Zagazig J.Agric. Res., Vol .30 No.(3) 2003 819 - 832

EVAPOTRANSPIRATION RATES FROM WHEAT AS AFFECTED BY SCHEDULING IRRIGATION, TIMING AND RATES OF NITROGEN FERTILIZER

*** El –Garhi, I. A. ; * M.K.Matter ; ** S.A. Abd El-Hafiz and ** N.N. Sidrak**

*Soil Science Department, Faculty of Agriculture, Zagazig University.
** Soil, Water & Environment Res. Institute (SWERI), ARC , GIZA

Received 9 / 3 / 2003 Accepted 4 / 5 / 2003

ABSTRACT: Two field experiments were carried out at Giza farm, Agric. Res. Center Giza Governorate, during 1998/1999 and 1999/2000 seasons to identify the effective pan coefficient (selected from 0.6, 0.8 , 1.0 and 1.2 treatments (IW: CPE) needed for scheduling irrigation of wheat crop sids 7 variety (using pan evaporation records) under two nitrogen application times , one dose (presowing) and two doses (presowing and at life watering after 21 days) and 3 levels of nitrogen fertilizer (50,75and 100 kg N/ fad.). Sowing dates were November 18 and 21 November in 1998-1999 and 1999-2000 seasons, respectively, while , harvesting took place on April 21 and 23 April in the respective years .

Results of the two wheat growing seasons indicated that the seasonal water consumptive use values were 421.7 and 436.2 mm. in the first and second seasons, respectively. Also results indicated that the most efficient method for calculating wheat crop evapotranspiration (ETC) in Middle Egypt is penman Monteith followed by Modified-penman formula.

Key words: (IW: CPE) : irrigation water commulative pan evaporation ratio .

INTRODUCTION

Wheat is the first cereal crop in the world. Water and nitrogen are considered the most important factors affecting wheat production.

Water is the limiting factor of agriculture in arid and semi-arid regions. The response to fertilizer nitrogen depends on the level of available soil moisture and hence irrigation practices need to be modified. The present study aims to identifying the effective evaporation pan coefficient selected from 0.6 , 0.8 , 1.0 and 1.2 (IW : CPE) ratio needed for scheduling irrigation of wheat crop under the timing of N- fertilizer application and the best rate of N-fertilizer .

In this connection, Jensen and Middleton (1965) described and applied the accumulative pan evaporation method in scheduling irrigation in USA. Eid *et al* ., (1982) in Egypt used the evaporation pan method for Scheduling irrigation . El-Marsafawy (1995) in Giza , identified the effective evaporation pan coefficient for maize crop . More studies on determination of the effective evaporation coefficients were made in Egypt on soybean in Middle Egypt (Yousef, 1989) , faba been in Middle Egypt (Foad , 1995) and many others are being done for the same purpose .However Rayan *et al.*, (1999) found that seasonal consumptive water use values of wheat crop at Upper Egypt region were 1983 and 1930 m^3 / fad. in 1995 /96 and 1996/97 seasons, respectively . Rayan *et al* (2000) indicated that consumptive water use values for wheat crop in Shandaweel region were about 1752 and 1411 m^3 / fad. in the first and second seasons , respectively .

MATERIALS AND METHODS

The present investigation was carried out at Giza farm, Agric. Res . Center during 1998 /1999 and 1999/2000 seasons to study the effect of irrigation regime , timing of N fertilizer application and N fertilizer levels on actual seasonal evapotranspiration (consumptive water use) .

The experiment was laid out in split split plot design with four replications.

The main treatments were irrigation regime (evaporation pan coefficient): 0.6, 0.8, 1.0 and 1.2 represent (Prolonged – dry treatment), (Infrequent), (medium) and (frequent).

Where as the Sub-plots is time of N fertilizer application, which were all dose applied at presowing time or splitting the rate into two equal doses, one at presowing time and the other one before life watering irrigation. The sub –sub plots were nitrogen fertilizer rate, which were 50, 75 and 100 kg N /fad .

The nitrogen fertilizer was added in the form of ammonium nitrate (33 % N) .

The experimental field were ploughed and calcium superphosphate (15.5 % P_2 O_5) at the rate of 100 kg / fad. and potassium sulphate (48% K_2O) at rate of 50 kg / fad . were brodcasted before the first irrigation . Actual consumptive use (ETa) .

