Impact of Deficit Irrigation on Sesame Growth, Yield and Water Relations under Toshka Climatic Conditions

A.M.S. Elshamly[1], M.A. Gameh[2], Ahmed Ghallab[2] and T. A. El-Samman[3]

[1]Water Studies and Research Complex .National Water Research Center, Cairo, Egypt.

[2]Soil Sci. Dept., Faculty of Agriculture, Assiut University, Assiut, Egypt.

[3]Channel Maintenance Res.Inst.National Water Research Center, Cairo, Egypt.

Abstract:

Field experiments were carried out at the experimental farm of the Water Studies and Research Complex (WSRC), Station, National Water Research Center, Toshka – Abu simbel City, Egypt during the two growing seasons of 2011 and 2012 to assess the effect of water stress [25% , 50% and 75% of available soil moisture depletion] on water consumptive use (ETa) of sesame (Giza - 32 ,variety) as well as yield and yield component under sprinkler irrigation system. Reference evapotranspiration (ET_o) was estimated by some ET formulas to compare them with the actual evapotranspiration (ETa). The crop coefficient (K_C), plant characteristics and the water application efficiency (WAE) were measured.

The experiments were laid out in RCBD experiment with five replicates and three treatments of available soil moisture depletion, under sprinkler irrigation system.

Results indicated that the highest seasonal ETa value was recorded at 25% available soil moisture depletion (ASMD) treatment, while the lowest one was recorded at 75% ASMD treatment. The seasonal ET_a values were 703.6, 602.0 and 561.4 mm for 25, 50 and 75 % ASMD, respectively in the first season and 737.1, 647.5 and 608.0 mm for the corresponding irrigation regime in the second season. The results indicated also that the most efficient method for calculating sesame water use in Toshka district is the Priestly- Taylor formula.

The highest seed yield/ feddans of 370.44 and 385.25 kg/fed were obtained with 25% ASMD in the first and second season, respectively. The lowest yield 344.24 and 350.75 kg/fed were obtained with 75% ASMD in the respective seasons. Oil content percentage was significantly increased with increasing available soil moisture, in both seasons.

Finally , under the current experimental condition , it could be concluded that irrigated sesame crops at (25 %ASMD) is suitable under Toshka climatic condition and caused significant increases in sesame yield and yield component.

Keywords: Water consumptive use, available soil moisture depletion, Irrigation regimes.

Received on: 23/10/2013 **Accepted for publication on:** 21/11/2013

Referees: Prof. Mahmoud A. Morsi Prof. Kamal K. Attia

Introduction:

Deficit irrigation is a strategy which allows a crop to sustain some degree of water stress in growth stages of less sensitive to water or throughout the whole growing season in order to save irrigation water Kirda (2002). The fundamental objective of deficit or limited irrigation is to increase water productivity and water use efficiency, either by reducing irrigation adequacy or by eliminating the least productive irrigations.

Potential evapotranspiration (PET) is an important index of hydrologic budgets at different spatial scales and is a critical variable for understanding regional biological processes. In the past several years, various investigations have evaluated equations for calculating ET_o to testing the accuracy of these methods in new environment Kashyap and Panda (2001) ; Xu and Singh, (2002) ; Sumner and Jacobs,(2005) ; Nandagiri and Kovoor,(2006) and Landeras *et al* , (2008).

Sesame (*Sesamum indicum L.*) is considered one of the promising crops to cover the increasing demands for edible oils due to its high oil content (47-52%), good oil quality and adaptability to the environmental conditions in Egypt. It is the most appropriate crop for growing in the newly reclaimed land, which is expanded on a large scale outside the Nile Valley in Egypt. Sesame area under cultivation in Egypt in 2008 was about 66354 fed with average productivity of 0.55 ton per fed (Agricultural Economic Research Institute Bulletins, Volume 2009).

Most researches are carried out to establish methods that improving agricultural management which help to conserve water to fulfill reclamation and produce more food.

El- Tantawy *et al* (2002) reported that high WUE value of 0.303 kg seed/m^3 with 1934 m^3 15 days irrigation intervals and with 50 kg K_2O/fed. Treatment.

Kassab *et al* (2005) found that the total water requirements of sesame grown at Kalubia Governorate was 1839 , 999 and 999 m^3 / fed., under controlled surface irrigation, sub-surface drip irrigation and surface drip irrigation, respectively. While El-Samanody *et al*., (2010) at Shandaweel reported average values of ET 2647 m^3/ fed in 2005 and 2006 with the average values of K_C for sesame at the three growth stages of 0.35, 1.15, and 0.60.

Also Kassab *et al*, (2012) reported that the highest Etc values of sesame grown at El-Nubaria El-Buheira governorate was 2698.2 m^3/fed., with average WUE values varied widely between 0.09 and 0.16 kg seed /m^3.

The aims of this study were to detect the water requirements, water use efficiency .and finding the best empirical equation which can be used for the growth and yield of sesame under different depletions of available soil moisture at Toshka district.

Table (1): irrigation water requirement for sesame in some locations in Egypt, as cited in the literature.

Crop	Average ETa values (m^3/fed)	Location	References
sesame	1932 1974	North Delta Giza	Metwally *et al.* (1984)
	2226 2058	Giza Nubaria	Attia *et al.* (1999)
	1839(surface system) 999(sub-surface) 999(drip system)	Kalubia	Kassab *et al.* (2005)
	1986.47	Giza	El-Tantawy *et al.* (2002)
	1985.8 (5 irrigation) 2694 (7 irrigation)	Shandaweel	Tantawy *et al.*(2007)
	2646.5	Shandaweel	El-Samanody *et al.* (2010)
	2698.2	El-Buheira	Kassab *et al.* (2012)

Table (2): Water use efficiency (WUE) for Sesame in some locations in Egypt, as cited in the literature.

