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Cut off Wheat (*triticum Sp.)* Irrigation as an Effective Technique for Improving Water Management

Kassab, M.M and M.A.M. Ibrahim [1]

ABSTRACT

Two field experiments were conducted during the two successive seasons 2004/2005 and 2005/2006 to assess the effect of irrigation length on wheat yield and wheat water use parameters. Five irrigation length treatments were examined; 100% of strip length (S.L) without cut off (Trt. A), 95% (Trt. B), 90% (Trt. C), 85% (Trt. D) and 80% S.L (Trt. E).

The obtained results revealed that:

Average of seasonal water applied were, in descending order as follows: A (2516.6) > B (2412.24) > C (2278.06) > D (2201.26) > E (2111.51) m^3fed^{-1}. Average water saving, in the two growing seasons, was 238.54 m^3/fed. i.e. 9.48% for the best treatment 90% cut off in comparison with 100% without cut off. This water saving might be represented more than 0.5 mil. m^3 of irrigation water for the wheat national cultivated area (2.5 x 10^6 fed.). Average water consumptive use could be arranged in descending orders: A (45.46) > B (43.35) > C (41.27) > D (40.01) > E (37.98) cm. The corresponding rates of consumptive use were0.27, 0.26, 0.24, 0.23 and 0.22 cm/day for the same treatments, respectively. The average values of consumptive use efficiency ranged between 91 to 94% for different treatments. Significant differences were found among the studied treatments regarding grain and straw yields as well as biological yield, 1000-grain weight and harvest index. The highest grain yield (2984.75 kg/fed. (7.1 ton/ha)) was scored with 90% cut off (Trt. C); i.e. watering till 90% of the cultivated wheat strip. The highest average of water utilization efficiency (WUtE) was about 1.61 kg/m^3 which associated with the 90% cut off (Trt. C). On the other hand, the lowest value of about 1.16 kg/m^3 was obtained from the control Trt A.

INTRODUCTION

In Egypt, irrigated agriculture is the dominant type of farming. Moreover, the per capita of water for different purposes is decreasing gradually to less than the water poverty edge (1000 m^3 per annum). Water shortage that faces Egypt is continuously increasing, and it is prospected to reach to the threshold level of less than 500 m^3/yr/capita. Under such situation of water deficit, it is impossible to get any improvement in any economic sector in the country. On the other hand, wheat is the main strategic cereal crop in Egypt. It is the most used food for of the people and is cultivated in large area of more than one third of the total cultivated winter crops. Strip or border irrigation is a common type of surface irrigation, it is most suitable for wheat irrigation especially in the clayey soils. Under traditional irrigation practiced by local farmers, the wetting front is allowed to reach to the tail end of the border. On other words, a long time is allowed for water to stay in the upper portion of the irrigated strip which results in more water losses by deep percolation. Then, to generate the advantage of the horizontal water movement in such clayey soils, irrigation front should stop before the end of the cultivated border i.e. cut off technique procedure. Following to cut irrigation event, water front will move in advancement to irrigate more cultivated area before stopping. Such procedure considered as a direct, simple effective way in water saving. In addition, less water will percolate down to the drainage system at the area.

Wheat irrigation parameters were studied widely in Egypt and worldwide. El-Mowelhi *et al.* (1990), calculated the mean value of actual evapotranspiration at North Delta as 3.4 $mm.day^{-1}$ during winter season. Sharma *et al.* (1990) reported that water use efficiency of winter wheat was highest under good irrigation conditions as compared with that under water stress conditions. Ibrahim and Walker (1993) found that dead level has a higher value of crop-water productivity (WUtE) in relation to the soil slope. Khater *et al.* (1997) found that number of $spikes.m^{-3}$, 1000 grain weight, straw and grain yield/fed. Significantly decreased with decreasing available soil moisture content. Yousef and Eid (1999), concluded that the irrigation at 30% available soil moisture depletion gave the highest water use efficiency values. Abul-Nass *et al.* (2000) indicated that wheat plants that received four irrigations significantly out-yielded those received three, two or one irrigation.

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Emara and Ibrahim (2004) stated that the highest values of crop-water function of WUtE (10.75 kg m^{-3} and 1.76 $kg.m^{-3}$) and WUsE (14.56 $kg.m^{-3}$ and 2.36 $kg.m^{-3}$) for root and sugar yield, respectively resulted from the moderate amount of applied and consumed water in comparison with 100% of furrow length. Also, they stated that by increasing the crop consumptive use (CU), the resulting efficiency was increased and vise versa. Also, many investigations were studied by researchers world wide such as Singh and Patel (1995). Armstrong *et al.* (1996). Garabet *et al.* (1998), Reynalds *et al.* (1999) and Nabipour *et al.* (2002).

So, the objective of this study was to determine the most suitable cut off related to wheat irrigation under border irrigation i.e. when to stop the irrigation front. Thus, the Specific goals were to determine the amount water saving under this technique, monitor the water movement after stoping irrigation, compute wheat-water relations, improve the wheat-water productivity relations and characterized the associated advancement and recession curves.

