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Schedule Irrigation Water for the Grape Crop (Table Grapes) at the Almarai Company in Hail

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ABSTRACT: *This study showed a high rate of evaporation during the summer and its decline in the winter season, ranging from 950 mm in summer months to 250 mm in winter months. The water consumption of grapes crop varies from month to month, peaking in July and August by 277.4 mm and 266.7 mm, respectively. While the quantity of water consumption of the crop during the months of January and February by 18.7 mm and 23.5 mm, respectively. The irrigation requirements for grapes ranged between 71 mm in January and 335 mm in July. Climate factors play an important role in this variation as well as in the growth stages. The soil of the study area is sandy Loma, the total available water capacity is approximately 163.5 mm, and the available water capacity is 108.7. Irrigation periods range from 4 days to one day. The need for irrigation is increased during the maturing season, which also occurs in months of high temperature, which requires increased irrigation. In January, irrigation is done every four days, in February every three days, March, November and December every two days, while irrigation is carried out once during the months (April - May - June - July - August - September- October).*

Keywords: *table grapes, Reference crop evapotranspiration, available water, Readily available water, Wilting Point, Irrigation requirements, Penman-Monteith equation.*

I. INTRODUCTION

The process of securing food in arid and semi-arid regions has become an obsession that worries many countries and their inhabitants, so many countries of the world have made securing food a strategic goal that they seek to achieve, especially since the world's population is steadily increasing, and their growth is estimated at about 70 million people annually. It requires doubling of agricultural production to meet food needs and food self-sufficiency (Foley,2010 ; Bishop, 1983). Agricultural lands in arid and semi-arid regions suffer from the lack of arable areas, the lack of rain and its fluctuation in some dry areas. Therefore, countries in these areas tend to rely on irrigated agriculture, which increases the pressure on ground water or underground storage, and wastes water by random irrigation, in light of dry climatic conditions, away from concern for water potential and its type, and knowing the amount of water needed for agricultural crops. (Alhader, 2016; Al-Roqi, 2012). The water needs (evapotranspiration) of agricultural crops are affected by several factors, the most important of which are: the prevailing climatic conditions (temperature, insolation, solar brightness, amounts of precipitation, and wind speed), as well as the quality of agricultural soil and its physical properties, water constants, crop quality and growth periods. (Vanino,2015; Al-Omran,1997). it indicated many studies conducted in arid and semi-arid regions, in different places of the world (Wang 2018; Al-Saaran, 2016; Al-Orman, 2016; Phogat,2017; Müller, 2015; Anita, 2020; Al-Athba,2010; Al-Saaran2017; Fandiño,2012), and other studies ; Attention to the water needs of agricultural crops must take into account the quantities of water, whether it is an increase in irrigation or a decrease, as the crop production is damaged when the amounts of irrigation are less than its need, and studies have shown that the increase in irrigation operations beyond the crop's need leads to salinization of agricultural soil And their degradation, as most soils in arid and semi-arid regions contain large quantities of dissolved salts in the water, whether irrigated or rainwater. Abundant and incorrect irrigation also contributes to the loss of a large amount of water and leads to the deterioration of agricultural soils because of washing colloidal substances from the soil and its nutrients (Al-Roqi, 2012). It is appropriate to know the quantities of the water requirements of the agricultural crop and determine them. The Penman-Monte method is one of the good relations in estimating water needs, and it is a reference for estimating the evaporation reference transpiration. This study seeks to achieve the following objectives: Calculating the water needs of the grape crop in the study area and estimating it by means of mathematical climate relations. In addition to scheduling irrigation water for the grape crop in Almarai Company.

II. Study Problem

The Hail region is one of the important agricultural areas in the Kingdom of Saudi Arabia, which is carried out by major agricultural companies, led by Almarai Agricultural Investment Company. Despite technological progress and technical development, the problem of water consumption and the depletion of groundwater remain among the issues that constitute a major problem for the Saudi Arabi and farmers alike, and the misconception among many farmers that the increase in the amount of irrigation of the crop increases the quantities of production, and the farmers' lack of interest in the governorate. On agricultural soils, there is no schedule to properly irrigate crops. What helps to exacerbate the problem is the location of the study area in the dry desert area with little rain. Therefore, it is appropriate to set up a mechanism to rationalize water consumption and protect it from waste and depletion of agricultural soil, estimate the quantities of water needed by the grape crop, and plan the irrigation process for the crop.