Seasonal consumptive water use (evapotranspiration) and monthly C.W.U were recorded.

The actual evapotranspiration (ETa) was estimated from the soil sampling. Soil samples were taken before and after irrigation as well as at harvesting time to calculate consumptive water use according to the equation of Israelsen and Hansen (1962) .

The monthly consumptive water use were obtained from daily water use multiplied by the number of days in the month .

Potential evapotranspiration (ETp) were estimated using three different empirical equations , i . e . Penman Modified , Penman Monteith

And Doorenbos –Pruitt where as the " WATER" model (Zazueta and Smajstrla 1984) was used to calculate the reference evapotranspiration

The " CROPWAT" model (Smith 1991) was used to calculate (ETp) values for Penman – Monteith equation .

Mechanical analysis of soil according to Piper, (1950) is shown in Table (1). Soil moisture constants i.e. bulk density, field capacity and permanent wilting point were determined and presented in Table (2). Meteorological data of Giza region are shown in Table (3) .

RESULTS AND DISCUSSION

1- Actual evapotranspiration (ETa).

1.1 Seasonal actual consumptive water use(ETa) :

Seasonal actual consumptive water use as affected by irrigation regimes , Time of N fertilizer application and N fertilizer levels are recorded in Table (4). The average values irrespective to irrigation regime, time of N application and N fertilizer levels together were 421.7 and 436.2 mm. in the first and second seasons, respectively.

With respect to irrigation regime, ETa values in 1998 / 99 were 333.2, 403.7 , 445.7 and 504.0 mm. for 0.6 , 0.8 , 1.0 and 1.2 (IW: CPE) ratio, receptively.

The corresponding values in 1999/2000 were 343.3, 419.7 458.2 and 523.6 mm. in the same order . It is clear that ETa gradually increased as the available soil moisture increased in the root zone of wheat plants (i.e. irrigation wheat at short irrigation intervals increased ETa values) . However subjecting wheat plants to water difficit reduced the ETa values.

In this respect Mohamed and Tammam (1999) found that the treatments which received all irrigations recorded the highest amount of water and consumed more water than the other treatments . These results are in full agreement with those obtained by Badawi *et al.* (1984) ;Metwally *et al* ., (1984) , El –kalla *et al* (1994) ; Khater *et al* , (1997) ; Rayan *et al* ., (1999) and El Marsafawy (2000) .

They confirmed that water consumptive use increased as soil moisture content increased.

Regarding to timing of N fertilizer application ETa values in 1998/99 were 411.9 and 431.4 mm . for one and two times of N applications , respectively .

The values in 1999/2000 were 426.2 and 446.2 mm. for the same respective treatments. These results indicated that ETa values were slightly inceased with the splitting rate of N fertilizer into two equal doses. Data recorded in Table (4) revealed that increasing levels of N fertilizer increased ETa of the wheat crop .

The values in 1998 / 1999 were 398.4 , 421.8 and 444.8 mm. whereas in 1999/2000 were 406.5 , 441.5 and 460.7 mm for 50, 75 and 100 kg N / fad ., respectively.

However results indicated that ETa values were increased by increasing N fertilizer levels in both seasons.

Regarding the interaction between the three studied treatments Table (4) showed that the highest value of ETa was obtained at 1.2 (IW: CPE) ratio with treatment of applying 100 kg N / fad . splitting into two equal doses . However, the lowest value was recorded at 0.6 (IW: CPE) ratio with treatment which received the rate of 50 kg N / fad. applied at one dose.

The monthly consumptive water use as affected by different treatments are recorded in Table (5). Monthly ETa values for irrigation regime were increased by increasing number of irrigation (i. e. 1.2 pan evaporation coefficient) in the two seasons . The highest monthly ETa values were recorded through March in all treatments. This can be attributed to the increase in air temperature and to the vigorous growth of wheat plants.

Monthly ETa values were increased when N fertilizer rate was applied into two equal doses and it increased also by increasing N rate up to 100 kg N / fad. The results are in full agreement with those found by El-Refaie *et al.*,(1988), who reported that the monthly rates of water consumptive use at Middle Delta (Gemmeiza) were 22.40 , 55.28 , 53.48 , 90.07 , 85.26 and 70.70 mm . , respectively , from December to May . Regarding the values of ETa and ET crop (mm / month) estimated by modified Penman, Penman Monteith and Doorenbos-Bruitt as recorded in Table (6), the data revealed that in 1998 / 99 and 1999 /2000 seasons ET crop values were 2.59, 2.97,3.14 and 2.56,2.93 and 3.05 mm for modified Penman , Penman Monteith and Doorenbos – Pruitt formulae , respectively . Generally, results recorded in Table (6) showed that Doorenbos-Bruitt formula gave the maximum value, while modified Penman gave the minimum one. At the same time values of Penman Monteith was found to be in between in the two seasons.

