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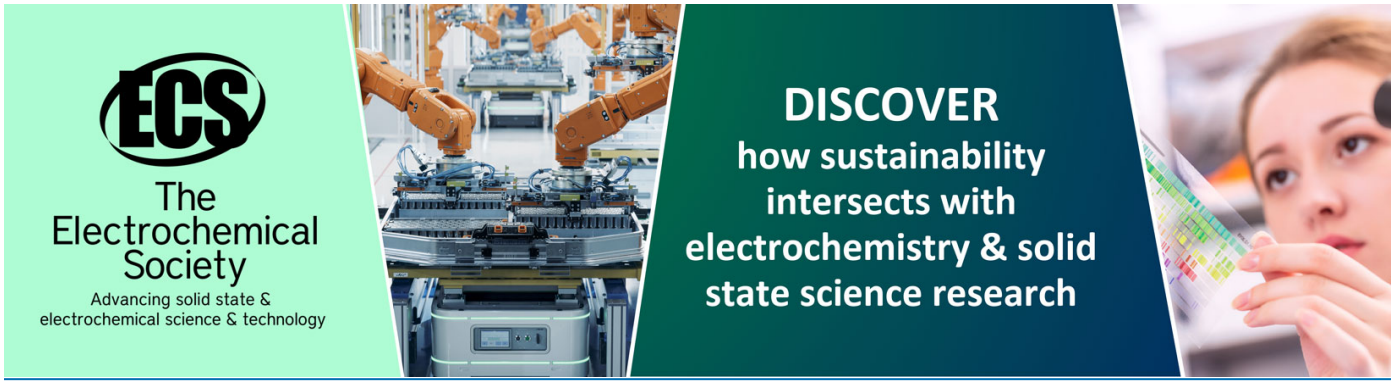

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Calculation Crop Coefficient of Okra with respect to Multi parameters by using dimensional analysis

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Abstract. The dimension analysis is solve to more difficult problem, simplify to difficult equation, reduce the many parameters in equations and search on the parameters more effect of equations. Increase the evaporation from soils and surfaces water with increase transpiration from plants because of raising in temperatures and reducing in humidity are problems of the times which effect on reducing of water. To solve the problems must research on formulas which give actual effects to control on the water reduction by evapotranspiration. In this study will search on methods to solve the crop coefficient (K_c) and evapotranspiration (ET) with multi variables. In this research will be driven equations by statistic of excel program of reference evapotranspiration (ET_o) and crop evapotranspiration (ET_c) with respect to. From equations and drawings were obtained on maximum value of correlation coefficient(R^2). In addition to use the dimension analysis to multi variables (time, number hours of days, relative humidity, change of moisture content, hydraulic conductivity, root depth and temperature) with maximum value of (R^2). Researching on equations and methods help to obtain results instead of going back to tables and curves as well reducing field tests that are tired. From equations of ET_o and ET_c are obtained on R^2=0.999 and R^2= 0.997, respectively from data. From statistic and dimension analysis equations are obtained on result very close with field data with little difference 10% and 4.28%, respectively.

1. Introduction

The utilization of dimensional analysis and statically analysis methods were best methods to solve and simplify equations as well as connect the variables with each other to obtain on best methods to connect multi parameters. These methods help to simplification equation and connection among variable. Many from researches tended to simplify the equations and reduce the effort on the farmers and workers by simulations, optimization equation and dimensions analysis.

The idea using dimension analysis is to simplify the physical laws that not depend on arbitrarily selected basic units of measuring [1]. [2] mentioned the utilization the dimensional analysis for simplifying and finding the equations to connect among variables. The absolute numerical equality of quantities may be finding only during a quantities are same a qualitatively.[17]states that in Dimensional analysis theory is explained by a similarity law for the phenomenon below consideration. In dimension

analysis the variables turn to dimension simple which are Mass, Length, Time and Temperature (M LT θ).[3] mentioned about calculation crop coefficient (K_c) value was equal to the ratio between actual evapotranspiration (ET_c) and reference evapotranspiration (ET_o). The properties of crop are varying through the season that influence on the K_c value.[4] estimated the crop coefficient (K_c) values of crops through the stages of growth for various sites in Iraq. The estimated K_c values were estimated by utilizing equations estimated by FAO for growing season, that depending on humidity , temperature and wind speed in that areas.[5] assess the influence of different irrigation ways on okra ET_c. The research was carried out in four experimental plots in the soil sand soil texture sited in Ghana. Crop coefficient (K_c) values of crop were calculated for growing season by utilizing FAO-56 also.[6] used the membrane sheet subsurface water retention technology (SWRT) below okra crop's root zone. The experimental work was done in site of the growing season 2017, at Sadat Al-Hindyia, Babylon of Iraq. The surface trickle irrigation system was used in the irrigation process inside the greenhouses. The accumulated crop evapotranspiration (ET_c)values in two treatments symbols T_1 andT_2 were identical. The average value of ET_c (mm/day) for treatment plots $T_1$and T_2 was 2.54 mm/day. The predicted crop coefficient (Kc) values of okra crop through growing season were 0.21, 0.63, 0.81, 0.5, of initial, development, mid of season and late of season respectively. [11], [13], [14],[15], [16] and [18] using the subsurface water retention technology to prevent the deep percolation water of crop water irrigation and increasing the productivity.

