Mathematical model for irrigation water management to improve the Bottle Gourd Production

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Abstract: This study was carried out at Faculty of Agricultural- Suez Canal University which located in north eastern Egypt, within the Governorate of Ismailia. The experiment was conducted to assess the influence of different amounts of water and plant distance on Bottle Gourd production. Thus; the factor of water amounts comprise into three treatments (Q_1, Q_2 and Q3) with average (352.4, 704.8 and 1409.6 mm) respectively under different plant distances (0.5m and0.75m).Thus; the results revealed that the highest values for (LAI) have recorded with distance S2 comparing with S1 whatever the amounts of water. Obviously; that the LAI values have a good behavior with S2 and Q2 by ($5.1 m^2.m^{-2}$). On the other hand; the (LAI) needs to approximately 1556.72, 831.5 and 929.26 heat units to increase ($1m^2.m^{-2}$) under treatments Q1, Q2 and Q3 respectively with S1. However with S2; (LAI) needs for low heat units by 394.4, 304.2 and 449.09 heat units under Q1,Q2 and Q3 respectively to get ($1m^2.m^{-2}$). Generally; LAI needs for low heat units to increase with Q2 comparing with other quantities whatever changing on plant distance. Furthermore; In addition; there is a significant influence for S1 comparing with S2 on yield production where S1 obtained 5.8(ton.fed^{-1}) and S2 obtained 4.1 (ton.fed^{-1}). However; with treatment Q1 recorded a highest value for IWUE by (3.5 Kg/m^3). Further; the highest value for Heat use efficiency (HUE) obtained under Q3 with S1 by (4.3 Kg. fed^{-1} $C^{-1}day^{-1}$). Thus; from previous data analysis that best treatment is Q1 (low amount of water) which gain a good value both (IWUE).

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Key words: water quantities, plant distance, Heat use efficiency and Bottle Gourd production.

1. Introduction

Sundry previous studies have modeled the impact of climate parameters on crop water requirements and future water resource need for irrigating agriculture. Consequently, the main challenge confronting water management in agriculture is to improve water use efficiency and its sustainability. This can be achieved through (i) an increase in crop water productivity (an increased in marketable crop yield per unit of water transpired) through irrigation, (ii) a decrease in water losses through soil evaporation that could be used by plants for their growth, and (iii) an increase in soil water storage within the plant rooting zone through better soil and water management practices at farm. Thus; they are focusing to deal with this problematic by more rationalized and efficient manner than ever before. Therefore, two issues that need attention are a) finding means of lowering the current level of water demand by some efficient water use techniques, and b) promote economic return to the farmers to enhance economic incentives. These can be obtained through high crop production and increasing the water productivity using new irrigation approach.

Drip irrigation system has considered an essential irrigation technique for manipulating crop growing and for improving and expanding yield production. In addition, this method is widely used because it allows efficient management for both water and fertilizer (Rajurkar *et al.,* 2012). Thus, the role of irrigation at proper level and stages of plant growth has great significance in improving the yield (Singh *et al.,* 1990). For instance; Dry season vegetables production such as bottle gourd and okra through cost-effective techniques of irrigation and fertilization seems promising. But decreased water availability during this season has been identified as a constraint on vegetable production (Yih-Chi Tan, *et al.,* 2009).

Noticeable; that the dry weather during this season creates a condition of water scarcity for many crops requiring frequent irrigation. Several studies reported mulch to conserve soil moisture and improve crop yield (Singh *et al.,* 1976). Moreover; Water stress can affect the canopy architecture, the use of radiation and reduce leaf area index. The leaf area index is a parameter that is a directly related to evapotanspiration (Rezende, 2014). For instance; most plants live and grow in a temperature range of 0 to 50°C. The occurrence of different phonological events during a growing season of any crop and the effect of temperature on plant growth can be inferred using accumulated heat units (growing degree days) (Sunil & Sundera; 2005).

Notable; that the Bottle gourd fruits are generally grown as a vegetable in Africa and Asia. Immature fruits are consumed by boiling, frying, or stuffing like the fruit of *Cucurbitapepo*. Shoots, tendrils, and leaves are also cooked, and the seeds are used for oil extraction or for cooking. The tendrils and young leaves are also utilized for some medicinal purposes (Tindall, 1983). Moreover; Bottle gourd has also been used routinely as a source of rootstock for watermelon and other cucurbit cropsin some countries to reduce the incidence of soil-borne diseases and to develop the vigor of the root system of the crop under conditions of low temperature (Lee and Oda, 2003).

