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Estimation of Water Requirements and Plant Coefficient (Kc) for Cotton Plants

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ABSTRACT

Cotton is one of the most important industrial plants that can produce products in different climates. This project aimed to assess the water requirements, evapotranspiration, and transpiration of cotton plants using a lysimeter device measuring 1.5×2×2 m^3. The study was conducted at the Agricultural Research Station in Kashmar, Iran, utilizing soil with a silty loam texture. Before planting the type of soil, the important points of the soil moisture indicators, including the moisture in the agricultural capacity (FC) and the wilting point (PWP) were determined. The amount of fertilizer required was determined based on the soil test and the fertilizer recommendation of the Soil and Water Research Institute. The amount of irrigation water was determined in each shift. Irrigation was done when the easily accessible moisture of the soil was drained and the amount of irrigation water was calculated using the formula and was given to a maximum of 10 percent. A water drain should be created. The water given to the lysimeter at each irrigation turn was measured by the water meter and the amount of drain water was also determined after irrigation. Based on the balance equation, plant evapotranspiration (ETc) was calculated. The results showed that the average evaporation and transpiration of cotton plants in the years of implementation of the project (4 years) is equal to 1183 millimeters. This is while this amount has been estimated as 1000.4 mm in the book of estimating the water requirement of plants by Penman-Monteith's formula.

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1. Introduction

Irrigation based on the plant's water needs is very important because excessive irrigation causes energy and cost loss, and insufficient irrigation also causes a decrease in yield and income. One of the most accurate methods of measuring water needs is using the lysimetric method. Plant evapotranspiration is usually calculated using reference plant evapotranspiration and plant coefficient Kc from the formula $ET_{crop}= K_c \times ET_o$ (ETcrop potential plant evaporation and transpiration, K_c crop coefficient and ET_o reference plant evaporation and transpiration). Blaney et al. (1930) defined plant water consumption as the sum of water evaporated from the plant cover and the surface where the plant grows, which was later referred to as evaporation and transpiration. Penman (1948) combined the energy balance and aerodynamic equations and obtained what is now known as the composite equation. In 1969, the work program of the International Irrigation and Drainage Committee was devoted to the water needs of plants. In 1977, the World Food and Agriculture Organization (FAO) introduced four methods of estimating reference plant evaporation and transpiration as an international standard in its publication 24. Several researches have been conducted to determine the need for cotton in the country, some of which are mentioned:

Kresović et al. (2016) in a research on the effect of different irrigation regimes on water consumption efficiency, found that the water consumption efficiency under the treatment of 75% of the water requirement is the highest. Kolahi et al. (2021) in a research on the effect of different levels of irrigation on the yield of the first row of cotton plants, concluded that seed propagation by providing 66% of the water requirement while achieving optimal yield can be more

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stable by inducing tolerance mechanisms to drought stress. Naderi Arefi and Ghorbani Nasrabad (2022) in the final report entitled "Determining the water consumption of cotton in Iran" announced that the average water consumption of cotton in Razavi Khorasan, Fars, Golestan, North Khorasan, Ardabil, Semnan and Alborz provinces is equivalent to 9830, 9945, 5070, 6815, 7543, 10536, 8393 cubic meters per hectare.

Rahimian and Kakhki (2007) stated the average potential evapotranspiration of cotton in the Kabutrabad region of Isfahan was 863.6 mm. They have stated the rate of evaporation and transpiration of this plant in the region of Kashmar is 1000.4 mm. The evapotranspiration potential of cotton by lysimeter method (1993-94) in the Gorgan Agricultural Research Station located in Hashim Abad Gorgan is 778 mm. Marashi and Vaghefi (1975) have stated that according to the experiments of 1956 by the Agricultural Engineering Company, the total amount of water required for one hectare of cotton in Varamin is about 6000 to 8000 cubic meters. In this article, the results of the research on the water requirement of cotton using the drained lysimeter method in the Kashmar region during four crop years are given.

