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Response of quinoa crop for water stress and planting date in the middle Egypt

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ABSTRACT

Two field experiments were carried out at Mallawy Experiment Station, El-Minia Governorate in the Middle Egypt during the growing winter seasons of 2012/2013 and 2013/2014 to study the effect of water stress and planting date on actual crop water requirements, crop coefficient, and yield of Quinoa as an alternative crop for food security in Egypt. In addition, this study aimed at evaluating and comparing the potential evapotranspiration (ET_P) equations for estimating actual crop water requirements under El- Minia Governorate conditions.

The experiment was carried out on three treatments of planting dates (A) and two irrigation regimes (B) with four replications; also, the experiment was implemented in a split plot design. Sowing dates treatments were November 25th, December 25th and January 25th. The irrigation regime treatments were irrigation at a depletion of 20% from A.W. (b1), irrigation at a depletion of 40% from A.W. (b2), and irrigation at a depletion of 60% from A.W. (b_3). Sowing dates were distributed randomly in the main plots, while irrigation regime treatments were distributed in the sub- plots.

The results indicated that the actual water consumptive use from planting until harvest were 22.62 , 21.41 and 21.47 (cm/season) for treatments A_1, A_2 and A_3, respectively under all different irrigation regimes. The results indicated that from the view point of the highest values of total yield (t/fed), they were obtained from treatment irrigation at 60% depletion of valuable water (b_3) and sowing on 25th November (A_1) (1.06 ton/fed.)

Monthly reference potential evapotranspiration (ET_o) for El-Minia Governorate, the Middle Egypt, was calculated using the modified Penman, modified Blaney & Criddle and Pan Evaporation method. Average (Kc) values of the three methods for different treatments were calculated to come up with accurate one value representing the (Kc). The average values of Kc for A_1 , A_2 and A_3 were 0.47 , 0.37 and 0.29 under irrigation regime (b_1), respectively, while its values for the same treatments under irrigation regime b_2 were 0.48, 0.45 and 0.35, respectively, and its values for the same treatments under irrigation regime (b_3) were 0.53, 0.41 and 0.36, respectively. The results also indicted that modified Blaney & Criddle equation achieved the highest average value for potential evapotranspiration ET_P (629.41 mm/season), while the Pan Evaporation method recorded the lowest average value (504.12 mm/ season) in the two winter seasons.

The average values of potential evapotranspiration (ET_P) by modified penman were nearest to the scientific literature average values (+2.79 %), while the farthest values to scientific literature average ones were obtained by modified Blaney & Criddle and Pan Evaporation method +11.18 % and -12.64 %, respectively.

In conclusion, it is recommended that irrigation of quinoa plants with depletion 60% of available water in the upper 60cm layer of soil (40 days apart between each two irrigation events) with cultivation date of 25/11 in order to produce high yield under the experiment conditions. On the other hand, this study indicated that the average values of potential evapotranspiration (ETcal) by modified Penman was nearest to the actual water consumptive use of quinoa crop. Therefore, modified Penman equation is recommended for calculating the potential evapotranspiration of quinoa under the Middle Egypt conditions.

Key words: Quinoa crop, water stress, planting date , Middle Egypt

INTRODUCTION

Water is fast becoming an economically scare resource in many areas of the world especially in arid and semi-arid regions. In Egypt , there are many plants for increasing cultivable land and agriculture production to overcome problems of the food security soil soil moisture is one of the most important factors which influence the yield and quality of crops as it affects the chemical, biological and physical conditions of soil . Available water in soil is essential for the life and function of plants. Water is necessary for growth, nutrient , absorption, transpiration, biological reactions and many other life activities. therefore, water requirements should be achieved to reach a well controlled scientific use of water. In all countries, all over the world, water is considered a limiting factors in agricultural expansion . The various phases of water consumption and direct use by human begins, animal, industry and irrigation .

As population increases , greater competition among the various phases makes conservation of water imperative . Agriculture is by no means the major competitor for water consumption. Adding too much or too little water may cause a serious damage for crops, water requirements must be carefully determined. In order to achieve this goal, the evapotranspiration (consumptive use of water) for each crop growing in various soil types under different climatologically conditions, must be calculated so as to evaluate the water regimes . this could be aided by the determination of the periodical evapotranspiration rates for each crop and define the most critical periods in which a crop either requires maximum or minimum amounts of water. Measuring or calculating evapotranspiration rate could be achieved by many ways such as soil moisture depletion method and using the meteorological data throughout the growth seasons.The late method leads to evaluate an imperial constant , for specific vegetation grown in particular location , which can be used afterwards as an index for direct calculation of evapotranspiration. In addition , salinity is considered as main major problem in agriculture, particularly because saline soils are found primarily in arid regions where draught , extreme temperatures , and nutrient deficiency go hand in hand , and where scarce precipitation and high evaporation hinder a leaching out of the salts that accumulate in the upper soil layers .It is estimated that between 340 and as much as 950 billion squares kilometers, equivalent to about 20% of the arid and semiarid soils of the world, or 6% of the world land area are saline. There is an increase in salinization due to irrigation , which is estimated to affect 50% of irrigated land (Jacobsen *et al.*, 2001). There are only few crops can be grown under marginal and extreme saline, dry and cold areas, quinoa is one of them (Jacobson and Mukica, 2001). In Europe, quinoa was suggested to be as a break crop between cereal crops and after potato crops .When grown in areas to which it is best adapted , it should be able to compete with cereals in both human diets and animal rations (Galway,1992) .So far , the results regarding quinoa as a drought resistant crop of high nutritive quality, which can be grown on poor, infertile soils, seem promising (Jacobsen and Stolen,1993). It was suggested to be an important new for Pakistan agriculture, providing highly nutritive and versatile food products for the population and a new raw material for the industry. In particular, it could be cultivated in many of the marginal environments afflicated by drought or salinity stress , which currently suffer from very low productivity (Jacobsen *et al.*, 2002) . Environmental extreme conditions of Southem America ,Pakistan and Egypt deserts tend to participate similar features (both of them face draught and salinity problems side by side), so that, quinoa could be suggested as an attractive alternative crop for the arid and semiarid regions, where water deficiency and salinity have been recognized as major agricultural problems (Prado *et al*., 2000). Many investigators showed in this connection Koziol (1993) showed that Quinoa (*Chenopodium quinoa*) grain contains 1.8-9.5% oil on a FW basis. The oil is concentrated inn the germ, which represents 25-30% of the grain weight. The germ can be removed by polishing to give a fraction containing about 19% oil. Geel