Crop	WUE Kg /m^3	Location	References
sesame	0.355	Shandaweel	El-Shimi, *et al.*(2005)
	0.303	Giza	El-Tantawy *et al.* (2002)
	0.23- 0.33	Shandaweel	Tantawy *et al.*(2007)
	0.303	Shandaweel	El-Samanody *et al.* (2010)
	0.13	El-Buheira	Kassab *et al.* (2012)

Materials and Methods:

A field experiments were carried-out at the experimental farm of Water Studies and Research Complex (WSRC), station, National Water Research Center, Toshka – Abu simbel City, Egypt during the summer seasons of year 2011 and 2012. The soil texture is loamy sand. Some physical and chemical properties and irrigation water were measured according to Klute (1986) and Page (1982) and were given in table 3. The experiments were laid out in RCBD experiment with five replicates and three treatments under sprinkler irrigation system, with three levels of available soil moisture depletion. That the blocks were bounded with buffer zone (12 m width) to avoid the interaction between Sprinklers. The blocks were assigned for irrigation regimes (25, 50 and 75 % ASMD) soil moisture depletion from the available water and expressed as D1, D2 and D3 respectively. The plot was 12 m in length and 5 m in width. Sprinkler system is fixed and in square spacing pattern (12m X12m) with an area of 144 m^2 (almost 1/29 fed). The sprinkler system is constant (Brass impact rotate, Rain Baird, U.S.A) with lateral line length of 72 m and 12 m space. The rotating sprinkler system were 1.0 m above the ground with flow rate of 1.2-1.4 m^3 / hour at 2-3 bars.

Table (3) Some analytical data of the studied soil and groundwater of the experimental site before cultivation.

A- Physical properties of the studied soil.

Soil depth (cm)	Particle size distribution (%)			Tex. class	S.P. (%)	F.C (%)	W.P (%)	A.W. (%)	BD (g/cm^3)
	Sand	Silt	Clay						
0-20	86.19	0.86	12.94	L. s	28.70	13.9	2.0	11.9	1.41
20-40	86.21	1.17	12.61	L. s	29.30	13.6	2.0	11.6	1.41
40-60	90.80	1.23	7.90	s	27.40	12.3	2.1	10.2	1.40

L.S = Loamy sand , S = Sand , S.P= Saturation percent , F.C= Field capacity
W.P = Wilting point , A.W= Available water , B.D= Bulk density

B- Chemical properties of the studied soil.

Soil depth (cm)	OM (%)	$CaCO^3$ (%)	pH (1:1) Soil extract	EC (dS/m) (1:1) Soil extract	Soluble ions (meq/l)						
					Anions			Cations			
					CO_3^{-2}+$HCO3$	SO_4^{+2}	Cl^-	Ca^{+2}	Mg^{+2}	Na^+	K^+
0-20	0.37	5.00	7.88	1.20	0.20	9.20	2.60	6.60	0.40	5.40	0.10
20-40	0.39	4.58	7.90	1.25	0.20	9.30	3.00	7.40	0.40	4.80	0.20
40-60	0.17	4.17	7.92	0.65	0.20	3.50	2.80	4.40	0.60	1.10	0.01

C- Chemical analysis of the ground water (irrigation water).

Date	pH	TDS		Cations (meq/l)				Anions (meq/l)			SAR
		EC dS/m	mg/l (ppm)	Na^+	K^+	Mg^{+2}	Ca^{+2}	Cl^-	CO_3^{-2}+$HCO3^-$	SO_4^{+2}	
April -2011	6.96	0.71	454.4	4.56	0.22	0.86	1.59	3.52	2.55	1.06	4.12
April -2012	6.95	0.73	464.0	4.75	0.30	0.89	1.6	3.55	2.6	1.1	4.26

TDS = Total dissolved solids. SAR= sodium adsorption ratio.

In the summer seasons of year 2011 and 2012, sesame seeds (Giza 32 cultivar) were sown on May 15 and May 17 in 2011and 2012 seasons, and were harvested on September 13 and September 15 of the same seasons, respectively. All agronomic practices were following the recommendation of Egyptian Ministry of Agriculture .As to fertilization of sesame, all treatment received 200 kg super phosphate (15.5 %P_2O_5) which broad coasted , in one dose , during soil preparation processes. Nitrogen was added as ammonium nitrate (33.5 % N) in three doses: the 1st (10 kg N / fed) after 15 days, the 2nd (20 kg N / fed) after 30 days and the 3rd (15 kg N / fed) after 45 days from the plantation. Potassium fertilizer in the form of potassium sulphate (48 % K_2O) at the rate of (100 kg / fed) was added in two equal portion after 45 and 60 days from the plantation.

To obtain the actual water consumptive use ETa, the soil moisture percentage was determined gravimetrically on dry basis just before irrigation. Soil samples for moisture determination were taken from each 20 cm depth up to 60 cm from the soil surface by a soil auger. The amount of water consumed in each irrigation interval was obtained from the difference between soil content before the following irrigation and field capacity. Which was calculated according to Israelsen and Hansen (1962). The seasonal ETa values were determined as the summation of irrigation water from planting till harvesting. The reference evapotranspiration (ET_O) values were computed from the meteorological data of Toshka weather station (Table 4), fourteen empirical methods (Makkink According to Makkink, (1957); Jensen and Haise according to Jensen and Haise, (1963); Stephens - Stewart According to McGuinness and Bordne , (1972) ; Doorenbos and Pruitt , Pan Evaporation and Blaney-Criddle according to Doorenbos and Pruitt, (1977) ; Modified Penman , Turc and priestly – Taylor according to Jensen *et al.* , (1990) ; Penman Monteith according to Allen *et al* , (1998) ; Elbably 1 , 2 and 3 according to El-Bably, (2002). Modified Hargreaves according to Hargreaves and Allen , (2003) were chosen to estimate ET_O to find the most suitable empirical equation for regional use in Toshka district. The crop coefficient (Kc) values of sesame were estimated during the growing season according to Abdel-Mawgoud *et al*., (2007) using none stress irrigation treatments. At harvest time, ten plants were chosen randomly from each treatment to determine some morphological characteristics (number of capsules/ plant, length of fruiting zoon (cm), seed weight / plant (g), 1000-seed weight (g) , seed yield (kg / fed) and oil content (%). The statistical analysis of variance and treatment means were compared for significant differences using the L.S.D at p = 0.05. The SAS (version 6.12) was used to perform all the analysis of variance in agreement with the procedure outlined by Steel and Torrie, (1980).

Table (4). Average monthly meteorological data of Toshka weather station during the growth seasons.

