STATISTICAL EQUATIONS OF MAIZE CROP COEFFICIENT (Kc)

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ABSTRACT

An experiment was conducted at Ismailia Agric, Res. Station in two adjacent areas, one of them was cultivated with maize crop and the second was cultivated with alfalfa crop permanent all over the year.

Maize crop was cultivated for three years, in a time of 114 days each, started from day of year 160 to 274 in 1st year, from 138 to 252 in 2nd year and from 160 to 274 in 3rd year. From maize area crop evapotranspiration **(ET_C)** was calculated and from alfalfa area potential evapotranspiration **(ET_O)** was calculated. Area of maize crop was irrigated by drip regime but alfalfa crop was irrigated by sprinkler regime.

The results of **(ET_C)**, **(ET_O)**, were using calculated **(Kc).** **ET_O** - FAO-Penman-Montieth equation are summarized as follow:

- The average of maize coefficients **(Kc)** on alfalfa, and FAO-penman-monteith of the average of three seasons as well as the average of both was the same. Crop factor depend upon the growth stage of plant, whereas increased in the start period and then decreased in the late period.
- **ETc** , **ETo-alfalfa** , **ETo-FAO** , **maize-Kc** calculated on **ETc/ETo-alfalfa** , **ETc/ETo-FAO** and average of **ETc/ETo-alfalfa** and **ETc/ETo-FAO** , which they calculated daily or average ten days data, as well as **Kc** for growth stages, they were subjected to polynomial equations**.**
- Regression equation coefficient R^2 of the polynomial equation, the above items were 0.91, 0.36, 0.89, 0.74, 0.86 and 0.83 for daily data and 0.99, 0.67, 0.98, 0.91, 0.96 and 0.95 for ten days average, respectively, also 0.99 for growth stage.

INTRODUCTION

Maize (Zea Mays) is one of the most important cereals for both human and animal consumption and it's grown for grain and forage. The average yield of maize in the world is 2830 kilograms per hectare, in spite of considerable fluctuations in different countries and continents **(Ustimenko-Bakumovsky 1983)**. The crop is grown in climates ranging from temperate to tropic during the period when mean daily temperatures are above 15^{o}C and frost-free. Adaptability of varieties in different climates varies widely. When mean daily temperatures during the growing season are greater than 20^{o}C, early grain varieties take 80 to 110 days and medium varieties 110 to 140 day to mature. When grown as a vegetable, these varieties are 15 to 20 days shorter. Maize is moderately sensitive to salinity. Yield decrease under increasing soil salinity is: 0% at ECe 1.7 mmhos/cm, 10% at 2.5, 25% at 3.8, 50% at 5.9 and 100% at ECe 10 mmhos/cm. **(Doorenbos and Kassam 1986)**.

The reference **ET_O** represents an index of climatic demand. **K_C** varies predominately with the specific crop characteristics and only to a limited extent with climate. The coefficient, $\mathbf{K_C}$ is basically the ratio of the crop $\mathbf{ET_C}$ to the reference $\mathbf{ET_O}$, and it represents an integration of the effects of four primary characteristics that distinguish the crop from reference grass. These characteristics are; crop height, albedo, canopy resistance and evaporation from soil, especial exposed soil. $\mathbf{ET_C}$ is calculated by multiplying the reference crop evapotranspiration $\mathbf{ET_O}$ by a crop coefficient $\mathbf{K_C}$, *i.e.* $\mathbf{ETc = K_C * ET_O}$ **(Allen et al 1998). Jensen et al (1990)** mentioned that the factors affecting evapotranspiration are wetness of the surface soil with little or no crop cover, transpiration as influenced by leaf area and characteristics of the leaves as crop cover develops and transpiration as the crop matures

Crop water requirements, Kc determination, and comparison to existing FAO Kc values were determined over 3yeaar period for maize. Accumulated seasonal crop water use raged between 441 an 641 mm. The Kc values determined during the growing seasons varied from 0.2 to 1.2. Some of the values corresponded and some did not correspond to those, **(Piccinnia et al 2009).**

Conventional tillage was the reference treatment in order to establish relative comparisons. Summing the evaporation at the soil surface and the plant transpiration calculated the $\mathbf{ET_C}$. Transpiration represented 80 to 90% of the total $\mathbf{ET_C}$. During the vegetative period, just before tasseling, $\mathbf{ET_C}$ in the no-tillage system was 13% lower than in the conventional system. During the flowering period, $\mathbf{ET_C}$ was higher in the no tillage by about 10%, which can be attributed to increased soil water availability. Evapotranspiration in no-tillage treatments was highest system during grain filling. Overall, the no till system had 15-20%, higher evapotranspiration. Conventional tillage was the reference treatment in order to establish relative comparisons, **Dalmago, et al (2004)** who concluded that the maize crop evapotranspiration is lower in no-tillage system than in conventional tillage during the vegetative growth. The contrary occurs during the flowering period (critical stage) and grain filling.

The measured grass-reference value closely matches the standard value after adjustment for aridity. The timescale of the standard Kcb curves fit the measured data fairly well but are improved by normalization relative to full cover and use of thermal time. The basal crop coefficient (Kcb) is linearly related to fractional canoy ground cover up to an effective full ground cover of 0.8. This relationship be used to adapt Kcb values for specific condition and is a better option than regionally specific Kcb relationships, **(Trout et al 2018).**

This research - although relatively old data - aim to depict the curvature and their statistical regression formulae of KC for maize crop upon $\mathbf{ET_C}$ -maize, depend upon $\mathbf{ET_{O}}$-alfalfa and **ETo**-FAO- Penman-Monteith equation.

MATERIALS AND METHODS

An experiment in Ismailia Agriculture Research Station was conducted in two adjacent areas; one of them was cultivated with maize crop (*Zea mays L.*) and the second with alfalfa crop (*Trifolium alexandrinum L.*), all over the year through three years, in a time of 114 days each.

The experiment was started from day of year 160 to 274 in the 1st year (1997)، from 138 to 252 in the 2nd year (1998) and from 160 to 274 in the 3rd year (1999). The growth period for the three years was 114 days The research farm is located 10 m above sea level. It is located at GPS coordinates of latitude of 30.60 N and longitude of 32.28 **E**.

