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MAIZE WATER PARAMETERS UNDER CUT-OFF IRRIGATION

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ABSTRACT: *A field trial was conducted during the two successive summer seasons 2010and 2011at Sakha Agricultural Research Station, Kafr El-Sheikh Governorate to find out the effect of irrigation length on maize grain yield and its water parameters. Five irrigation length were examined; 100% of strip length (S.L) as control (Trt. A), 95 %(Trt. B), 90% S.L(Trt. C), 85% S.L(Trt. D) and 80% S.L (Trt. E).*

The main findings could be summarized as follows:

- *Mean values of seasonal water applied for the two seasons can be ranked in descending order as; A(2956.0) > B (2823.3) > C(2683.2) > D(2571.0) > E(2432.2) m^3 fed^{-1}. Comparing with water applied to the traditional treatment A, average water saving in the two growing seasons by using 95 % and 90% S.L for watering maize could be amounted with 132.72 and 272.82 m^3 or 4.5 and 9.3%. Average, water saving might be equaled more than 0.4 billion m^3 for the maize national cultivated area (2.0 * 10^6)fed.*
- *Average crop-water consumption could be arranged in descending order as; A(64.39) > B(61.62) > C(58.77) > D(56.90) > E(54.26) cm. The corresponding rates of CU were; 5.6, 5.4, 5.1, 4.9 and 4.7 mm day^{-1} for the same treatments, respectively.*
- *The main values of consumptive use efficiency ranged between 91.0 to 93.5% for different treatments.*
- *Significant differences were found among the studied treatments regarding grain yield as well as 100 grain weight, ear length and ear diameter.*
- *The highest grain yield 3771.3 kg. fed^{-1} (26.94 ardab. fed^{-1}) and 3648.0 kg. fed^{-1} (26.1 ardab. fed^{-1}) were scored with 95% cut off (Trt. B) and 90% cut off (Trt. C)of the cultivated maize strip, respectively.*
- *The highest average of yield per unit of applied water or water utilization efficiency (W Ut E) as well yield per unit consumed water or water use efficiency (W U E) averaging 1.36 and 1.48 kg m^{-3} were obtained under 90% S.L (Trt C).*

Key words: *Cut off irrigation, Water saving, crop-water efficiencies*

INTRODUCTION

In Egypt, irrigated agriculture is the dominant type of farming, the per capita from water for different purposes is decreasing gradually to less than the water poverty edge (1000 m^3 per annum). Irrigation uses more than 85% of the total renewable water supply. So, tremendous efforts should be implemented in this sector to rationalize water at the national level. One of the most effective ways for irrigation is to determine precisely the actual irrigation water should be applied to meet the needs of the growing plants. Water excessive as well as insufficient irrigation results in decreasing crop yield. Maize (*Zea mays* L.) is one of the main strategic cereal crops in Egypt and it ranks as the third after wheat and rice in the world (Gibbon and Pain, 1985). It is used for human consumption, animal feeding, and a source for starch as well as edible oil. So, it is important to increase the productivity of such crop to meet the requirements of growing population.

Furrow irrigation is a common type of surface irrigation and it is suitable for maize watering especially in the clayey soils. Under traditional irrigation practiced by local farmers, the wetting front is allowed to reach the tail end of the strip. In other words, a long time is allowed for water to stay in the upper portion of the irrigation strip which results in more losses by deep percolation. Then to generate the increase of the advancement of water movement in such clayey soils, irrigation front should be stopped before the end of cultivated border.

Following cut-off irrigation event, water front move to irrigate more cultivated area. This technique considered as a direct simple effective way in water saving. In addition, less water will percolate down ward to the drainage system at the area.

Maize irrigated parameters were studied widely in Egypt and world wide. Kassab and Ibrahim (2007) reported that cut-off wheat irrigation was effective technique for improving water management via saving irrigation water. They stated that the highest values of crop-water functions .i.e. water utilization efficiency (WUtE) was1.61 Kg m^{-3} and water use efficiency (WUE) was 1.73 Kg m^{-3} obtained from 90 % cut-off e.g. irrigation till 90 % of strip length. Ibrahim and Emara (2009) stated that by irrigation till 90 % of furrow length or so-called cut-off irrigation as modified surface irrigation method in watering sugar beet crop, saving water amount with 11.0% or 300 $m^3 fed^{-1}$ could be attended. Ko and Piccinni (2009) in Texas, states that irrigation management of corn at 75% evapotranspiration (ETc) is feasible with 10% reduction of grain yield and increased water use efficiency. The greatest W U E (1.69 $m^2 mm^{-1}$) achieved at 456 mm of water input while, grain yield rectitude at less than 600 mm. Abdel-Fatah, M.(2011) revealed that cut-off miaze irrigation 85% strip length, saving water amounted with 11.23% could be obtained .