Element / Month	S.R. (watt/m²/day)	W.S. (m/sec)	corrected E pan (mm/day)	R.H. (%)	Temperature Max (c)	Temperature Min (c)	barometric pressure mbar
summer season 2011							
May	292.2	3.3	9.7	15.4	39.2	21.5	989.6
June	314.9	3.5	10.2	17.1	41.3	24.3	986.8
July	305.7	2.6	10.2	17.0	43.1	24.7	986.1
August	241.4	2.9	10.6	19.8	42.3	25.7	986.3
September	223.6	3.3	10.0	22.8	40.1	24.1	987.6
summer season 2012							
May	295.1	3.2	9.5	14.9	40.1	22.9	990.2
June	317.2	3.6	10.1	16.1	42.1	24.6	988.8
July	307.6	2.8	10.3	17.9	43.2	24.9	987.2
August	282.3	2.9	10.6	19.8	42.3	25.7	986.3
September	255.5	3.3	10.0	22.8	40.1	24.1	987.6

S.R.=Solar Radiation W.S.= Wind Speed R.H.= Relative Humidity

Results and Discussion:

Actual evapotranspiration (ETa)

Actual evapotranspiration (ETa) as affected by moisture regime under sprinkler irrigation system through the growth stages of sesame plants in summer season of 2011 and 2012 are presented in table 5. The seasonal ETa values were 707.6, 602.0 and 561.4 mm at 25, 50 and 75 % soil moisture depletion, respectively.

Table (5): Actual evapotranspiration (mm) measured as affected by 25, 50 and 75% ASMD treatment under sprinkler irrigation at different growth stages of sesame during the summer seasons of 2011 and 2012.

Treatment (ASMD)		Growth stages: Initial stage 2011	Initial stage 2012	Development stage 2011	Development stage 2012	Mid-season stage 2011	Mid-season stage 2012	Late-season stage 2011	Late-season stage 2012	Total gross season 2011	Total gross season 2012	Average of two seasons
25 %	Period (day)	15May to 3 June (20)	17May to 5 June (20)	4 June to 8 July (35)	6 June to 10 July (35)	9 July to 17 Aug. (40)	11 July to 19 Aug. (40)	18 Aug. to 13 Sep. (33)	20 Aug. to 15 Sep. (33)	15May to 13 Sep. (128)	17May to 15 Sep. (128)	720.4
	Value (mm)	30.4	32.9	190.3	213.1	307.8	311.8	184.9	179.3	703.6	737.1	
50 %	Period (day)	15May to 3 June (20)	17May to 5 June (20)	4 June to 8 July (35)	6 June to 10 July (35)	9 July to 17 Aug. (40)	11 July to 19 Aug. (40)	18 Aug. to 7 Sep. (27)	20 Aug. to 10 Sep. (28)	15May to 7 Sep. (122)	17May to 10 Sep. (123)	624.8
	Value (mm)	30.4	32.9	176.7	200.6	242.1	251.2	152.6	162.8	602.0	647.5	
75 %	Period (day)	15May to 3 June (20)	17May to 5 June (20)	4 June to 8 July (35)	6 June to 10 July (35)	9 July to 17 Aug. (40)	11 July to 19 Aug. (40)	18 Aug. to 4 Sep. (24)	20 Aug. to 7 Sep. (25)	15May to 4 Sep. (119)	17May to 7 Sep. (120)	584.7
	Value (mm)	30.4	32.9	165.8	188.7	232.2	247.2	132.8	139.2	561.4	608.0	

The results indicated that the highest values of ETa were recorded in the mid season growth stages followed by development and end - seasons stages; the lowest values were recorded in the initial stages. The data also revealed that the average seasonal values of ETa decreased as the percentage of soil moisture depletion increased (more available water extracted) the values were 720.4, 624.8 and 584.7 mm at 25, 50 and 75 % soil moisture depletion from available water, respectively. It is clear that increasing the available soil moisture in the root zone of sesame crop caused a significant increase in the seasonal water consumption by sesame plants. The increase in actual evapotranspiration under lowest moisture stress treatment may be attributed to the increase in direct evaporation resulting from frequent wetting the surface layer and the presence of relatively high amount of available water under this regime. Therefore, the seasonal actual evapotranspiration is higher under 25 % ASMD regime followed by 50% ASMD. while the lowest values observed under 75 % ASMD regime.

These results may be attributed to the high availability of water at low moisture depletion which in turn increases transpiration from vigor vegetative growth of existed plants and evaporation from the soil surface by more water capillary movement.

The data in table 6, show the daily ETa values for sesame in the two seasons for initial, development, mid and the end growth stages, respectively. They were advance in growth stages then the ETa values were decreased at the late one. In other words the results of both seasons showed that the daily water consumed varied with growth stages. It started small at the initial stages (in May and first of June) then it increased gradually to reach the peak values at flowering stage in the Mid-season stage (July and first of August) after that it declined to reach its minimum values at Late-season stage in September. The highest value of daily consumptive use (6.75 mm, average value of two seasons) was obtained during mid stage at 25 % ASMD. While the lowest value of daily consumptive use (1.58 mm, average value of two seasons) was obtained during initial stage. The overall average values of daily consumptive use (Through the growing season) were 5.63, 5.10 and 4.90 mm at 25, 50 and 75 % ASMD, respectively. The obtained results can be ascribed as that at May and first of June, the vegetation has not been established yet and most of the water loss was due to evaporation from the bare soil. Thereafter, as the vegetation growth increased during (July and first of August) the rate of consumptive use increased and reached its maximum rate during flowering and early seed filling. During late August the rate of consumptive use decreased when the lower leaves of the plants dried and the rate reached its minimum values on September (harvesting time).The obtained results are harmonies with Ibrahim. *et al*, (1987). Also the results showed that increasing the available soil moisture in the root zone of sesame crop caused delayed harvesting date and increasing the plant growth duration of sesame, Therefore the average plant growth duration were 128 , 123 and 120 day at 25, 50 and 75% ASMD, respectively. The results of the current study are in close agreement with that reported by El- Emery *et al*, (1997) and El-Samanody *et al.*, (2010).

Table (6): Daily consumptive water use (mm) measured as affected by 25 , 50 and 75 % ASMD treatment under sprinkler irrigation at different growth stages of sesame during the summer seasons of 2011 and 2012.