Comparing ET crop with the Actual ET, data recorded in Table (6) revealed that the average ratios between ET crop / Actual ET were 0.90 , 1.03 and 1.08 for modified Penman, Penman Monteith and Doorenbos-Bruitt , respectively.

It can be concluded that Penman Monteith formula has the superior in calculating ET crop for wheat in Middle Egypt , due to It's least difference from the actual ETa value compared with other formulae .

However soil moisture extraction paterns, Table (7) showed that values of soil moisture extraction pattern within the root zoon of 60 cm as affected by irrigation regime , time of N fertilizer application

Table (1) particle size distribution of the experimental plots

Soil Fractions	Content %
Coarse sand	3.11
Fine sand	13.12
Silt	30.53
Clay	53.24
Textural class	clay

Table (2) : Experimental soil moisture constants at Giza research region .

The constants / The Depth (cm)	Field capacity	Wilting point (%)	Available water (%)	Bulk density (gm /cm^3)
0-15	39.90	18.40	21.50	1.15
15-30	33.50	17.65	15.85	1.22
30-45	27.95	16.60	11.35	1.23
45-60	28.35	16.40	11.95	1.29

Table : (3) Meteorological data at Giza Agricultural Research Station in 1998 /99 and 1999 / 2000 seasons .

Season	1998 / 99								1999/2000							
Month	Tmax	Tmin	W.S	R.H	R.F	S.S	S.R	E Pan	Tmax	Tmin	W.S	R.H	R.F	S.S	S.R	E Pan
November	26.6	15.7	1.6	47.0	0.0	8.1	326	3.50	26.97	14.87	3.27	62.67	0.00	8.1	326	3.69
December	21.6	11.1	1.8	68.0	3.4	7.1	268	2.59	22.27	11.23	3.20	70.33	0.00	7.1	268	2.34
January	20.7	9.30	1.1	72.0	0.8	7.0	280	2.36	18.43	8.37	3.50	70.67	3.00	7.0	280	2.08
February	21.9	10.0	1.8	67.0	0.3	7.9	354	3.50	20.17	8.80	3.43	69.00	0.00	7.9	354	2.75
March	25.4	11.7	2.2	59.0	0.1	8.6	441	5.24	22.20	10.57	4.10	67.33	1. 60	8.6	441	3.75
April	29.2	12.8	2.5	60.0	0.0	9.6	519	6.06	30.40	16.20	4.23	57.67	0.00	9.6	519	6.53

Where :

T_{max} . T_{min} = maximum and minimum temperatures c°.

W.S = wind speed (m / sec .) . R.H = relative humidity (%) .

R. F = rain full (mm) . S .S = actual sum shine (hour) .

S.R = solar radiation (cal / cm^2 / day) . and Epan = evaporation pan (mm / day)

Table (4) : Seasonal consumptive water use in mm of wheat as affected by irrigation regime, N fertilizer application timing and N fertilizer level in 1998-1999 and 1999-2000 seasons

Irrigation regime	Time of N. Application	1998-1999				1999-2000			
		N – levels (Kg / fad .)							
		50	75	100	Average	50	75	100	Average
0.6	One	301.8	330.2	359.2	330.4	307.7	338.6	358.7	335.0
	Two	319.0	330.8	358.2	336.0	322.3	356.5	376.1	351.6
Average		310.4	330.5	358.7	333.2	315.0	347.6	367.4	343.3
0.8	One	372.9	383.0	402.1	386.0	382.0	416.6	421.0	406.5
	Two	397.1	417.4	449.8	421.4	409.6	435.2	453.9	432.9
Average		385.0	400.2	426.0	403.7	395.8	425.9	437.5	419.7
1.0	One	414.8	437.7	468.5	440.3	431.0	452.4	466.2	449.9
	Two	435.0	451.7	466.4	451.0	443.0	465.0	491.4	466.5
Average		424.9	444.7	467.5	445.7	437.0	458.7	478.8	458.2
1.2	One	464.7	494.4	513.8	491.0	467.8	523.6	548.8	513.4
	Two	482.1	529.0	539.8	517.0	488.8	543.6	569.0	533.8
Average		473.4	511.7	526.8	504.0	478.3	533.6	558.9	523.6
Average for all time	One	388.6	411.3	435.9	411.9	397.1	432.8	448.7	426.2
	Two	408.3	432.2	453.6	431.4	415.9	450.1	472.6	446.2
N Levels average		398.4	421.8	444.8	421.7	406.5	441.5	460.7	436.2

