Estimation of Growing Degree Days and Actual Evapotranspiration for Squash Crop Using Heat Units and Neutron Scattering Method

Yousef. Kh. M., Salama M.A. and Mostafa A.Z.

Soil and Water Research Department, Nuclear Research Center, Atomic Energy Authority, 13759 Abou Zaabl, Egypt
mostafa_zhran@yahoo.com

Abstract: Actual evapotranspiration (ET_a) is the actual amount of water uptake by plant, which is determined by measuring changes in soil water content, using neutron scattering method at depths of 30, 50 and 70 cm. The values of ET_a were estimated through the plant growth stages initial, crop development, mid-season and late-season. the actual amount of water evaporate and uptake by squash was lower (457.4 mm) than that estimated with the seasonal crop water requirement for the squash crop CAVILLI variety (516.1 mm), The maximum actual water use is 173.5 mm (1735 m^3 ha^{-1}) was occurred with the critical 21 days (mid-season) of the squash growth stage. Cumulative growing degree days (AGDD) for squash were calculated during the experiments using daily minimum and maximum temperature and squash crop required 186 GDD to complete 100% of its initial stage. In the mid-season the GDD for squash crop recorded high value (425.5 mm) when compared to the all growth stages. Generally, the squash plant requires 1381 GDD to complete all its growth stage.

[Yousef. Kh. M., Salama M.A. and Mustafa A. Z. **Estimation of Growing Degree Days and Actual Evapotranspiration for Squash Crop Using Heat Units and Neutron Scattering Method.** *J Am Sci* 2013;9(10):302-307]. (ISSN: 1545-1003). http://www.jofamericanscience.org. 39

Key words: Growing degree days, Actual evapotranspiration, Squash, Neutron probe.

1. Introduction

Cucurbits play a significant role in human nutrition, especially in tropical countries where their consumption is high. Cucurbits crops constitute a major portion and are grown in different regions in Egypt. Squash was ranked the second among the popular cucurbits preceded by watermelon for the cultivated area where it was grown on an area of 23445 hectare with production of 1181527 ton and productivity of 50.4 ton ha^{-1} **(According to Ministry of Agriculture Static's, 2008).**

Temperature is a major environmental variable influencing plant development, and heat units (HUs) or growing degree-days are used extensively to normalize time to crop developmental events in response to temperature **(Ritchie and NeSmith, 1991)**. The HU approach is used for a variety of vegetable crops including sweet corn (*Zea mays* L.), peas (*Pisum sativum* L.), tomato (*Lycopersicon esculentum* Mill.), lettuce (*Lactuca sativa* L.), and cucumber (*Cucumis sativus* L.) (**Boswell, 1929; Madariaga and Knott, 1951; Arnold, 1959; Logan and Boyland, 1983; Perry *et al.,* 1986**). Generally, Cucurbits are warm climate crops which are both cold weather and frost sensitive and most of them require relatively high temperatures for germination (**Nerson, 2007**). Minimum and maximum germination temperatures have been reported from 15 to 45°C, respectively, with large differences among cultivars (**Singh, 1991**). Optimum germination temperatures (T_o) range from 20 to 32°C; while 15 and 38°C are the minimum and maximum germination temperature, respectively (**Milani *et al.,* 2007**).

Crop evapotranspiration are an important components used in the planning, design, construction, operation, and maintenance of irrigation systems (**Güngr, 1990**). Because crop evapotranspiration largely depends on soil and climatic conditions, it must be determined for each crop in different regions (**Ertek *et al.,* 2002**). The conducted studies reveal that climate change will play a restrictive role for water resources all over the world **(Fıstıkoğlu, 2008)**. In order to set up the most suitable irrigation program for cultivated crops, one needs to know the predicted evapotranspiration values of crop.

ET is the water used by a crop for growth and cooling purposes. This water is extracted from the soil root zone by the plant root system, which represents transpiration and is no longer available as stored water in the soil. "ET" is used interchangeably with crop water use. **(Al-Kaisi and Broner 2009).**

Neutron moisture scattering method offers the advantage of measuring a large soil volume, and the possibility of scanning at several depths to obtain a profile of moisture distribution. However, it also has a number of disadvantages: the high cost of the instrument, radiation hazard, insensitivity near the soil surface, insensitivity to small variations in moisture content at different points within a 30 to 40 cm radius, and variation in readings due to soil density variations, which may cause an error rate of up to 15 percent **(Phene, 1988).**

The objective of the current study is to estimate growing degree days, actual evapotranspiration and water use efficiency (WUE) for summer CAVILLI squash crop using heat units and neutron scattering method.