The main objective of the current study was to determine the most suitable cut-off related to maize irrigation under strip irrigation. i.e. when to stop irrigation front.

Thus, the specific goals were to,

- ✓ optimizing water productivity using cut-off technique as improved surface furrow irrigation.
- ✓ determining of water saving could be achieved under this technique.
- ✓ computing maize- water relations

MATERIALS AND METHODS

Two field experiment were conducted during the successive summer seasons2010 and 21011 at Sakha Agricultural Research Station, Kafr El-Sheikh Governorate, Egypt using maize crop to study the effect of irrigated strip length on maize production as well as its water relation. Table (1) shows some physical properties of the soil of the field where the experiments were carried out.

Maize crop was sown on June 2, 2010 and June 7, 2011 and harvested on September 22, 2010 and October 2.2011, respectively. All the agronomic practices, used in the study area were followed except the length of irrigation run treatments which were as follows:

A- 100% strip length (control)
B- Cut off at 95 % of strip length
C- Cut off at 90 % of strip length
D- Cut off at 85 % of strip length
E- Cut off at 80 % of strip length

Length of each cultivated strip was 70 m, irrigation was stopped at water front reached 70.0 (control) treatment, 66.3, 63.0, 59.5 and 56.0 m for A,B,C,D and E treatments, respectively.

Table (1): Some physical characteristics of the studied soils before cultivating the crop.

Soil depth (cm)	Physical characteristics								
	Particle size distribution %			Texture class	Bulk density Mg/m^3	Total porosity %	Field capacity %	PWP %	A.W %
	Sand	Silt	Clay						
0-15	12.3	33.3	54.4	Clayey	1.26	52.45	47.50	25.69	21.81
15-30	20.2	34.2	45.6	Clayey	1.30	50.94	39.87	21.66	18.21
30-45	20.4	41.4	38.2	Clay loam	1.29	51.32	38.40	20.86	17.54
45-60	21.1	41.5	37.4	Clay loam	1.38	47.92	36.39	19.78	16.61
Mean	18.5	37.6	43.92		1.31	50.66	40.54	22.00	18.51

PWP = Permanent wilting point, AW = Available water, Mg = Mega gram (10^6 g)

Statistical design of the experimental was laid out in a complete randomize block design with four replicates. Each strip unit included 6 ridges, 60cm apart redundant, the area of strip was 210 m^2 i.e. 1/20 fed.

It is worth mention that for each irrigation interval the timing of irrigation was the same for all treatments.

Date collected:

1- Irrigation control:-

Application of irrigation water was controlled and measured by a rectangular constructed weir fixed upstream with a discharge rate of 0.01654 m^3 sec^{-1} at 10 cm as effective head over the crest. Distribution of irrigation water was maintained by spills inserted beneath the strip bank.

2- Advance and recession curves:

Along each cultivated strip, different stations 10 m apart were stalked all the way till the end of the proposed irrigation run. Time of reached water front during irrigation at reach station as well at the end was recorded from the beginning of watering event. Consequently, the corresponding elapsed time, to disappear water at each station was also recorded from the beginning of irrigation. The vertical distance between the two curves of advance and recession indicated or expressed as the opportunity time of irrigation water at each station.