2. Materials and methods

This project was implemented in order to determine the water consumption of cotton at the Kashmar Agricultural Research Station. The dimensions of the cultivated land were 40×40 square meters, in the center of which a drainage lysimeter device with dimensions of 2×2×1.5 (cubic meters) was built and installed. Before planting, a soil sample was taken from the soil to determine its chemical properties (Table 1) and physical properties (Table 2).

Table 1. The results related to the physico-chemical analysis of the soil of Kashmar Agricultural Research Station

S.A.R.	P.W.P. (%)	F.C. (%)	texture	Cu	Zn	Mn	Fe	K	P	N (%)	O.C. (%)	T.N.V. (%)	pH	E.C. (dS m^{-1})	Depth (cm)
				mg kg^{-1}											
4.92	7.8	17.8	Loam silty	1.32	2.86	3.04	2.2	214.5	8.8	35	0.48	21.4	7.8	4.72	0-30

Table 2. Results of water analysis of Kashmar Agricultural Research Station

S.A.R.	S.S.P. (%)	Total anions	Total cations	Na^+	Mg^{2+}	Ca^{2-}	$(So_4)^{2-}$	Cl	HCO_3^-	pH	E.C. (dS m^{-1})
		meq lit^{-1}									
3.9	61	8.2	9.3	5	1.2	2.0	1.8	2.5	5	8.1	0.9

The required fertilizer was given to the soil based on the soil test. All agricultural operations, including planting and weeding (irrigation, fertilizing, weeding, weeding, spraying, etc.) were done on time. During the entire growth period, irrigation was done when the easily accessible soil moisture was used up, so when 40% of the soil holding capacity (Fc-Pwp) was used up in the root area, irrigation was done. This humidity was determined by sampling and weight method. The amount of irrigation water was such that a maximum of 10% of the water drain was created. The amount of the irrigation water was determined from Equation 1 (Alizadeh, 1993).

(1) $F_n = MAD.(Fc\text{-}pwp).D.d/100$

Where Fn is the height of irrigation water in centimeters, Fc and Pwp are the crop capacity point and wilting point respectively, D is the root depth in centimeters, d is the apparent specific gravity of the soil (grams per cubic centimeter), and MAD is the amount of management discharge, which is 0.4 in this research.

After each irrigation, the volume of water consumed was measured. With the help of water balance and using Equation 2, the amount of evaporation and transpiration of the cotton plant was calculated (Doorenbos and Pruitt, 1977).

(2) $ET_p = P+I-D\pm dw$

Where I is the amount of irrigation, P (cm) is the amount of rainfall, D (cm) is the amount of drainage (cm) and dw is the change in soil moisture between two irrigations. We ignore changes in soil moisture (dw) because during irrigation, the moisture is in flux and it has been tried to irrigate when the easily accessible water (equivalent to 40% of the soil storage capacity) has been consumed. This moisture was equal to 14%.

According to Equation 1, if Fc=17.8% and PWP=7.8% and MAD=0.4, the amount of percent moisture required during irrigation is equal to 14%, which was applied in all irrigations. Having the amount of water entering the lysimeter (I) and The amount of drained water (D) and rainfall (P) and humidity changes between two irrigations (dw=0) and the amount of evaporation and transpiration in the time interval without two irrigations were obtained (Equation 2).

3. Results and discussion

The evaporation and transpiration of cotton plants in the years were equal to 838.3 (mm), 1219.6 (mm), 1275.5 (mm) and 1447.9 (mm) respectively, and by averaging them, the average evaporation and transpiration of cotton are equal to 1183 (mm) (Fig. 1).