The aim of research is finding equations by dimension analysis to simplify the finding methods K_c value of crops and reducing the fieldwork, which was very tired. The using of dimensional analysis and statically analysis methods were best methods to solve and simplify equations as well as connect the variables with each other to obtain on best methods to connect multi parameters with crop coefficient (Kc). This study aims to obtain on real consumption of crops to obtain real water duty

2. Material and Method

In this study will be research on equations to reduce and simplify work and many equations. Utilizing the okra crops in study as sample of crop to obtain on equation of crop coefficient to simplify and reduce the effort of labors and farmers. Traditional calculation of K_c depending on the FAO 56 [3] was undertaken for calculating the irrigation requirement and scheduling the irrigation process through the growing stages. The K_c values is basically according to [3]

$$K_c = \frac{ET_c}{ET_o} \quad (1)$$

where:
ET_c: actual consumptive use of crop (mm /day), and
ET_o: reference evapotranspiration (mm /day),

From the experimental work and daily reading of ET_o estimated by atmometer device [6].

$$ET_o = \frac{0.408*\Delta(R_n-G)+\gamma\frac{900}{Tmean+237}U_2(e_s-e_a)}{\Delta+\gamma(1+0.34U_2)} \quad (2)$$

where:

R_n: net radiation at the crop surface (MJ/m^2 day), G: soil heat flux density (MJ/ m^2 day), T_{mean}: mean daily air temperature at 2m height (^{o} C), U_2: wind speed at 2 m height (m/s), e_s: saturation vapor pressure (kPa), e_a: actual vapor pressure (kPa), e_s-e_a : saturation vapor pressure deficit (kPa), Δ: slope vapor pressure curve (kPa/^{o} C) .γ: psychrometric constant (kPa/^{o} C)**[3].**

$$\Delta = \frac{4098\left[0.6108\exp\left(\frac{17.27\text{Tmean}}{\text{Tmean}+237.3}\right)\right]}{(\text{Tmean}+237.3)^2} \quad (3)$$

$$\boldsymbol{\gamma = 0.665 * 10^{(-0.33)} * Pa} \quad (4)$$

where Pa = atmospheric pressure [kPa].

In Iraq **[7]** and **[8], [12]** and **[18]** calculate ETo using atmometer.
Crop evapotranspiration (ET_c)
To estimate ET_c, the soil samples were taken to evaluate water content at previous day $\boldsymbol{\theta_p}$ and next day, $\boldsymbol{\theta_n}$. The crop evapotranspiration (ET_c) values for crops were calculated according to the following equation: **[9]**.

$$\boldsymbol{ET_c = (\theta_p - \theta_n) * D} \quad (5)$$

where D:depth of root zone

3. Study Area and Methodology

The equations, which are done depending on data, work of **[6]** that is working in sadat –Alhindiya township that sited in Babylon governorate 78 Km south of Baghdad. The latitude 32 º 40’ 47.62”N and longitude 44º 15'55.42"E, and altitude: 30m as **Fig.1**. The collection data of ET_o by atmometer apparatus as shown in **Fig.2** via measuring the reading of sight tube every day and calculate ET_o by deference between two successive reading.**[6]** used okra crops and planted it in loam soil and irrigate it by drip irrigation systems inside greenhouses. According to the measurements and related calculations , the values of Acc. ET_o and Acc. ET_c at growing season are summarized in **Table.1**.