III. Study area

The Hail region is in the northwestern part of the Kingdom of Saudi Arabia. Astronomically, the study area is located between longitudes 50 '42' and 03 '43' east and latitudes 25 '27' and 54 '27' north. Figure 1). The study area is within the sedimentary region, in which the terrain varies between plains, sandy formations and rock formations (Al-Shammari,2012). The climate of the study area is considered a continental climate in which the temperatures rise in the summer and decrease in the winter, and a change in temperature may occur during the day, as it falls within the range of the dry subtropical continental desert (Mahsoub, 1999), and the temperatures vary in the Hail region during the seasons. The year, where the summer temperatures range between 30 ° C and 40 ° C, while in the winter temperatures range between 5 and 15 ° C, and rain falls in the Hail region during the period. From the second half of October through April, the summer is the dry season. (Alhader,2016). According to the reports and data of the Almarai Agricultural Company, the prevailing textures in the study area are sandy clay, the percentage of sand is 68%, the percentage of clay is 24%, while the percentage of silt is 8%.

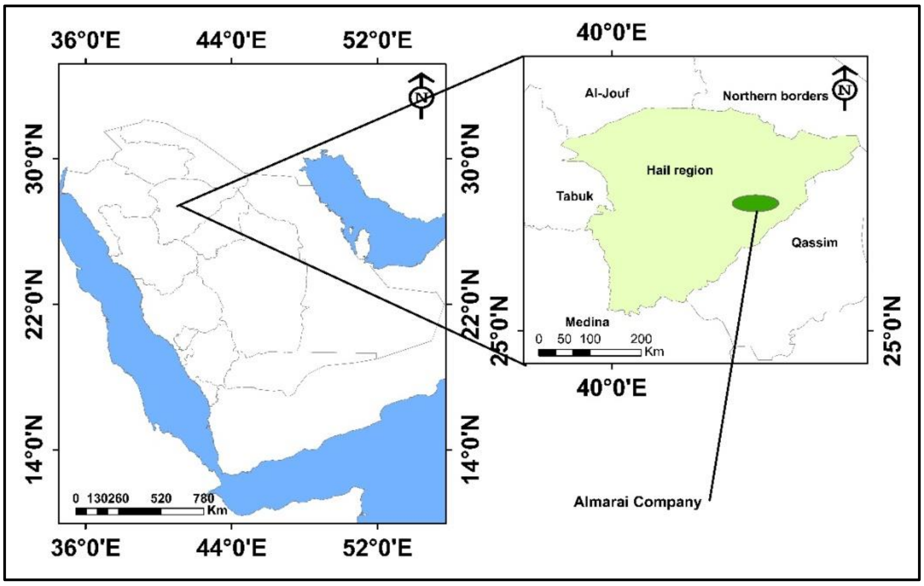

Figure 1: The location of the study area

IV. Study methodology and methods

A- The study was conducted on the grape crop (Table Grapes), which is one of the most important fruit crops in the Kingdom of Saudi Arabia. And it is considered one of the most important crops in the study area.

B- The daily weather and climate elements data for each of the maximum and minimum temperature, maximum humidity, wind speed as well as hours of brightness, which were recorded at the Almarai Agricultural Company station in Hail for the period from 1985-2011 AD, were used to calculate the quantities of evaporation.

C: There are many mathematical relationships used in the process of calculating evaporation transpiration, but the Food and Agriculture Organization has adopted a mathematical method in which the evapotranspiration is calculated accurately, represented by the Penman-Monteith equation.

1) Calculate the water requirements (evaporation transpiration) of the grape crop using the Penman-Monte equation, which takes the following formula: (Allen, 1998).

$$ET_o = \frac{0.408\,\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34\,u_2)}$$

Where: ET_o 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- mean daily air temperature at 2 m height [°C],
u2 -wind speed at 2 m height [m s-1],
es -saturation vapor pressure [kPa],
ea -actual vapor pressure [kPa],
es-ea saturation vapor pressure deficit [kPa],
Δ -slope vapor pressure curve [kPa °C-1],

2) Calculating the evaporation caused by the grape crop (water consumption) under standard conditions (ETc), by the following equation: (FAO, 1996):

$$ET_c = K_c * ET_o$$

where ET_c -crop evapotranspiration [mm d-1],
K_c -crop coefficient [dimensionless],
ET_o- reference crop evapotranspiration [mm d-1].