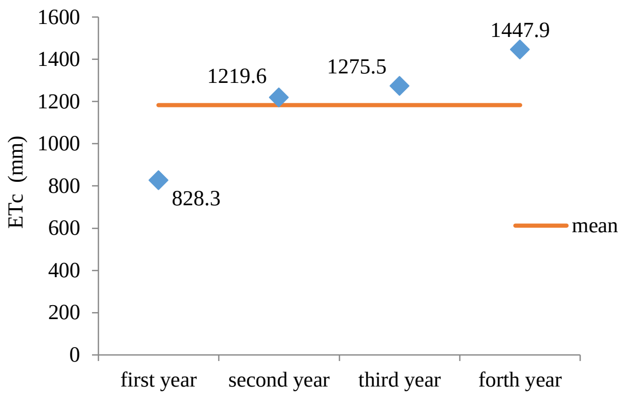

Figure 1. Water requirement of cotton and its four-year average in Kashmar region

The evaporation and transpiration of the cotton plant using meteorological data in the long-term statistical period (39 years) which was carried out in the book on the estimation of the water requirement of agricultural and garden plants and according to the Penman-Monteith method is equal to 1000.4 mm, which is about 20% of the actual value. The lysimeter differs and is less. This difference can be due to the high temperature in recent years (which is higher than normal) and also the consideration of all real climatic factors in the formula. The coefficient of the cotton plant is obtained by dividing the evaporation and transpiration of the cotton plant by the evaporation and transpiration of the grass plant. The grass plant was planted in the lysimeter and its guard from the second year. The crop coefficient (Kc) was determined for cotton in Kashmar as shown in the diagram below (Fig. 2).

It can be seen from Fig. 2 that the plant coefficient of cotton was 0.4 at the beginning of growth and its value gradually increased so that three months after planting its value reached the maximum (1.15) and then remained constant for some time. And from the sixth month to the time of harvest, it has decreased to 0.7. From the implementation of this plan, it can be concluded that in the years when the heat and monthly temperature are high and more than the normal limit, the use of the results of Penman-Monteith's theory, which is given in the book on estimating the water needs of plants (Farshi *et al*., 1997), needs to be modified. This project showed that in such cases, evaporation and transpiration can be considered up to 20% more than the results listed in the book on the estimation of plant water needs.

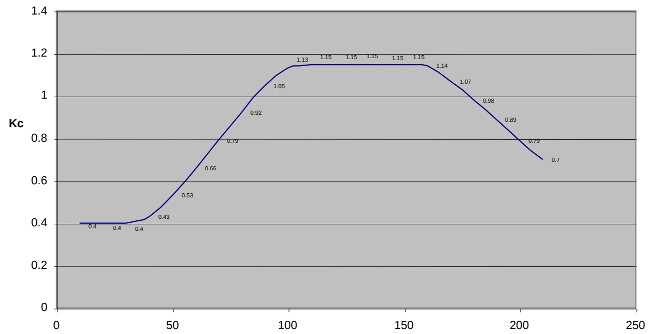

Figure 2. Crop coefficient of cotton by Penman-Monteith method in Kashmar region

4. Conclusion

The average evaporation and transpiration potential of cotton in the 4 years of implementation of the project was 1183 mm, which can be used in calculations due to the high temperature that we have seen in recent years in this city due to the continued drought. The plant coefficient of cotton was 0.4 at the beginning of growth and its value gradually increased so that three months after planting its value reached the maximum (1.15) and then remained constant for some time. And from the sixth month to the time of harvest, it has decreased to 0.7. Penman-Monteith's theory method shows less numbers than the real lysimeter method in the 4 years of project execution (832 mm average of four years). This value shows a 40% difference with the lysimeter method, which is due to the high temperature and the consideration of all climatic factors in the formula. Evaporation and the definition obtained in the library of the water requirement of agricultural and garden plants (Farshi *et al*., 1997) is equal to 1000.4 mm, which is about 20% different from the actual value of the lysimeter and less. Therefore, when the weather is very hot, the amount of evapotranspiration should be taken into account more than what is estimated. It is recommended to use the Penman-Monteith method to obtain the plant coefficient in cases where the grass plant has not grown optimally.

Conflict of interests

The author declares no conflict of interest.

Ethics approval and consent to participate

No humans or animals were used in the present research. The authors have adhered to ethical standards, including avoiding plagiarism, data fabrication, and double publication.

Consent for publications

The author read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

The first draft of this manuscript was written by the researcher and has been revised and modified.

Informed consent

The author declares not to use any patients in this research.

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