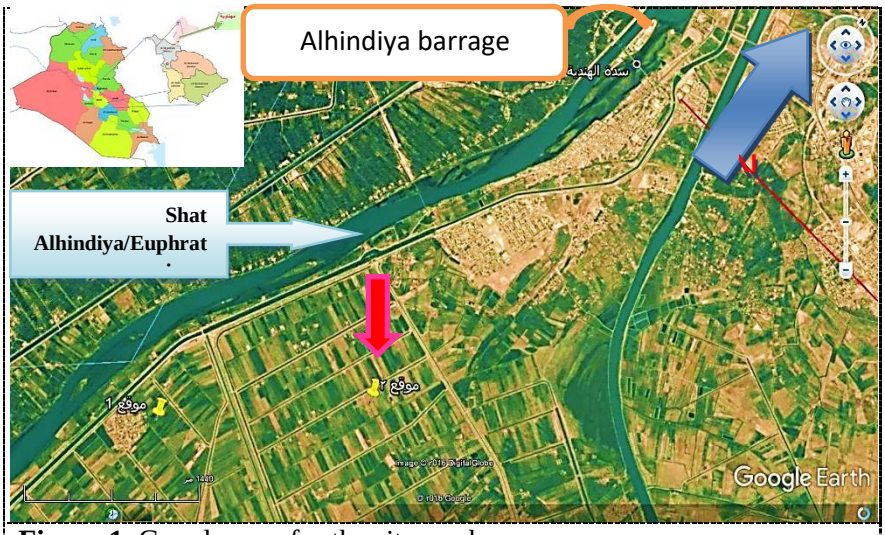

Figure 1. Google map for the site work

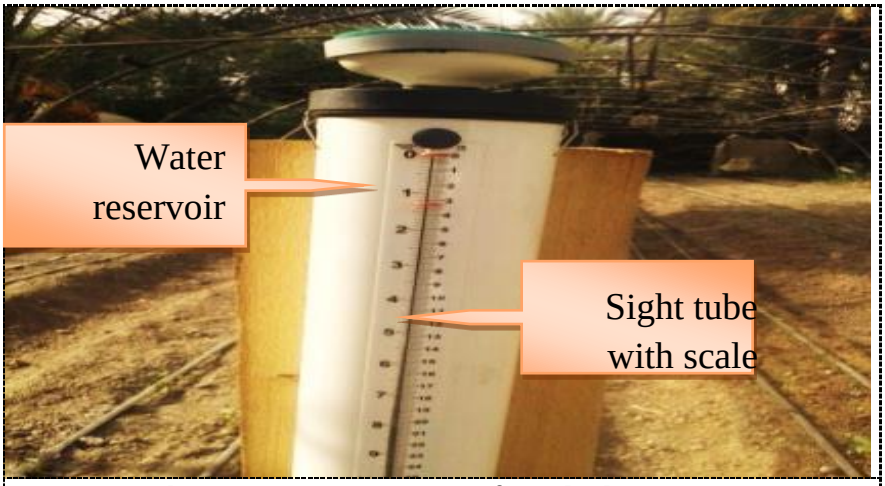

Figure 2. The Atmometer apparatus for calculating ETo.

Table 1. Daily values of Acc. ET_c, Acc. ET_o, and predicted K_c of okra crop depending on **[6]**

Date	Week	Acc. ET_o (mm)	Acc. ET_c	K_c
05-11Feb.	1	13	1.51	0.12
12-18Feb.	2	27	2.83	0.10
19-25Feb.	3	44.5	4.81	0.11
26-Feb.-4March	4	62.75	10.15	0.29
05-11March	5	86.25	19.67	0.41
12-18 March	6	108	34.78	0.70
19-25 March	7	128.26	48.19	0.66
26- March-1April	8	146.93	61.25	0.70
02-08 April	9	170	72.30	0.48
09-15 April	10	197.52	93.99	0.79
16-22 April	11	224.52	114.70	0.77
23-29 April	12	256.02	149.62	1.11
30- April-6May	13	292.03	176.32	0.74
07-13 May	14	329.03	209.44	0.90
14-20May	15	369.53	237.2	0.68
21-27May	16	402.86	260.98	0.70
28 May-03June	17	435.52	294.58	1.03
04-10June	18	472.52	326.19	0.86
11-17June	19	514.02	352.04	0.62
18-24June	20	552.52	376.56	0.64
25 June - 1 July	21	592.52	405.49	0.72
02-08 July	22	631.52	411.53	0.17
09-13 July.	23	663.52	416.44	0.15

4. The consumption of equation – time relationship

The table 2. shows the physical properties for the soil of the site work and from tringle texture obtain on loam texture of soil.

Table2.Physical properties for the soil of the site work.

kind of the test	Soil specifying
Bulk density (g/cm^3)	1.48
Sand	46.5
Silt	38
Clay	15.5
Texture	Loam

4.1 statistic equations

Using the statistic equations from data which is taking from Table1 and using Excel program will be obtained on Figure 3 and Figure4 which show the accumulated crop evapotranspiration (ETc) and reference evapotranspiration (ETo) with week by linear equation and power equation respectively. the relation in Figure 3 nonlinear is polynomial equation to compare with result of figure 4.