3) Estimate soil leaching requirements and the values of LR for grapes can be estimated through the following equation in the surface irrigation process.

(Al-Omran,1987):

$$LR = \frac{EC_w}{5\,(EC_e) - EC_w}$$

Where: LR = minimum washing requirements for salinity control within ECe tolerance values for each crop.

ECw = salinity of irrigation water (ds / m).

ECe = medium salinity of the soil tolerated by the plant, without a low level of productivity (ds / m).

4) Calculation of irrigation requirements using the following relationship: (Al-Omran,2016):

$$IWR = ET_c \times \frac{1}{1-LR}$$

Where: IWR = irrigation needs of the crop (mm).

ETc = crop water consumption (mm / d).

LR = Washing Requirement.

5) Determining the humidity curve using the following relationship: (Genuchten, 1980):

$$\theta_\psi = \theta_r + \frac{\theta_s - \theta_r}{\left(1+|\alpha \cdot \psi|^n\right)^m}$$

Where: θΨ = volumetric soil water content (m^3 / m^3).

θr = residual water content.

θs = saturated water content.

α, n, m experimental coefficients

6- a) Determine the available water by the following relationship: (Al-Saaran, 2009)

AWC = $\theta_{fc} - \theta_{wp}$

Where: AWC = available water in soil (m^3 / m^3).

FC = field capacity (m^3 / m^3).

WP = wilt point (m^3 / m^3).

6-b) Determine the total available water by the following relationship (Kirkham,2014):

$$TAW = AWC. Z$$

Where: TAW = Total Available Water in Soil.

Z = depth of crop roots (mm).

7) Calculating easily available water by the following relationship: (Tam, 2014)

$$RAW = TAW. MAD$$

Where: RAW = water readily available in soil (mm).

MAD = permissible decrease, and it is 0.40 for grape crop.

8) Determination of the irrigation cycle: the interval between the two irrigation crops per month (the time interval between irrigation and the other), calculated by Irrigation in the Pacific Northwest by Oregon State University using the following relationship: (Luff, 1983):

$$F = \frac{AWC \,.\, R .MAD}{ETc}$$

Where: F = the time between the two irrigations of the crop (day)

AWC = Available water capacity (mm)

R = depth of crop roots (mm)

MAD = permissible depletion of 0.40 for grape yields (FAO, 1996

ETc = crop water consumption (mm / month)

9) Use the Cropwat program to determine the values of the evapotranspiration reference.

10) Using the Soil Hydraulic Model (Rosetta) method through the Hydrus-1D program, to determine the moisture content values.

Fourth: Data sources: The data of Almarai Company was used according to Table:(1)

Crop type	Grapes	Unit
Depth of roots	1.5	M
soil type	Sandy loam	
PH	6.4- 8.6	
The degree of salinity of irrigation water(EC_w)	1.4	**dS/cm**
The degree of salinity of the saturated soil paste (EC_e)	1.5	**dS/cm**
sand	68	**%**
Celts	8	**%**
Clay	24	**%**

V. Discussions

5-1: Descriptive statistics of the monthly values of the measured meteorology variables: Table (2) shows the monthly averages of the climatic values measured at Almarai Company's station in the Hail region, represented by the maximum and minimum air temperature, average relative air humidity, the number of hours of daily brightness, and wind speed, in the region The study of Almarai Company for Agricultural Investment for the period 1990-2011. It was found that the average annual maximum temperature was 31.3 °C, and the monthly average ranged between 18 °C in January and 43.3 °C in August. As for the minimum temperature, the monthly average for January was 4 °C, the monthly average for August was 23.3 °C, and the annual average was 13.9 °C. The monthly mean humidity ranged between 79.2% and 21.1% for January and June, respectively. The average annual humidity was 50.6% (Figure2). The annual humidity increases during the winter and decreases during the summer, and this big change between lower temperatures and higher humidity and vice versa, during winter and summer, is not a change in the actual amount of air humidity (actual water vapor pressure), but rather due to an increase in the capacity of the air to absorb as much Greater than water vapor (saturated water vapor pressure), with an increase in air temperature in summer.