2. Materials and methods

Filed experiment was conducted at the farm of soil & water research department, nuclear research center, atomic energy authority. Chicken manure was added at the rate of 48 m^3 ha^{-1} according to Egyptian Ministry of Agriculture, was mixed with the upper 20 cm of the soil layer, before cultivation.

Plant *Cucurbita pepo* CVVILLI variety was cultivated at spacing of 30 cm between plants inter row and 75 cm between plant row. Neutron moisture meter was used to detect soil moisture to 70 cm depth to determine the actual evapotranspiration; the moisture values were recorded from 30 to cm depth before and after irrigation, the surface layer was measured by gravimetric method to estimate the depletion has done **(Evett *et al.,* 1993)**. Tables (1, 2 & 3) show some physical and chemical properties of the soil.

Table (1): Some physical properties for investigated soil

Soil depth cm	Particle size distribution			Texture class	Bulk density g/cm^3	Total porosity cm^3 cm^{-3}
	Sand	Silt	Clay			
30	98.73	0.80	0.47	Sand	1.78	0.32
50	98.63	0.87	0.50	Sand	1.77	0.33
70	98.57	0.70	0.70	Sand	1.73	0.34

Table (2): Some physical properties for investigated soil

Soil depth cm	Soluble cations (meq/L)				Soluble anions (meq/L)				SAR	EC dS/m Soil paste	PH 1:2.5
	K^+	Mg^{++}	Ca^{++}	Na^+	CO_3^-	HCO_3^-	Cl^-	SO_4^{--}			
30	0.19	1.3	4.4	2.7	--	3.2	5.2	0.19	1.599	0.62	7.76
50	0.19	1.3	4.5	2.6	--	3.2	5.2	0.19	1.527	0.64	7.76
70	0.18	1.6	4.0	3.6	--	3.5	5.1	0.78	2.151	0.67	7.77

Table (3): Some chemical properties for chicken manure

Determination	Values
Dry matter (% d.w.)	75.6 ± 3.2
pH(H2O)	8.00 ± 0.32
EC (dS m-1)	6.2 ± 1.36
Ash (% d.w.)	23.0 ± 0.1
Organic C (% d.w.)	37.8 ± 2.2
Total N (% d.w.)	5.14 ± 0.45
C/N ratio	7.35 ± 0.54
K (% d.w.)	3.30 ± 0.20
Ca (% d.w.)	2.64 ± 0.63
Mg (% d.w.)	1.030 ± 0.31
Na (% d.w.)	1.33 ± 0.340

Irrigation water was applied every two days based on calculated water requirements for cucurbits according to reference crop evapotranspiration using Penman-Monteith equation ***(Equation 1)*** and single crop coefficient (K_c) **(Allen *et al.,* 1998)**, the amount of water scheduled throughout the plant growth season and crop coefficient (K_c).

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

Where:

Δ: Slope vapour pressure curve [kPa °C^{-1}],
ET_o: Reference evapotranspiration [mm d^{-1}],
R_n: Net radiation at the crop surface [MJ m^{-2} d^{-1}],
G: Soil heat flux density [MJ m^{-2} d^{-1}],
u_2: Wind speed at 2 m height [m s^{-1}],
γ: Psychometric constant [kPa °C^{-1}].
e_s - e_a: Saturation vapour pressure deficit [kPa],

Cumulative growing degree-days (GDD) for squash were calculated during the experiments using daily minimum and maximum temperature data recorded near the site. The ***Equation (2)*** used for calculating GDD was;

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

Where:

T_{max}: daily maximum temperature (°C),
T_{min}: daily minimum temperature (°C), and
T_{base}: base temperature (°C).
T : Air temperature at 2 m height [°C],
e_s : Saturation vapour pressure [kPa],
e_a : Actual vapour pressure [kPa],

Two additional conditions or constraints were used in the calculation. If Tmin was less than T_{base}, then it was set equal to T_{base}. Also, if T_{max} exceeded 32 °C, it was set equal to 32 °C. The base temperature and the 32 °C ceiling temperature were assumed for these calculations based on germination data for several of these cultivars at constant temperatures **(NeSmith and Bridges, 1992).**