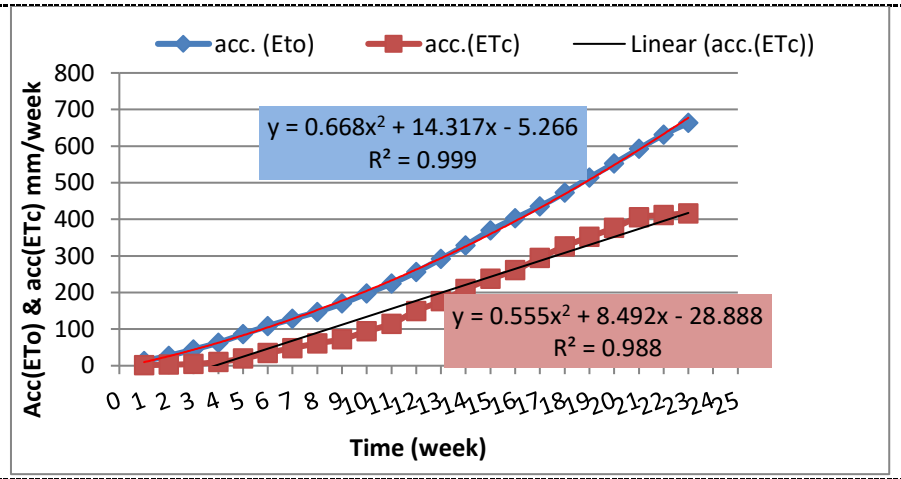

Figure 3. Relationship between acc. ET_c , acc. ET_o .and time (week) liner equation.

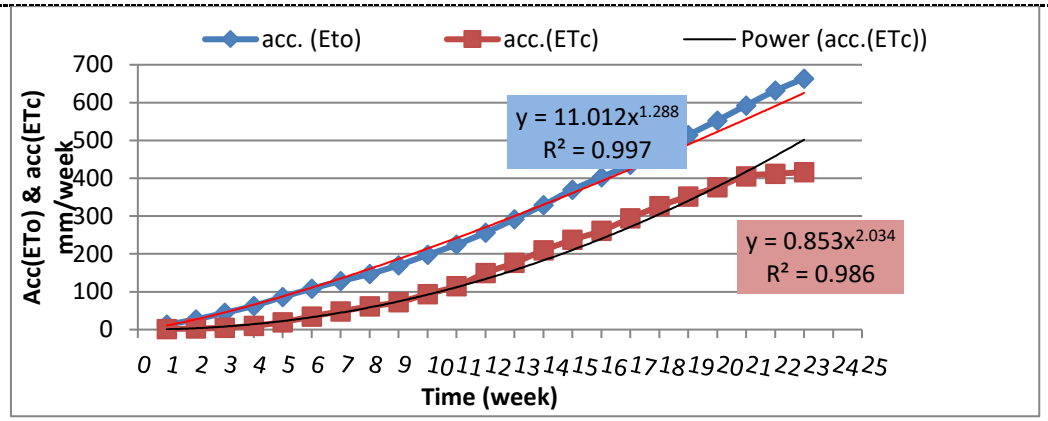

Figure 4. Relationship between acc. ET_c , acc. ET_o .and time (power relation)

From **Fig.3** obtain on equations 6 to 8 as following:

$Y1 == 0.668x^2 + 14.317x - 5.266$ (6)

Y1 (mm/day) : accumulated ET_o

X=T = accumulated time since planting (week) starts from 7day.

$Y2 = 0.555x^2 + 8.492x - 28.888$ (7)

Y2(mm/day) : accumulated ET_c

X=T = accumulated time since planting (week) starts from 7day.

$$K_{c1} = \frac{Y2}{Y1} = \frac{0.555x^2 + 8.492x - 28.888}{0.668x^2 + 14.317x - 5.266} \quad (8)$$

K_c at 16th week at 21-27th May-2017 was 0.67.

Make up for eq. (8) $Kc1 = \frac{0.555(16)^2 + 8.492(16) - 28.888}{0.668(16)^2 + 14.317(16) - 5.266} = 0.631$

Percent deference = (0. 7-0.631)/0.7)*100%=9.85%

From **Fig.3** obtain on equations 9 to 11 as following:

$Y3 = 11.012x^{1.288}$ Y3(mm/week) = acc. ETo (9)

$Y4 = 0.853t^{2.034}$ Y4(mm/week) = acc. ETc (10)

$$Kc2 = \frac{0.853t^{2.034}}{11.012t^{1.288}} = 0.078t^{0.75} \quad (11)$$

For example K_c at 16th week at 21-27th May-2017 was 0. 7.