The month	Min temperature °C	Min temperature °C	Relative humidity %	Brightness hours Hour/day	Wind speed Km/h
Jan	18	4	79.2	8.9	11
Feb	20.3	4.9	72.5	10	13
Mar	24.7	8.2	65.9	10.2	14
April	30.8	13.6	58.8	10.3	15
May	36.9	18.7	40.1	11.2	14

June	41.8	21.9	21.1	12.6	12
July	42.3	22.9	22.6	13	12
August	43.3	23.3	25.1	13	11
Sep	40.5	20.4	31.3	11.5	10
Oct	34.9	15.9	43.5	11	11
Nov	25.5	10	65.1	9.4	11
Dec	20.04	5.3	74.4	9.5	11
Average	31.3	13.9	50.6	11	12.2

Table (2): The monthly average of climate elements in the Almarai Company station from 1990 to 2011

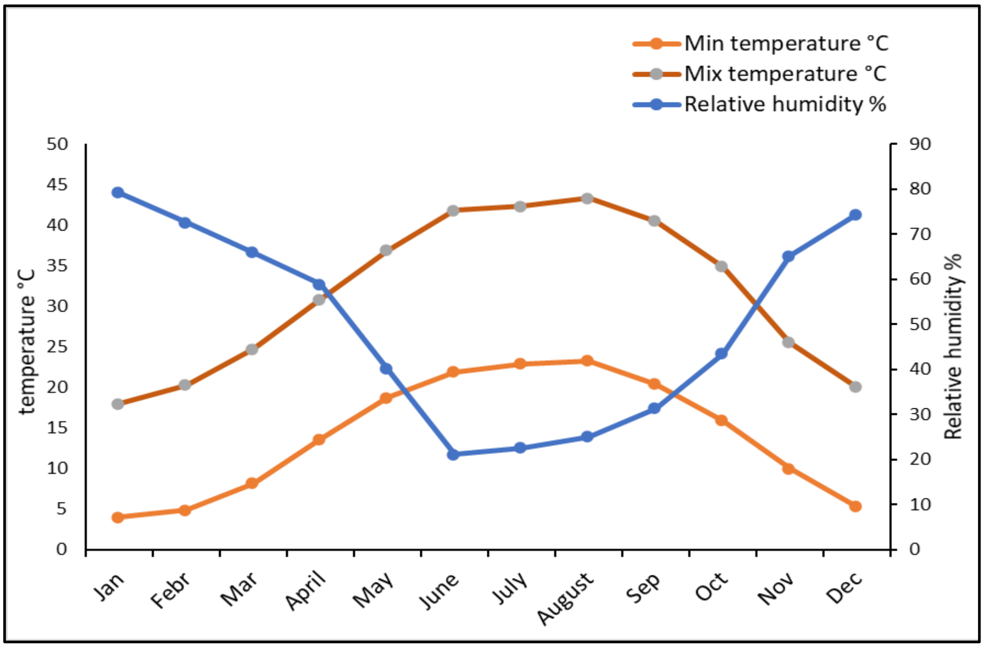

Figure (2) The monthly distribution of temperatures and relative humidity in the study area