(1997) showed that Seed yields ranged from 1.5 to 5 ton ha^{-1}. Low yields were caused by low total production , a low harvest index in late –maturing cultivars and seed shedding during ripening. Nunez *et al.* (1997) showed that exposing Quinoa (*Chenophodium quinoa*) cv. Kancolla plants to water stress at branching , flowing or grain filling , affected on leaf water potential, stomatal conductance , photosynthesis , osmotic potential , turgor pressure and leaf water content showed that quinoas drought resistant . Koyro and Eisa (2008) reported that Plant growth and total seed yield were all significantly reduced in the presence of salinity. They also demonstrated that a highly protected seed interior leading to a high salinity resistance of quinoa seeds . Martinez *el al.* (2009) evaluated grain yield of two quinoa Inadraces (Don Javi and Palmilla) from lowlands of Central Chile (34^{o}C) during two seasons (2005 and 2006), they showed that Yield of 2006 harvesting season (7 ton ha^{-1}) was higher than that of the previous seasons (5.5 ton ha^{-1}), they suggested that better yields needs additional irrigation and addition of organic matter. Rijtema (1966) pointed out that in order to calculated the evapotranspiration from certain crop, the potential value must be multiplied by crop coefficient (K.c). He also declared may methods calculate the potential evapotranspiriation and some of these methods or formulas gave reasonable accuracy under certain climatological conditions. Others methods agree only with the observed values of correction for time log and wind speed . Doorrenhbos and puritt (1975) stated that Blaney–Criddle method may be used when temperature data were the only available measured weather data . They reported that the radition method was more reliable than the presented Blaney & Criddle approach. In equatorial zone , on small island or at high altitudes , the radiation method might be more reliable even if measured sunshine or cloudless data were not available . Solar radiation maps were prepared for most locations in the world and they provided the necessary solar radiation data . He also pointed out crop water requirements are normally expressed by the rate of evapotanspiration (ET) in mm/ day or mm/ period. The level of ET has been shown to be related to evaporative demand off air which could be expressed as reference evapotranspiration and added calculated the crop evapotranspiration by using the following formula : ETc= Kc x ETo

Where :
ETc= Crop evapotranspiration
Kc=Crop coefficient .
ETo= Reference crop evapotranspiration

They added that the determination of crop coefficient (Kc) could be used as reference crop evapotranspiration (ETo) to maximum crop evapotranspiration when water supply full met water requirements of the crop. The objective of the resent work was evaluated the effect of sowing date and irrigation regime on water applied, water consumptive use, crop coefficient and , yield for Quinoa .

MATERIALS AND METHODS

Two field experiments were carried out for two winter seasons of 2012/ 2013 and 2013 / 2014 seasons, at Mallawy, Water Requirements Research Station – El Minia Governorate; Water Management Research Institute- National . Water Research Center . The present research was carried out to study the effect of sowing dates and irrigation regime on water applied, water consumptive use, crop coefficient and yield of Quinoa crop .

The experiments included three treatments of sowing dates (A) and two regime of irrigation (B) with four replicated so that the experiment was arranged in a split plot design . Sowing dates treatments were 25th November, 25st December and 25th January. The irrigation regime treatments were irrigate at a depletion of 20% from A.W. (b_1), irrigate at a depletion of 40% from A.W. (b_2) and irrigate at a depletion of 60% from A.W. (b_3) . Sowing dates were distributed at random in the main plots .While irrigation regime treatments were distributed at random in the sub- plots ..Each plot area was $12m^2$ consisted of 4 rows with 5 m length , and the pacing was 0.6m bwtween rows , and both sides of row were cultivated and sowing rate was 3gm per 5m equal about 75 plant m^{-2} (4.2kg fed^{-1} , feddan=$4200m^2$) and a sowing depth of 2 cm.

Soil analyses :

Soil analyses showed that the experimental soil was silt clay loam containing (0.11 and 0.10 % of total N) , (11.8 and 11.0 ppm available P) , and (0.44 and 0.40 meq/100 g soil K) with pH 8.10 , in both studied seasons, respectively. Also same the physical characteristic as shown in Table (1). Organic and Calcium super phosphate (15.5% of P_2O_5).Fertilizers were applied fully prior to planting at the rate of 150 kg fed^{-1} . Urea (46.5% N) was added at the rate of 150 kg fed^{-1} and Potassium Sulphate (50% K_2O) was added at the rate of 150 kg fed^{-1} (Gesinski ., 2006) and (Geel.,1997) .

Climatic condition :

Some metrological data during the two growing seasons are presented in Table 2 . These data were obtained from metrological Mallawy Station located at the ̊ 27 9^- latitude and 30 5^- logtiude and its altitude is about 44m above sea levels . These data are used to get potential evapotranspination mm/ day
by different empirical formula such as modified Panman , modified Blaney & Criddle and pan method.

Recorded data :
Soil- water relations
Water Applied

In both growing seasons , water was measured by using a rectangular sharp crested weir. The discharge was calculated using the following formula :

$\mathbf{Q = CLH^{3/2}}$ (Masoud, 1967)

Where:
Q : The discharge in cubic meters per second.
L : The length of the crest in meters.
H : The head in meters.
C : An empirical coefficient that must be determined from discharge measurements .

Water consumptive use (CU) :

The quantities of consumptive use were calculated for the 60 cm soil depth which was assumed to be the depth of the root zone as reported by many investigators .

Monthly and seasonal water consumptive use were calculated by the summation of water consumed for the different successive irrigation through the whole growth season**.** Calculation of CU was repeated for all irrigation until the harvesting .
Water consumptive use per feddan ($4200m^2$) can be obtained by the following equation:

$\mathbf{CU= [(\theta_2 - \theta_{1)/100]}\ X\ (b.d)\ X\ (depth/100)\ X\ Area\ (4200\ m^2)}$
which described by Israelsen and Hansen (1962)

Where :
CU= Amount of water consumptive use (m^3/ fed.) .

θ_2=Soil moisture content (% by weigh) after irrigation .
θ_1=Soil moisture content (% by weigh) before the next irrigation
b.d = Bulk density (g/ cm^3)

Potential evapotranspiration (ET_p)
Modified Penman equation:

$$ET_p=c\ [\ (\ W.Rn + 1-w\ ) .f\ (u)\ .(ea-ed)]\ \text{mm/day}\ .$$

Where :
$ET_{p=}$ Reference crop evapotranspiration mm/ day .
W=Temperature –related weighting factor.
Rn=Net radiation in equivalent evaporation in mm/day.
f (u) =Wind-related function.
ed=Saturation vapour pressure of the air in (mm bar).
ea= Mean actual vapour pressure of the air in (m bar)
=ea x RH mean /100 , in which , RH = relative humidity .
(ea-ed) =Difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air , both in mbar .
c=Adjustment factor to compensate for the effect of day and night weather conditions.