Neutron calibration curves for neutron moisture meter at different soil depths were determined, according to **IAEA (2003)** ***Table (4).***

Table (4): Calibration curves of neutron moisture meter at different soil depths at the studied soil layers

Soil Depths	Regression equation	Coefficient of determination (R^2)
30	θ =8.25 C.R +0.620	0.994
50	θ =31.25 C.R -9.228	0.994
70	θ =25.24 C.R -6.963	0.845

3. Results and discussion

3.1 Weather characteristics

The field experiment was conducted during the growing season 2011 from 3rd June to 23rd Augusts (82 days), which is equivalent to three months. The experiment site, which located at latitude 30° 24\` N , longitude 31° 35\` E and altitude of 20 m (above mean sea level), is characterized by Mediterranean climate (arid and semiarid zone conditions), Season was characterized by absence of rains during the growing season of squash crop ***Table (5),*** and high daily temperatures until July, The most notable observation among the monthly trends of the growing season that the monthly average maximum and minimum temperatures was approximately 35.32 °C and 23.57 °C respectively during June and July, then it tend to decline by 13 °C approximately during Augusts.

Table (5)*:* Metrological data of Inshas area during the growing season of squash crop

Period		Temperature		Relative humidity		Wind speed	Sun shine	Net radiation	Preci-pitation
Months	**Duration**	T_{max}	T_{min}	RH_{max}	RH_{min}	U_2	**n**	R_n	**P**
	D	**(°C)**	**(°C)**	**(%)**	**(%)**	**(m s^{-1})**	**(hr d^{-1})**	**(MJ m^{-2} d^{-1})**	**(mm d^{-1})**
Jun.	**3-12**	33.90	21.20	76.60	18.60	6.80	12.3	15.79	0.00
	13-22	35.90	23.20	82.20	21.90	4.80	12.3	16.41	0.00
	23-30	35.50	23.50	79.63	24.13	5.00	12.3	16.42	0.00
Jul.	**1-10**	34.60	23.50	81.70	23.80	5.40	12.3	16.39	0.00
	11-20	36.70	25.30	81.20	21.40	5.60	12.1	16.17	0.00
	21-31	35.36	24.73	83.00	29.27	4.00	12.0	16.24	0.00
Aug.	**1-10**	22.50	12.90	78.40	23.40	3.20	11.8	14.31	0.00
	11-20	22.20	11.10	77.20	21.80	4.80	11.3	13.40	0.00
	21-23	22.33	7.67	85.00	19.00	5.00	10.9	12.71	0.00

The Crop evapotranspiration (ET_c), reference crop evapotranspiration (ET_o), crop coefficient (K_c), actual evapotranspiration (ET_a) and growing degree days (GDD) for squash at different growth stages of growing season are shown in ***Table (6).*** It is important to mention that the irrigation water requirements of squash through the growing season were calculated based on the determination of crop evapotranspiration (ET_c) according to **Allen *et al.,* 1998.** The seasonal crop water requirement for the CAVILLI squash was estimated at 516.1 mm. The planting date was 3rd June 2011. From planting to 10 % ground cover took 10 days and the average total water applied through the initial stage was 16.9 mm (169 m^3 ha^{-1}). The next critical period was the development stage (20 days) which was the point of 75 % ground shading. The period from 13 June to 2 July was a critical 21 days period of maximum water use 187.5 mm (1875 m^3 ha^{-1}). The irrigation was turned off on day 82. Similar trends were observed with the actual evapotranspiration, where the actual amount of water uptake by CAVILLI squash increased with the growth stage, it's values ***Table (6)*** varied with the variation of the squash growth stage, soil and climatic conditions. The maximum actual water use 173.5 mm (1735 m^3 ha^{-1}) was occurred with the critical 21 days (mid-season) of the squash growth stage. Generally, the actual amount of water evaporate and uptake by squash crop was lower (457.4 mm) than that estimated with the seasonal crop water requirement for the CAVILLI squash (516.1 mm).