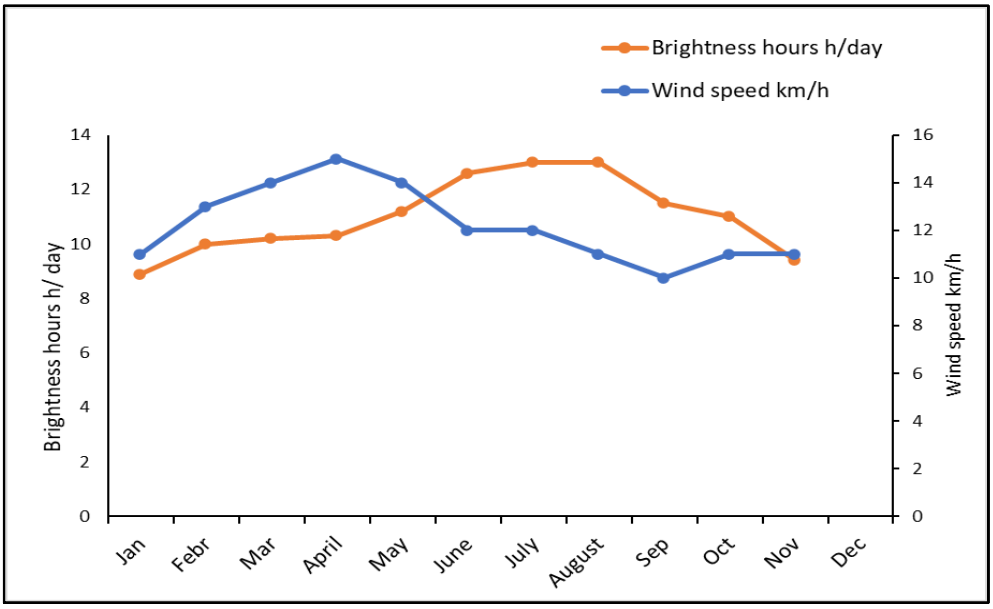

Figure (3): The monthly distribution of hours of brightness and wind speed in the study area

It was found from Table (2) and Figure 2 and3, that the annual average hours of actual brightness in the study area ranged between 8.9 hours/day in January and 13 hours/day in August and July. With an annual average of 11 hours/day. The average annual wind speed was 12.2 km/hour, varying from 10 km/hour during September to 15 km/hour during April.

5-2: Evaporation Transpiration Reference for Grape Crops (ETo): By applying the Penman - Montmontith equation to calculate the monthly water requirements for the grape crop on the Almarai Investment Company farm in Hail, which was based on mathematical relationships, it was found that the values of the reference transpiration evaporation ranged from 74.27 mm in In January, to 326.30 mm in July, the amount of reference evaporation values reached 2408.48 mm. Table (3) and Figure (4).

Table (3): Determining the water consumption, washing requirements, and irrigation needs of the grape crop

The month	IWR	(LR) %	The water consumption of the crop mm /month	Kc	Evaporation transpiration(mm) ET_o
Jan	70.44	,24 0	18.6418	0.251	74.27
Feb	73.64	,24 0	23.4806	0.260	90.31
Mar	89.24	,24 0	38.3901	0.272	141.14
April	147.2	,24 0	78.5597	0.438	197.36
May	228.76	,24 0	166.1604	0.604	275.10
June	295.45	,24 0	238.8558	0.771	309.8
July	334.85	,24 0	277.355	0.850	326.30
August	325.15	,24 0	266.56	0.850	313.6
Sep	274.1	,24 0	219.215	0.850	257.9
Oct	236.22	,24 0	184.75	0.850	217.30
Nov	142.37	,24 0	86.953	0.721	120.6
Dec	81.1	,24 0	42.909	0.506	84.8
	2298.52		864.946		2408.48

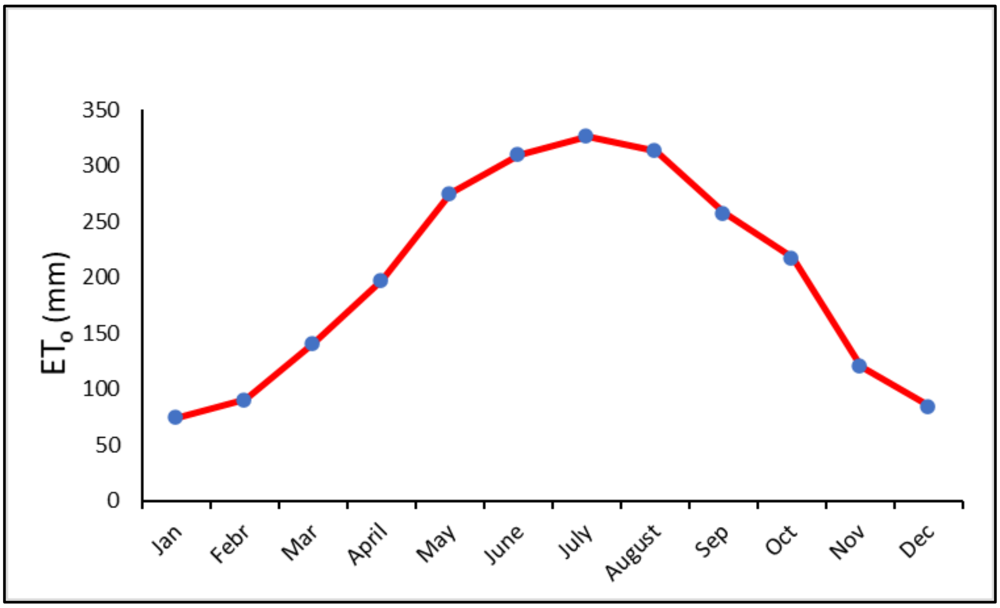

Figure (4): Distribution of monthly reference evapotranspiration in the study area.