Make up for eq. (11) $Kc2 = 0.078(16)^{0.75} = 0.63$

Percent deference = (0.7-0.63)/0.7*100%=10%

4.2 The dimension analysis equations

The utilization dimensional analysis method is best method to solve and simplify equations as well as connect the variables with each other to obtain on best methods to connect multi parameters. Using the dimension analysis equations depending on Buckingham theory (**π** theory)**[2]**. From method of **π** theory using as following:

The crop evapotranspiration (ET_c) and reference evapotranspiration (ET_o) from **[3]** as shown in equation 12-a.

$$ET_c = ET_o * K_c \quad (12\text{-a})$$

By utilizing dimension analysis will be searching on the variables that ET_c depends on them are ΔΘ, RD, Ks, T, P, RH and tn to obtain on as following:

$ET_c = F(\Delta\Theta, RD, Ks, T, P, RH, t)$

where:

ΔΘ = Change in soil moisture content % by vol. Dimensionless.

RD = root depth of plant . L

Ks = Saturation hydraulic conductivity. LT^{-1}.

Te = Mean temperature. Θ

P = Number of hour day as % from day. Dimensionless

RH = Relative humidity as %. Dimensionless.

t = time calculate from planting till end late of season. T

$$ET_c = C\alpha\ \Delta\Theta^{c1}\ RD^{c2}\ Ks^{c3}\ Te^{c4}\ P^{c5}\ RH^{c6}\ t^{c7} \quad (12\text{-b})$$

Cα = dimensionless constant depending on **π-term** may be number or depending on variables in equation as **π-term.**

No. of **π** = S, No. of quantity = n , No. of dimension = b.

S = n-b = 7-2 = 5

No. of **π = 5**

π 1 = ΔΘ, **π 2 = P**, **π 3 = RH, π 4 = Te**

$ET_c = C\alpha\ \Delta\Theta^{c1}\ RD^{c2}\ Ks^{c3}\ Te^{c4}\ P^{c5}\ RH^{c6}\ t^{c7}$

$LT^{-1} =$ **π 1*** $(L)^{c2}\ (LT^{-1})^{c3}$ **π 4 * π 2 π 3*** $(T)^{c7}$

L : 1 = C3+C2 ⟶ C2 = 1- C3

T: -1 = -C3 + C7 ⟶ C7 = -1 +C3

$$ET_c = C\alpha\ \Delta\Theta\ RD^{1-c3}\ Ks^{c3}\ Te\ P\ RH\ t^{-1+c3} \quad (12\text{-c})$$

$$ET_c = f(\Delta\Theta, Te, P, RH) * \frac{RD}{t} * \left(\frac{Ks*t}{RD}\right)^{c3} \quad (12\text{-d})$$

$$\frac{ETc*t}{RD} = f(\Delta\Theta, Te, P, RH) * \left(\frac{Ks*t}{RD}\right)^{c3} \quad (12\text{-e})$$

$$\frac{ETc*t}{RD} = C\alpha * \Delta\Theta * Te * P * RH * \left(\frac{Ks*t}{RD}\right)^{c3} \quad (12\text{-}f)$$

Where time in week from planting, RD = depth of root zone mm, Ks of loam = 1747.2 mm/week (24.96 cm/day) [10]

ET_c α % of hour days in week(P%), relative humidity(RH), temperature(Te), time(t), saturation hydraulic conductivity (Ks) and change of soil moisture content(ΔΘ).