3- Water-consumptive use:

To compute the actual consumed water of the growing plants, soil moisture percentage was determined on weight basis before and after each irrigation as well as at harvest. Soil sample were taken from successive layers in the effective root zone (0-15, 15-30, 30-45 and 45-60 cm). This method of consumed water is depending upon soil moisture depletion (SMD) or so called actual crop-water consumed (ET_C). The amount of CU was calculated in the effective rot zone of 60 cm as stated by Hansen *et al.* (1979).

$$CU = S.M.D. = \frac{\sum \phi_2 - \phi_1}{100} \times D_b \times d \times A$$

Where:

CU = Water consumptive use (cm) in the effective root zone of 60 cm depth = S.M.D. (soil moisture depletion).
i = Number of soil layer (1-4)
d = depth of effective root zone, 0.6m
D_b = Bulk density (Mg/m^3).
ϕ_1= Soil moisture percentage before irrigation and
ϕ_2 = Soil moisture percentage, 48 hours after irrigation.
A = irrigated area, 1 fed.= 0.42 ha

4- Crop-Water efficiencies:

Crop water efficiency was calculated according to Bos (1980), as follows:

$$WUtE = \frac{Y}{Wa}$$

$$WUE = \frac{Y}{CU}$$

Where:

WUtE = Water utilization efficiency (kg m^{-3}).
WUE = Water use efficiency (kg m^{-3}).
Y = Seasonal yield, kg/fed.
Wa = Seasonal water applied, m^3 and
CU = Seasonal crop-water consumed, m^3.

5- Consumptive use efficiency (Ecu):

Values of consumptive use efficiency (Ecu) was calculated according to bos (1980).

$$Ecu = \frac{ETc}{Wa} \times 100$$

Where:

Ecu = Consumptive use efficiency
Etc = Total cevapotranspiration ~ consumptive use
Wa = Water applied to the field.

6- Crop yield and its attributes.

- Maize grain yield was recorded in ton/ fed
- Weight of 100 grains, (gm)
- Ear length, cm
- Ear diameter, cm

RESULTS AND DISCUSSION

Data tabulated in Table (2) showed that the control(Trt.A no cut off. 100% S.L) received the highest amount of irrigation water (I.W.) of 2956.02 m^3 fed^{-1}, while strip

Table 2

length of 80% (Trt E) received the lowest average of water applied (2432.1 m^3 fed^{-1}). Thus, mean values of I.W. for the two seasoms can be arranged in descending order as; A(2956.02)> B (2823.30) > C(2683.20)> D(2571.02) >E (2432.10) m^3 fed^{-1}

In comparison with the control (Trt.A no cut off.) corresponding average water saving in the two growing seasons were 132.72, 272.82, 385 and 523.92 m^3 fed^{-1} . or 4.49, 9.23, 13.02 and 17.72 % for the cut off treatments B, C, D and E, respectively. Saving water by using 95% and 90% SL for watering Maize could be amounted with about 132.72 and 272.82 m^3 fed^{-1} . Saving water could be used in irrigating more crops as well in horizontal expansion in agriculture

From Table (3), it is clear that after stop irrigation, the advanced of water front stilling on towards the lower end of the cultivated strip. Meaningfully, 9-10 m was wetted under treatment E of 80% SL cut off, while it was 3.5 m for the 95% SL cut off (Trt. B). This is the main advantage of using such technique of cut off watering to save same irrigation water.

Therefore, by irrigate 90% from the strip length instead of the traditional watering till the end of the strip (Trt. A), the remaining dry area of 7.0 m could be wetted by the accumulated water of the irrigated area of 90% S.L. Moreover, saving water with 9.23% along with less water could be drained.

These findings are in the same line with that obtained with Ibrahim and Emara (2009), They found that by irrigating till 90% of sugar beat furrow, almost 11.0% saving water could be attained.

b. Advance, recession curves and opportunity time:

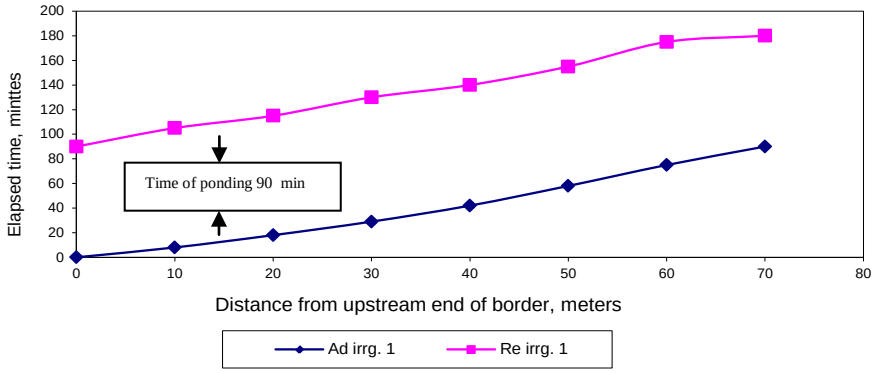
The direction of both curves of advance and recession are almost parallel for all treatments (Figs. 1 throught 5). Time of ponding, which equaled the consumed time needed to infiltrate the accumulated water at each station from the soil surface to inside soil, is clear affected with the cut-off treatments. The opportunity time has the adverse direction with the level of cut-off. On other words, by increasing the length of irrigation run (traditional without cut-off) the highest opportunity time is resulted and vise versa. So, it is obvious that by irrigating only 90% from cultivated strip (Trt. C), the corresponding time is less than that of Trt. A and this means less water could be drained underneath the root zone.