Regarding to growing degree days (GDD) for squash ***Table (6),*** the plant required 186 °C to complete 100 % of its initial stage. During the initial stage and the next growth stage, growing degree days were calculated with air temperature which not necessarily reflect the soil temperature to which seeds and hypocotyls are exposed to. According to other studies optimum germination temperatures range from 20 to 32 °C; while 15 and 38 °C are the minimum and maximum germination temperatures, respectively (**Milani *et al.,* 2007**).

The GDD needed to reach each phonological stage were estimated by calculating the distribution and height of plants at a determined stage within the growing degree days. The GDD for each stage was determined when 75 % of the plants had reached that stage. The initial stage go from emergence to 10 % ground cover took, 394 GDD is required for development stage. After that the plant goes onto the mid and late season where the GDD required was higher than these required for the first two stages. An expected GDD required for the mid-season recorded high value (425.5) when compared with all growth stages. Generally, the squash plant needs 1381 GDD to complete all its growth stage.

The typical values (Typical K_c) for $K_{c\ ini}$, $K_{c\ mid}$ and $K_{c\ end}$ are 0.5, 0.95 and 0.75 respectively **(Allen *et al.,***

1998), Table 6 represent those for a sub-humid climate with an average daytime minimum relative humidity (RH_{min}) of about 45 %, with calm to moderate wind speeds averaging 2 m s^{-1} and mean plant height during the stage (m). For more humid or arid conditions, or for more or less windy conditions, the K_c coefficients for the initial, mid-season and end of late season stage should be modified (Modified K_c) as resulted in Table 6.

Table (6): Crop evapotranspiration (ET_c), reference crop evapotranspiration (ET_o), crop coefficient (typical K_c and modified K_c), actual evapotranspiration (ET_a) and growing degree days (GDD) for squash at different growth stages of growing season.

Growth Stages	Day (No.)	ET_c (mm/stage)	ET_o (mm/stage)	Typical K_c (-)	Modified K_c (-)	ETa (mm/stage)	GDD (^oC)
Initial	10	16.9	96.5	0.50	0.18	16.6	186.0
Development	20	135.6	186.5	-	-	109.0	394.0
Mid-season	21	187.5	191.8	0.95	0.98	173.5	425.5
Late	31	176.1	205.4	0.75	0.84	158.3	375.5
Total	82	516.1	680.2	-	-	457.4	1381.0

A hypothetical 10- day temperature data set illustrates how to calculate 10- day growing degree days (GDD). The basic equation used is $GDD=[(T_{max}+T_{min})/2]-T_{base}$. A difference of the real temperature and adjusted temperature occurred between the upper temperature (32 ^oC) and low temperature two (8 ^oC) for squash ***(Table 7).*** In situations where T_{max} exceed T_{ut} (upper threshold temperature) then T_{max} equal T_{ut}, also when T_{min} less than T_{base} then T_{min} equal T_{base}. This is the most commonly used method in calculating GDD for squash, but is used for other crops as well **(e.g., Tollenaar *et al.,* 1979; Russelle *et al.,* 1984; Baker *et al.,* 1986; Edwardson and Watt, 1987; Wilhelm *et al.,* 1987, 1989; Bauer *et al.,* 1988; Cutforth and Shaykewich, 1989; Ketring and Wheless, 1989; Masoni *et al.,* 1990; Swanson and Wilhelm, 1996).**

Table (7): Example of calculating growing degree-days (GDD) using the average method for squash crop. The data are hypothetical and used to various temperature combinations. The base temperature (T_{base}) used is 8 ^oC and upper threshold temperature (T_{ut}) is 32 ^oC.

Day	Real temperature (^oC)			Adjusted temperature (^oC)			GDD	AGDD
	T_{max}	T_{min}	T_{avg}	T_{max}[a]	T_{min}[b]	T_{avg}	(^oC day)	(^oC day)
1	37	25	29.0	**32**[c]	25	28.5	20.5	20.5
2	38	27	31.0	**32**	27	29.5	21.5	42.0
3	25	17	32.5	25	17	21.0	13.0	55.0
4	23	10	21.0	23	10	16.5	8.5	63.5
5	23	17	16.5	23	17	20.0	12.0	75.5
6	20	14	20.0	20	14	17.0	9.0	84.5
7	22	16	17.0	22	16	19.0	11.0	95.5
8	22	15	19.0	22	15	18.5	10.5	106.0
9	23	15	18.5	23	15	19.0	11.0	117.0
10	23	6	19.0	23	**8**	15.5	7.5	124.5
11	22	8	14.5	22	**8**	15.0	7.0	131.5
12	22	11	15.0	22	11	16.5	8.5	140.0
13	25	15	16.5	25	15	20.0	12.0	152.0
14	24	5	20.0	24	**8**	16.0	8.0	160.0
15	22	3	14.5	22	**8**	15.0	7.0	167.0