From the previous substantiation; firstly ; The most useful measure of performance of an irrigation system, in terms of its effect on crop yield, is the water use efficiency (WUE) (Algheriani, 2002) which evaluates the proportion of the applied water beneficially used by the crops, WUE often defined by the ratio between the crop biomass or grain production and amount of water consumed by the crop, including rainfall, or the irrigation water applied, or the crop transpiration (Zhang and Oweis, 1999). Likely, the term WUE should be used as an indicator of the plants performance (Luis, S. Pereiar.*et al*., 2002).

Anew; creation a model which is a simplified version of a part of reality, not a one to one copy. This simplification makes models useful because it offers a comprehensive description of a problem situation. However, the simplification is, at the same time, the greatest drawback of the process. Doubtless; the main purpose for using models is explaining, understanding or improving performance of a system. It is a difficult task to produce a comprehensible, operational representation of a part of reality, which grasps the essential elements and mechanisms of that real world system and even more demanding, when the complex systems encountered in environmental management (Murthy, 2002). Eventually; statistical models are expressing the relationship between yield or yield components and weather parameters.

Clearly, there is some tantalizing potential for using low amount of water for upcoming a highest value for product and water unit. Thus; the aim of this study is to monitoring the influence of two water quantities with average (352.4, 704.8and 1409.6mm) and different plant distance (0.5m and0.75m) on yield production, plant parameters. finally; a good water uses, Heat use efficiency and leaf are index. in addition; create a simple mathematic relation between yield and factor of experiments.

2. Materials and Methods

The experimental was carried out at farm faculty of agricultural – Suez Canal university – Ismailia governorate. The study site, established in late May of (2013-2014), (30° 37' 10.91"N - 32° 16'1.33"E). The site of experiment falls into an arid area with a Mediterranean climate. The site is about 30 m above sea level with an annual rainfall of 29 mm/year. The average climate characteristics for temperatures, relative humidity, wind speed and evapotranspiration (ETo) represented at table (1).

Table 1: Climatic characteristics at Ismailia governorate.

Month	Prc.	Wet days	Tem. max	Tem min.	Hum.	Sun shine	Wind (2m)	ETo
	mm/m		°C	°C	%	%	m/s	mm/d
may	2	0.6	31.5	17	45.1	78.8	2.8	6.8
Jun	0	0	34.4	20.1	48.4	87.3	2.8	7.5
Jul	0	0	35.2	21.8	51.9	85.3	2.5	7.3
Aug	0	0	34.9	22	54.6	86.5	2.4	6.8
Sep	0	0	32.8	20.4	56.4	81.9	2.4	5.7

(*Prc*. = Precipitation; *Wet days* = Number of days per month with >0.1mm of precipitation; *Tmp. min/max* = minimum/maximum temperature; *hum.* = relative humidity; *Sun shine* = Sun shine as percentage of day length; *Wind*(*2m*) = wind speed at 2m; *ETo*= Reference evapotranspiration)

Analyses of soil and some physical and chemical characteristics were carried out according to Martin, (1993). These analyses are presented in tables (2) and (3). The soil of the experimental site is sandy texture, none saline, and none calcareous. Silt and clay content are quite low there for both field capacity and available water are very low (5.6 % and 4.5 %).

Table 2. Some chemical characteristic for the experimental site.

Depth (cm)	PH	EC dS/m	Solublecationsmeq/l				soluble anions meq/l			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
0-20	5.63	0.21	1.1	0.15	0.67	0.18	0	0.6	0.61	0.89
20-40	5.76	0.1808	1.03	0.114	0.46	0.195	0	0.533	0.352	0.913

Table 3.Particle size distribution for the experimental site.

Depth Cm	Particle size distribution % (mm)				Textural class
	C.Sand	F.Sand	Silt	Clay	
0-20	8.21	87.24	2.4	2.15	S*
20-40	10.61	85.12	3.1	1.17	S*
S* = sand					

The total water applied calculated related to the FAO "Irrigation and Drainage Paper #56: Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements." Further; Crop water requirement and total water applied. Using an average Reference Evapotranspiration (ETo) and the Crop coefficients (Kc) [table (4).] by the following equations.

