL and LW of 3.8 cm and 4.2 cm were measured at 16 DAP (Figure 8). However, as shown in Figure 8, the leaf's length and width rose to 11.2 cm and 6.8 cm at 27 DAP and then abruptly increased to 15.8 cm and 12.2 cm at 61 DAP. The coefficient of determination R^2 values of 0.857 and 0.840 were estimated between the LL and DAP, and LW against DAP. Hence, it showed that the effect of moisture stress was less from the initial to development growth stages. The results were consistent with those of [11], who found that phenological reactions to water shortages can occasionally interfere with reproduction. Water deficiencies may potentially hasten senescence, according to [12], despite reports that they promote progressive leaf fall and obstruct effective N transfer [13].

Table 3. Statistical metrics for experimental treatments

Phenological growth	N	Mean	Std. dev.	Std.Error	P-value
LL	9	9.10	5.26	1.75	0.0004
LW	9	7.53	4.77	1.59	

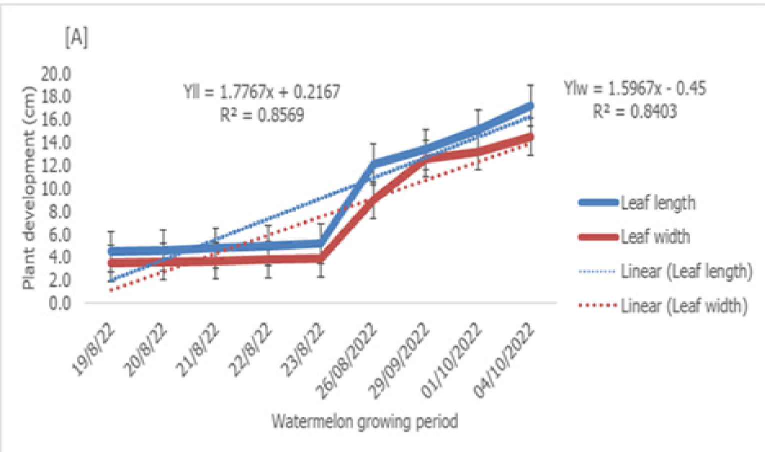

Figure 8. Watermelon phenological development

Figure 9 presents the exhibited relationship among the phenological variables such as plant height (PH), emergency of a new leaf (PLE), and number of plant leaves (PNL) with respect to the growing cycle length. 4.2 cm, 0 and 4 numbers of leaves were recorded at the 16 DAP (19/08/2022). On August 21, 2022 (19 DAP), one (1) leaf emerged (recorded), corresponding to PH and PNL values of 4.7 cm and 6 leaves (Figure 10 and Figure 11). Hence, the greatest PH of 4.8 cm was measured at 21 DAP and sustained throughout the water melon growth cycle. The watermelon plant height (PH) analysis of variance result showed a high level of significance at $P < 0.005$ as shown in Table 3.