Some Physical, chemical properties and nutritional status of soil under experiment was shown in Table (1) . Soil available nutrients were determined according to **Murphy and Riley (1962), Jackson (1967, Page (1982)** and **Soltanpour (1985).**

Table (1): Some physical, chemical properties and nutritional status in the experiment area .

Physical properties		Chemical properties & nutritional status	
FC (%)	7.90	EC (dSm^{-1})	0.25
WP (%)	1.42	O.M (%)	0.52
AW (%)	6.48	$CaCO_3$ (%)	2.55
BD (gm^{-3})	1.69	P (ppm)	1.58
Porosity (%)	39.52	K (ppm)	43.35
Sand (%)	94.25	Zn (ppm)	0.34
Silt (%)	4.35	Fe (ppm)	4.59
Clay (%)	1.40	Mn (ppm)	0.85
Texture	Sandy	Cu (ppm)	0.87

Measure the evapotranspiration of the crops; one of them was in maize crop (to calculate crop evapotranspiration **ET_C**, the data from lyzimeter) and the other was in alfalfa crop in the same period of maize crop (to calculate potential evapotranspiration **ET_O**). Also, potential evapotranspiration **ETo** was estimated upon FAO penman-monteith equation. Statistical analyses had been done according to **Freed et al. (1989).**

Scientific consideration:

(I) **(ET_C)** and **(ET_O)**, were calculated as follow :

(a): (ET_C) , was calculated from the equation of :

$$ET_C = - \Delta S + P - D - R$$

Whereas:

ΔS = the change in water stored in the soil profile (depth of water).

P = Precipitation and irrigation (depth of water).

D = Drainage (depth of water).

R = Runoff (depth of water).

(b): ET_O, was calculated by the following equation of FAO-Penman-Montieth equation **(Allen et al 1998)**:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} \mu_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34\mu_2)}$$

ET_o = Reference crop evapotranspiration (mm d^{-1}).
G = Soil heat flux (MJ $m^2 d^{-1}$).
T = Average temperature at 2 m height (^oC).
μ_2 = Wind speed measured at 2 m height (m s^{-1}).
(e_s-e_a) = Vapor pressure deficit for measurement at 2 m height (VPD)(kPa).
Δ = Slope of saturation vapor pressure-temperature curve (kPa^{o}C^{-1}).
γ = Psychometric constant (kPa^{o}C^{-1}).
900 = Coefficient for the reference crop (kJ^{-1}kgKd^{-1}).
0.34 = Wind coefficient for the reference crop (s m^{-1}).
0.408 = Units for the coefficient are m^2 mm MJ^{-1}.
Whereas:

- **Δ = Slope of saturation vapor pressure-temperature curve (kPa^{o}C^{-1}):**

$$\Lambda = \frac{2503 \, \boldsymbol{exp}\left(\frac{17.27\boldsymbol{T}}{\boldsymbol{T} + 237.3}\right)}{(\boldsymbol{T} + 237.3)^2}$$

- **γ = Psychometric constant (kPa^{o}C^{-1}):**

$$\gamma = \frac{c_p \, P}{\Sigma \, \lambda}$$

γ = Psychometric constant (kPa^{o}C^{-1}).
C_p = Specific heat of moist air = 1.013 (kJ kg^{-1} $^oC^{-1}$).
P = Atmospheric pressure (kPa).
λ = Ratio molecular weight of water vapour /dry air = 0.622.
whereas:
λ = Latent heat of vaporization (MJ kg^{-1})

$$\lambda = 2.501 - (2.361 \times 10^{-3})T$$

P = Atmospheric pressure (kPa):

$$p = 101.3\left(\frac{293 - 0.0065Z}{293}\right)^{5.26}$$

whereas **, Z =** Station elevation (m)

(II) The used formulae of Statistical Equations:

The tren/regression type were;

Logarithmic $Y = b \ln(x) \pm a$

Exponential $Y = a e^{bx}$

Power $Y = a x^{b}$

Liner $Y = bx \pm a$

Polynomial order (2) $Y = b_2x^2 \pm b_1x \pm a$

“ (3) $Y = b_3x^3 \pm b_2x^2 \pm b_1x \pm a$

“ (4) $Y = b_4x^4 \pm b_3x^3 \pm b_2x^2 \pm b_1x \pm a$

“ (5) $Y = b_5x^5 \pm b_4x^4 \pm b_3x^3 \pm b_2x^2 \pm b_1x \pm a$

“ (6) $Y= b_6x^6 \pm b_5x^5 \pm b_4x^4 \pm b_3x^3 \pm b_2x^2 \pm b_1x \pm a$

RESULTS AND DISCUSSIONS

Evapotranspiration was calculated with soil in which crops are grown under natural conditions to measure the amount of water lost by evaporation and transpiration. This method provides a direct measurement of evaporation rate and is frequently used to study climatic effects on evaporation rate and to evaluate estimating procedures.

The limitations are placed on crop growth or evapotranspiration from soil water and salinity stress, crop density, pests and diseases, weed infestation or low fertility. **ETc** is determined by the crop coefficient approach whereby the effect of the various weather conditions are incorporated into **ETo** and the crop characteristics into the **Kc** coefficient:

$$ETc = (Kc) \times (ETo) \quad \text{or} \quad Kc = \frac{ETc}{ETo}.$$

(I) Maize evapotranspiration (ETc):

Table (2) showed the ETc values of minimum (Min.), maximum (Max.), average (Aver.) and the stander deviation (S.D) of the three cultivated years. As shown in this table , **(ETc)** values ranged (0.03 and 8.43 with average ~ 4.77), (0.37 and 12.89 with average ~5.60) and (0.28 and 12.57 with average ~5.83) mm/day for 1st, 2nd and 3rd, cultivated years, respectively.

Tables (3 & 4) denoted the different equations which can be expressed the daily and the average of the ten days **(ETc)**. Graphics patterns defined of the daily evapotranspiration **(ETc)** of maize (mm/ten days) were showed in **(Fig.1)** and the average of ten days evapotranspiration showed in **(Fig.2)**, all over the periods of cultivated three years .

Table (2) : Statistical parameter of maize crop evapotranspiration (ETc).

Cultivated year	Maize crop (ETc) mm/day			
	Min.	Max.	Aver.	S.D
First	0.03	8.43	4.77	2.28
Second	0.37	12.89	5.60	3.04
Third	0.28	12.57	5.83	3.36

Table (3) : Daily different equations of data measure of ETc maize crop.