ETc = ETo * KC (1)

Where;

Etc Crop Evapotranspiration, (mm/day).

ETo Reference Evapotranspiration, (mm/day).

Kc Crop coefficients.

IRn = ETc – Peff (2)

where;

IRn Net irrigation requirement, (mm/day).

Etc Crop evapotranspiration, (mm/day).

Peff Effective rainfall, (mm/day).

IRt= IRn/Ea (3)

where;

IRt total water applied (mm/day).

IRn Net irrigation requirement, (mm/day).

Ea Overall irrigation efficiency for modern irrigation system (drip. Approximately (95%).

And for surface irrigation is (65 – 75%) (Phocaides, 2000).

Table 4. The average crop coefficients (Kc) for Bottle Gourd

		Bottle Gourd			
Item	Init.	Dev.	Mid.	Late.	Total.
Days	20	30	30	20	100
KC	0.6	1.0	1.0	0.8	

The total water applied is (704.8mm).

The experiment was laid out on spilt plot design for two seasons 2013 and 2014 with amounts of water as a main plot factor comprise three treatments (Q1, Q2 and Q3) with average (352.4, 704.8 and 1409.6mm) from total water applied respectively; and plant distance as sub-blot factor comprise two treatments (S1 and S2) with (0.5 and 0.75m) respectively, thus; The experiment used a trickle irrigation system(built-in line) [(*GR 4L/50cm/h – 1.2bar*).

Water was analyzed by standard analytical methods for pH, electrical conductivity and ion composition **(APHA 1992).** Average values of the analyzed parameters for irrigation water are given in [table (5)].

Table 5. Some chemical characteristic for the different irrigation water type.

pH	EC (dS/m)	Soluble Cations (meq/L)				Soluble Anions(meq/L)				SAR
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO^{-2}_{3}	HCO^{-3}	CL^{-1}	SO^{-2}_{4}	
7.34	1.18	2.8	0.6	8.2	0.2	0	2.92	6.83	2.05	6.36

Measurements and calculations.

Leaf area index (LAI):

Leaf area index (LAI) was estimated using one method By multiplying the plant population by the leaf area per plant as described in (Kar et al., 2006). Area of the leaf was measured manually using the following equation:-

$$LAI = 0.75\ x\ \rho\ x \left(\frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(L_{ij} x B_{ij})}{m}\right) (4)$$

Where:-

LAI = Leaf area index ($m^2.m^{-2}$).

p = plant density (plant. m^{-2}).

m = the number of measured plants.

N = the number of leaves for plant.

Lij = Leaf length (m).

Bij = Leaf width (m).

Growing degree-days (heat units) (GDD)

Growing degree days (GDD) or heat units was calculated using the single sine curve method (Baskerville & Emin, 1969) during growing season of Bottle Gourdcrop. This simple linear method requires only daily minimum and maximum air temperatures, which recorded by the local meteorological weather station in site of experiment, equation (5) give explanation for calculating growing degree days:

$$GDD = [(T_{max} + T_{min}) /2] - T_{base} \quad (5)$$

Where:

T_{max}	=	Daily maximum temperature (C°)
T_{min}	=	Daily minimum temperature (C°), and
T_{base}	=	Base temperature (C°).

Heat use efficiency (HUE) is the ration of yield to accumulated growing degree days according to Kingra & Prabhjyot-Kaur, 2012 equation (6).

HUE = Yield(Ygi) / (AGDD). (6)

Where:

HUE	=	Heat use efficiency (kg fed^{-1} $C°^{-1}$ day^{-1})
Y_{gi}	=	The economic yield (kg/fed).
GDD	=	Accumulated growing degree days (C° day).

Heat units are often used to predict the rate of phonological development of plant species. Developmental rates increase approximately linearly as a function of air temperature (Snyder et al., 1999), therefore the higher or lower temperature will be affected on crop by reducing the plant growth and total yield. So; the lower temperature (Tbase) for bottle gourd, was set as 10C° (Sunil & Sundera; 2005).

Irrigation water use efficiency using the Bos, M.G. (1979) equation (7).