Treatment	Growth stages								Gross season	
(ASMD)	Initial stage		Development stage		Mid- season stage		Late-season stage			
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
25 %	1.52	1.65	5.44	6.09	7.70	7.80	5.60	5.43	5.50	5.76
50 %	1.52	1.65	5.33	5.73	6.05	6.28	5.65	5.81	4.93	5.26
75 %	1.52	1.65	4.74	5.39	5.81	6.18	5.53	5.57	4.72	5.07

Reference evapotranspiration (ET_0)

The data in table 7 show that the estimated seasonal ET_o values in both growing seasons followed the descending order of Jensen and Haise› Pan Evaporation › Modified Penman › Elbably (2) › Penman Monteith › Modified Hargreaves › Blaney-Criddle › Elbably (3) › Doorenbos and Pruitt › Makkink › priestly – Taylor › Elbably (1) › Stephens - Stewart › Turc equations. The data indicate that the values of ET_o which has been calculated by Jensen and Haise equation was the superior one the exceeded the actual evapotranspiration (ETa) by 94.0 and 74.5 % in the first and second seasons , respectively. The ET_o values estimated by Pan Evaporation equation was exceeded by 75.7 and 69.4% in the first and second seasons , respectively.. While, the ET_o values estimated by Turc equation was under estimated the ETa values by 41.1 and 44.3 % in the corresponding seasons. The data which are represented in table 7 revealed that the ET_o values estimated by priestly – Taylor equation was over estimated the ETa values by 1.3 % in the first seasons (2011), and the values was under estimated the ETa values by 0.01 % in the second seasons (2012), so the average seasonal values of ET_o which has been estimated by priestly – Taylor equation was over estimated the ETa values by 0.57 %. While the average seasonal ET_o values estimated by Elbably (1) and Stephens - Stewart equation was under the ETa values by 3.9 and 5.03 %, respectively. On the other hand the average seasonal ET_o values estimated by Makkink and Doorenbos and Pruitt equation was exceeded the ETa values by 5.8 and 8.2 %, respectively. Data of ET_o values estimated by different empirical equations in both seasons revealed that the ET_o values started small according to the small plant cover in the early stage. They increased to reach their maximum values in mid – season (July and August) due to the maximum temperature and plant canopy, and then tended to decline again until the crop maturity due to crop canopy changes. Also the data which are represented in table 7 show satisfactory correlations which have been noticed for these methods, except the relation between growth stage and the mount of water which each method has Identifies, which reflect doubtful results. For example at the summer growing seasons (2011) and (2012) in the initial stage Blaney- Criddle was the closer value to (ETa) value for this stages , the average seasonal ET_o values estimated by Blaney-Criddle equation was under estimated the ETa values by 5.6%**,** also in the development stage Blaney - Criddle was the nearest one, the average seasonal ET_o values estimated by Blaney - Criddle equation was over estimated the ETa values by 29.9 % **,** while in the mid season stage Doorenbos and Pruitt value was the closer than other methods, the average seasonal ET_o values estimated by Doorenbos and Pruitt equation was over estimated the ETa values by 5.3%**,** while Blaney- Criddle has been in the late stage, the average seasonal ET_o values estimated by Blaney- Criddle equation was over estimated the ETa values by 9.5 %.

Also the results indicated to the variation between the suitable empirical method and ETa values throw growth stages, the evaluate of each growth stage show that Blaney-Criddle equation was more suitable in the initial and development and late season stage, while Doorenbos and

Pruitt suitable in the mid season stage.

Due to that irrigation scheduling will ensure that water is applied to the crop when needed and in the amount needed, Effective scheduling requires knowledge of many factors including the stage of crop development. Similar notice has been reported by Fontenot, (2004) who indicated that it is important to provide the proper amount of water via irrigation. Too much or too little water at the wrong stage of crop development can damage the crop and reduce yield. The encouraging results obtained from this notes should be investigated further in more researches by using suitable empirical method for each growth stage.

To evaluate the used empirical equations and their efficiency in calculating ET_o, a comparison between ET_o values and actual evapotranspiration (ETa) values is shown in table (8). The obtained results indicated that the ratio between average seasonal ET_o of Priestly-Taylor equation and seasonal ETa was 1.01. it is clear that the Priestly-Taylor, Elbably (1), Stephens- Stewart and Doorenbos and Pruitt equations calculated ET_o efficiently but Priestly- Taylor equation was the most efficient in calculating ET_o of sesame crop in Toshka district due to its least over estimation, as it was only 0.57 % as an average value of both seasons, compared to that underestimated by Elbably (1), Stephens-Stewart and Doorenbos and Pruitt equations which was 3.85, 5.02, 8.18%, respectively as an average value of both seasons.

Table (8): The ratio between (ETo) calculated with different empirical equations and (ETa) for sesame during the two summer seasons (2011) and (2012).

Equation	ETo		Ratio		Means
	2011	2012	2011	2012	
Jensen and Haise	1365.0	1286.3	1.94	1.75	1.85
Evaporation Pan	1236.1	1248.7	1.76	1.69	1.73
Modified Penman	1214.6	1172.5	1.73	1.59	1.66
Elbably (2)	1137.3	1134.6	1.62	1.54	1.58
Penman Monteith	1200.0	847.3	1.71	1.15	1.43
Modified hargreaves	1023.4	998.6	1.46	1.36	1.41
Blaney-Criddle	1027.3	892.4	1.46	1.21	1.34
Elbably (3)	915.4	913.2	1.30	1.24	1.27
Doorenbos and Pruitt	783.4	775.1	1.11	1.05	1.08
Makkink	747.8	777.1	1.06	1.05	1.06
Priestly- Taylor	713.0	737.0	1.01	1.00	1.01
Elbably (1)	693.5	691.8	0.99	0.94	0.97
Stephens- Stewart	685.9	682.4	0.98	0.93	0.96
Turc	414.3	410.5	0.59	0.56	0.58
Actual evapotranspiration at 25% ASMD	703.6	737.1			720.4

This results was disagree with El-Shimi *et al* ,(2005) who indicated that the most efficient method for calculating sesame water use in upper Egypt is Doorenbos- Pruitt formula. And Ramadan *et al*, (2006) who indicated that the modified FAO Penman-Monteith method for ET_o calculations has given best verification proving in Toshka district.

Crop coefficient (Kc).