The relation between the dimensionless groups are shown in figures 5,6,7,8 and 9

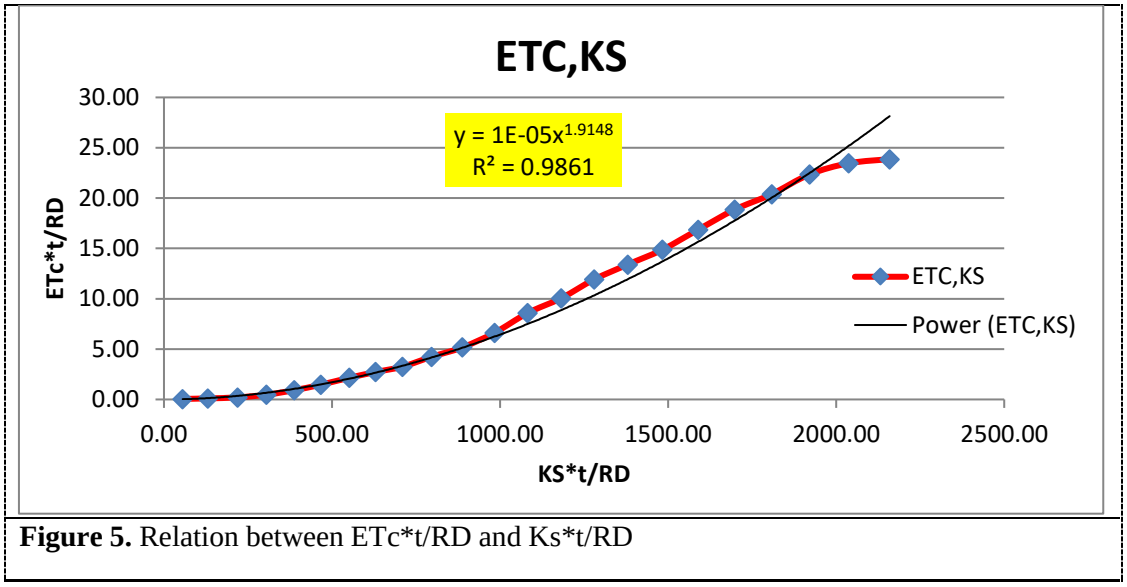

Figure 5. Relation between ETc*t/RD and Ks*t/RD

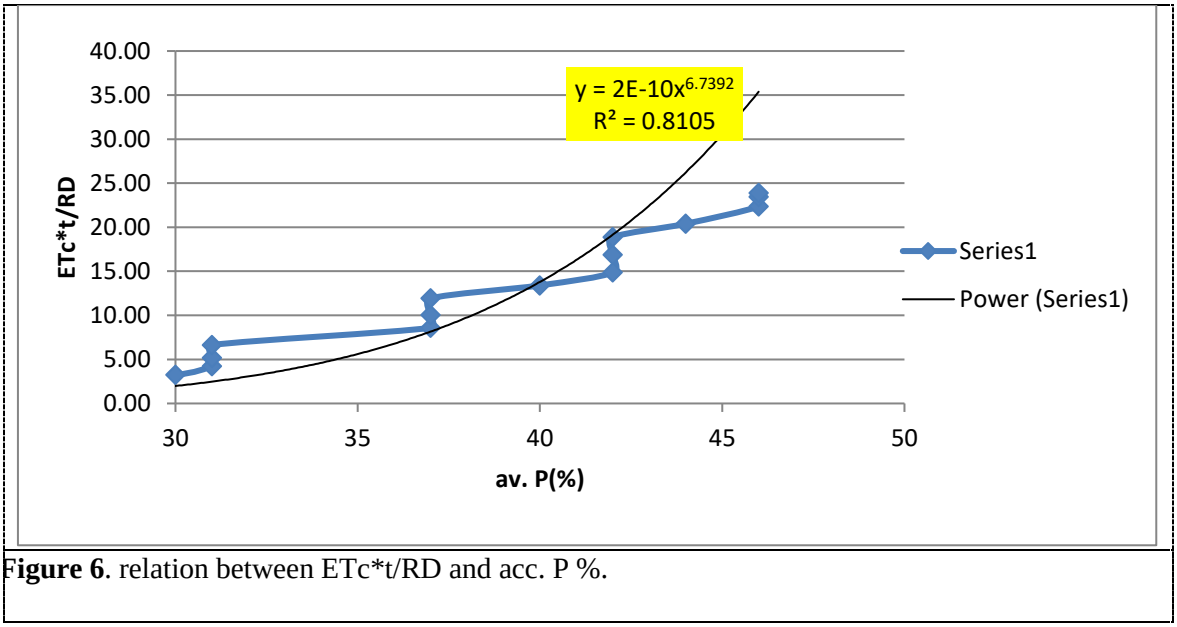

Figure 6. relation between ETc*t/RD and acc. P %.

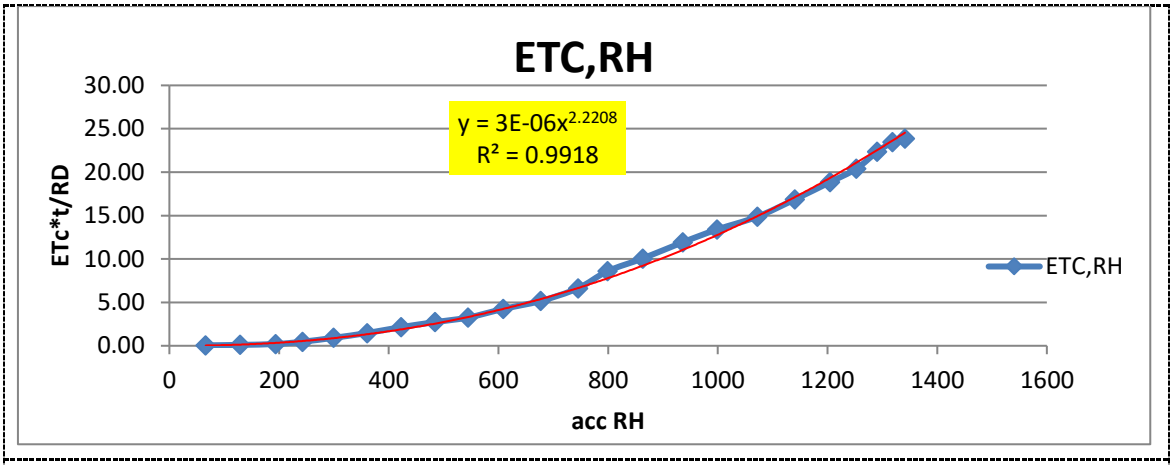

Figure 7. Relation between ETc*t/RD and acc. RH%.