$IWUE = [Y_{gi} – Y_{gd}]/ IRR_i$	(7)

Where:

IWUE	=	Irrigation water use efficiency (kg / m^3).
Y_{gi}	=	The economic yield (kg/fed).
Y_{gd}	=	The dry yield (kg/fed). (Actually, the crop yield without Irrigation).
IRR_i	=	The irrigation water applied (m^3 / fed)

* Often, in most semiarid to arid locations, Y_{gd} may be zero.

Statistical analysis for modeling:

The data were analyzed using the two way ANOVA split plot procedure with Duncan's HSD test at p<0.05 using the COSTAT 3.03 System software.

The simple regression models with predictor variables $X_1; …… ; X_p$ can be describe by equation (2).

$y = B_0 + B_1X_1 + ……………. + B_pX_p + k$	(8)

Where:

Variable y, called a responseor dependent variable, depends on another variables $X_{(1..p)}$ which is called the independent or predictor variable (also called the regressor variable), B_0 is intercept, $B_{1\text{-}P}$ is the slope parameters and the variability of the error (*k*) is constant for all values of the repressor.

Results And Discussion

Leaf area index:-

As shown at fig. (1) Data represented that there are a variations on the values (LAI) related to the different treatments. For instance; the highest values for (LAI) has recorded with distance S2 comparing with S1 whatever the amounts of water. Furthermore; after 90 dayes from sowing date; the amount of water Q2 obtained a highest value for (LAI) by 1.8 and 5.1 ($m^2.m^{-2}$) under both S1 and S2 respectively. Noticeable; that the (Q3) has a different influence on (LAI) under S1 and S2 comparing with Q1. Thence; the value of (LAI) under Q3 was higher than Q1 by 65% with S1.In a contrast; with S2 the value of (LAI) under Q1 was higher than Q3 by 14%. Obviously; that the LAI values have a good behavior with S2 and Q2 because that the bottle gourd needs to cultivated into a large scale to give plant an opportunity to accomplish its physiological process during a different growth stage. (Sunil & Sundera; 2005). In addition;

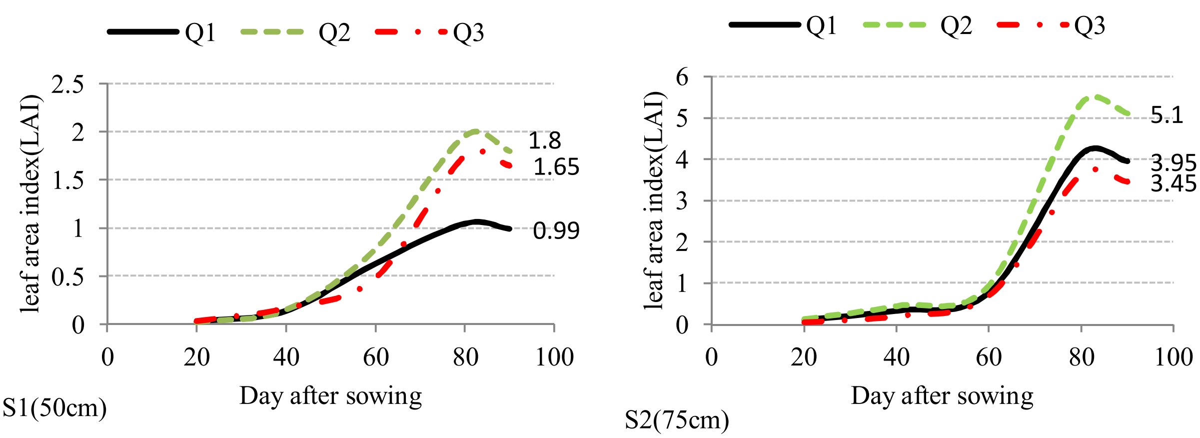

Fig. (1). Variations of Leaf area index (LAI) for Bottle Gourd during growing season under different treatments.

Accumulated growing degree days (AGDD) and LAI:

Table (6) illustrate the mean 10 day monthly, real and adjusted temperature, growing degree days (GDD) and accumulated growing degree days (AGDD) during Bottle Gourd growing season; Generally, the total amount of heat units for Bottle Gourd to develop from one point to another in its life cycle was 2069 C °/ season or (heat unit).