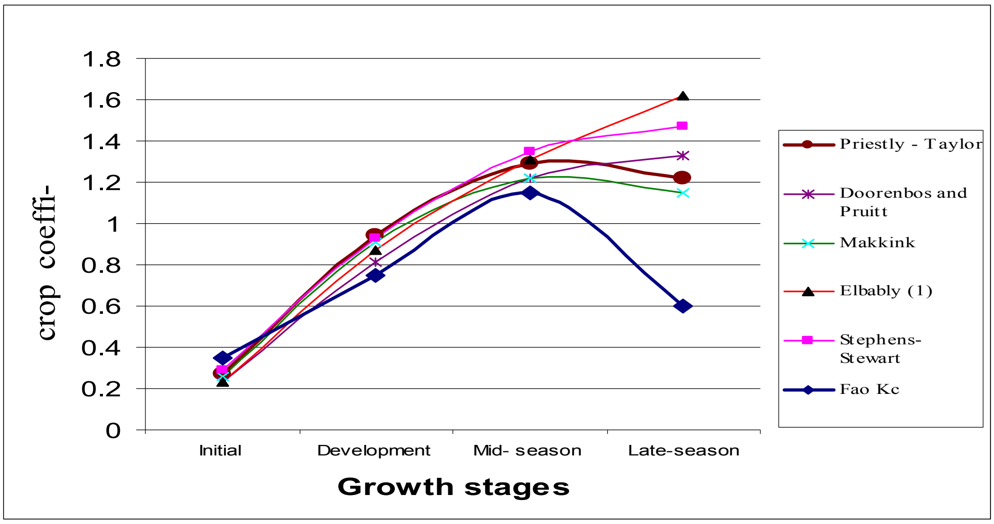
In general, the data which are represented in table 9 revealed that the calculated k_c values at different sesame crop growth stages by various equations were not always identical in both seasons. They were less in the first season than those in the second one. The obtained results of k_c values for both seasons indicated that the Priestly – Taylor equation was the best one to calculate ET_o for the two growing seasons in Toshka district. This may be due to the differences of the hypothetical reference crop that was calculated by Priestly – Taylor equation relative to the crop canopy and aerodynamic resistance were more constant in the both growing seasons than aerodynamic hypothetical reference crop that was calculated by the other equations. The average k_c values of sesame crop in two seasons which calculated by Priestly – Taylor equation during growth stages were 0.27 , 0.94 , 1.29 , 1.22 for initial , development , mid season , late season, respectively. While the seasonal averages of sesame k_c values under the same equation were 0.93. This results was disagree with El-Samanody *et al* ,(2010) who reported that the seasonal averages of sesame k_c values were 0.7.also , data indicate that the crop coefficient vary from growth stages to another in the two seasons . these values were low at the beginning of the growing seasons , because plant vegetation growth has not established yet and so the loss of moisture is mostly by evaporation from soil surface. As plant developed a gradual increase is observed in crop coefficient . The crop coefficient reaches their peaks in mid – season stage. After reaching the peak of vegetation development the rate of crop coefficient pronouncedly decrease the late season of plants.

Coefficient of water stress (Ks).

Soil water shortage may reduce soil water uptake and limit crop evapotranspiration. At field capacity, the depletion of water content from root zone is minimized. When soil water is extracted by evapotranspiration, the depletion increases and the soil water stress will be induced. Stress at deferent growth stages affected the obtained k_c values (estimated from ETa at 50 and 75% ASMD and ET_o data) that greatly were lowered with the pronologed table (10 & 11) `which indicate that the crop coefficient vary from growth stage to another in the two growing seasons.

The obtained results indicated that the k_s values followed the same trend of k_c values either through the growth stages The obtained results of Ks values for both seasons indicated that the Elbably (1) and Stephens-Stewart equation could be calculate ET_o efficiently under water stress but Stephens- Stewart was the best one to calculate ET_o for the two growing seasons in Toshka district**.** This may be due to the differences of the hypothetical reference crop that was calculated by Stephens- Stewart equation relative to the crop canopy and aerodynamic resistance were more constant in the both growing seasons than aerodynamic hypothetical reference crop that was calculated by the other equations**.**

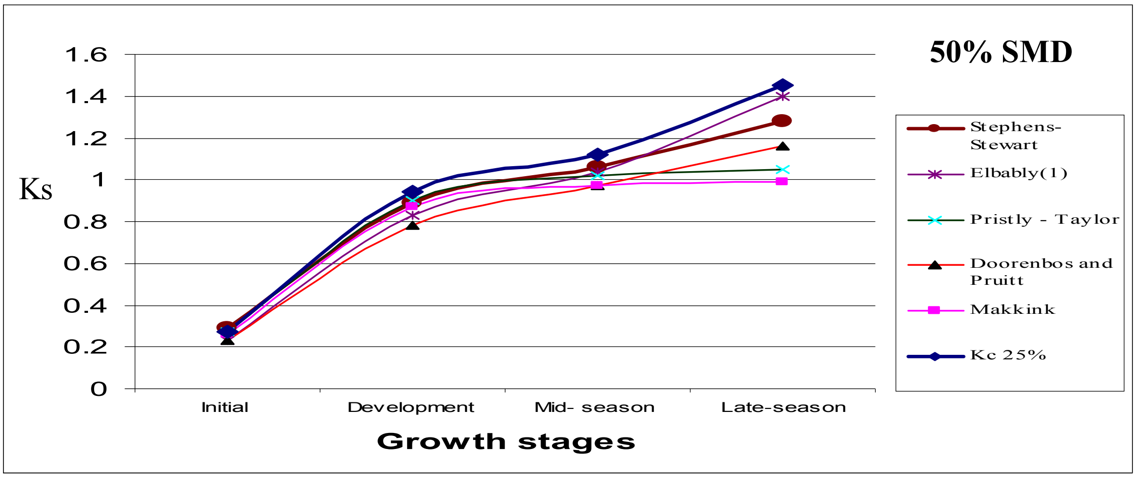
Fig. (1): The nearest five ranked methods during the growth stages for crop coefficients for sesame through the growing seasons.

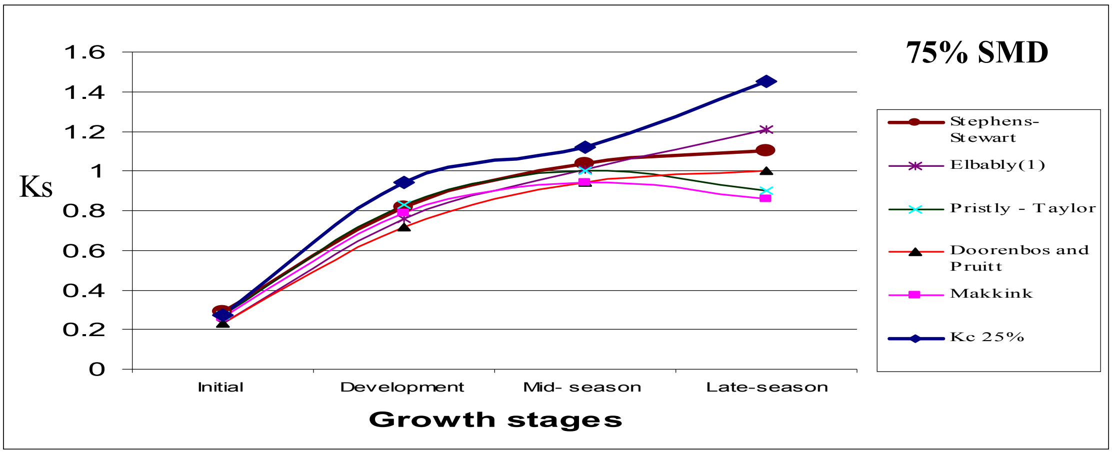


Stage / ASMD	Initial stage	Development stage	Mid-season stage	Late-season stage
Average 25 % ASMD	0.24	0.81	1.10	1.17
Average 50 % ASMD	0.24	0.75	0.87	1.00
Average 75 % ASMD	0.24	0.71	0.84	0.86
Fao K_c for sesame	0.35	0.75	1.15	0.60

Stressed treatment

Fig. (2): The top five ranked methods during the growth stages water stress coefficient (Ks) for 50 % and 75 % ASMD for sesame through the growing seasons.