Modified Blaney & Criddle equation :

Blaney and Criddle (1955) observed that the amount of water consumptive used by crop during their growing seasons was closely correlated with means monthly temperature and day light hours .

$$ET_p = C\ [\ P\ 0.64T + 8.13\ )\ ]\ \text{mm/day}\ .$$

Where :
ET_p= Potential evapotranspiration in mm/ day .
T= Mean daily temperature in ^oC
P= Mean daily percentage of total annual daytime hours for given month and latitude .
C=Adjustment factor which depends on minimum relative humidity , sunshine hours and day time wind estimate .

Pan evaporation method :

Reference crop evapotranspiration (ET_p) can be obtained from the following equation
ET_p=KP.E_{pan} (mm/ day) .
Where :
K_p= Pan coefficient depends on type of Pan , condition of Humidity, wind speed and speed and pan environmental conditions (=0.75) .

Crop Coefficient (Kc)

Crop coefficient defined as the ratio between actual crop evapotranspiration (ET_a) and potential evapotranspirtaion (ET_p) when both are in a large fields , under optimum growing conditions (FAO , 1977) . In the experiment the following equation was applied to compute the Kc values: .

$$Kc = ET_a / ET_p$$

Where :
Kc= Crop coefficient
ET_a= Actual evapotranspirtation (mm/ day) .
ET_p= potential evapotranspiration calculated by modified Penman (mm/ day) .

Statistical analysis :

Data obtained from experimental treatments were subjected to statistical analysis and treatments means were compared using the L.S.D methods according to Snedecor and Cocharn (1980) .

RESULTS AND DISCUSSIONS

Total yield (ton/ fed.) :

Data given in Table (3) showed significant differences in fed at different sowing dates . The highest yield of Quinoa was obtain by sowing Quinoa on 25th November. Data in Table 3 indicated also that yield increased by 20.53a and 45.08 % by sowing Quinoa crop on 25th November A_1 compared with sowing it on 25th of December A_2 and 25th and January A_3 respectively . This may be due to the higher infection by insects , and diseases in the late sowing on 25th December A_2 and 25th January A_3 than sowing 25th A_1 November.

Data in Table 3 showed also that yield of Quinoa crop was influenced statically by the studied irrigation regime where the yield of Quinoa crop increase by about 36.75 and 7.59under irrigation at a depletion of 60% from available water b_3. than b_1 and b_2 respectively . Concerning the interaction between the two studied factors , data in Table 3 show that , rom water view point the highest values of total yield (ton / fed) were obtained from treatment which irrigated at 60% depletion of A.W and sowing on 25th November (A_1b_3) and this treatment was the most superior treatment on this character (1.06 ton/fed.) in the both studied seasons This result is line with those reported by Geel (1997) , Nunez et al (1997) and Martinez *et al* . (2009).

Daily, monthly and seasonal actual water consumptive use :

Daily and monthly actual water consumptive use values were presented in Tables (4 and 5). The obtained indicated that daily water consumptive use increased gradually until reached its maximum values in flowing and milk stage in both seasons which is considered the critical stage period in water demands of com crop. Then, it declined by the end of growing and the water loss is almost due to evaporation from soil surface, while small amount loss by consumptive use. These results are in agreement with those reported by Isrealen and Hasaen (1962). Data in Table 4 show that average quantity of actual water consumptive use (cm / season) from planting until harvest were 21.68 , 19.40 , and 18.01 for A1 ,A2 , A3 cm/ season under irrigation regime (b_1), respectively. While , were 22.56 , 22.11 and 21.09 cm/ season for treatments sames A_1,A_2 ,A_3, respectively under irrigation regime (b_2) While , were 23.63, 23.09 ,22.01 cm/ season for treatments sames A_1,A_2 ,A_3, respectively under irrigation regime (b_3). Jenerally, results indicate that in Table (5) the actual water consumptive use from planting until harvest were 22.62 , 21.41 and 21.47 (cm/ season) for treatments A1, A_2 , and A_3 respectively under all different irrigation regime

Potential evapotranspiration (ET_p) :

Data in Table (6) shows that the computed values of daily , monthly and seasonal potential evapotranspiration (mm/ day,mm/ month and mm/ season, respectively) according to modified Penman, modified Balney & Criddle and pan method for two studied seasons .It can be observed from data in Table 6 that the lowest average of ET_P values (58.02 and 504.20 cm/season) were obtained from modified Panman and pan method, respectively during both studied seasons. While , the highest average ET_P (62.94 cm/season) was obtained by modified Blany and Criddle during both studied seasons . This due to the estimated factors in these equations . Results in Table 6 shown also that the average values of potential evapotransperation (ET_p) by modified penman was nearest to general average values (+ 2.79%) while , the farthest values to general average were obtained by pan method and motifed Blany & Criddle about (-12.64 % and +11.18 %) , respectively .

It could be noticed that the nearest ET_P values to the average are those which are obtained form modified Penman while , the farest obtained from the pan method .These results are in agreement with those obtained by Doorenhbos anmd Pruitt (1975) .

Crop coefficient (Kc) :

Effect of cop characteristics on crop water requirement was indicated by the crop coefficient (Kc) which represent the relationship between reference potential (ET_p) and actual crop evapotranspiration (ETa)

Data of crop coefficient for Quinoa crop for each treatment calculated using the actual consumptive use (ETa) and potential evapotranspiration (ETp) ($Kc= ET_a /ETp$) using the modified Penman , modified Blaney & Criddle and pan method . The values of Kc for different treatments are shown in Tables (7 , 8 and 9). It is clear that the values of Kc show slight increase with time after planting till reached their peak in formation of flowering and then decreased at the end of growth season. Results show that average Kc for the all treatments were calculated to be 0.47 , 0.37 and 0.29 for A_1,A_2 and A_3 under irrigation regime (b_1), respectively. While, were 0.48, 0.45 and 0.35 for same treatments under irrigation regime b_2 respectively . While , were 0.53,0.41 and 0.36 for same treatments under irrigation regime b_3 respectively . It could be noticed that the nearest values to average Kc those which calculated by modified Penman while the farthest were by pan method .

The calculated evaotranspiration ($ET_{cal.}$) :

The calculated evapotranspiration ($ET_{cal.}$) mm/ month, mm/ season and cm /season) are shown in Tables 10,11 and 12 for different treatments using the relation $ET_{cal.}$= Kc average X ET_p and its comparison with actual consumptive use (ET_a) for different treatments in Tables (13,14 and 15) and Figures 1 , 2 and 3) . Data in Tables (13 ,14 and 15) indicated that calculated evapotranspiration ET_{cal}) by modified Penam followed by modified Bleny & Crridle easily clarify the degree of accuracy for the calculated evapotranspiration as it show that the only values outside the 95% confidence limits are those of the modified Bley & Crridle for A_1 under irrigation regime (20% depletion of A.W) while , the farthest values outside the 95% confidence limits for all treatments A_1,A_2 and A_3 , are those of the pan method . So we can recommend this equation (Modified penma) for estimating ET_P in Minia region with the average crop coefficient due to the highest accruing for Quinoa crop These results are in agreement with those reported by Rijtema (1966) and Doorenhbos and Pruit (1975) .