Moreover; Fig.2 illustrates the Dynamic changes in (LAI) for Bottle Gourdwith accumulation of growing degree-days (AGDD) under different treatments. Even though the LAI in different treatments was not identical, the trends in LAI over AGDD were similar for all treatments: LAI increased between 500°C and 1000°C, more rapidly between 1000°C and 1600°C, and then decreased slowly. Consequently; data indicated that the (LAI) needs to approximately 1556.72, 831.5 and 929.26 heat units to increase ($1m^2.m^{-2}$) under treatments Q1, Q2 and Q3 respectively with S1. However with S2; (LAI) needs for low heat units by 394.4, 304.2 and 449.09 heat units under Q1,Q2 and Q3 respectively to get ($1m^2.m^{-2}$). Generally; LAI needs for low heat units to increase with Q2 comparing with other quantities whatever changing on plant distance. Further; there is a Dynamic response between both (LAI) for Bottle Gourdand accumulation of growing degree-days (AGDD) in three water quantities treatment with R^2 more than 0.91. (Equation 9 & 10).

$$LAIs_1 = 0.0156*exp^{[0.0027(AGDD)]} \quad (9)$$

$$LAIs_2 = 0.0384*exp^{[0.0027(AGDD)]} \quad (10)$$

Table 6. Mean 10day monthly, temperature, growing degree days (GDD) and accumulated growing degree days (AGDD) during Bottle Gourd growing season.

Month	Day	T_{max}	T_{min}	GDD	AGDD
(2014-2015)	D	C°	C°	(C°)	(C° day)
May.	10-19	29.2	23.4	163	163
	20-29	32.4	26.3	193.5	356.5
June	30-8	33.1	26.7	199	555.5
	9-18	33.8	28	209	764.5
	19-28	34.8	28.6	217	981.5
July	29-8	34.5	28.9	217	1198.5
	9-18	34.5	29	217.5	1416
	19-28	33.6	28.5	210.5	1626.5
August	29-7	35	29.7	223.5	1850
	8-17	34.6	29.2	219	2069

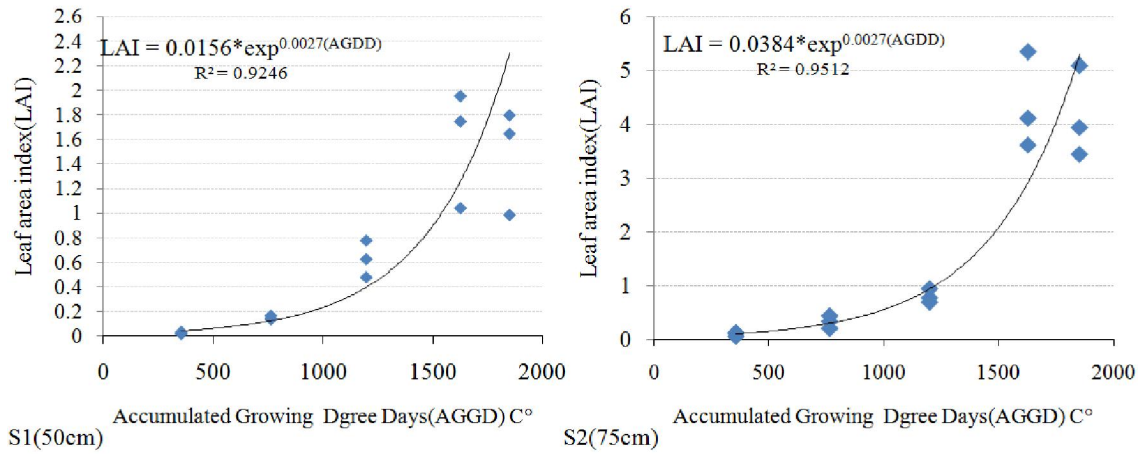

Fig.2 Illustrates the Dynamic changes in (LAI) for Bottle Gourdwith accumulation of growing degree-days (AGDD)

Where:

$LAIs_1$	=	Leaf area index for plant distance (0.5m)[$m^2.m^{-2}$].
$LAIs_2$	=	Leaf area index for plant distance (0.75m)[$m^2.m^{-2}$].
AGDD	=	Accumulated growing degree days (C° day).

Hence; these relations can be used to determine LAI depending on one climatic factor (air temperature) for Bottle Gourdcrop under such water conditions.