Thus, in order to choose the most proper cut-off level two items should be taken into consideration and must be evaluated:

i. Amount of water saving, and
ii. Crop yield along with productivity of water applied unit.

Table (3): Average of soil distance without irrigation and reach time to stop water front (W.F.) irrigation cut off for different treatments.

Treatments	Unirrigated distance	W.F. advancement after cut off	Time to stop (W.F)
A = 100% of S.L. (control)	None	None	None
B = 95% of SL	3.5 m	= 3.5 m	10-12 min.
C = 90% of SL	7.0 m	= 7.0 m	18-20 min.
D = 85% of SL	10.5 m	~ 10.5 m	28-32 min.
E = 80% of SL	14.0 m	~11 m	28-32 min.



(time of ponding = infiltration opportunity time)

Fig.1. irrigated length and elapsed time for A treatment (control).

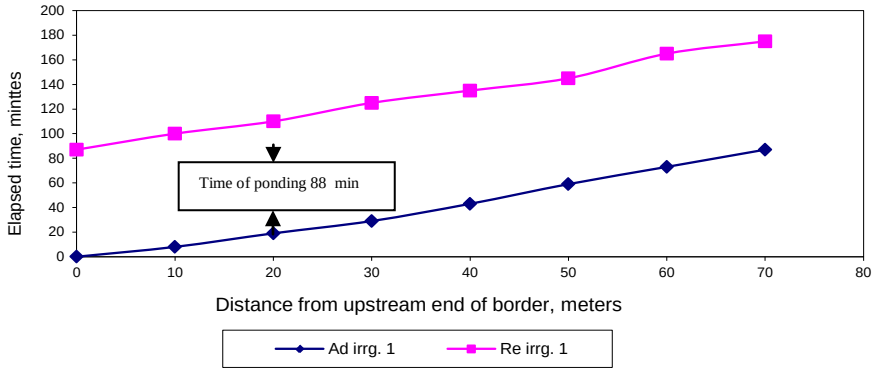


Fig.2. irrigated length and elapsed time for B treatment .

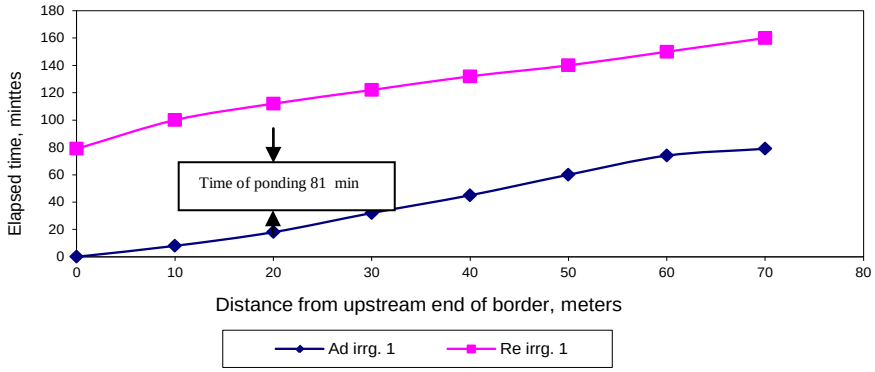


Fig.3. irrigated length and elapsed time for C treatment .