5-3: Water consumption of the crop (ETc): The water consumption of the grape crop was calculated as shown in Table No. (3), from the beginning of germination or planting seedlings at the beginning of February and throughout the entire season, and the consumption of grape crops varied from month to month According to the stages of its growth and the prevailing climatic conditions. The highest water consumption of the crop was in July with 277.355 mm/day, followed by August with 266.56 mm/day. The consumption of the watery grape crop decreases during January as it reached 18.6418 mm / day. Water consumption reached its peak in the summer months, that is, when the crop matured, it reached 782.771 mm, and in the winter it decreased to 85.0314 mm, and this goes back to the stage after the season is harvested. In this period, the stems are devoid of leaves and buds, and the crops are pruned and trimmed to start a new season. The yield factor for grapes was also calculated daily (Figure 5) during its growth stages as follows:

1- The stage of germination: it reached 100 days.

2- The growth phase: It starts from the end of the first phase and has reached 50 days.

3- The mid-season stage extends to the beginning of maturity and reached 125 days.

4- The stage of maturity or harvest: it lasts for approximately 59 days.

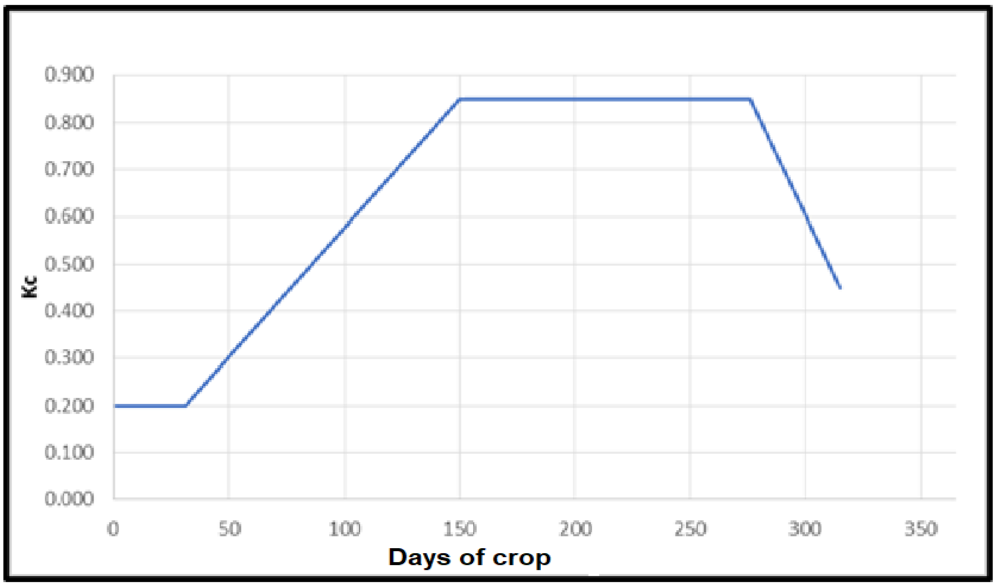

Figure (5) the grape crop factor in the study area

5-4: Estimating soil leaching requirements (LR): It is the quantities of water needed to wash the excess salts accumulated in the soil to ensure the salt balance so that the productivity of the crop is not affected (Al-Athba,2010), as it is very necessary when irrigating crops to take into account the soil need For washing, as a result of the accumulation of salts in it from irrigation or from the addition of chemical compounds or fertilizers, and the percentage of washing in the study area reached 22%, so this percentage must be added to the irrigation process, Table No(3).

5-5: Irrigation requirements for the grape crop: When irrigating crops of various types, consideration must be given to the type of crop and the type of soil, to irrigate the crop to the extent needed without wasting quantities or a shortage of irrigation quantities needed by the crop. Irrigation quantities for a single crop differ from one period to another according to its different growth stages, and as indicated in Table No. (2), from the amounts of evaporation transpiration, which decrease in the winter season and increase in the summer season, we find from Table No. (3), We find that the irrigation need for grape crops in the study area varies from month to month, as it decreases during January and February by 70.44 mm / month and 73.64 mm / month respectively, and during July and August it increases to 334.85 mm/month, 325.15 mm / month. Respectively. The need for irrigation increases during the summer, as the grape crop needs 955.45 mm, and this is because the plant is in the stage of maturity as well as high temperatures and low humidity, while in the winter they need for irrigation decreases, reaching 225.18 mm, and it increases in the autumn than in the spring It was 465.2 mm and 652.69 mm, respectively.