Equation type	Y= x	R^2
Logarithmic	Y= 0.7959 ln(X) + 2.532	0.1029
Exponential	$Y= 5.579\ \mathbf{e}^{(0.0031(X)}$	0.0200
Power	$Y= 2.9955\ X^{(0.118)}$	0.0233
Linear	Y= 0.0007 X + 5.4879	0.0001
Polynomial	$Y= - 0.00001\ X^3 + 0.0003\ X^2 + 0.1703\ X + 1.3598$	0.9097

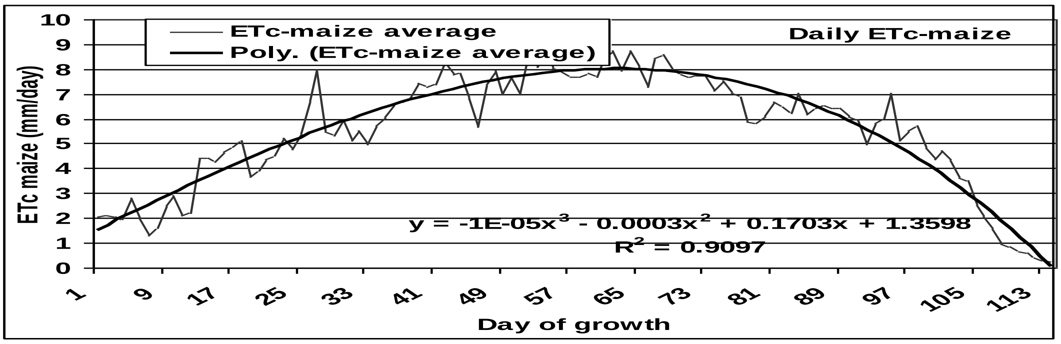


Fig (1): Daily 3 years average of evapotranspiration (ETc) of maize crop.

Table (4): Ten days different equations data of ETc maize crop.

Equation type	Y= x	R^2
Logarithmic	Y= 0.5922 Ln (X) + 4.1404	0.0308
Exponential	$Y= 6.4467\ \mathbf{e}^{(-0.0701\ X)}$	0.0829
Power	$Y= 4.3494\ X^{(-0.0374)}$	0.0010
Linear	Y= -0.0742 X + 5.6091	0.0110
Polynomial	$Y= - 0.0093\ X^3 - 0.0468\ X^2 +1.906\ X - 0.0275$	0.9890

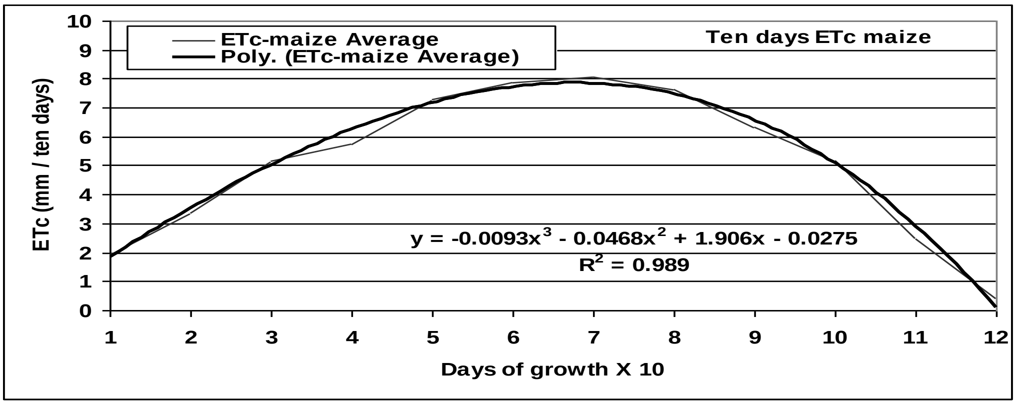


Fig (2): Ten days of three years general average of evapotranspiration (ETc) of maize crop.

As shown in **Tables (3 & 4)** and **Figs (1 & 2),** polynomial equations whatever for daily data or average of ten days, were the highest ones (*i.e.* R^2 = 0.9356 for daily, 0.9845 for the average of ten days) and those were represented the suitable ones for maize **(ETc)**.

(II) Alfalfa reference evapotranspiration (ETo):

Table (5), showed the average of Alfalfa **(ETo)** for the typical daily during the three growing seasons, which recorded 5.83, 6.57 and 5.04 (mm/day) respectively.

Regression (R^2) values of alfalfa **(ETo)** in **Table (6)** were 0.166, 0.074, 0.198, 0.053 and 0.371 for daily and in **Table (7)** were 0.264, 0.108, 0.316, 0.081 and 0.741 for the average of ten days, for five equation of logarithmic, exponential, power, linear and polynomial, respectively.

Table (5): Statistical parameter of alfalfa crop evapotranspiration (ETo).

Cultivated year	**Alfalfa crop (ETo) mm/day**			
	Min.	**Max.**	**Aver.**	**S.D**
First	2.01	9.44	5.83	1.66
Second	1.24	10.70	6.57	1.98
Third	1.80	7.48	5.04	1.46

Table (6): Daily different equations of data measure of ETo alfalfa crop

Equation type	Y = x	R^2
Logarithmic	Y= 0.1625 Ln (X) + 5.2574	0.0235
Exponential	$Y= 5.8774\ e^{-(0.003X)}$	0.0029
Power	$Y= 5.0434\ X^{(0.0362)}$	0.0349
Linear	Y= 0.0028 X + 6.0305	0.0088
Polynomial	$Y= -0.000008X^3 - 0.002X^2 + 0.1261X + 4.1627$	0.3573

In **Fig.(3)**, alfalfa daily **(ETo)** (mm/day) showed that their values kept rising and falling throughout the crop growing season. Alfalfa crop in the average of three seasons was developed and shaded more and more of the ground, evaporation becomes restricted and transpiration gradually becomes the major process. Also, **Fig (4)** defined the trend at the average of the ten days of evapotranspiration. In general, polynomial equations whatever for daily data (R^2 = 0.3708) or for average of ten days (R^2 =0.7409), were the highest ones and those were represented the suitable ones for alfalfa **(ETo) (Figs 3 & 4)**.