Stage / ASMD	Initial stage	Development stage	Mid-season stage	Late-season stage
Average 25 % ASMD	0.24	0.81	0.95	1.38
Average 50 % ASMD	0.24	0.75	0.87	1.00
Average 75 % ASMD	0.24	0.71	0.84	0.86

Sesame yield and yield components.

Sesame (*Sesame indicum* L.) is considered as one of the most important oil crops in Egypt due to its high seed oil content (47-52%). It is the most appropriate crop for growing in the newly reclaimed land, which is expanded on a large scale outside the Nile Valley in Egypt. Therefore its growth and high productivity depend mainly on the proper water management . The various crop development stages posses different sensitivities to moisture stres where time , duration and the degree of the stress all affect yield. Water management that maximize yield per unit of water consumed by plant are highly desired.

Growth characteristics.

The effects of available soil moisture depletion on growth characteristics (plant height, number of plant / m^2, number of branches / plant, number of leaves / plant, number of capsules / plant, dry matter of leaves / plant, dry matter of stem / plant, dry matter of capsules / plant) at 85 days of sowing during the two growing seasons were presented in tables 12 .The obtained results revealed that the irrigation regimes has significant affected growth characteristics. Generally, decreasing the irrigation regimes to (25% ASMD) caused significant increases in the aforementioned characteristics. Vegetative growth stage characters were gradually decreased with increasing water stress. The decrease in plant growth as a result of water stress is due to its effect on plant turgidity and division, increasing respiration and decreasing photosynthesis. Increasing the available soil moisture in the root zone encourages the sesame plants to absorb sufficient water and consequently increase the photosynthesis activity. The available soil moisture may increase the rate of leaf appearance and leaf growth which resulted in increasing the other growth parameters. These results are harmony with those reported by Choi *et al*, (1990); Sekhara and Reddy, (1993) and Abdel-Gawad *et al*, (2001).

Yield and yield component.

Generally, the obtained results which are represented in table 13 revealed that the irrigation regime has significant affected growth characteristics. The results indicated that the average (number of capsules/ plant, length of fruiting zoon (cm), seed weight/ plant (g), 1000-seed weight (g) , seed yield (kg/ fed) and oil content (%) was significantly effected by the available soil moisture depletion (ASMD) in both seasons .

Table (12): Effect of available soil moisture depletion(ASMD) on the growth characteristics of sesame as affected by water regimes at 85 days of sowing during of 2011 and 2012 seasons.

Characters / Treatment	plant height (cm)	Number of plant /m^2	Number of branches / plant	Number of leaves / plant	No. of Capsules /plant	Dry matter of leaves (g/plant)	Dry matter of stem (g /plant)	Dry matter of Capsules (g /plant)
2011								
25 % ASMD	142.20	111	2.50	70.78	42.40	11.80	27.24	16.80
50 % ASMD	122.10	92	2.10	61.65	38.34	10.42	21.20	13.77
75 % ASMD	87.90	74	1.48	51.00	32.10	8.50	17.33	11.80
L.S.D 5%	5.52	6.94	0.78	3.35	4.47	0.54	1.04	0.58
2012								
25 % ASMD	166.40	118	3.00	73.81	47.44	13.33	31.25	18.77
50 % ASMD	161.10	97	2.40	65.00	39.20	11.75	24.30	15.40
75 % ASMD	152.20	81	1.60	53.40	34.30	9.15	18.00	12.11
L.S.D 5%	5.52	5.52	0.53	3.61	3.59	1.11	1.38	1.07

Table (13): Effect of available soil moisture depletion (ASMD) on the yield of sesame crop during 2011 and 2012 seasons.

Characters / Treatment	No. of Capsules /plant	Length of fruiting zoon(cm)	Seed weight/ plant (g)	1000-seed weight (g)	Seed yield (kg/fed)	oil content (%)
2011						
25 % ASMD	55.20	132.40	12.89	3.97	370.40	58.65
50 % ASMD	47.20	80.50	10.70	3.88	360.15	56.10
75 % ASMD	39.20	66.2	9.74	3.55	344.20	55.10
L.S.D 5%	1.27	4.73	0.67	0.10	2.40	0.93
2012						
25 % ASMD	56.25	137.50	12.9	4.13	385.25	59.00
50 % ASMD	49.20	85.50	11.02	3.91	366.25	57.50
75 % ASMD	40.00	71.30	9.81	3.70	350.75	55.40
L.S.D 5%	1.27	1.45	0.56	0.12	0.74	1.12

Water use efficiency (WUE):

Data of Table 14 reveal that increased irrigation regime treatment from 25 to 75 % ASMD increased water use efficiency by sesame plants from (0.13 to 0.15) and (0.12 to 0.14) in 2011 and 2012 seasons, respectively. The results show that the values of sesame WUE were slightly increased in summer season of 2011 compared to that in summer season of 2012.Result may prove that withholding irrigation at capsule development stage could save water and encourage increase in number of capsules, seeds weight/ plant and seed yield / fed. It could be concluded that withholding irrigation at any stage of growth resulted in higher (WUE) values compared to the control irrigation treatment. El-Samanody *et al* , (2010) .These results could be confirmed by the results of El-Wakil and Gaafar,(1988) ; Haikel and El-Badry,(1995) ; Haikel and Bassal ,(1996); Haikel and Farid, (2001); El-Tantawy *et al*, (2002); Tantawy *et al*,(2007) and Kassab *et al*, (2012).

Irrigation water use efficiency (IWUE):

The results were presented in table 14 show that the values of sesame (IWUE) in the first season (2011) were 0.09, 0.11 and 0.11 kg / m^3, while it was in the second season (2012) were 0.09, 0.10 and 0.10 kg / m^3 for 25, 50 and 75% ASMD, respectively. Although, it is obvious that increasing the amount of applied irrigation water was accompanied by increasing in total yield / fed but the irrigation water use efficiency increased as the percentage of ASMD increased. This may due to that increasing the mount applied irrigation water was inappropriate with that of yield Mohamed, (2007).