Amounts of water with growth parameters and yield:-

At table (7) data indicated that there are not any significant impacts for amounts of water on No. of fruits and yield. However; the treatment Q2 gave the highest mean value (28.16) for No. of fruits compare with the other water quantities (Q1 and Q3), further; Q2 recorded the highest mean value by (5.5 ton.fed^{-1}) for yield production comparing with the other water quantities (Q1 and Q3). In addition; there is a significant influence for S1 comparing with S2 on yield production where S1 obtained 5.8 (ton.fed^{-1}) and S2 obtained 4.1 (ton.fed^{-1}).

Heat use efficiency (HUE) and Irrigation water use efficiency (IWUE).

IWUE is one of the most important indices for determining optimal water management practices. The obtained results for IWUE and HUE are given in Table 8, the lower IWUE values was observed for treatment (Q3*S2) while higher values was in treatment Q1. That's means too much irrigation led to a decrease of IWUE and effective deficient irrigation may result in a higher production and IWUE (Jin, Zhang, & Gao, 1999). In addition; the result of IWUE under water treatments (Q1, Q2and Q3) were 3.5, 1.1and 1.5(Kg/m^3) respectively with S1. Thus; Bottle Gourd does not need to irrigate by higher amount of water to obtained a highest yield value for unit of water but irrigate by low amount of water can acquired an effective and economical irrigation water unit.

Moreover, the observation for HUE reflects that highest of crop yield under treatment Q2 did not need to obtain a high HUE. Further; the highest value for Heat use efficiency (HUE) obtained under Q3 with S1 by 4.3 (Kg. fed^{-1} $C^{-1}day^{-1}$).on the other hand; the lowest value for (HUE) recorded with Q3 under S2 by 1.07 (Kg. fed^{-1} $C^{-1}day^{-1}$). (Heat use efficiency (HUE), i.e., efficiency of utilization of heat in terms of dry matter accumulation, depends on crop type, genetic factors and sowing time and has great practical application (Rao, Singh, 1999). However; with treatment Q1 which recorded a highest IWUE by (3.5 Kg/m^3) obtained HUE 2.4 (Kg. fed^{-1} $C^{-1}day^{-1}$). Thus; from previous data analysis that best treatment is Q1 (low amount of water) which gain a good value both (IWUE) and (HUE).

Table 7. Illustrate an influence of different treatments on Number of fruits and Yield.

ITEMS	Treatments				
	Q1	Q2	Q3	S1	S2
N.fruits	24.66a	28.16a	22.66a	27.6a	22.6a
LSD0.05	19.544			7.549	
Yield	4.2a	5.5a	5.11a	5.8a	4.17b
LSD0.05	4.4			1.49	

Table 8. IWUE and HUE for Bottle Gourd under different treatments.

Treatments		IWUE (Kg/m^{-3})	HUE (Kg. fed $^{-1}$ $C^{-1}day^{-1}$)
Q1	S1	3.5	2.4
	S2	3.4	2.4
Q2	S1	1.1	1.6
	S2	1.8	2.5
Q3	S1	1.5	4.3
	S2	0.4	1.07

Finally the regression models (using multiple regressions at statistical program COStat which collect all parameters to determine the yield production under such conductions is:-

Y = [0.00034*Q] + [5.04 *S] $R^2 = 0.73$

Where:-

Y = Total yield (Ton / fed).

Q = Total water applied (m^3/fed/season).

S = plant distance on plant line (m).

Conclusion

To conclude; this study ultimately a several points. For instance; the highest values for (LAI) has recorded with distance S2 comparing with S1 whatever the amounts of water. Obviously; that the LAI values have a good behavior with S2 and Q2 by ($5.1m^2.m^{-2}$). On the other hand; the (LAI) needs to approximately 1556.72, 831.5 and 929.26 heat units to increase ($1m^2.m^{-2}$) under treatments Q1, Q2 and Q3 respectively with S1. However with S2; (LAI) needs for low heat units by 394.4, 304.2 and 449.09 heat units under Q1,Q2 and Q3 respectively to get ($1m^2.m^{-2}$). Generally; LAI needs for low heat units to increase with Q2 comparing with other quantities whatever changing on plant distance. Furthermore; In addition; there is a significant influence for S1 comparing with S2 on yield production where S1 obtained 5.8(ton.fed^{-1}) and S2 obtained 4.1 (ton.fed^{-1}). However; with treatment Q1 recorded a highest value for IWUE by (3.5 Kg/m^3). Further; the highest value for Heat use efficiency (HUE) obtained under Q3 with S1by 4.3 (Kg. fed $^{-1}$ $C^{-1}day^{-1}$). Thus; from previous data analysis that best treatment is Q1 (low amount of water) which gain a good value both (IWUE).