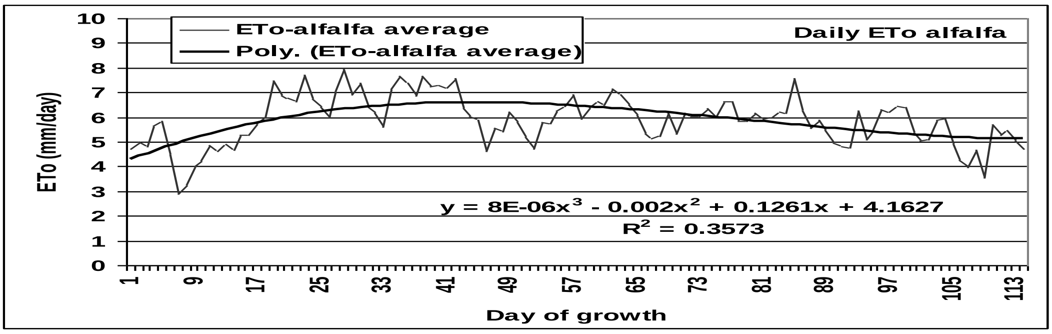


Fig (3): Daily of three years general average of evapotranspiration (ETo) of alfalfa crop.

Table (7):Ten days different equations of data of ETo alfalfa crop

Equation type	Y = x	R^2
Logarithmic	Y= 0.13883 Ln (X) + 5.604	0.0193
Exponential	$Y= 5.9157 e^{(-0.0033 X)}$	0.0084
Power	$Y= 5.5071 X^{(0.03)}$	0.0298
Linear	Y= -0.0261 X + 6.0039	0.0156
Polynomial	$Y= 0.0063 X^3 - 0.1753 X^2 + 1.3164 X + 3.5651$	0.6681

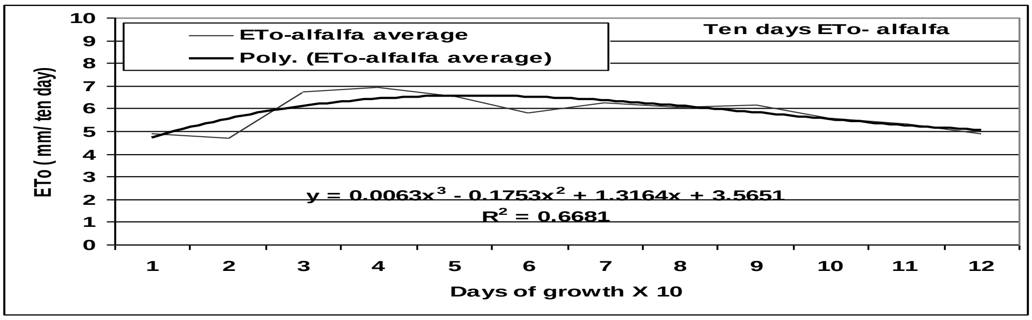


Fig (4): Ten days of three year general average of evapotranspiration (ETo) of alfalfa crop.

(III): Reference evapotranspiration (ETo) from FAO-Penman-Montieth equation:

Table (8) listed minimum (Min.), maximum (Max.), average (Aver.) and the stander deviation (S.D) of the three years cultivated. The values ranged 2.80 – 8.70, 4.84 – 9.88 and 2.58 – 5.52 mm/day for 1st, 2nd and 3rd cultivated between the three cultivated seasons, respectively.

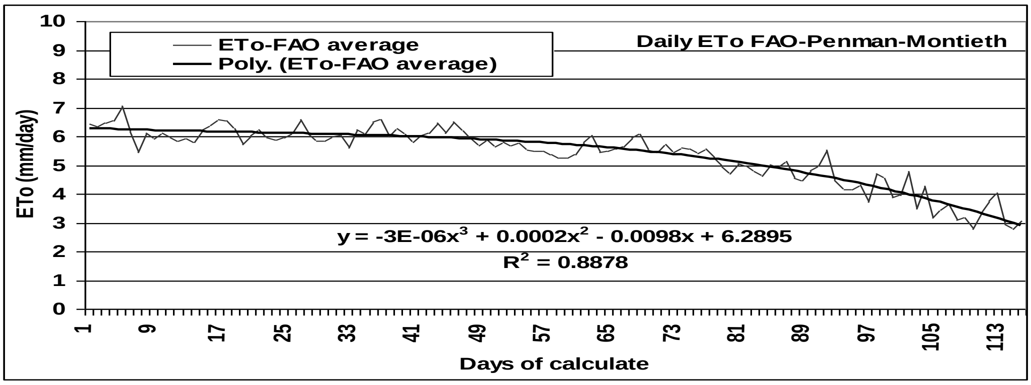
ETo was calculated upon FAO-Penman-Monteith equation for reference evapotranspiration as mentioned above. **Table (9) and Fig (5)** as well as **Table (10) and Fig (6)** represented the trends of different types of statistical equations can be used to express the trends of **ETo**-FAO**. Fig (5)** showed daily **ETo**-FAO equation there a defined pattern with the average of data through seasons, and **Fig (6)** showed the average of ten days of **ETo**-FAO equation and that for the three seasons take the same trend. Generally, polynomial equation was the best ones can explain both daily and ten days **ETo-**FAO , where R^2 were 0.864 and 0.975 , respectively.

Table (8): Statistical parameter of FAO-Penman-Montieth equation. (ETo)

Cultivated year	**FAO-Penman-Montieth equation (ETo) mm/day**			
	Min.	**Max.**	**Aver.**	**S.D**
First	2.80	8.70	6.02	1.20
Second	4.84	9.88	6.61	0.75
Third	2.58	5.52	3.98	0.67

Table (9): Daily different equations data of FAO –Penman-Montieth equation

Equations	Y = x	R^2
Logarithmic	$Y= - 0.7074 Ln(X) + 8.0324$	0.4476
Exponential	$Y= 7.1441 e^{(-0.0053 X)}$	0.7002
Power	$Y= 8.9978 X^{(-0.1425)}$	0.3957
Linear	$Y= - 0.0255 X + 6.8461$	0.7498
Polynomial	$Y= - 0.000003 X^3 + 0.0002 X^2 – 0.0098 X + 6.2895$	0.8878



Fig(5): Daily general average of the three year calculated evapotranspiration (ETo) of FAO.