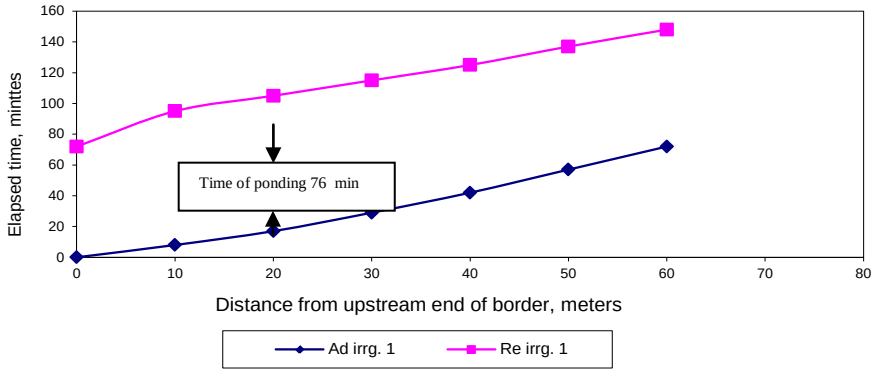


Fig.4. irrigated length and elapsed time for D treatment .

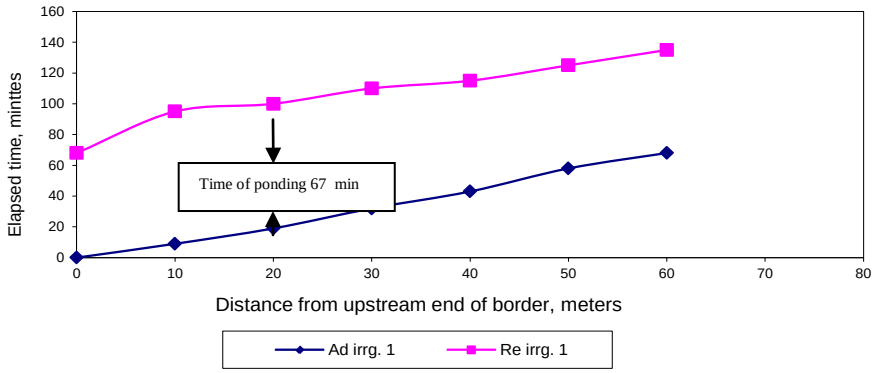


Fig.5. irrigated length and elapsed time for E treatment .

Crop consumptive use (ETc):

Seasonal crop water consumptive (CU) which may be referred as crop evapotranspiration (ETc) was computed on the basis of water depletion from the effective root zone of the upper 60 cm soil depth. The general trend of seasonal consumptive use values is with that of the irrigation water. The overall average values of seasonal consumptive use for Maize in the two growing seasons (Table 2) are ; A(64.39)> B (61.62) > C(58.77)> D(56.90) >E (54.26)cm. It is obvious that the highest CU 64.39 cm with 100% S.L (Trt. A), was resulted from irrigation till the end of the cultivated strip and accompanied with the highest water delivered to treatment A. On the other hand, the lowest value 54.26 cm resulted from 80% S.L (Trt. E). The average values of seasonal rate of CU for the treatments have the same trend (5.60,5.36,5.11, 4.95 and 4.72 mm day^{-1}, respectively). The results are in the same agreement with those obtained by Shahin and Mosa (1994).

Crop-water efficiencies:

Crop-water efficiency is a parameter which indicates the productivity of unit water. This function could be evaluated in the two terms of water utilization efficiency (WUt.E) which related yield to the water applied and water use efficiency (WUsE) which relates yield to water consumed.

Regarding water utilization efficiency (WUt.E), the overall values of the two seasons for treatments A, B, C, D and E

were 1.23,1.34,1.36,1.33 and 1.30 kg m^{-3}, respectively (Table 2), Therefor, treatment C (90% S.L) cleared the highest average of W.Ut.E of 1.36 kg m^{-3}. While the lowest value 1.23 kg m^{-3} was associated from treatment A (0% cut-off).

Concerning, water use efficiency (W.U.E), values of WUE for treatments A, B, C, D and E are 1.35,1.45,1.48,144 and 1.38 kg m^{-3} (Table 2).

The highest values of 1.48 kg m^{-3} was obtained under treatment C (90% S.L), while the lowest 1.35 kg m^{-3} was recorded from treatment A (100% S.L.). So in general, one kg grain maize needs 0.704 m^3 of consumed water. This finding are in a good agreement with those obtained by Kheira (2009) and Ibrahim and Emara (2009 &2010).