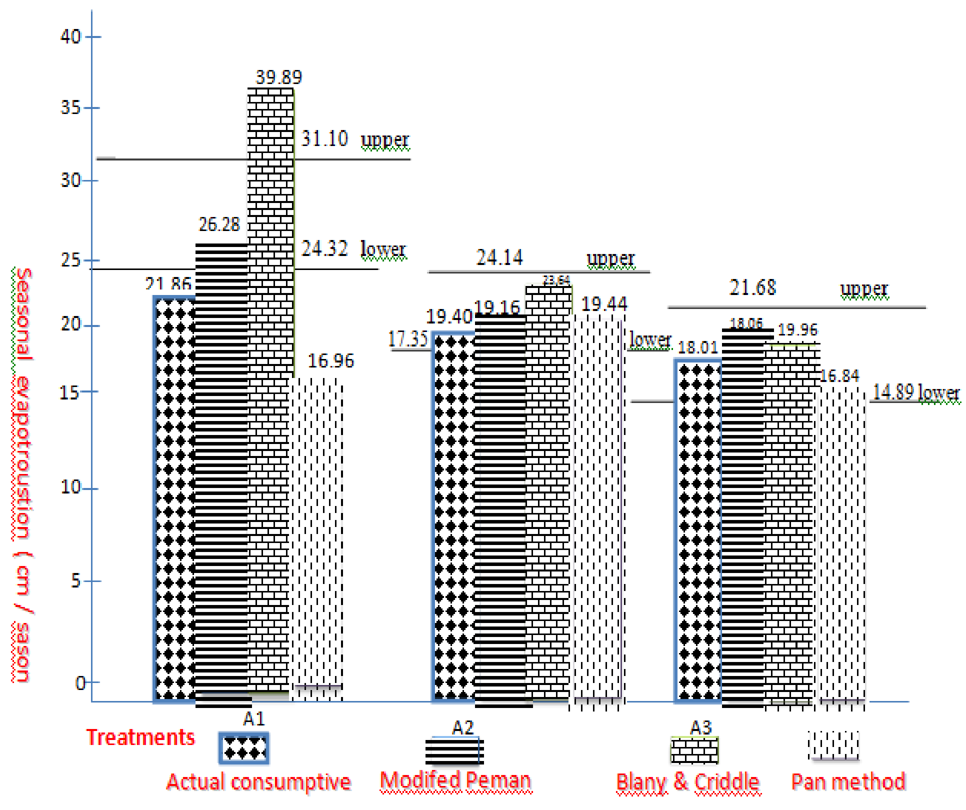

Fig (1) comparison between actual consumptive (cm/season) and calculated evapotrous piration (cm / season) under irrigation regine b_1(20% depletion of A.W) for quino crop .

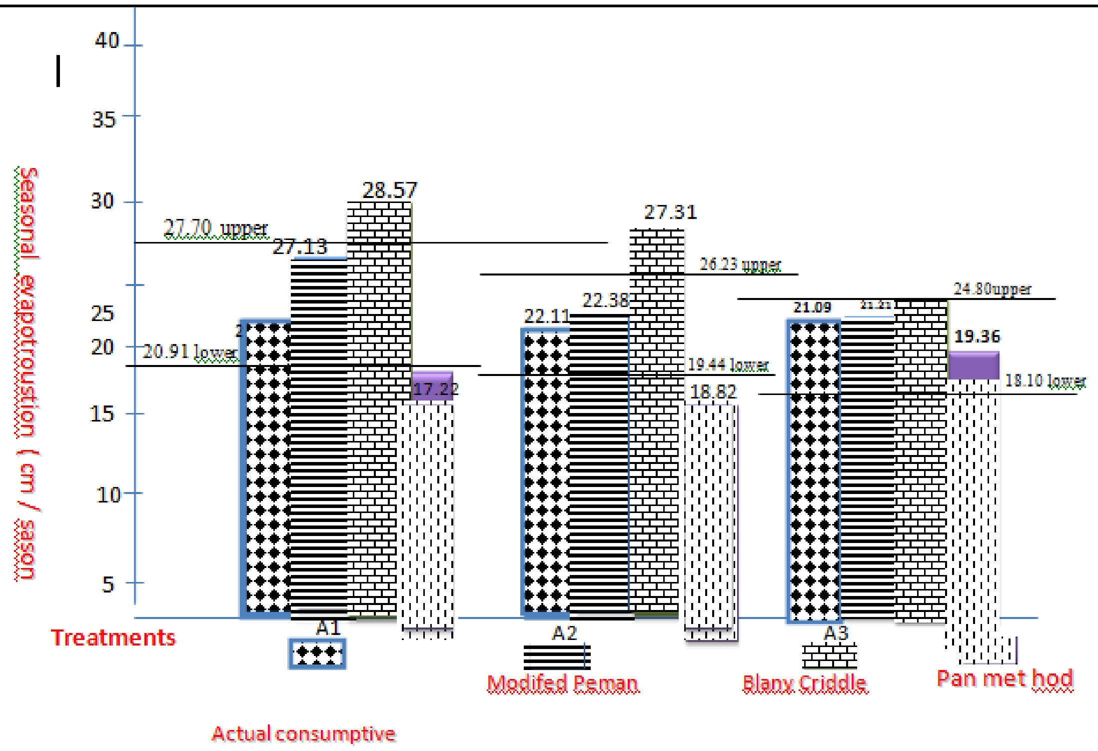

Fig (2). comparison between actual consumptive (cm/season) and calculated evapotrouspiration (cm / season) under irrigation regime b_2(40% depletion of A.W) for quino crop .