Table (10): Ten days different equations of data of FAO –Penman-Montieth equation

Equations	Y = x	R^2
Logarithmic	$Y= - 1.098 Ln(X) + 7.2207$	0.6567
Exponential	$Y= 7.4833 e^{(-0.0534X)}$	0.8113
Power	$Y= 7.5773 X^{(-0.2159)}$	0.5827
Linear	$Y= -0.2644 X + 7.1103$	0.8663
Polynomial	$Y= - 0.0044 X^3 + 0.0581 X^2 – 0.3618 X + 6.8503$	0.9805

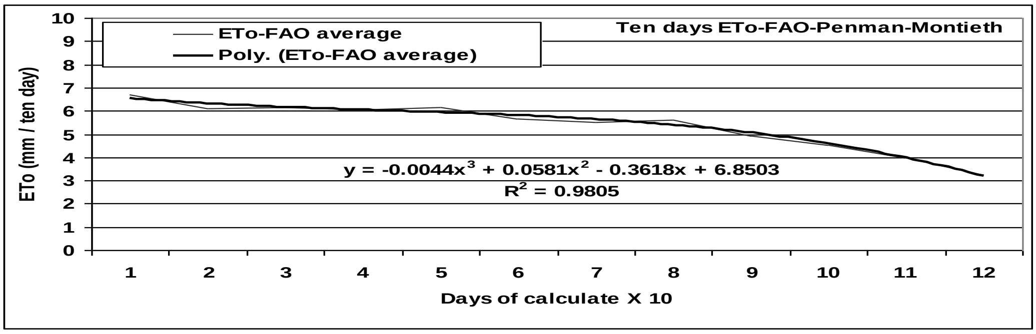


Fig (6): Ten days of three years general data calculated evapotranspiration (ETo) of FAO-Peniman-Monteith equation.

(IV): Maize crop coefficient (Kc) (maize-ETc / ETo-alfalfa as well as maize-ETc/ETo-FAO):

Data of maize crop **(Kc)** in **Table (11)** ranged from 0.01 to 2.30, 0.12 to 2.19 and 0.05 to 5.24 mm/day, for first, second and third years of alfalfa , respectively.

Data of maize crop **Kc** in **Table (11)** ranged from 0.01 to 1.72, 0.06 to 1.71 and 0.10 to 3.01 mm/day for the three seasons of FAO-Penman Montieth.

Table (11): Statistical parameters of coefficient Kc of maize-ETc/ETo alfalfa crops, and maize-ETc/ETo-FAO

Cultivated year	Min.	Max.	Aver.	S.D
Maize crop (Kc) on alfalfa				
First	0.01	2.30	0.88	0.53
Second	0.12	2.19	0.83	0.38
Third	0.05	5.24	1.30	1.02
Maize crop Kc on FAO-Penman-Montieth				
First	0.01	1.72	0.79	0.40
Second	0.06	1.71	0.85	0.45
Third	0.10	3.01	1.48	0.90

A). Maize crop Kc (ETc-maize/ETo-alfalfa):

Different regression equations of daily data for maize Kc and ETo–alfalfa in **Table (12)**, showed that the regression coefficient (R^2) of the logarithmic, exponential, power, linear and polynomial equations were 0.272, 0.076, 0.246, 0.134 and 0.775, respectively.

Table (12): Daily different equations data of Maize Kc of alfalfa

Equations	Y = x	R^2
Logarithmic	Y= 0.2783 Ln(X) -0.1981	0.2724
Exponential	$Y= 0.4978\ e^{(0.053\ X)}$	0.0758
Power	$Y= 0.1451\ X^{(0.4061)}$	0.2460
Linear	Y= 0.0046 X + 0.5801	0.1341
Polynomial	$Y= - 3E\text{-}06\ X^3 + 0.0004\ X^2 – 0.0016\ X + 0.2109$	0.7414

On the other hand, different regression equations of data of ten days average for maize Kc and ETo–alfalfa in **Table (13)**, showed that the regression coefficient (R^2) of the logarithmic, exponential, power, linear and polynomial equations were 0.261, 0.034, 0.169, 0.103 and 0.800, respectively.

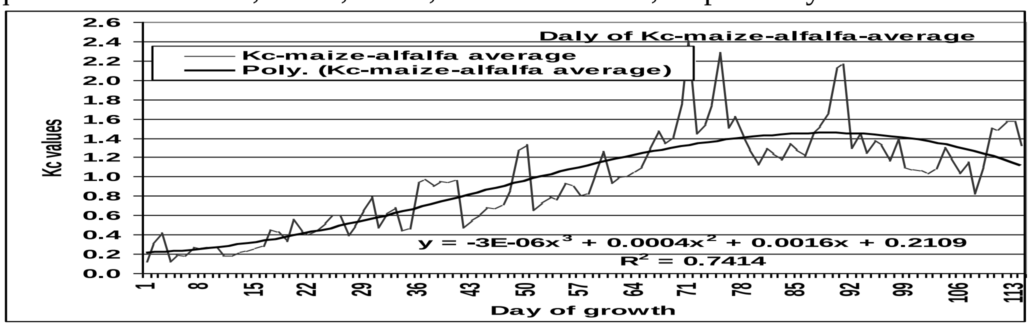


Fig (7): Daily data of crop coefficient (Kc) of maize-ETc/ETo alfalfa crop.

From the previous equations, it can conclude that, the equation of polynomial is the suitable equation for estimated **(Kc)** for both of daily data and the average of ten days data**.** The polynomial equation at order (3) was suitable for express daily data of crop coefficient (Kc) of maize-ETc/ETo alfalfa crop **(Fig. 7)** , was :

$Y= - 4E – 06\ X^3 + 0.0005\ X^2 – 0.0002\ X + 0.2275$ ($R^2 = 0.7752$) While, the trend of the polynomial equation at order (3) suitable for ten days general average of crop coefficient (Kc) of maize-ETc/ETo alfalfa crop **(Fig. 8)**, was:

$Y= – 0.0034\ X^3 + 0.0491\ X^2 – 0.0368\ X + 0.241$ ($R^2 = 0.9365$)