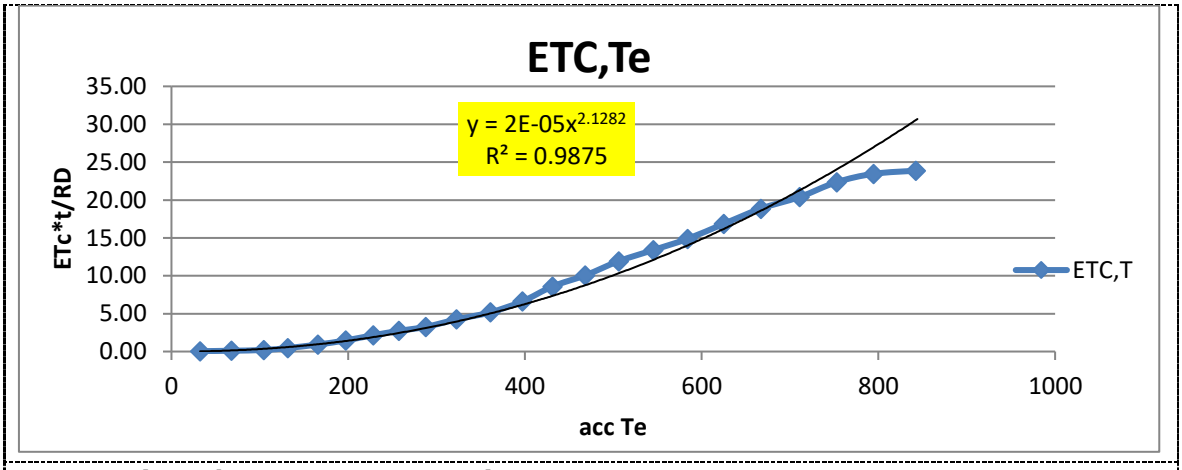

Figure 8. relation between ETc*t/RD and acc Te.

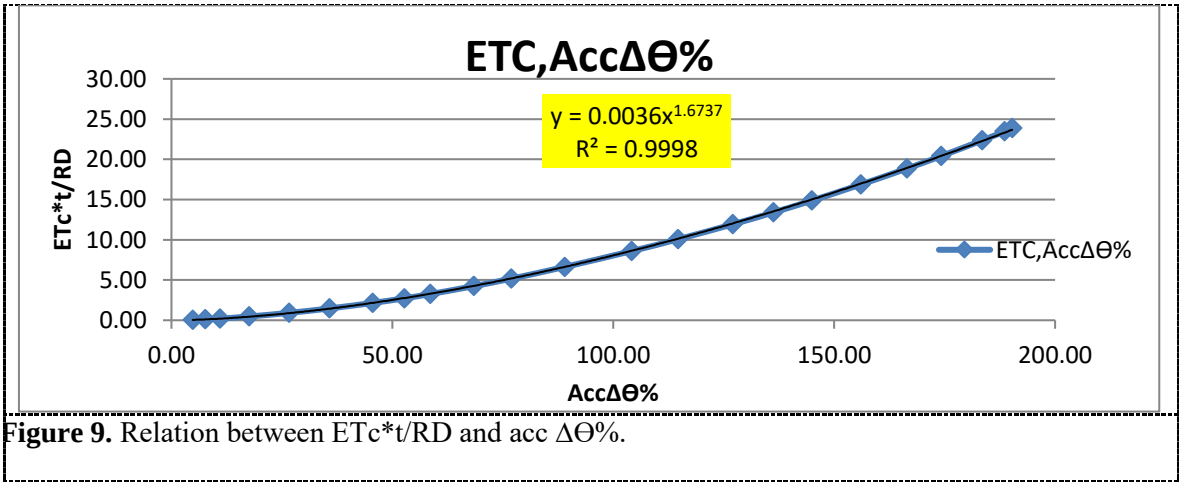

Figure 9. Relation between ETc*t/RD and acc ΔΘ%.