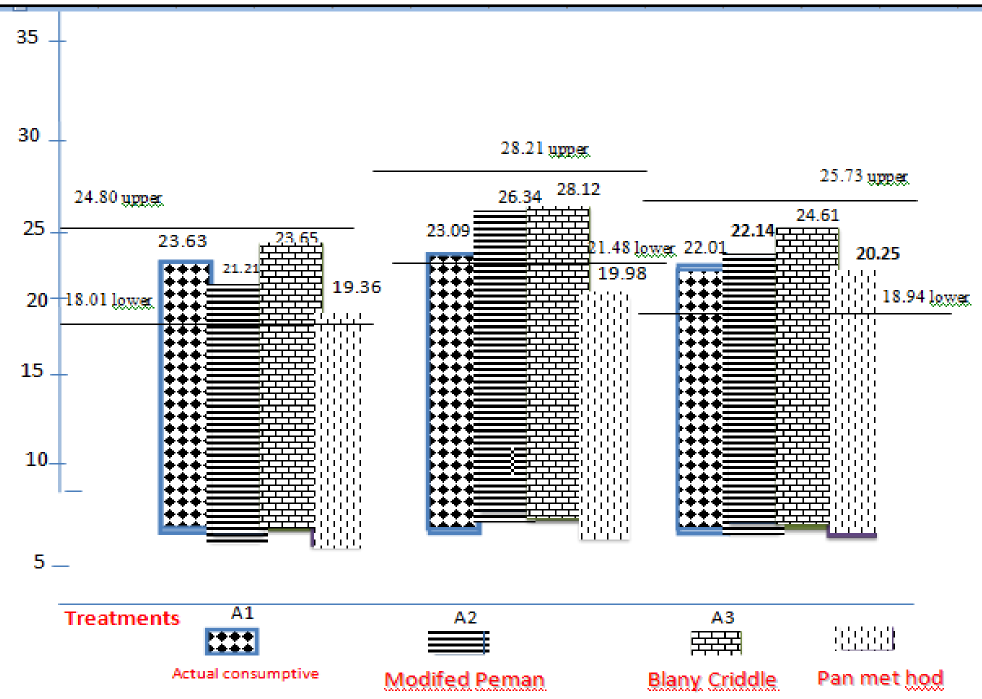

Fig (3). comparison between actual consumptive (cm/season) and calculated evapotrous piration (cm / season) under irrigation regime b_3(60% depletion of A.W) for quino crop .

Table (1) : Some soil – water characteristics for the experimental sites during the two growing seasons of Quinoa crop at different depths in 2000 and 2001 seasons.

Depth (Cm)	*Bulk density g/cm³	2000					
		**Field capacity		Wilting point		***Available Water	
		%	Cm	%	Cm	%	Cm
0-15	1.19	43.4	7.75	20.35	3.63	23.05	2.13
15-30	1.24	37.90	7.05	17.75	3.30	21.95	3.75
30-45	1.28	35.15	6.82	16.25	3.12	18.9	3.70
45.60	1.37	31.99	6.33	15.5	3.19	16.49	3.14
Average	**1.27**	**37.2**		**18.2**			

*Bulk density it was determined by using the undistributed core samples according to Kluke (1986) .
**Field capacity (f.c%) it was determined by field method according to (Black ,1965) .
***Available water (A.W) it was calculated as the difference between the F.C. and P.W.P .

Table (2) : The average values of temperature degree (°C) relative humidity (%) , sun shine (hours/ day), wind speed (kg/ day) and evaporation rate (mm/day) for both growing seasons under studied .

Month	Temperature (°C)			Relative humidity (%)			Sun shine (hours/ %)	Wind speed Kg/day	Evaporation (mm/ day)
	max	min	average	max	min	average			
November	25.85	19.03	22.44	100	16.2	58.1	11.55	217.73	4.57
December	20.5	6.7	13.6	100	44	72	8.4	198.72	2.66
January	26.2	5.24	15.72	100	48.5	74.25	8.3	263.52	3.53
February	31.24	5.75	18.5	97.3	30.94	64.12	8.86	253.15	4.32
March	36.16	8.89	22.52	97.39	25.85	61.62	9.69	285.78	6.33
April	29.24	11.41	20.32	90.37	26.03	58.2	10.83	318.69	8.14
May	36.41	17.94	27.17	73.48	15.9	44.69	11.47	203.4	12.22

Table (3) : Effect of planting dates and irrigation regime on productively of Quinoa crop in both studied seasons .

Treatments	Total yield (ton/ fed.)			Mean
	Irrigation regime			
	b_1	b_2	b_3	
A_1	0.75	0.99	1.06	0.93
A_2	0.655	0.77	0.905	0.775
A_3	0.554	0.69	0.720	0.641
Mean	0.653	0.83	0.893	
LSD 0.05	A= 0.007	B=0.004		AB=0.008

Where ;

A_1=Planting date at 25th November — b_1 = irrigation at a depletion of 20 % from A. W
A_2= Planting date at 25st December — b_2 = irrigation at a depletion of 40 % from A. W
A_3 = Planting date at 25th January — b_3= irrigation at a depletion of 60 % from A. W

Table (4) : Average actual water consumptive use values (daily , monthly and seasonal) for Quinoa plants as affected by planting dates and irrigation regime in both studied seasons .

	A_1								
	b_1			b_2			b_3		
	mm/day	Cm/month	m3/fed.	mm/day	Cm/month	m3/fed.	mm/day	Cm/month	m3/fed.
Nob.	1.77	0.86	36.12	1.33	0.66	27.72	1.26	0.63	26.46
Dec.	2.41	7.47	313.74	2.25	6.98	293.16	2.21	6.85	287.70
Jan	2.63	8.15	342.30	2.47	7.66	321.72	2.36	7.32	307.44
Feb	2.01	5.63	236.48	2.20	6.17	256.72	2.11	5.91	248.22
March	0.61	1.52	63.84	0.44	1.10	46.20	0.39	0.97	40.74
April	.	.	.	.	.	.	.	.	.
May	.	.	.	.	.	.	.	.	.
Total		23.63	992.46		22.56	947.52		21.68	910.56

	A_2								
	b_1			b_2			b_3		
	mm/day	Cm/month	m3/fed.	mm/day	Cm/month	m3/fed.	mm/day	Cm/month	m3/fed.
Nob.	.	.	.	.	.	.	.	.	.
Dec.	1.49	1.04	43.68	1.43	1.00	42	0.93	0.65	37.30
Jan	2.34	7.25	304.50	2.27	7.01	294.42	1.94	6.01	252.42
Feb	2.83	7.92	332.64	2.75	7.7	323.40	2.25	6.32	265.43
March	1.75	5.43	227.64	1.67	5.18	217.56	1.62	5.01	210.42
April	0.62	1.43	60.06	0.53	1.22	51.24	0.46	1.06	44.52
May		.		.	.	.	.	.	
Total		23.07	968.94		22.11	928.20		19.05	800.1

	A_3								
	b_1			b_2			b_3		
	mm/day	Cm/month	m3/fed.	mm/day	Cm/month	m3/fed.	mm/day	Cm/month	m3/fed.
Nob.	.	.	.	.	.	.	.	.	.
Dec.	.	.	.	.	.	.	.	.	.
Jan	1.17	0.82	34.44	1.13	0.79	33.18	0.77	0.54	22.68
Feb	2.51	7.03	295.26	2.39	6.70	281.4	1.88	5.26	220.92
March	2.49	7.72	324.27	2.45	7.59	318.78	1.91	5.94	249.48
April	1.74	5.22	219.24	1.66	4.98	209.16	1.63	4.90	205.8
May	0.51	1.22	51.24	0.43	1.03	43.26	0.57	1.37	57.54
Total		22.01	924.42		21.09	885.78		18.01	756.42

Table (5). Average seasonal actual water consumptive use (cm/season) for corn crop plants as effected by planting dates and irrigation regime in both studied seasons .