Consumptive use efficiency (Ecu):

Consumptive use efficiency (Ecu) is a parameter which indicates the capability of plants to utilize the soil moisture stored in the effective roots zone.

Percentage of Ecu was showed in Table (2) cleared that the highest value 93.70% obtained from (80% S.L., Trt. E.). Therefore, by decreasing the applied water, higher amount of irrigation water could be beneficially used by the growing plants which resulting in decreasing water losses. These data were obtained also by Ibrahim and Emara (2009) and Emara and Ibrahim (2010)

Maize grain yield (kg fed^{-1})

Length of irrigation run had a significant effect on grain yield in both seasons (Table 4). The highest grain yield 3771.3 kg fed^{-1} (26.94 ardab fed^{-1}) was recorded under the 95% SL (Trt. B). On the other hand, the lowest yield 3145.15 kg fed^{-1} (22.47 ardab fed^{-1}) was obtained under 80% SL (Trt. E). This finding might be attributed to that, under treatment B 95% SL, witting front following stop irrigation reached the tial end of strip.

The same trend was observed for treatment C (90% SL) that produced 3648.0 kg fed^{-1} (26.1 ardab fed^{-1}). On the other hand irrigation till the end of the Maize cultivated strip of common Trt, A, resulted in excess water more than the actual needs of the growing plants. Either exess or less water leads to reduction ingrain yield. Similar results were obtained by Abdel-fattah, 2011. Who reported that yield of Maize and its components increased by 85% of strip (Trt. B cut off).

yield component

- 100 grain weight, gm
  Weight of 100 grain was significantly affected by length of irrigation run as tabulated in Table 4. The highest mean value 41.89 gm was obtained under 95% SL (Trt. B), while the lowest value 37.47 gm was obtained under 80% SL (Trt. E).
- Ear length, cm
  Length of irrigation run had a significant effect on ear length over both seasons. The highest mean value 20.5 cm was obtained under 95% SL (Trt. B), while the lowest value 17.0 cm was obtained under 80% SL (Trt. E, Table 4).
- Ear diameter, cm
  In the two growing seasons, statistical analysis as shown in Table 4 revealed that ear diameter was significantly affected with the different irrigation regime. The highest mean value 16.2 cm was obtained under 95% SL (Trt. B), while the lowest value 14.1 cm was obtained under 80% SL (Trt. E).

CONCLUSION AND REMARKS

Cut-off irrigation is considered as one tool under the umbrella of effective on-farm irrigation management.

From data analysis, it is advisable to watering Maize till 90 % of strip length or as implemented under treatment C as a result of following advantages.

i. Water saving 272 m^3 fed^{-1}, i.e. 9.2 % which equal more than half bill cubic metre at the national level
ii. Almost the same yield obtained in comparison with the best treatment of (Trt B) i.e. watering till 95% S.L
iii. High yield per unit of applied water (W Ut E) as well as water consumed (W U E) average 1.36 and 1.48 kg/m^3 respectively.

Table 4

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العلاقات المائية للذرة تحت تقنية تحديد طول جبهة الري

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الملخص العربي

اقيمت تجربتان حقليتان بمحطة البحوث الزراعية بسخا . كفر الشيخ لمنطقة شمال الدلتا خلال موسمى 2010 ، 2011م لمعرفة التأثير الرئيسى لطول شريحة الرى الواجب إيقاف الرى عندها فيما يسمي بـ cut-off وأثر ذلك علي العائد المحصولي من وحدة الماء المضاف والعلاقات المائية لمحصول الذرة

وكانت المعاملات:-

أ- الري التقليدي الي نهاية الخط و الشريحة (100%)

ب- ايقاف الري عند 95% من طول الشريحة

ج- ايقاف الري عند 90% من طول الشريحة

د- ايقاف الري عند 85% من طول الشريحة

هـ- ايقاف الري عند 80% من طول الشريحة.

وقد أوضحت النتائج المتحصل عليها ما يلي:-

1- المتوسط الموسمي للماء المضاف ما بين 2432.2م^3/فدان إلى 2956.0م^3/فدان ويتراوح المتوسط الموسمي للماء المضاف على الترتيب 2956.0 > 2823.3 > 2683.2 > 2571.0 > 2432.2 م3/فدان للمعاملات أ ، ب ، جـ ، د ، هـ على الترتيب.