Table (5): Monthly consumptive water use , cm as affected by irrigation regime , N fertilizer levels and time of application in 1998/99 and 1999/2000 seasons

Season	1998 /1999				1999/2000				1998/1999			1999/2000			1998/1999		1999/2000	
Treatments	* Irrigation regime								Nitrogen levels (N . kg / fad .) .						Time of application			
Month	0.6	0.8	1.0	1.2	0.6	0.8	1.0	1.2	50	75	100	50	75	100	ONE	TWO	ONE	TWO
November	2.08	2.08	2.08	2.08	1.87	1.87	1.87	1.87	2.08	2.08	2.08	1.87	1.87	1.87	2.08	2.08	1.87	1.87
December	4.34	4.65	4.96	5.27	4.96	5.27	5.89	6.20	4.11	4.43	4.64	4.01	4.35	4.83	4.33	4.33	3.89	3.92
January	5.89	7.13	8.06	8.99	5.89	6.82	7.75	9.30	7.11	7.22	7.63	7.11	7.78	7.94	7.44	7.74	7.61	7.95
February	6.44	7.56	8.96	9.80	6.67	8.12	9.57	9.86	7.82	7.96	8.70	7.85	8.46	8.91	7.59	8.95	8.31	9.48
March	8.06	9.92	10.25	12.71	8.06	10.23	10.85	13.02	9.90	10.63	11.46	10.01	11.48	11.66	10.85	11.13	11.02	11.36
April	6.51	9.03	9.66	11.55	6.90	9.66	9.89	12.19	8.82	9.85	9.96	9.80	10.26	10.85	8.91	8.91	9.92	10.09
Total	33.32	40.37	44.57	50.40	34.35	41.97	45.82	52.44	39.84	42.17	44.47	40.65	44.20	46.06	41.20	43.14	42.62	44.67

*** Irrigation based on irrigation water cumulative pan evaporation (IW : CPE) record ratio 0.6 , 0.8 , 1.0 and 1.2.**

Table (6) :Comparison of wheat potential ET (estemated by different methods) and actual consumptive water use by wheat (mm / day) in 1998 / 1999

Season	1998 / 1999		1999 / 2000		Average	
Formulae	ET	Ratio	ET	Ratio	ET	Ratio
Penman Monteith **	2.97	1.04	2.93	1.01	2.95	1.03
Doorenbos- Pruitt *	3.14.	1.10	3.05	1.06	3.10	1.08
Modifid Penman*	2.59	0.91	2.56	0.89	2.58	0.90
Actual ETa	2.85		2.89		2.87	

(Growth season of wheat 155 days)
* (FAO No. 24 , 1977)
** (Smith 1991)

Table (7): Distribution of moisture (Percentage) extracted by the root for different layers in 1998-1999 and 1999-2000 seasons

Season	1998 – 1999				1999-2000			
	Depth of soil in cm				Depth of soil in cm			
Irrigation regime	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
0.6	35.00	28.50	24.49	12.01	36.20	30.30	23.10	10.40
0.8	38.70	27.80	22.75	10.75	39.10	28.35	22.86	9.69
1.0	45.10	26.20	20.40	8.30	45.43	26.16	20.11	8.30
1.2	47.65	25.70	18.80	7.85	48.71	24.72	18.72	7.85

and N fertilizer level in 1998 /99 and 1999 /2000 seasons declared that in 1998 /99 and 1999/2000 seasons showed that extraction percentage of water from the top soil (0-30 cm) was 63.50 , 66.50 ,71.30 , 73.35 and 66.50 , 67.45 , 71.59 and 73.43 , for 0.6 , 0.8 , 1.0 and 1.2 (IW: CPE) ratio, respectively . The respective values for the subsurface layers (30-60 cm) were 36.50, 32.50, 28.70, 26.65 and 33.50, 32.55, 28.41 and 26.57 for the same irrigation regime, respectively.