Planting dates	Seasonal actual water consumptive use (cm/season)			
	Irrigation regime			
	b_1	b_2	b_3	Average
A_1	23.63	22.56	21.68	22.62
A_2	23.07	22.11	19.05	21.41
A_3	22.12	21.01	18.01	20.37
Average	22.92	21.92	19.58	21.47

Table (6): Average computed daily monthly , seasonal evapotranspiration (mm)ET_P and deviation percentage during both studied seasons .

Empirical formula		November Daily (mm)	November Monthly (mm)	December Daily (mm)	December Monthly (mm)	January Daily (mm)	January Monthly (mm)	February Daily (mm)	February Monthly (mm)	March Daily (mm)	March Monthly (mm)	April Daily (mm)	April Monthly (mm)	May Daily (mm)	May Monthly (mm)	Total mm /season	Total cm /season	Deviation percentage (%)
A_1	Modified Penman	6.99	34.95	5.43	168.33	2.54	78.74	4.71	131.88	5.21	130.25	-	–	-	-	544.15	54.41	+9.97
	Modified Blaney & Criddle	5.20	26.00	3.91	121.21	4.34	134.54	4.91	137.48	5.90	147.5	-	-	-	-	566.73	56.67	+14.54
	Pan method	3.43	17.15	2.00	62.0	2.65	82.15	3.34	93.52	4.75	118.75	-	-	-	-	373.57	37.36	-24.51
Average		-	-													494.8	49.48	-
A_2	Modified Penman	-	-	5.43	38.01	2.54	78.74	4.71	131.88	5.21	161.51	5.05	116.15		-	526.29	52.63	-2.73
	Modified Blaney & Criddle	-	-	3.91	27.37	4.34	134.45	4.91	137.48	5.900	182.90	5.98	137.54		-	619.74	61.97	+14.52
	Pan method	-	-	2.00	14.0	2.65	82.15	3.34	93.52	4.75	147.25	6.10	140.30		-	477.22	47.22	-11.81
Average		-		-	-											541.07	54.11	
A_3	Modified Penman	-	-	-	-	2.54	17.78	4.71	131.88	5.21	161.51	5.05	151.50	8.65	707.60	670.27	67.03	+1.13
	Modified Blaney & Criddle	-	-	-	-	4.34	30.38	4.91	137.48	5.90	182.90	5.98	179.4	7.15	171.60	701.76	70.17	+3.49
	Pan method	-	-	-	-	2.65	18.55	3.34	93.52	4.75	147.25	6.10	183.00	9.16	219.84	612.16	66.22	-23.3
Average		-		–	-											678.06	67.80	

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Table (7) : The crop coefficient ($Kc= ET_a /ET_p$) for different treatments for Quinoa crop (under irrigation regime b_1) in both studied seasons.

Treat ments / month	A_1b_1				A_2b_1				A_3b_1			
	Kc				Kc				Kc			
	Modifieied panman	Modified Blaney & Criddle	Pan method	(kc) Average	Modifieied panman	Modified Blaney & Criddle	Pan method	(kc) Average	Modifieied panman	Modified Blaney & Criddle	Pan method	(kc) Average
No.	0.25	0.34	0.73	0.44	-	-	-		-		-	-
Dec.	0.44	0.62	1.21	0.76	0.27	0.38	0.75	0.47	-	-	-	-
Jan	1.04	0.61	0.99	0.88	0.92	0.54	0.88	0.78	0.46	0.27	0.44	0.39
Feb.	0.43	0.41	0.60	0.48	0.60	0.58	0.85	0.68	0.53	0.51	0.75	0.60
Mar.	0.12	0.10	0.13	0.12	0.34	0.30	0.37	0.34	0.48	0.42	0.52	0.47
Apr.	-	-	-	-	0.12	0.10	0.10	0.11	0.34	0.29	0.29	0.31
May	-	-	-	-	-	-	-	-	0.06	0.07	0.05	0.06
Av.	0.64	0.42	0.73	0.54	0.45	0.38	0.59	0.48	0.37	0.31	0.41	0.37

Table (8) : The crop coefficient ($Kc= ET_a /ET_p$) for different treatments for Quinoa crop (under irrigation regime b_2) in both studied seasons.

Treatments month	A_1b_2				A_2b_2				A_3b_2			
	Kc				Kc				Kc			
	Modifieied panman	Modified Blaney & Criddle	Pan method	(kc) Average	Modifieied panman	Modified Blaney & Criddle	Pan method	(kc) Average	Modifieied panman	Modified Blaney & Criddle	Pan method	(kc) Average
No.	0.19	0.25	0.39	0.28	-	-	-	-	-	-	-	-
Dec.	0.41	0.57	1.12	0.70	0.26	0.36	0.71	0.44	-	-	-	-
Jan	0.97	0.57	0.93	0.82	0.89	0.52	0.85	0.75	0.44	0.26	0.43	0.38
Feb.	0.45	0.45	0.66	0.52	0.58	0.56	0.82	0.65	0.51	0.49	0.71	0.57
Mar.	0.08	0.07	0.09	0.08	0.32	0.28	0.35	0.32	0.47	0.41	0.52	0.47
Apr.	-	-	-		0.1	0.09	0.09	0.09	0.33	0.28	0.27	0.29
May	-	-	--		-				0.04	0.06	0.05	0.05
Average	0.42	0.38	0.64	0.48	0.43	0.36	0.59	0.45	0.36	0.30	0.40	0.35

Table (9) : The crop coefficient ($Kc= ET_a / ET_p$) for different treatments for Quinoa crop (under irrigation regime b_3) in both studied seasons.

Treatments month	A_1b_3				A_2b_3				A_3b_3			
	Kc				Kc				Kc			
	Modifieied panman	Modified Blaney & Criddle	Pan method	(kc) Average	Modifieied panman	Modified Blaney & Criddle	Pan method	(kc) Average	Modifieied panman	Modified Blaney & Criddle	Pan method	(kc) Average
No.	0.18	0.24	0.38	0.27	-	-	-		-	-	-	-
Dec.	0.41	0.57	1.10	0.69	0.07	0.24	0.47	0.26	-	-	-	-
Jan	0.93	0.54	0.91	0.79	0.76	0.45	0.73	0.65	0.30	0.18	0.29	0.26
Feb.	0.45	0.43	0.63	0.50	0.48	0.46	0.67	0.54	0.40	0.38	0.56	0.45
Mar.	0.07	0.07	0.08	0.07	0.31	0.27	0.34	0.31	0.37	0.32	0.40	0.36
Apr.	-				0.09	0.08	0.07	0.08	0.32	0.27	0.27	0.29
May	-								0.07	0.08	0.06	0.07
Average	0.41	0.37	0.62	0.47	0.34	0.30	0.46	0.37	0.29	0.25	0.32	0.29

Table (10) : The Average calculated monthly evapotranspiration (Kc average x ETp) mm / month, mm/season and cm/season (under irrigation regime b_1) for different treatments for Quinoa crop in both studied seasons .