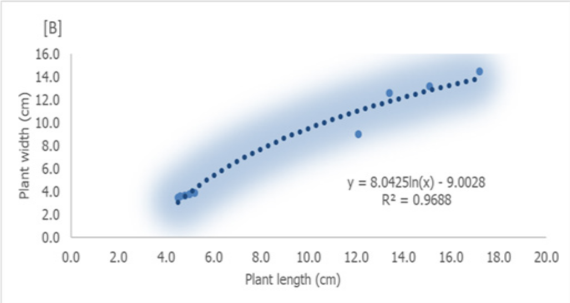

Figure 9. Changes in plant leaf width and plant leaf length

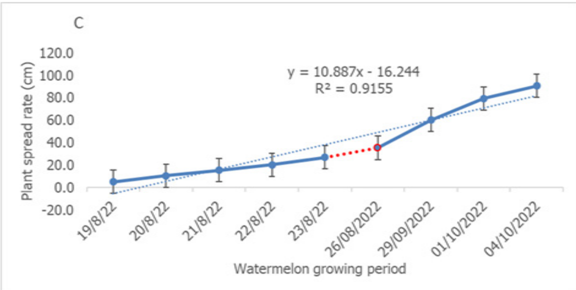

Figure 10. Watermelon spread rate

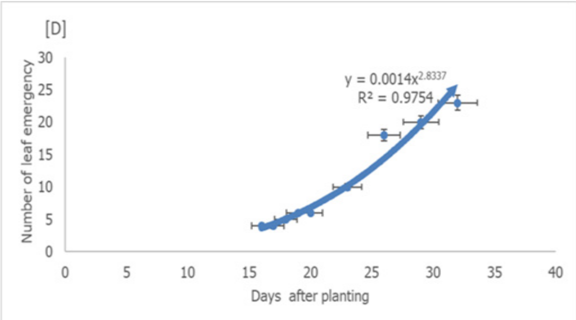

Figure 11. Leaf emergency rate

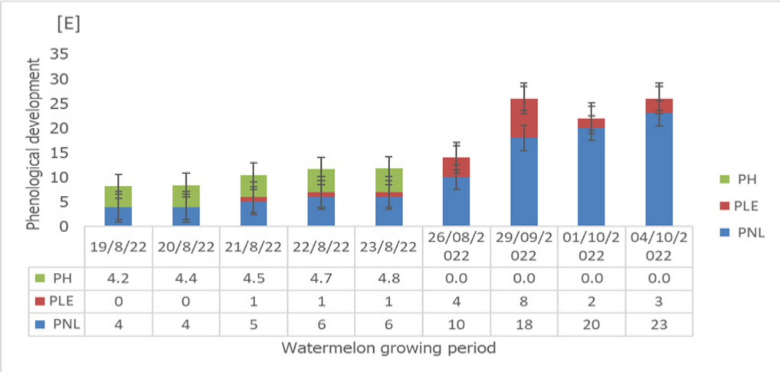

Figure 12. Total watermelon phenological development

4. Conclusions

Using a process-based model (CROPWAT), the study examines the consumptive water use of watermelon using CROPWAT Software version 8.15. The software was also used to calculate crop water requirements (CWR), effective rainfall (EffRain), and irrigation requirements (Irr.req.). The entire simulation revealed seasonal consumptive water use (CWU), CWR, EffRain, and ETo of 175.9 mm, 195.0 mm, 333.8 mm, and 279.8 mm for the growing crop period of 62 days (August, September, and October). However, a total growing period of 110 days was projected from the CROPWAT model, with the harvest day on November 20, 2022. Therefore, a total supplemental water application of 23.1 mm and 59.4 mm will be required to meet the estimated CWR and CWU of 340.2 mm and 310.1 mm by the end of November 2022. Additionally, there was a strong correlation between the growing cycle length and the established association between phenological data. Since the crop requires between 300 mm and 400 mm of crop water requirements during a short maturity period of about 110 days, it is advised that extra water be included in the design whenever farmers intend to go for watermelon production.

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References

1. S.P. Harry, Origin and Emergence of the Sweet Dessert Watermelon, Citrullus lanatus, *Journal of Annals and Botany*, 116(2), 2015, pp.133–148.
2. FAOSTAT, FAO Statistical Database. Agriculture 4th March 2004. http://apps.fao.org/faostat/default.jsp (downloaded on 12.09.2012).
3. G. Anons, *Nasarawa State Agricultural Development Programme, Annual Crop Area and yield Survey (CAYS), Lafia, Nasarawa State*, Unpublished survey report, 2006.
4. FAO, 2001 *Statistics of horticultural crops*. faostat.fao.org/site/365/default.aspx (downloaded on 5.01.2013).
5. M.A. Husaini, A.A. Ramalan, M.K. Othman, Soil Moisture Regime Effect on the Performance of Watermelon under Varying Nitrogen levels in a Semi-Arid region, *Journal of Applied Horticulture*, 6 (2), 2004, pp. 72–75.
6. S. Bekele, K. Tilahun, Regulated deficit irrigation scheduling of onion in semi-arid region of Ethiopia, *Agric Water Manage*, 89, 2007, pp. 148-152.
7. A. Phocaides *Technical Handbook on Pressurized Irrigation Techniques*. FAO, Rome, 2000.
8. A. Kadayifci, G.I. Tuylu, Y. Ucar, B. Carmak, Effects of Mulch and Irrigation Water Amounts on Lettuce's Yield, Evaporation, Transpiration and Soil Evaporation in Isparta Location, Turkey. *Journal of biological sciences*, 4(6), 2004, pp. 751-755.
9. P.Hembram, C. Suibudhi, R. Subudhi, Water and Irrigation Requirement for Watermelon (Citrullus lanatus) Crop of North Central Plateau Zone of Odisha, *South Asian Research Journal of Biology and Applied Biosciences*, 2(4), 2020, pp. 1-6.
10. A.H. Orta, Y. Erdem, T. Erdem, Crop water stress index for watermelon, *Scientia Horticulturae*, 98, 2002, pp. 121–130.
11. T. Poos, E. Varju, Mass Transfer Coefficient for Water Evaporation by Theoretical and Empirical Correlations, *International Journal of Heat and Mass Transfer*, 153, 2020, pp.3-8.
12. J. Aronson, J. Kigel, A. Shmida, J. Klein, Adaptive phenology of desert and mediterranean populations of annual plants grown with and without water-stress, *Oecologia*, 89(7). 1992, pp.17-26.
13. J.M. Delarco, A. Escudero, M.V. Garrido, Effects of site characteristics on nitrogen retranslocation from senescing leaves, *Ecology*, 72(5), 2020, pp. 701-708.

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