5-6: Soil moisture curve (SWCC): It is a curve that represents the relationship of moisture content with the tensile stress, and the value of this tensile varies depending on the texture of the soil. In Table (4). The humidity curve has calculated the field capacity and the wilting point, as shown in Figures 6-a and 6-b.

Table (4) Determination of moisture curve values

m	n	α	θ_s	θ_r
0.24	1.316	0.027	0.376	0.065

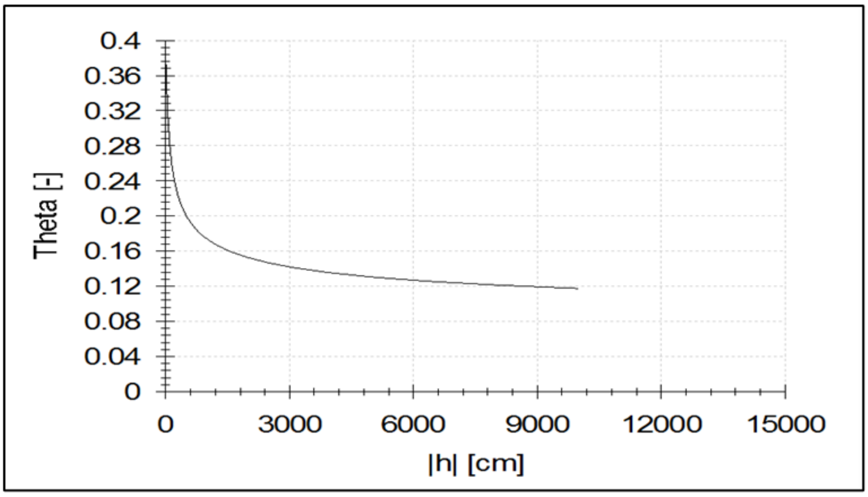

Figure (6-a) Moisture curve for the soil in the study area by Hydrus 1D program

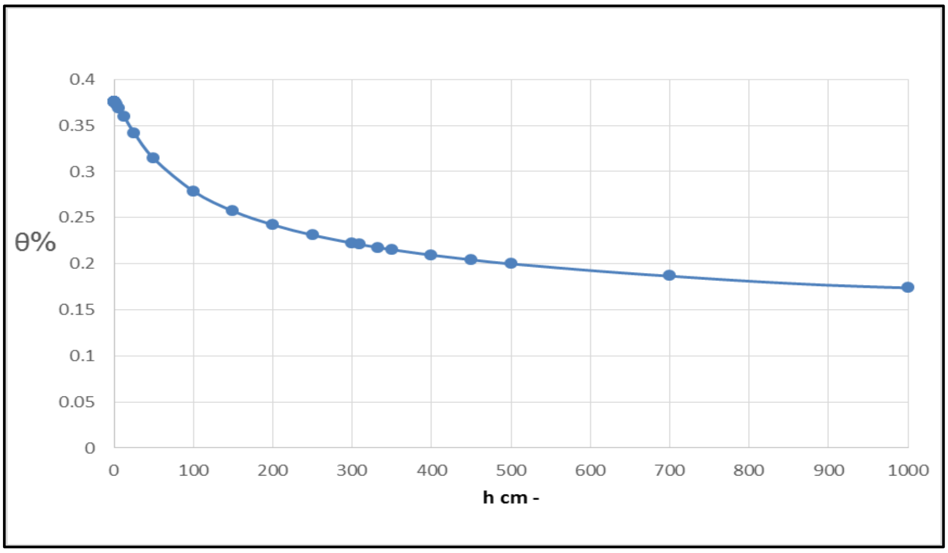

Figure (6 - b) Moisture curve for the soil in the study area through the Excel program

5-7: Available water: It refers to the amount of water that the soil can store for use by plants, and the capacity varies according to the properties of the soil that affect the retention of water in it, such as the content of organic matter, soil texture, bulk density, etc., and the capacity is Available water is an important factor in selecting plants or crops to grow and in designing and managing irrigation systems (Romero, 2017). The difference between the field capacity and the point of the withering of the grape crop - Table (5) - is the available water capacity, and it reached 0.109, (11%).