Also These results could be confirmed by the results of El-Wakil and Gaafar, (1988); Haikel and El-Badry,(1995) ; Haikel and Bassal ,(1996); Haikel and Farid, (2001); El-Tantawy *et al*, (2002); Tantawy *et al*,(2007); El-Samanody *et al*,(2010) and Kassab *et al*., (2012).

Table (14): Water use efficiency (WUE) and Irrigation water use efficiency (IWUE) as affected by available soil moisture depletion for sesame crop during summer seasons of 2011 and 2012.

ASMD	Grain Yield (Kg/fed)		Irrigation water applied (m^3 / fed)		Actual evapotranspiration (m^3/ fed)		Water use efficiency (Kg / m^3)		Irrigation water use efficiency (Kg / m^3)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
25 %	370.4	385.2	3987.5	4173.5	2955.1	3095.8	0.13	0.12	0.09	0.09
50 %	360.2	366.2	3359.6	3716.6	2528.4	2719.5	0.14	0.14	0.11	0.10
75 %	344.2	350.6	3157.9	3422.2	2357.9	2553.6	0.15	0.14	0.11	0.10

References:

Abdel-Gawad, A.A.; K.A. El-Shouny ; A.M. El-Gindy and H. A. Sorour (2001). Studies on phosphatic fertilization and irrigation of mung bean.1. Individual effect of P_2O_5 dose, water regime and irrigation system on growth criteria. Arab Univ. J. Agric. Sci. Ain Shams Univ. Cairo, 9: 201-212.

Abdel-Mawgoud, A. S. A.; M. A. Gameh; S. H. Abdel-Aziz and M.M. El-Sayed (2007). Wheat water relations at various irrigation regimes with modern irrigation systems under climatic condition of Assiut governorate, upper Egypt. J. Agric. Sci. Mansoura Univ., 32 (7): 6051-6066.

Agricultural Economic Research Institute Bulletins. Volume No. 2009. Ministry of Agriculture.

Allen, G. R.; L. S. Pereira; D.Raes and M.Smith (1998).Crop

evapotranspiration guidelines for competing crop water requirements.FAO. Irrigation and drainage paper 56. Rome, Italy.
Attia, M.M.; A.M. Osman; M.A. Sayed and A. EL-Kafoury (1999). Effect of irrigation intervals and row width on yield, water use efficiency and some economic studies on sesame (Sesamum indicum L.) in calcareous soil. Paper No. 39, the 3rd Conf. On-Farm Irrigation and Agroclimatology, January 25-27, Dokki, Egypt.
Choi, H.K.; Y.J. Kim; J.O. Guh; W.Y. Choi and H.J. Kim (1990). Influence of drought period in different growth stages on agronomic characters in sesame. Kor. J. Crop Sci., 35: 295-303.
Doorenbos , J. and W.O. Pruitt (1977). Crop water requirement. Irrigation and drainage paper, No.24, FAO, Rome.
El-Bably, A.Z. (2002). Estimation of evapotranspiration using statistical model. Conference on the Relationships between Global Trades and Local Resources in the Mediterranean Region, 57: 441-449, Apr, Rabat, Morocco.
El-Emery, M. I.; S. T. EL-Serogy and H. G. El-Rabia (1997).Effect of irrigation and harvesting treatments on yield and quality of some sesame (Sesamum indicum L.) genotypes. Egypt. J. Appl. Sci., 12 (11): 168-187.
El-Samanody,M.K.M.; S.M.El-Marsafawy and H. K. A. Rehab (2010) Impact of deficit irrigation at different growth stages on some sesame varieties in upper Egypt. J. Plant Production, Mansoura Univ., 1 (7): 857 – 871.
El-Shimi, A. ; M. M. El-Tantawy and K. M. Abd-Ella (2005). Effect of water stress on yield and yield components for some sesame varieties and its relation with wilt disease. Annals of Agri. Sci. Moshtohor, 43(3):1045-1055.
El-Tantawy, M. M.; M. K. M. El-Samanody; H. E. Khalifa and H.M. Eid (2002). Effect of Irrigation Intervals and Potassium Fertilizer Levels on Sesame Yield and Water Relations. Meteorological Research Bulletin, 17, (1): 114-131.
El-Wakil, A.M. and S.A. Gaafar (1988). Effect of water stress on sesame. Assiut J. Agric. Sci., 9: 363-374.
Fontenot, R. L. (2004). An evaluation of reference evapotranspiration models in Louisiana . M.Sc.Thesis, A&M College, Louisiana Univ. USA.
Haikel, M.A. and O.Z.El-Badry (1995). Response of corn to different irrigation systems in newly reclaimed soil. Ann.Agric.Sci.Moshtohor, 33:1025-1034.
Haikel, M.A. and S.A.Bassal (1996).Effect of irrigation systems, plant density and methods of nitrogen application on growth and yield of soybean under sandy soil conditions.J. Agric.Sci.Mansoura Univ., 21:1229-1240.
Haikel, M.A. and S.M.Farid (2001).Effect of different irrigation systems on faba bean productivity in newly reclaimed soil. Agric.Sci.Mansoura Univ. Egypt, 26:3411-3418.
Hargreaves, G.H. and R.G. Allen (2003) History and evaluation of Hargreaves evapotranspira-

tion equation. J. Irrig. Drain Eng , 129(1):53-63.

Ibrahim, A.F.; A.M. EI-Wakil and A.N. Sharaan (1987). Study on water requirements of sesame in Middle and upper Egypt. Egypt. .J. Agron. 12 (1-2): 77-93.

Israelson, O.W. and V.E. Hansen (1962). Flow of water into and through soils.Irrigation principles and practices. 3rd Edition, John Wiley and Sons, Inc., NewYork , U.S.A.

Jensen, M.E. and H.R. Haise (1963). Estimating evapotranspiration from solar radiation. J. Irrig. Drainage Division, 89:15-41.

Jensen, M.E.; R.D. Burman, and R.G. Allen (1990). Evapotranspiration and Irrigation water requirements. American society civil engineers No. 70, New York, U.S.A. (C.F. Aly, A.S., 2000. Contribution from ground water to water requirements of some crops. M.Sc. Fac. Agric. Fayoum, Cairo Univ., Egypt.

Kashyap, P.S. and R.K.Panda (2001). Evaluation of evapotranspiration estimation methods and development of crop coefficients for potato crop in a sub-humid region. Agricultural water management. 50(1): 9-25.