Generally results indicated that most of the water extracted by plants was from the top soil (0-30 cm) . However the highest extraction percentage from the top 30-cm layer was recorded under 1.2 (IW: CPE) ratio treatment in both seasons .

This results are in accordance with various workers, Vasquez and Taylor (1958) , Bennett , and Doss (1960), Israelsen and Hansen (1962), Ainer (1983)and Shahin and Mosa (1994) .

REFERENCES

Ainer, N. G. (1983) Studies on the inter-relation ship among irrigation and plant population in maize (Zea Mays , L) . Ph . D thesis, Fac. Agric. Mansura Univ.

Badawi , A. Y .; W.I.Miseha; H.W. Tawadros ; A.AboElenine and A.S.A. Gomaa (1984) : Wheat crop as affected by the irrigation regime and nitrogen fertilization rate . Part II Seasonal evapotranspiration water use efficiency and irrigation scheduling for some wheat cultivars in Egypt. EMCIP symposium proceeding No . 84 vol ,2 .

Bennett , O. L . and B. D. Doss (1960): Effect of soil moisture level in root distribution of cool season forage species. Agron. J. 52 (2) : 204-207 .

Eid , H . M.; A Metwaly and F. N . Mahrous (1982) : Evaporation pan as index to consumptive use of water and scheduling irrigation in some field crops. Argic . Res . Rev.60 No. 5.

El- Kalla, S.E;A.A . Leilah ; A.H. Basoiny and Samira M . Hussein (1994): Effect of irrigation and foliar nutrition treatments on growth and yields of some wheat cultivars under Al-Arish area conditions. Sixth conf. Agron. Fac. Agric. Al – Azhar.

Univ.Vol.1.

El-Marsafawy, S.M . (1995): Scheduling irrigation of maize using the evaporation pan method under different fertilizer regimes and their effect on soil characteristics. Ph.D. Thesis, Fac. of Agric. Moshtohor, Zagazig Univ.

El- Marsafawy , S.M. (2000): Scheduling irrigation of wheat crop under different phosphorus fertilizer application times in Middle Egypt. 5th . Conference – Meteorology & sustainable development. 22-24 Feb.2000 182-195 .

El-Refaie , M.M.A.; H.H.Abdel-Maksod and A.A. Abdel-Shafi (1988) : Comparison of basin, sprinkler and drip irrigation methods for wheat crop . Conf. .of field irrigation and Agroclimatology . Soil and Water Res . Inst. ARC., ministry of Agric . And land reclamation, Giza, June 20-25 , 1988 .

Foad , A.F.(1995) : Scheduling irrigation of faba been using evaporation pan under different sowing dates . M.Sc . Thesis, Fac . of Agric . Moshtohor , Zagazig Univ .

Israelsen , O.W. and V.E. Hansen(1962) : Irrigation Principales and practices. 3ed Jhon wiley and sons inc . New York

Jensen. M.C. and J. E Middleton (1965): Scheduling irrigation from pan evaporation Washington Agric. Axp. Station College of Agric Washington St.Unvi. Cercular 386.

Khater, A.N.; H.H. Abdel Maksoud and H.M.Eid (1997): Response of some wheat cultivars and their water relation to different irrigation levels in Middle Delta. Egypt . J . Appl. Sci, 12, (5) .

Metwally , M .A; M.N . Seif El – Yazal ; A.Y. Badawi ; H. W. Tawadros and A. Serry (1984): Effect of moisture stress and nitrogen on some wheat varieties. The 2nd general conference of ARC. Giza.

Mohamed, K . A and A.M. Tammam (1999) : Drought resistance of some wheat varieties in Upper Egypt . Third Conf. On Farm Irrigation and Agroclimatology, January 25-27 , 1999 , Giza , Egypt.

Piper, C.S. (1950): Soil and plant analysis . Univ. of Adelaide Australia.

Ray, S.O.P. Gautan and N. G. Destine. (1964): water requirement of crops on soil moisture basis 5th irrigation practices seminar NESA Region , New Delhi , India .

Rayan , A.A.; S.M. El-Marsafawy and K.A. Mohamed (1999): Response of some wheat varieties to different sowing dates and irrigation regimes in Upper Egypt , Third Conf. On Farm Irrigation and Agroclimatology, January 25-27, 1999, Giza, Egypt. .