Treatment		Kc Averagex EXP (mm / month)								
		November	December	January	February	March.	April	May	Total /season mm	cm
A_1b_1	Modified Panman	15.38	127.93	96.29	63.30	15.63			291.53	29.15
	Modified Blaney &Criddle	11.44	92.11	118.40	95.99	17.70	-	-	335.64	33.56
	Pan method	7.55	47.12	72.29	44.41	14.25		-	185.62	18.06
Average										
$A_2 b_1$	Modified Panman	-	17.90	61.42	89.67	54.91	39.39		263.39	26.34
	Modified Blaney &Criddle		12.68	104.87	93.48	54.91	15.13		281.25	28.12
	Pan method		6.85	64.1	36.59	50.1	15.34		199.87	19.98
Average										
$A_3 b_1$	Modified Panman			6.93	97.30	75.91	64.96	12.64	221.36	22.14
	Modified Blaney &Criddle			11.84	82.50	85.96	55.61	10.29	264.11	24.61
	Pan method			7.23	65.1	69.21	65.73	13.19	202.47	20.25
Average										

Table (11) : The Average calculated monthly evapotranspiration (Kc average x ETp) mm / month, mm/season and cm/season (under irrigation regime b_2) for different treatments for Quinoa crop in both studied seasons .

Treatment		Kc Averagex EXP (mm / month)								
		November	December	January	February	March.	April	May	Total /season mm	Total /season cm
A_1b_2	Modified Panman	9.79	117.83	64.66	86.07	10.42	-	-	271.27	27.13
	Modified Blaney &Criddle	7.28	84.85	110.32	71.84	11.80	-	--	285.73	28.57
	Pan method	4.80	43.40	67.36	74.17	9.50	-	-	172.23	17.22
Average										
A_2 b_2	Modified Panman	-	16.94	59.05	85.72	51.86	10.54		223.84	22.38
	Modified Blaney &Criddle		12.04	100.83	89.63	58.53	12.37		273.13	27.31
	Pan method		6.18	61.16	60.86	14.12	12.63		188.22	18.82
Average										
A_3 b_2	Modified Panman			6.67	75.17	75.91	43.93	10.38	212.15	21.21
	Modified Blaney &Criddle			11.54	87.36	85.96	52.03	8.58	236.47	23.65
	Pan method			7.05	53.30	69.21	53.07	10.99	193.62	19.36
Average										

(12): The Average calculated monthly evapotranspiration (Kc average x ETp) mm / month , mm/season and cm/season (under irrigation regime b_3) for different treatments for Quinoa crop in both studied seasons .

Treatment		Kc Averagex EXP (mm / month)								
		November	December	January	February	March.	April	May	Total /season mm	Total /season cm
A_1b_3	Modified Panman	9.44	116.14	62.20	65.49	9.12	-	-	262.84	26.28
	Modified Blaney &Criddle	7.02	83.63	106.29	86.74	103.25	-	-	386.93	36.89
	Pan method	4.63	42.87	64.89	46.26	8.31			166.78	16.96
Average										
A_2 b_3	Modified Panman	-	9.90	51.18	71.21	50.07	9.29	-	192.65	19.16
	Modified Blaney &Criddle	-	7.12	87.4	74.23	56.70	11		263.45	23.64
	Pan method		3.64	53.40	50.50	45.65	11.22		164.41	16.44
Average										
A_3 b_3	Modified Panman	-	-	4.62	59.34	58.14	43.93	14.53	180.56	18.06
	Modified Blaney &Criddle	-	-	7.90	61.87	65.84	52.03	12.01	199.65	19.96
	Pan method	-	-	4.82	42.08	53.01	53.07	15.39	186.37	16.84
Average										

Table (13) : Comparison between the actual consumptive use (cm / season for two seasons) and calculated evaportanspiratio (cm/ season for both seasons) for different treatments for Quinoa crop (under irrigation regime b_1).

Treatments / Empirical formula	Average of actual water consumptive use (cm/ season for both growing seasons)		
	A_1 23.63	A_2 23.09	A_3 22.01
	Calculated evapotranspiration (Kc average ETp)		
Modified Penman 1	21.21	26.34	22.14
Modified Blaney & Criddle 2	23.65	28.12	24.61
Pan method 3	19.36	19.98	20.25
Average	21.41	24.81	22.33
Standard deviation	2.15	4.28	2.19
Confidence limits (95%) Upper	24.80	28.21	25.73
Confidence limits lower	18.01	21.42	18.94

Table (14) : Comparison between the actual consumptive use (cm / season for two seasons) and calculated evaportanspiration (cm/ season for two seasons) for different treatments for Quinoa crop (under irrigation regime b_2) .

Treatments / Empirical formula	Average of actual water consumptive use (cm/ season for both growing seasons)		
	A_1 22.65	A_2 22.11	A_3 21.09
	Calculated evapotranspiration (Kc average ET_p)		
Modified Penman 1	27.13	22.38	21.21
Modified Blaney & Criddle 2	28.57	27.31	23.65
Pan method 3	17.22	18.82	19.36
Average	24.31	22.83	21.41
Standard deviation	6.18	4.26	2.15
Confidence limits (95%) Upper	29.10	27.50	24.80
Confidence limits lower	20.91	19.44	18.01

Table (15) : Comparison between the actual consumptive use (cm / season for two seasons) and calculated evaportanspiratio (cm/ season for both seasons) for different treatments for Quinoa crop (under irrigation regime b_3).

Treatments / Empirical formula	Average of actual water consumptive use (cm/ season for both growing seasons)		
	A_1 21.86	A_2 19.40	A_3 18.01
	Calculated evapotranspiration (Kc average ETp)		
Modified Penman	26.28	19.16	18.06
Modified Blaney & Criddle	39.89	23.64	19.96
Pan method	16.96	19.44	16.84
Average	27.71	20.75	18.29
Standard deviation	11.53	2.51	1.57
Confidence limits (95%) Upper	31.10	24.14	21.68
Confidence limits lower	24.32	17.35	14.89

Conclusion

Sowing dates on 25th November with irrigate at a depletion of 60% from A.W . preferable and recommend for Quinoa crop in El Minia region to produce the highest yield with least possible amount of water. On the other hand this study indicate that the average values of potential evapotranspirations (ET_{cal}) by modified Penman was nearest to actual consumptive use of Quinoa crop . So , we can recommend modified penman for calculating the potential evapationsiration Quinoa crop under El-Minia conditions and other corresponding conditions .