Kassab O.M.; A.A. El-Noemani and H.A. El-Zeiny (2005). Influence of some irrigation systems and water regimes on growth and yield of sesame plants. J Agron 4(3):220–224.

Kassab, O.M.; H.M. Mehanna and A. Aboelill (2012). Drought impact on growth and yield of some sesame varieties. J. Applied Sci. Res., 8(8): 4544-4551.

Kirda, C. R. (2002). Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Deficit Irrigation Practices, FAO Water Reports, 22: 3–10.

Klute, A. (1986). Method of soil analysis.Part-1.physical and Mineralogical methods. (Second edition) American Society of Agronomy, Madison, Wisconsin, U.S.A.

Landeras, G.; A.O. Barredo and J.J. Lopez (2008). Comparison of artificial neural network models and empirical and semi-empirical equations for daily reference evapotranspiration estimation in the Basque country (Northern Spain). Agric. Water Management, 95(5): 553-565.

Makkink, G. F. (1957). Testing the penman formula by means of lysimeter. Inst. J. Water Eng., 11(3): 277-288.

McGuinness, J.L. and E.F. Bordne (1972). A comparison of lysimeter derived potential evapotranspiration with computed values .Tech. Bull. 1452, Agric. Res. Serv., U.S. Dept. of Agric., Washington, D. C.

Metwally, M.A.; M.N. Seifel-Yazal and F.N. Mahrous (1984). Effect of irrigation regimes and nitrogen fertilizer on sesame. Egypt. J. Soil Sci. 24:129-136.

Mohamed, M.M.E. (2007).Water requirement of wheat and sunflower under different irrigation system at Assiut. M.Sc. Fac. Agric., Assiut, Univ. Egypt.

Nandagiri. L and G. Kovoor (2006).Performance evaluation of reference evapotranspiration equations across a range of Indian climates. J. of Irri. and Drain. Eng. 132(3): 238-249.

Page, A.l. (1982). Method of soil analysis. Part-2 : Chemical and microbiological properties,

(2^{nd} Ed.) , American Society of Agronomy, Madison, Wisconsin, U.S.A.

Ramadan, M. H.; M. A. El-Adl ; H. A. El-Mageed , and M. Maher (2006) Computer-Aided Mapping Irrigation Scheduling for Arab Republic of Egypt. The second International Conf. on Water Resources & Arid Environment, November 26-29 , King Saud Univ., Riyadh.

Sekhara, B.C. and C.R. Reddy (1993). Correlation and path coefficient analysis in sesame (Sesamum indicum L.). Ann. Agric. Res., 14: 178-184.

Steel, R.G.D. and J.H.Torrie (1980) .Principles and Procedures of Statistics. Second Edition, McGraw-Hill Book, New York, USA.

Sumner, D. M. and J. M. Jacobs (2005). Utility of Penman-Monteith, Priestley-Taylor, reference evapotranspiration, and Pan evaporation methods to estimate pasture evapotranspiration, J. of Hydrology, 308: 81-104.

Tantawy, M. M.; S. A. Ouda and F. A. Khalil (2007).Irrigation optimization for different sesame varieties grown under water stress conditions. J. App. Sci. Res, 3(1): 7-12.

Xu CY. and V.P. Singh (2002). Cross Comparison of Empirical Equations for Calculating Potential Evapotranspiration with Data from Switzerland. Water Res. Management 16(3): 197–219.

تأثير نقص المياه علي النمو والإنتاجية والعلاقات المائية لمحصول السمسم تحت الظروف المناخية لتوشكي.

ايمن محمد صالح[1] ، محسن عبد المنعم جامع[2]، أحمد غلاب محمد [2]، طارق أحمد السمان[3]
[1]طالب دراسات عليا –قسم الاراضي والمياه كلية الزراعة جامعة أسيوط
[2] قسم الاراضي والمياه كلية الزراعة جامعة أسيوط
[3] المركز القومي لبحوث المياه – القاهرة

أجريت هذه الدراسة في مزرعة تجارب الأبحاث الزراعية بمجمع الدراسات والبحوث المائية بتوشكي خلال موسمي 2011 و 2012 وذلك لدراسة تأثير إجهادات مائية متغيرة (25 – 50 – 75 % نقص للماء المتاح) تحت نظام الري بالرش علي الإستهلاك المائي وكذلك علي المحصول ومكوناته وعلي العلاقات المائية لمحصول السمسم صنف (جيزه – 32) ، وكذلك تم تقدير النتح بخر المرجعي عن طريق إستخدام بعض المعادلات الرياضية ومقارنته بالإستهلاك المائي الفعلي لتقدير كفاءة إضافة وإستخدام ماء الري ، وقد تم تصميم التجربة عن طريق إستخدام القطاعات الكاملة العشوائية حيث تم توزيع ثلاث معاملات من الإجهاد المائي (25 – 50 – 75 % نقص للماء المتاح) علي القطاعات الرئيسية وتم تقسيم كل قطاع لخمسة مكررات .

أظهرت النتائج أن أعلي قيمة للإستهلاك المائي السنوي سجلت عند إستخدام معاملة (25 % نقص في الماء المتاح) بينما سجلت أقل قيمة عند إستخدام معاملة (75 % نقص في الماء المتاح) ، كذلك فإن النتائج المتحصل عليها لقيم الإستهلاك المائي السنوي بلغت (703.6 – 602.0 – 561.4 مم) لمعاملات الإجهاد المائي (25 – 50 – 75% نقص في الماء المتاح) علي التوالي وذلك بالموسم الأول بينما بلغت (737.1 – 647.5 – 608.0 مم) لنفس معاملات الإجهاد السابق ذكرها علي التوالي وذلك بالموسم الثاني، كذلك أظهرت النتائج أن معادلة بريستلي – تايلور أكثر كفاءة لحساب الإستهلاك المائي لمحصول السمسم بمنطقة توشكي.

أظهرت النتائج كذلك أن أعلي قيمة لإنتاجية حبوب السمسم قد سجلت 370.44 – 385.25 كجم / فدان عند إستخدام معاملة (25 % نقص في الماء المتاح) وذلك بالموسم الأول والثاني علي التوالي ، بينما سجلت أقل قيمة 344.24 – 350.75 كجم / فدان عند إستخدام معاملة (75 % نقص في الماء المتاح) وذلك لنفس الموسمين السابقين.

تلاحظ من خلال النتائج المتحصل عليها وجود زيادة ملحوظة للنسبة المئوية لزيت السمسم بزيادة الماء المتاح وذلك في كلا الموسمين.