Table (13): Ten days different equations data of maize Kc of alfalfa

Equations	Y = x	R^2
Logarithmic	Y= 0.1247Ln (X) + 0.7764	0.0478
Exponential	$Y= 1.1127\ e^{(-0.042\ X)}$	0.0489
Power	$Y= 0.8442\ X^{(0.0018)}$	4E-06
Linear	Y= -0.0019 X + 0.9962	0.0002
Polynomial	$Y= - 0.0038\ X^3 + 0.0388\ X^2 + 0.0599\ X + 0.435$	0.9120

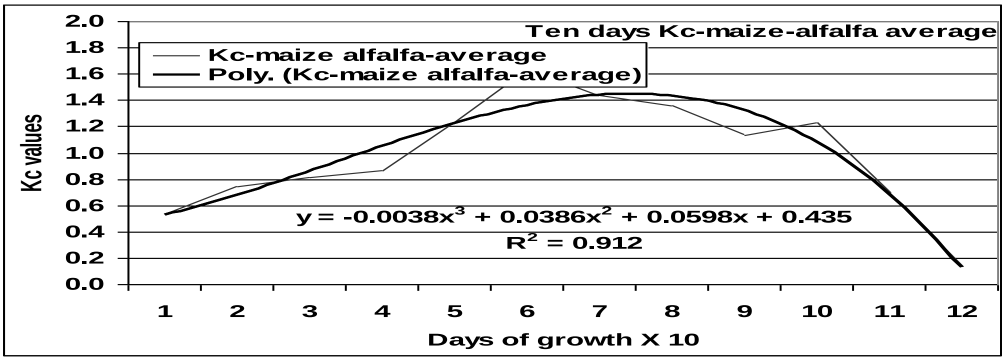


Fig (8): Ten days general average of crop coefficient (Kc) of maize-ETc/ETo alfalfa crop.

B). Maize crop Kc (ETc-maize/ETo-FAO):

Regression equations in **Table (14)** of daily data and in **Table (15)** of the average ten days data for maize **Kc and ETo-FAO** showed that the, regression coefficient (R^2) of the equations of logarithmic, exponential, power, linear and polynomial of the daily data were 0.460 , 0.271 , 0.502 , 0.318 and 0.917 and of the ten days average data were 0.429 , 0.216 , 0.443 , 0.250 and 0.974 , respectively.

Table (14): Daily different equations data of maize Kc of FAO –Penman-Montieth equation

Equations	Y = x	R^2
Logarithmic	Y= 0.2226 Ln(X) + 0.1799	0.2488
Exponential	$Y= 0.7888\ e^{(0.0019\ X)}$	0.0097
Power	$Y= 0.3414\ X^{(0.2517)}$	0.1340
Linear	Y= 0.0032 X + 0.3823	0.0657
Polynomial	$Y= - 4E\text{-}06\ X^3 + 0.0003\ X^2 - 0.0169\ X + 0.2946$	0.8611

Thus, it can notice that, the polynomial equation is the suitable equation for estimated Maize **Kc of FAO** –Penman-Montieth equation with **R^2= 0.9167** for daily data **(Fig. 9)** and **R^2= 0.9744** for the average data of ten days **(Fig. 10).**

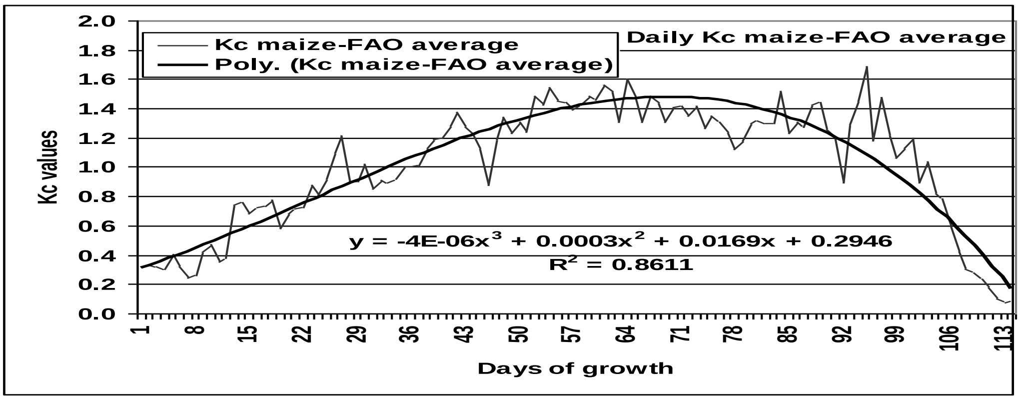


Fig (9): Daily data of crop coefficient (Kc) of maize-ETc/ETo-FAO.

Table (15): Ten days different equations data of Maize Kc of FAO –Penman-Montieth equation

Equations	Y = x	R^2
Logarithmic	Y= 0.2587 Ln(X) + 0.5484	0.2018
Exponential	Y= 0.7751 $e^{(0.127 X)}$	0.0047
Power	Y= 0.5321 $X^{(0.2753)}$	0.0984
Linear	Y= 0.0262 X + 0.8087	0.0472
Polynomial	Y= - 0.0036 X^3 + 0.0345 X^2 + 0.1147 X + 0.2047	0.9606

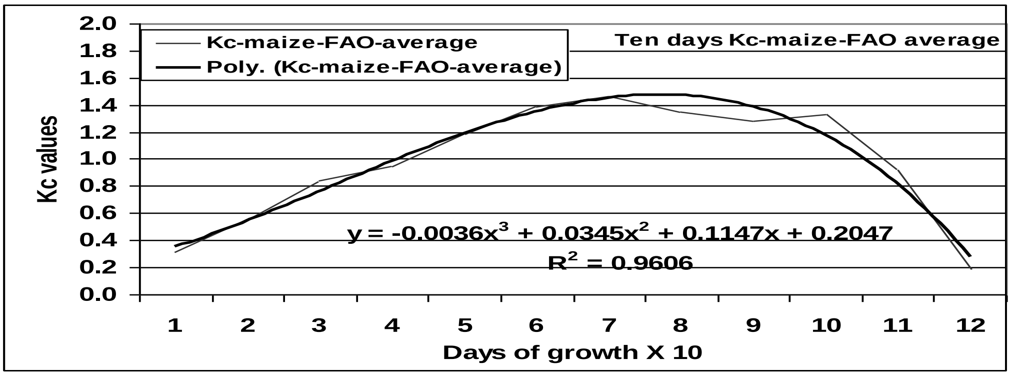


Fig (10): Ten days general average of crop coefficient (Kc) of maize-ETc/ETo FAO.