[a] If $T_{max} \geq T_{ut}$, then $T_{max}=T_{ut}$

[b] If $T_{min} \leq T_{base}$, then $T_{min}=T_{base}$

[c] Number in highlight were adjusted

Table (8) illustrate the mean 10 day monthly, real and adjusted temperature, growing degree days (GDD) and accumulated growing degree days (AGDD) during squash growing season, ***Figure (1)*** illustrated the relation between the accumulated crop evapotranspiration (ET_c) and accumulated growing degree-days (AGDD), there is a power response between (ET_c) and accumulated growing degree days. In addition, the same trends was found between (AGDD) and plant height ***Figure (2)***, and the relation between (AGDD) and growth seasons (days) ***(Figure 3)***, **Berti and Johnson, 2008** reported that there is a significant linear response between plant height and GDD. In addition, **Gesch et al. (2002)** reported that there is response with cuphea planted at different seeding dates, as GDD increased cuphea plant height increased linearly.

Table (8): Mean 10 day monthly, temperature, growing degree days (GDD) and accumulated growing degree days (AGDD) during squash growing season.

Month	Day	Real temperature (°C)		Adjusted temperature (°C)		GDD	AGDD
2012	D	T_{max}	T_{min}	(°C day)	(°C day)	(°C)	(°C day)
Jun.	3-12	33.9	21.2	32.0	21.2	186.0	186.0
	13-22	35.9	23.2	32.0	23.2	196.0	382.0
	23-30	35.5	23.5	32.0	23.5	158.0	540.0
Jul.	1-10	34.6	23.5	32.0	23.5	197.5	737.5
	11-20	36.7	25.3	32.0	25.3	206.5	944.0
	21-31	35.4	24.7	32.0	24.7	224.0	1168.0
Aug.	1-10	22.5	12.9	22.5	13.1	98.00	1266.0
	11-20	22.2	11.1	22.2	12.0	91.00	1357.0
	21-23	22.3	7.70	22.3	9.70	24.00	1381.0

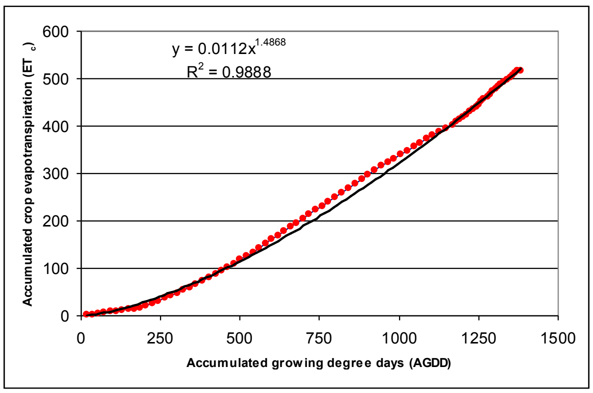

Figure (1): Power regression equation for squash plant crop evapotranspiration (ET_c) affected by accumulated growing degree days (AGDD) from planting date to harvest.

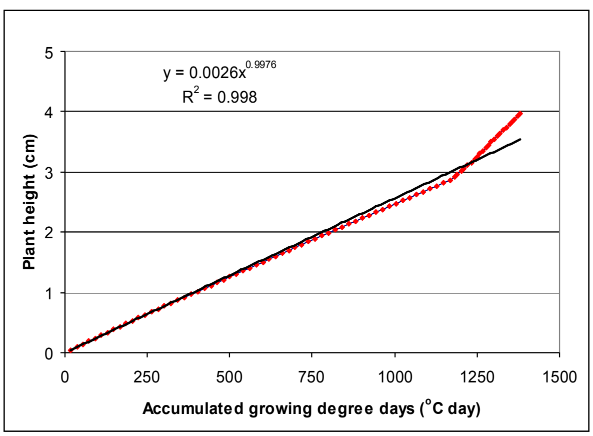

Figure (2): Power regression equation for squash plant crop height affected by accumulated growing degree-days (AGDD) from planting date to harvest.