2- القيم المتوسطة للوفر فى كمية المياه للمعاملات 90% و 95 % من طول الشريحة بالمقارنة بالمعاملة أ 100% من طول الشريحة كانت بما قيمته حوالى 132.72, 272.82م^3/فدان . هذا الوفر أكثر من نصف بليون متر مكعب على مستوى المساحة الكلية المنزرعة.

3- يمكن ترتيب قيم الاستهلاك المائي تنازليا كالآتي: 64.39 > 61.62 > 58.77 > 56.90 > 54.26سم للمعاملات أ ، ب ، جـ ، د ، هـ .

4- متوسط قيم كفاءة استهلاك المياه فقد تراوحت ما بين 91% إلى 93.5% للمعاملات المختلفة أ الي هـ.

5- هناك اختلافات معنوية بين المعاملات المدروسة لكل من المحصول ومحصول 100 حبه وطول الكوز وقطر الكوز. كانت أعلى القيم للمحصول 3771.3, 3648.0 كجم/فدان قد سجلت تحت معاملتي90% و 95 % من طول الشريحة.

6- أعلى متوسط لكفاءة استعمال المياه وكفاءة استخدام المياه 1.36, 1.48 كجم/م^3 والذى نتج من المعاملة "جـ" (90% من طول الشريحة).

Table (2): Water parameters of Maize as affected by length of irrigation run in the two growing season

Characters	Treatments														
	A (100 % S.I.)			B (95 % S.I.)			C (90 % S.I.)			D (85 % S.I.)			E (80 % S.I.)		
	1st season	2nd season	Average	1st season	2nd season	Average	1st season	2nd season	Average	1st season	2nd season	Average	1st season	2nd season	Average
IW (m^3 fed^{-1}.)	2891.25	3020.78	2956.02	2755.45	2891.15	2823.30	2628.19	2738.21	2683.20	2512.85	2629.18	2571.02	2382.20	2482.00	2432.10
CU (cm)	63.44	65.33	64.39	60.45	62.78	61.62	57.72	59.81	58.77	55.91	57.88	56.90	53.28	55.24	54.26
CU (cm day^{-1})	5.66	5.54	5.60	5.40	5.32	5.36	5.15	5.07	5.11	5.00	4.91	4.95	4.76	4.68	4.72
WUt.E(kg m^{-3})	1.22	1.24	1.23	1.33	1.34	1.34	1.36	1.36	1.36	1.36	1.33	1.33	1.31	1.28	1.30
WUsE(kg m^{-3})	1.33	1.36	1.35	1.44	1.47	1.45	1.48	1.48	1.48	1.45	1.44	1.44	1.39	1.37	1.38
Ecu (%)	92.16	90.83	91.49	92.14	91.20	91.67	92.24	91.73	91.98	93.45	92.46	92.95	93.44	93.48	93.70

S.L. = Strip length = 70.0 m

Table 4: yield, 100 grain weight as well as ear length and ear diameter as affected by length of irrigation run in the two growing seasons.

Characters	Treatments														
	A (100 % S.I.)			B (95 % S.I.)			C (90 % S.I.)			D (85 % S.I.)			E (80 % S.I.)		
	1st season	2nd season	Average	1st season	2nd season	Average	1st season	2nd season	Average	1st season	2nd season	Average	1st season	2nd season	Average
Yield kg Fed-1	3535.8c	3742.5b	3639.15	3668.3a	3874.3a	3771.3	3579.0b	2717.0b	3648.0	3407.5d	3492.0c	3449.75	3113.0e	3177.3d	3145.15
100grain weight gm	41.04a	42.04b	41.54	41.35a	42.43a	41.89	41.05a	41.71b	41.38	39.81b	40.84c	40.33	37.14c	37.80d	37.47
Ear length, cm	19.4a	20.8b	20.1	19.6a	21.4a	20.5	19.4a	20.7b	20.1	18.2b	18.8c	18.5	16.7c	17.2d	17.0
Ear diameter, cm	15.2b	15.4b	15.3	15.7a	16.7a	16.2	15.3ab	15.8b	15.6	15.1b	15.2b	15.2	13.9c	14.2c	14.1

S.L. = Strip length = 70.0 m