Rayan , A.A; S.M. El –Marsafawy ; N . G. Ainer and S.E. Soliman (2000) : Scheduling irrigation of wheat crop in Upper Egypt under different sowing dates.s Egypt J. Appl. Sci . 15(1) , P . 65-70

Russell, M.B. and R.E.Danielson (1956) : Time and depth patterns of water use by corn Agron . J . 48: 163-165 .

Sendicor , G. W. and W.G . cochran (1980): Statistical Methods . 7th Edition . Lowa State University Press . Ames. Lowa . U.S.A.

Shahin , M.M. and E.M. Mosa (1994) : Irrigation cycles in relation to yield and water relation for wheat . Annals of Agric . Sc ., Moshtaohor , Vol .32 (1) 35-49

Smith , N . (1991) " CROPWAT" model for Eto calculation using Penman Monteith method FAO.

Vasquez , R. and S.A. Taylor , (1958) : Stimulated root distribution and water removal rates from moist soil . Proc. Soil .Sci. Amer . 22 : 106-110

Virmani , S. M. (1971): Rooting patterns of dwarf wheat Indian J. of Agron . 16-1 .

Yousef , K. M .R . (1989): Scheduling of soybean irrigation using pan evaporation. PH.D . Thesis Fac . of Agric . Moshtohor , Zagazig . Univ.

Zazueta, F.S. and Smajstrla (1984) : Evapotranspiration estimation utilities " WATER" model. Agricultural Engineering Department, IFAS , Univ. of Florida Gainesville . Florida.

تأثير جدولة رى محصول القمح تحت معدلات ومواعيد مختلفة من التسميد الازوتى على معدلات البخر نتح .

* إبراهيم عبد الجليل الجارحي * محمد كمال الدين مطر **سيد أحمد عبد الحافظ
** نصحي نجيب سدراك

* قسم علوم الأراضي – كلية الزراعة جامعة الزقازيق
** معهد بحوث الأراضي والمياه والبيئة – مركز البحوث الزراعية .

أقيمت تجربتان حقليتان بمزرعة مركز البحوث الزراعية بالجيزة خلال موسمي ١٩٩٨-١٩٩٩ ، ١٩٩٩ / ٢٠٠٠ وذلك بهدف دراسة جدولة رى محصول القمح صنف سدس ٧ فى منطقة مصر الوسطى باستخدام البخر من الوعاء القياسي " باستخدام أربع معاملات للبخر من الوعاء القياسي (١,٢ – ١,٠ – ٠,٨ – ٠,٦) ومعاملتين لميعاد إضافة السماد الازوتى (دفعة واحدة عند الزراعة – دفعتان إحداهما عند الزراعة والثانية عند رية المحاياة) و ثلاث معاملات لمعدل التسميد الازوتى (٧٥،٥٠، ١٠٠كجم نيتروجين / فدان)

أوضحت النتائج أن قيم الاستهلاك المائي لمحصول القمح (صنف سدس ٧) في منطقة الجيزة (مصر الوسطى) كانت ٤٢١,٧ ، ٤٣٦,٢ ملليمتر . في الموسم الأول والثاني على الترتيب وقد زادت قيم الاستهلاك المائي السنوي بزيادة عدد الريات (اى مع المعاملة ١,٢ معامل بخر الوعاء-) كما زادت قيم الاستهلاك المائي زيادة طفيفة مع تقسيم السماد إلى دفعتين متساويتين وزاد كذلك الاستهلاك المائي السنوي مع المعاملة السمادية ١٠٠ كجم / نيتروجين / فدان . وقد سجل الاستهلاك المائي الشهري أعلى قيمة خلال شهر مارس فى كلا الموسمين لجميع المعاملات . قدرت قيمة الاستهلاك المائى النظرى باستخدام كل من معادلات بنمان المعدلة وبنمان مونتيث ودورنبوس حيث أوضحت النتائج تفوق معادلة بنمان مونتيث يليها بنمان المعدلة فى حساب الاستهلاك المائي النظري لمحصول القمح بمنطقة مصر الوسطى .كما أوضحت النتائج لكلا الموسمين ان معظم الاستهلاك المائى كان من الطبقة السطحية (٠-٣٠سم) من التربة.