V): Maize crop coefficient (Kc) (average of both maize ETc/ETo alfalfa and maize-ETc/ETo-FAO).

Tables (16 and **17)** denoted the different formula of statistical equation**s** for daily and average of ten days with their R^2. It's noticed that, R^2 of polynomial equation of order three were the best suitable equation for daily data, was values of 0.893 and 0.967, respectively. Previous trends were supported by graphics of **Figures (11** and **12)** daily data and for average data of ten days, which declared the averages of **Kc** of maize upon evapotranspiration of (ETc/ETo-alfalfa and

ETc/ETo-FAO-Penman-Montieth equation of meteorological data). On the other hand, **Figures (11 & 12)** revealed that the average of maize **Kc** on alfalfa, and FAO-Penmen-Monthieth of the average three seasons and the averages of both were the same.

Table (16): Daily crop coefficient Kc-maize of average of (ETc/ETo-alfalfa and ETc/ETo-FAO).

Equations	Y = x	R^2
Logarithmic	Y= 0.1726 Ln(X) + 0.3701	0.1491
Exponential	$Y= 0.929\ e^{(-0.0008\ X)}$	0.0017
Power	$Y= 0.5114\ X^{(0.1463)}$	0.0464
Linear	Y= 0.0017 X + 0.9194	0.0191
Polynomial	$Y= -\ 4E\text{-}06\ X^3 + 0.0003\ X^2 – 0.014\ X + 0.3919$	0.8323

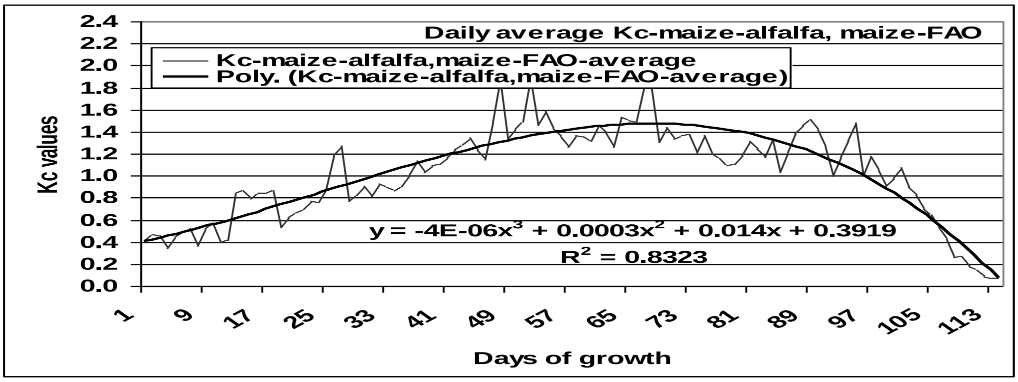


Fig (11): Daily crop coefficient Kc-maize of average (ETc/ETo-alfalfa and ETc/ETo-FAO).

Table (17): Ten days crop coefficient Kc-maize of average of (ETc/ETo-alfalfa and ETc/ETo-FAO).

Equations	Y = x	R^2
Logarithmic	Y= 0.1917Ln(X) + 0.6624	0.1133
Exponential	$Y= 0.9394\ e^{(-0.0155\ X)}$	0.0072
Power	$Y= 0.6831\ X^{(0.1310)}$	0.0227
Linear	Y= 0.0122 X + 0.9024	0.0106
Polynomial	$Y= -\ 0.0037\ X^3 + 0.0365\ X^2 + 0.0873\ X + 0.03198$	0.9509

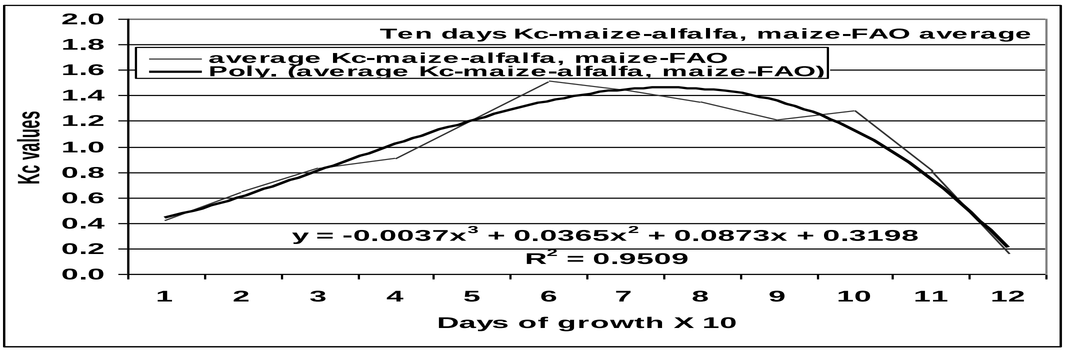


Fig (12): Ten days crop coefficient Kc-maize of average (ETc/ETo-alfalfa and ETc/ETo-FAO).

VI): Maize crop coefficient (Kc) of different growth stages (average of both ETc/ETo-alfalfa and ETc/ETo-FAO).

The regression equations and the coefficients in **Table (18)** reveled that the polynomial equation with coefficient (R^2=0.995) is the best one among the mentioned equations in the table. **Fig (13)** depicted the trend of polynomial in relations of establish, vegetative, flowering, yield, ripening and end growth stages. Crop factor **Kc** depends upon the growth stage of plant, whereas increased in the start period and then decreased in the late period. **Doorenbos and Kassam (1986)** summarized the growth stages and add the crop factor **(Kc)** relating water requirements **(ETc)** to reference evapotranspiration **(ETo)** for different crop growth stages of grain maize is for the initial stage 0.3– 0.5 (15 to 30 days), the development stage 0.7-0.85 (30 to 45 days), the mid-season stage 1.05-1.2 (30-45 days), during the late season stage 0.8-0.9 (10 to 30 days) and at harvest 0.55-0.6. As detailed before R^2 of polynomial equation was 0.995.

Table (18): Crop coefficient (Kc) of different growth stages maize-alfalfa, maize-FAO of three cultivated average.