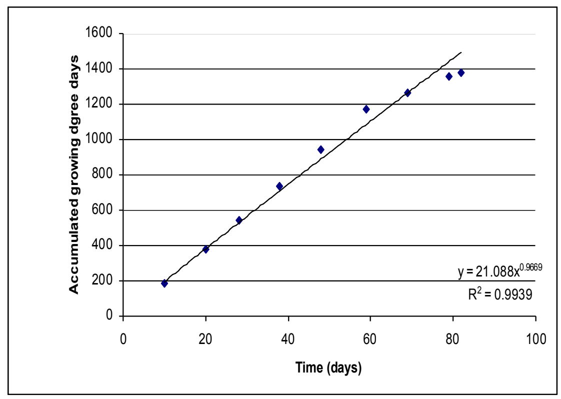

Figure (3): Power regression equation illustrates the relationship between accumulate growing degree days and growing days.

Heat use efficiency (HUE).

The heat use efficacy for squash crop estimated by the following formula, it was 3.9776 kg ha^{-1} $°C^{-1}$ day^{-1} for the squash plant under the experiment condition.

$$HUE = \frac{yield\,(Y)}{Accumulated\ heat\ units\,(AHU)} = \frac{5493}{1381} = 3.9776 \quad \text{kg ha}^{-1}\ {}^{o}\text{C}^{-1}\ \text{day}^{-1}$$

Where:

HUE : Heat use efficiency (kg ha^{-1} $°C^{-1}$ day^{-1})
AHU : Accumulated heat units (°C day)
Y : Yield (kg ha^{-1}),

4. Conclusions

Squash growth was characterized and related to thermal time. Plant height and crop evapotranspiration (ET_c) increased in a power relation as GDD accumulated during the growing season. Combined analysis across environments, for plant height, indicated a significant power response between plant height and AGDD ($P \leq 0.05$) (Fig. 1). Squash growth stages were classified as initial, crop development, mid-season and late-season.

In the mid-season, the actual evapotranspiration (ET_a) and GDD for squash crop recorded high values when compared to the all growth stages *(Table 6)*. Generally, the squash plant requires 1381 GDD and 4574 m^3 water ha^{-1} to complete all its growth stage.