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استجابة محصول الكينوا للاجهاد الماشى ومواعيد الزراعة فى منطقة مصر الوسطى

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المستخلص

اجريت تجربتين حقليتين خلال المواسم الشتوية لعامى 2013/2012 ، 2014/2013 م بمحطة مقننات رى ملوى البحثيه بمحافظة المنيا – مصر الوسطى ومنطقة البحث تقع عند تلاقى خط عرض 9َ 27 شمالا وخط طول 50َ 30ْ شرقاً وترتفع بمقدار 44 متر عن سطح البحر وتهدف هذه الدراسة الى تأثير الظروف الجويه واسلوب الرى على الاحتياجات المائية الفعلية للمحصول الكينوا ، معامل المحصول ، الاستهلاك المائى ، انتاجية المحصول هذا بالاضافة الى أن هذه الدراسة تهدف الى تقييم طرق قياس الاستهلاك المائى النظرى المحسوب من المعادلات المناخية المختلفة (بنمان المعدل ، بلانى وكرديل المعادلة ، حوض التبخر) وذلك بالمقارنه بالاحتياجات المائية الفعلية للمحصول تحت ظروف محافظة المنيا والمناطق الاخرى المماثلة لها فى الظروف الجوية

وقد اشتملت التجربة على 3 معاملات للمواعيد الزراعه وهى :

11/ 25 : A1   12/25 : A2   1/25 : A3

وكذلك اشتملت التجربة على 3 معاملات لاسلوب الرى المضاف

b1 : الرى بعد استنفاذ 20 % من الماء الميسر

b2 : الرى بعد استنفاذ 40 % من الماء الميسر

b3 : الرى بعد استنفاذ 60% من الماء الميسر

لذا اشتملت التجربة على 3 معاملات لمواعيد الزراعة 3 معاملات لاسلوب الرى و 4 مكررات لذا استخدم فى تنفيذ التجربة تصميم القطعة المنشقة المنشقة مرة واحدة plot–spilt

وفى ضوء ما سبق يمكن تلخيص النتائج المتحصل عليها كالتالى :

1-كانت قيم الاستهلاك المائى الفعلى للمحصول بمقدار 23.63 ، 23.09 ، 22.01 سم/ موسم وبمتوسط عام 22.91 سم/ موسم للمعاملات A_1، A_2 ، A_3 على التوالى تحت اسلوب الرى b_1 (20 % من الماء الميسر) بينما كانت بمقدار 22.56 ، 22.11 ، 21.09 سم / موسم بمتوسط عام 21.92 للمعاملات A_1,A_2,A_3 على التوالى تحت اسلوب الرى b_2 (الرى بعد استنفاذ 40% من الماء الميسر) وكانت بمقدار 21.68 ، 19.40 ، 18.01 سم/ موسم بمتوسط عام قدرة 19.58 سم/ موسم للمعاملات A_1، A_2 ، A_3 على التوالى تحت اسلوب الرى b_3 (الرى بعد استنفاذ 60 % من الماء الميسر)

2-و توضح النتائج بصفة عامة بأن الاستهلاك المائى الفعلى كان بمقدار 22.62 ، 21.41 ، 21.47 سم/ موسم للمعاملات الرئيسية A_1، A_2 ، A_3 على التوالى تحت جميع اساليب الرى المختلفة ويرجع ذلك لاختلاف مواعيد الزراعة لكل معاملة رئيسية عن الاخرى.

3-وجد أن معدل الاستهلاك المائى الفعلى اليومى والشهرى يكون منخفضاً فى بدايه الموسم ثم يزداد هذا المعدل مع الوقت ليصل الى أقصاه خلال الفترات الحرجه لمحصول الكينوا طبقاُ لكل ميعاد على حده ثم ينخفض هذا المعدل مرة أخرى فى نهاية موسم نمو المحصول .

4- اعطيت المعاملة الاولى الزراعة فى 11/25 اعلى انتاجية تحت جميع أساليب الرى المختلفة بزيادة قدرها 23.17 % ، 45.08 مقارنتاً A2 ، A3 على التوالى مقارنتاً A_2A_3 على التوالى

5-أعطى التفاعل المشترك A_1b_3 (الزراعة فى ميعاد 11/25 تحت اسلوب الرى b_3) الى الحصول على أعلى انتاجية من المحصول الرئيسى (1.06 طن للفدان) مقارنتاً بجميع المعاملات الاخرى للتجربة .

6-أعطيت معادلة بلانى وكرديل المعدله أعلى القيم من البخر -نتح بمعدل 629.41 مم/ موسم بينما اعطت معادلة حوض التبخر أقل القيم للبخر -نتح بمقدار 504.12 مم/ موسم .

7-كانت القيم الفعليه للاستهلاك الفعلى (ET_a) اقل من القيم المحسوبه بواسطه المعادلات المناخية (ETP) وذلك لوجود معاملات رياضيه فى تلك المعادلات .

8-كانت القيم المحسوب للاستهلاك المائى النظرى (ET_P) بواسطة معادله بنمان المعدلة أقرب المعادلات الى المتوسط العام بانحراف قياسى قدره + 2.79 % بينما كانت القيم المحسوبه للاستهلاك المائى النظرى بواسطة معادلتى بلانى وكرديل المعدله ووعاء البخر أبعد المعادلات عن المتوسط العام بانحراف قياسى قدره + 11.18% ، -12.64 % على التوالى .

9- أوضحت النتائج بأن متوسط معامل المحصول للمعاملات الرئيسية تحت نظام الرى b_1 (الرى بعد استنفاذ 20 % من الماء الميسر) كان بمقدار 47, ،37 , ، 29 وبمتوسط عام قدرة 37 , لمعاملات A1 ، A2 A3 بينما كان بمقدار تحت اسلوب الرى b_2 (الرى بعد استنفاذ 40% من الماء الميسر) 48, ، 45 , ، 35 لنفس المعاملات السابقة على التوالى وبمتوسط عام قدره 43 , كما تشير النتائج أيضاً أن متوسط معامل المحصول الموسمى للمعاملات الرئيسية تحت اسلوب الرى b_3 (الرى استنفاذ 60% من الماء الميسر) كان بمقدار 53 , ، 47 , ، 36 , لنفس المعاملات السابقة على التوالى وبمتوسط عام قدرة 0.45

10-كانت القيم المتحصل عليها للاستهلاك المائى النظرى المحسوب (ET_{cal}) =(Kc average X ETP) المحسوبة بواسطة معادله بنمان المعدلة أقرب القيم الى الاستهلاك المائى الفعلى لمحصول الكينوا بينما أعطت معادلتى بلانى وكرديل المعدلة وحوض التبخر ابعد القيم الى الاستهلاك المائى الفعلى ومن ثم توصى الدراسة باستخدام معادله بنمان المعدلة وذلك عند تقدير الاستهلاك المائى لمحصول الكينوا تحت ظروف محافظة المنيا والمناطق المماثله لها فى الظروف الجوية .