Equations	Y = x	R^2
Logarithmic	Y= 0.2478 Ln(X) + 0.4769	0.1100
Exponential	Y= 0.5721 $e^{(0.0028 X)}$	3E.05
Power	Y= 0.4108 $X^{(0.2930)}$	0.0455
Linear	Y= 0.0344 X + 0.6282	0.0169
Polynomial	Y= - 0.0417 X^3 + 0.267 X^2 – 0.0925 X + 0.0863	0.9945

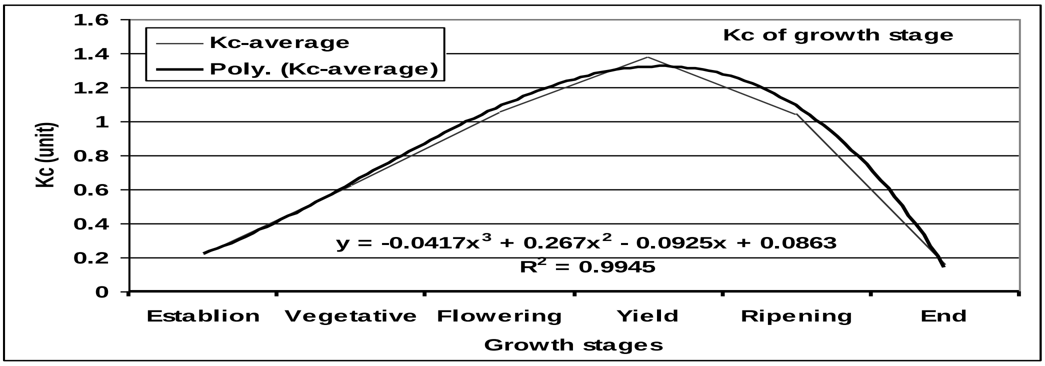


Fig (13): Crop coefficient (Kc) of different growth stages maize-alfalfa, maize-FAO and average cultivated.

Conclusion

In general, polynomial equation especially order three is the suitable equation whatever for estimated equation or curvature the maize-ETc, alfalfa-ETo, FAO-ETo or calculated crop coefficient (Kc) for maize whatever upon alfalfa-ETo or FAO-ETo. Table (19) summarize maize Kc calculated as maize ETc/alfalfa ETo as well as maize ETc/FAO-ETo and Table (20) summarize the average maize Kc whatever every ten days or at every growth stage.

Table (19): Maize Kc every ten days (Kc of ETo-maize/ETo-alfalfa) also (Kc of ETo-maize/ETo-FAO)

Kc every ten days (ETo-maize/ETo-alfalfa) also (ETo-maize/ETo-FAO)					
Day X 10	**Kc-alfalfa**	**Kc-FAO**	**Day X 10**	**Kc-alfalfa**	**Kc-FAO**
1	0.53	0.31	7	1.43	146
2	0.74	0.56	8	1.36	1.35
3	0.82	0.84	9	1.13	1.29
4	0.87	0.94	10	1.23	1.33
5	1.24	1.18	11	0.69	0.92
6	1.64	1.37	12	013	0.18

Table (20): Maize Kc every ten days (average of Kc-maize of alfalfa and Kc-maize of FAO) also every growth stage

Kc every ten days				Growth stage	
Days	**Kc**	**Days**	**Kc**		**Kc**
1	0.42	7	1.45	Establish	0.22
2	0.65	8	1.35	Vegetative	0.63
3	0.83	9	1.21	Flowering	1.06
4	0.91	10	1.28	Yield	1.38
5	1.21	11	0.80	Ripening	1.04
6	1.51	12	0.15	End	0.15

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المعادلات الإحصائيه لمعامل محصول الذرة

صادق على احمد الريس ، طارق عبد الرحمن ابوالضيفان، على شحاته على عثمان

اقيمت تجربـه حقلية فـى محطـة البحـوث الزراعيـة بالأسـماعيليه علـى مسـاحتين، احدهما تـم فيهـا زراعـة الـذره والأخـرى زراعـة البرسـيم الحجـازى ، وذلـك لحسـاب البخـر نـتح الأحتمـالى . وتـم زراعـة المحصول فى ثلاث سنوات متتالية وموسم النمو يبدأ من يوم ١٦٠ حتـى ٢٧٤ فـى الموسم الأول والثالث أمـا الموسم الثانى كانت الزراعة تبدأ من يوم ١٣٨ حتى ٢٥٢ وتم الحصاد بعد ذلك فى الثلاث اعوام. تم حساب ETcفى مساحة محصول الذرة وتم حساب ETo فى مساحة البرسيم الحجازى خلال نفس فترة نمو الذه وتم رى مساحة الذرة بطريقة الرى بالتنقيط اما رى مساحة البرسيم الحجازى فكانت بطريقة الرى بـالرش. نتـائج الـ ETc والـ ETo تم استخدامها فى حساب الـ Kc علي اساس أن الـ ETo محسوبة من البخر نتج للبرسيم الحجازى ومن معادلة بنمان مونتيث وكانت النتائج كما يلى:

- عند حساب معامل المحصول للذرة على اساس البخر نتح للبرسيم الحجـازى ومعادلـة الفـاو اختلفت قليلا عن بعضـها البعض.
- ان معامل المحصول على اساس البخر نتح للبرسيم الحجـازى وكذلك معاملـة الفاووالمتوسط بينهمـا خـلال متوسط المواسم الثلاث كانت متشابه، وان معامل المحصـول يتوقف علـى مراحل نمـو النبـات حيث يزيـد عند اعلى نمو وينخفض فى نهاية الموسم.
- البخرنتح للمحصول، البرسيم، الفاو، معامل المحصول المحسوب علـى اسـاس البرسيم،و المحسـوب علـى اساس الفاو، البخرنتح على متوسط المحسور على اساس البرسم + الفـاو سـواء المحسـوب يوميـا او عشـرة ايام وعلى اساس فترات النمو كانت متمثلة بمعادلة بولنميل.
- معاملات الآنحدار (R2) لمعادلات البولنميل كما ذكر سـابقا كانـت ٠.٩١ ، ٠.٣٦، ٠.٨٩، ٠.٧٤، ٠.٨٦، ٠.٨٣ للبيانات البومية وكانت ٠.٩٩، ٠.٦٧، ٠.٩٨، ٠.٩١، ٠.٩٦، ٠.٩٥ للبيانا كل عشرة ايام ، أيضـا ٠.٩٩ لمرحلة النمو.