References

1. *Al-Kaisi, M.M., Broner, I., 2009*. Crop water use and growth stages. Crop Series (Irrigation), No. 4. 715. Colorado State University Extension, www.ext.colostate.edu.
2. *Allen, R.G., Smith, M., Perrier, A., Pereira, L.S., 1998*. Crop Evapotranspiration, Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper No.56. Food and Agriculture Organization of the United Nations, Rome, Italy.
3. *Arnold, C.Y., 1959*. The determination and significance of the base temperature in a linear heat unit system. Proc. Amer. Soc. Hort. Sci. 74:430–445.
4. *Baker, J.T., Pinter, Jr., P.J., Reginato, R.J., Kanemasu, E.T., 1986*. Effects of temperature on leaf appearance in spring and winter wheat cultivars. Agron. J. 78, 605-613.
5. *Bauer, A, Garcia, R., Kanemasu, E.T., Blad, B.L., Hatfield, J.L., Major, D.J., Reginato, R.J., Hubbard, K.G., 1988*. Effect of latitude on phonology of Colt winter wheat. Agric. For. Meteorol. 44, 131-140.
6. *Berti, M., and B. Johnso., 2008*. Growth and development of cuphea. industrial crops and products 27: 265–271.
7. *Boswell, V.R., 1929*. Factors influencing yield and quality of peas. Maryland Agr. Expt. Stat. Bul. 306.
8. *Cutforth, H.W., Shaykewich, C.F., 1989*. Relationship of development rates of corn from planting to silking to air and soil temperature and to accumulated thermal units in a prairie environment. Can. J. Plant Sci. 69, 121-132.
9. *Edwardson, S.E., Watt, D.L., 1987*. GROWTH STAGE: Using growing degree days to predict the Haun scale of spring wheat. Appl. Agric. Res. 2, 224-229.
10. *Ertek, A., Şensoy, S., Yıldız, M, Kabay, T., 2002*. Açık su yüzeyi buharlaşmasından yararlanılarak sera koşullarında patlıcan bitkisi için en uygun sulama dozu ve aralığının belirlenmesi (in Turkish). K.S.Ü.Fen ve Müh.Dergisi, Cilt, Kahramanmaraş, 5: 57-67.
11. *Evett, S., Howell, A.T., Steiner, J.L., Cresap, L.L., 1993*. Management of Irrigation and Drainage, Div/ ASCE, Utah.
12. *Fıstıkoğlu, O., 2008*. Effect on the water sources of global climate change and adaptation measures. Global climate change and Turkey (in Turkish). TMMOB, Climate change Symposium, Ankara, pp.241-255.
13. *Güngör, H., 1990*. Research on a empirical method for determining of plant water consumption (in Turkish). Eskişehir Research Institute Publ., No: 223, Technical Publ., 23: 73.
14. Gesch, R.W., Forcella, F., Barbour, N.W., Phillips, B., Voorheees, W.V., 2002. Yield and growth response of Cuphea to sowing date. Crop Sci. 42, 1959–1965.
15. *IAEA, 2003*. Neutron and gamma probe: Their use in agronomy" Training course series 16 Vienna.
16. *Ketring, D.L., Wheless, T.G., 1989*. Thermal time requirements for phonological development of peanut. Agron. J. 81, 910- 917.
17. *Logan, S.H., Boyland, P.B., 1983*. Calculating heat units via a sine function. J. Amer. Soc. Hort. Sci. 108:977–980.
18. *Madariaga, F.J., Knott, J.E., 1951*. Temperature summations in relation to lettuce growth. Proc. Amer. Soc. Hort. Sci. 58:147–152.
19. *Masoni, A., Ercoli, L., Massantini, F., 1990*. Relationship between number of days, growing degree days and photothermal units and growth in wheat *(Triticurn uestiuum L.)* according to seeding time. Agric. Med. 120, 41 -51.
20. *Milani, E., Seyed, M., Razavi, A., Koocheki, A., Nikzadeh, V., Vahedi, N., MoeinFard, M., GholamhosseinPour, A., 2007*. Moisture dependent physical properties of cucurbit seeds. Int. Agrophys. 21: 157-168.
21. *Nerson, H., 2007*. Seed production and germinability of cucurbit crops. Seed Sci. Biotechnol. 1: 1-10.
22. *NeSmith, D.S., Bridges, D.C., 1992*. Summer squash germination in response to temperature. Proc. Natl. Symp. for Stand Establishment in Hort. Crops. Nov. 16–20, Ft. Myers, Fla. p. 15–22.
23. *Perry, K.B., Wehner, T.C., Johnson G.L., 1986*. Comparison of 14 methods to determine heat unit requirements for cucumber harvest. Hort. Science 21:419–423.
24. *Phene, C.J., 1988*. Soil water relations. Sensor and Techniques for Irrigation Management. Center for Irrigation Technology, California State Univ., Fresno, CA 93740-0018. pp. 127-138.
25. *Ritchie, J.T., NeSmith D.S., 1991*. Temperature and crop development. InRJ Hanks, JT Ritchie, eds, Modeling Plant and Soil Systems. Monograph Number 31. American Society of Agronomy, Madison, WI, pp 5–29.
26. *Russelle, M.P., Wilhelm, W.W., Olson, R.A., Power, J.F., 1984*. Growth analysis based on degree days. Crop Sci. 24, 28-32.
27. *Singh, D.K., 1991*. Effect of temperature on seed germinability of Momordica charantia L. cultivars. New Agriculturist 2: 23-26.
28. *Swanson, S.P., Wilhelm, W.W., 1996*. Planting date and residue rate effects on growth, partitioning, and yield of corn. Agron. J. 88.
29. *Tollenaar, M., Daynard, T.B., Hunter, R.B., 1979*. Effect of temperature on rate of leaf appearance and flowering date in maize. Crop Sci. 19, 363-366.
30. *Wilhelm, W.W., Bouzerzour, H., Power, J.F., 1989*. Soil disturbance-Residue management effect on winter wheat growth and yield. Agron. J. 81, 581-588.
31. *Wilhelm, W.W., Schepers, L.N., Mielke, J.S., Doran, J.W., Ellis, J.R., Stroup, W.W., 1987*. Dryland maize development and yield resulting from tillage and nitrogen fertilization practices. Soil Tillage Res. 10, 167-179.

9/22/2013