5-8. Determining readily available water: not all the water in the soil is readily available to the crop, as some water is tightly bound to soil particles, and the crop or plant, in general, cannot obtain it. (Romero, 2017) Readily available water is water that a plant can readily extract from the soil. Plant roots continue to take water from the soil after reaching the replenishment point, but this water is not readily available, and the crop has difficulty extracting it. If the soil dries up to the point of permanent wilting, the plant will no longer be able to get any water from it and some water may remain, but it is not available at all. The drier the soil, the more water must be added to restore the soil to the field capacity (Kramer, 1995). From Table No. (5), the soft water was easily calculated for the grape crop, which amounted to 65.4 mm.

Table (5) Available water, soft water, total available water, and permissible depletion

θf_c	θw_p	TAW mm	RAW mm	ADM	AW %
0.22	0.1113	163.5	65	0.4	11

5-9: Irrigation Frequency: The irrigation cycle of grapes was calculated as shown in Table (6), and the time interval between watering was calculated, which shows that in January the grape crop is irrigated by irrigation every 4 Days, with 8 irrigation during the month, during which the crop is irrigated by 9 mm per irrigation, with a total of 72 mm throughout the month, while in February the crop is irrigated every 3 days, by 9 irrigation during the month, during which the crop is irrigated by 8.5 mm, per irrigation, for a monthly total of 76.5 mm. In the month of March, the crop is irrigated every 2 days at a rate of 16 irrigation during the month of March, during which the crop is irrigated by 6 mm per irrigation, with a total of 96 mm during the month. While during the period from April to October, the crop is irrigated daily and with different amounts of irrigation depending on the conditions of the month. In November, the grape crop is irrigated every two days, at a rate of 15, during the month of November, during which the crop is irrigated by 10 mm per irrigation, and irrigation is done at a rate of 15 irrigation per month. In December, the grape crop is irrigated every two days at a rate of 5.5 mm per irrigation, and during which the crop is irrigated 16 times per month.

Table (6): The irrigation cycle (the time between irrigation and the other (day) for grape crops

Month	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
The time between irrigation	4	3	2	1	1	1	1	1	1	1	2	2
The number of Irrigation per month	8	9	16	30	31	30	31	31	30	31	15	16
Irrigation amount (mm)	9	8.5	6	5	7.5	10	11	11	9.5	8	10	5.5

VI. Results

1- The study showed a high rate of evapotranspiration during the summer and a decrease in the winter season, as it ranged between about 950 mm in the summer months and 250 mm in the winter months.
2- The water consumption of the grape crop varies from month to month, reaching its peak during July and August at 277.4 mm and 266.7 mm, respectively. While the quantity of crop water consumption decreased during January and February by 18.7 mm and 23.5 mm, respectively.
3- The irrigation needs of the grape crop ranged between 71 mm in January and 335 mm in July. Climatic factors play an important role in this variation, in addition to the stages of growth.
4- The soil of the study area is sandy lumé, the total available water capacity is approximately 163.5 mm, and the available water capacity is 11%.
5- The percentage of sand was 68%, Celt was 8% andClay24%. From these values and based on Rosetta's program, the moisture curve was constructed, and the field capacity and wilting point values were extracted from this curve which was 0.22 and 0.1113, respectively.
6- Irrigation periods range from 4 days to one day, as the need for irrigation increases during the ripening season, which also coincides with the months of high temperature, which requires an increase in irrigation.

VII. Recommendations

1- Conducting more studies on scheduling crop irrigation, as this contributes to reducing water consumption and mitigating the damage of soil salinization.

2- Increase farmers' culture and awareness of water use during crop irrigation.
3- Avoid irrigated agriculture by the method of flooding, because it causes salinization of the soil and waste of water and giving the plant more than its need, and this increase, in turn, draws salts and fertilizers into the groundwater, which causes contamination.
4- Activating the role of agricultural extension by conducting studies to schedule irrigation for all types of crops, distributing them to farmers, and training them on the mechanism of their application, which helps in raising the efficiency of their crops and reducing water waste.

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