According to these figures the dimension analysis equations are:

$$\frac{ETc*t}{RD} = 3.6*10^{-3}*\Delta\Theta^{1.674}*2*10^{-5}*Te^{2.128}*2*10^{-10}*P^{6.74}*3*10^{-6}*RH^{2.221}*5*10^{-4}*\left(\frac{Ks*t}{RD}\right)^{1.915} \quad (13\text{-a})$$

$\frac{ETc*t}{RD}$ = 2. 16*10^{-28} *ΔΘ$^{1.674}$ * Te$^{2.128}$ *P$^{6.74}$ * RH$^{2.221}$* $(\frac{Ks*t}{RD})^{1.915}$ (13-b)

c3 = 1.915 and C α = 5.4 *10^{-21}

then

ET_c = 2.16*10^{-28} *ΔΘ$^{1.674}$ * Te$^{2.128}$ *P$^{6.74}$ * RH$^{2.221}$ * Ks$^{1.915}$* $(\frac{t}{RD})^{0.915}$ (14)

With compassion with the equation of ET_o estimated by

Kharrufa formula in 1985[11]

ET_o = 0.34 P Te$^{1.3}$ (15)

From equation (14-6)

ET_c = 2.16*10^{-28} *ΔΘ$^{1.674}$ * Te$^{2.128}$ *P$^{6.74}$ * RH$^{2.221}$ * Ks$^{1.915}$* $(\frac{t}{RD})^{0.915}$

$Kc = \frac{ETc}{ETo} = \frac{2.16*10^{-26} *\Delta\Theta^{1.674}* Te^{2.128} *P^{6.74} * RH^{2.221} * Ks^{1.915}* \left(\frac{t}{RD}\right)^{0.915}}{0.34\ P\ Te^{1.3}}$

K_c = 6.353*10^{-28} *ΔΘ$^{1.674}$ * Te$^{0.828}$ *P$^{5.74}$ * RH$^{2.221}$ * Ks$^{1.915}$*t$^{0.915}$ * RD$^{-0.915}$ (16)

The equation (16) extracted from dimension analysis and tables using excel program

Applied same example at K_c at 16th week at 21-27th May-2017 was 0.67.
in Eq. (16) and minus with 15th week then

Acc.K_c at 16th week = 6.353*10^{-28}*127.02$^{1.674}$* 506.1$^{0.828}$*37$^{5.74}$*936$^{2.221}$*1747.2 $^{1.915}$*0.79$^{0.915}$= 1.91

Acc.K_c at 15th week = 6.353 *10^{-28}*114.59$^{1.674}$* 468.2$^{0.828}$*37$^{5.74}$*863$^{2.221}$*1747.2 $^{1.915}$*0.733$^{0.915}$= 1.18

Acc.K_c at 16th week = 0.73 compared with Table 1was 0.70 the deference was 4.28%.

5. Result

From equations above are obtain on results near from excat field result which collection in closed filed (green houses). The example which applies in equation 16 was near from data of field collection. From the equation, statically solution and utilizing the dimension analysis that obtained on solving near from data of field which lead to use dimension analysis to simplify and reduce the collection methods of samples of data and find brief solutions also unification results. From equation 11 and equation 16 the values was near from field data of statically and dimension analysis are 10% and 4.28 %, respectively.

6. Discussion

The equations are obtained by using dimension analysis and statistical analysis by excel program to obtain K_c value of this research can be applied to connect several variables with each other to find best solutions and best methods and facilitate the solution of the equations. The relationship between ETc

and hydraulic conductivity (Ks) was strong where the value of correlation coefficient (R^2) was 0.986 while the relationship between ETc and percent of our day (P%) was less from the other relationships where was 0.81. The relationship between ETc and relative humidity (Rh), temperature (Te) and change in soil moisture content ($\Delta\Theta$) were strong where the value of correlation coefficient(R^2) were 0.992, 0.9875 and 0.999, respectively. The ETc depending on Rh, Te, Ks, P% and $\Delta\Theta$. The dimension analysis best methods helps to simplify the equations and relation between parameters.

7. Conclusions

In order to simplify the equations of consumptive use, many researchers attempts to solve the problem in fast and simple method. In this research use the field data was used to drive the simple equation by diminution analyses to obtain a simple and general equation for the loam texture soil for okra crop evapotranspiration. The field data helped to drive the equations of ET_c by using excel program (statistic equation) and dimension analysis.

The percent of deviation between the value of crop coefficient which are used by ordinary equation and extracted equation of statistical method is 4.28%. the percent of deviation between the value of crop coefficient which are used by ordinary equation and extracted equation by dimension analysis is 10%. The extracted equations from statistical and dimension analysis are represented the value of K_c changes with time(week). This equations use to loam soil texture and okra crops inside greenhouse.

8. Recommendation

- Using the dimension analysis to connect the crop evapotranspiration (ETc) and crop coefficient (Kc) with multi variables which are mentioned of paper with other soil textures and other crops.
- Utilizing the dimension analysis to connect the crop evapotranspiration (ETc) and crop coefficient (Kc) with multi variables which are mentioned of paper with other soil textures and strategic crops (wheat, parley and rice).
- Utilizing the dimension analysis to evapotranspiration with relative humidity, wind speed, temperature, sun shine, land cover, and number of hour through day of reservoirs, rivers, lakes and marshlands.

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