References

1. American Public Health Association (APHA), 1992. Standard methods for the examination of water and wastewater (18th Edition).
2. APHA- AWWA- WPCF, Washington D.C. PP 118-130.
3. Alghariani, S.A., 2002. Future perspectives of irrigation in southern Mediterranean region: policies and management issues. In: Al-Rasheed, M., Singh, V.P., Sheriff, M.M. (Eds.), Proceedings of the International Conference on Water Resources Management in Arid Regions 23–27 March, vol. 4, Kuwait, pp. 313–320.
4. Baskerville, G. L. and Emin, P. (1969). Rapid estimation of heat accumulation from maximum and minimum temperatures. Ecological Society of America, 50(3), 514-517.
5. Bos, M.G. (1979). Standards for irrigation efficiencies of ICID. J. Irrig. Drain. Div., ASCE, 105 (IRI), 37–43.
6. RezendeF.C. , A.L. Dias Caldas, M.S. Scalco and M.A. de Faria,(2014).Leaf area index, plant density and water management of coffee. Coffee Science 9(3):374-384.
7. Jin, M. G., Zhang, R. Q., and Gao, Y. F. (1999). Temporal and spatial soil water management: a case study in the Heiloonggang region, PR China. Agricultural Water Management, 42, 173-187
8. Kar G, Verma HN, Singh R (2006) Effect of winter crop and supplementary irrigation on crop yield, water us efficiency and profitability in rainfed rice based on cropping system of eastern India. Agriculture Water Management. 79: 280–292.
9. Kingra, P. K., and Prabhjyot-Kaur. (2012). Effect of dates of sowing on thermal utilization and heat use efficiency of groundnut cultivars in central Punjab. Journal of Agricultural Physics, 12(1), 54-62.
10. Sunil K. m. and k. s. Sundara sarma, 2005. Characterizing thermal environment under Senaiarid Conditionsin Relation to Growth and Development of Bottle Gourd and Tomato Jour. Agric. Physics, Vol. 5, No.1, PP. 71-78.
11. Luis Santos Pereira, Theib Oweis and Abdelaziz Zairi, 2002 irrigation management under water scarcity. Agricultural water management 57 (2002) 175 – 206.
12. Martin. R.C. (1993). Soil Sampling and Methods of analysis. (2nd Edition) Lewis Puplishers, Washington D.C. USA, PP 499-569.
13. Murthy, V.R.K. 2002.Basic principles of Agricultural Meteorology. Book syndicate publishers, Koti, Hyderabad, India.
14. Phocaides.2000. Technical Handbook on Pressurized Irrigation Techniques; Food and Agriculture Organization of the United Nations.
15. Rajurkar G, Patel N, Rajput TBS and Varghese C (2012).Soil water and nitrate dynamics under drip irrigated cabbage. *Journal of Soil and Water Conservation* 11(3) 196-204.
16. Rao, V. U. M., Singh, D., and Singh, R. (1999). Heat use efficiency of winter crops in Haryana. Journal of Agro-meteorology, 1(2), 143-148.

17. Snyder, R., Spano, D., Cesaraccio, C., and Duce, P. (1999). Determining degree-day thresholds from field observations. International Journal of Biometeorology, 42, 177-182.
18. Singh J, Pandey UC, Kohli VP (1990) Response of vegetable pea to irrigation. Journal of vegetable science 17:11–15.
19. Singh K, Vashistha RN, Pandita ML, Batra BR (1976) Effect of mulching on growth, and yield of cucurbits under rain fed condition. Journal of Haryana Horticultural Science 5:87–91.
20. Tan Y, Lai J, Adhikari KR, Shakya SM, Shukla AK, and Sharma KR (2009). Efficacy of mulching, irrigation and nitrogen application on bottle gourd and okra for yield improvement and crop diversification.*Irrigation Drainage System* 23(2) 5-41.
21. Tindall HD (1983) Vegetables in the Tropics. Macmillan Press, London.
22. Zhang, H. and Oweis,T.,1999 water-yield relations and optimal irrigation scheduling of wheat in the Mediterranean region. Agric. water management. 38, 195-211.

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