MATERIALS AND METHODS

The present study was conducted at Sakha Agricultural Research Station, Kafr El-Sheikh Governorate during the two growing seasons 2004/2005 and 2005/2006, to study the effect of strip irrigation length on wheat production as well as its water relations. Soil of the experimental field was clayey in texture (Table 1).

Wheat (Sakha 93 variety) was sown on November 15, 2004 and November 17, 2005 with dry broadcasting method, crop was harvested on May 1, 2005 and May 5, 2006. Rate of fertilizers were 75 kg N, 15 kg P_2O_5 per feddan were applied at two doses. Applications were occurred before the first irrigation following the sowing and the second before the next watering. All the agronomic practices, used in the study area were followed except the length of irrigation run treatments which were as follows:

A. control (full length).
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, therefore, irrigation was stopped when water front reached 70.0, 66.5, 63.0, 59.5 and 56.0 cm for treatments A, B, C, D and E, respectively.

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

Execution and data collected:

1. Irrigation control:

Application of irrigation water was controlled and measured by rectangular constructed weir fixed upstream with a discharge rate of 0.1654 m^3sec^{-3}. 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 to the end of the proposed irrigation run. Time of reached water front, during irrigation at each station as well as 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.

Table 1. Physical properties of the soil of the experimental location where wheat was grown.

Soil depth (cm)	Physical properties								
	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	Clay	1.26	52.45	47.50	25.69	21.81
15-30	20.2	34.2	45.6	Clay	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: Megagram i.e. 10^6 g

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 samples were taken from successive layers in the effective root zone (0-15, 15-30, 30-45 and 45-60 cm). This a direct method for calculating consumptive use based on soil moisture depletion (SMD) or actual crop-water consumed (ET_C) as stated by Hansen *et al.* (1979).

$$CU = SMD = \sum_{i=1}^{i=4} \left(\frac{\phi_2 - \phi_1}{100} \times D_{bi} \times D_i \right)$$

Where:

CU=Water consumptive use (cm) in the effective root zone of 60

cm depth, SMD (soil moisture depletion).

i = Number of soil layers (1-4),

D_i = Soil layer thickness (15 cm),

D_{bi} = Bulk density (Mg m^{-3}) of the layer,

ϕ_1 = Soil moisture percentage before irrigation, and

ϕ_2 = Soil moisture percentage, 48 hours after irrigation.

Crop-Water efficiency:

Crop water efficiency was calculated according to Doorenbos and Pruitt (1975) as follows:

$$WUtE = \frac{Y}{Wa} \quad , \quad WusE = \frac{Y}{CU}$$

Where:

WUtE = Water utilization efficiency (kg m^{-3}),

WUsE = Water use efficiency (kg m^{-3}),

Y = Seasonal yield kg fed^{-1},

Wa = Seasonal water applied, and

CU = Water consumptive use.

Consumptive use efficiency (Ecu):

Values of consumptive use efficiency (Ecu) were calculated according to Doorenbos and Pruitt (1975).

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

Where:

Ecu= Consumptive use efficiency

ETc= Total cevapotranspiration ~ consumptive use

Wa= Water applied to the field.

Yield parameters:

- Grain yield.
- Straw yield.
- 1000-grain weight.
- Biological yield (grain + straw).
- Harvest index = $\frac{Grain\ yield}{(Biological\ yield(grain + straw))}$.

RESULTS AND DISCUSSION

Water parameters:

a. Seasonal water applied (Wa):

Seasonal water applied (Wa) for wheat consists of two components; irrigation water (IW) and rainfall (RF) Doorenbos and Pruitt (1975). Seasonal rainfall was 130 and 70 mm during the two growing seasons of 2004/2005 and 2005/2006 respectively (Table 2),. The obtained values of seasonal water applied showed that the control (Trt. A no cut off 100%S.L) had the highest Wa (2516.64 $m^3 fed^{-1}$.). This amount of water is the result of the sum of 49.92 cm as irrigation water and 10 cm as rainfall. Strip length of 80% (Trt. E) received the lowest average of water applied(2111.51 $m^3 fed^{-1}$.), which consists of 40.27 cm as irrigation water and 10 cm as rainfall. Thus, total water applied in descending order was, A (2516.6) > B (2412.24) > C (2278.06) > D (2201.26) > E (2111.51) $m^3 fed^{-1}$. Five irrigation were applied including the sowing one.In comparison with the control treatment A, average water saving in the two growing seasons were 104.36, 238.54, 31534 and 405.09 m^3 fed^{-1}. or 4.15, 9.48, 12.53 and 16.1% for the cut-off treatments B, C, D and E, respectively. Saving water by using 90% and 85% SL for watering wheat could be amounted with about 238.54 and 315.34 m^3 fed^{-1}. Based on the highest crop yield, saved water could be used for irrigating more crops and for horizontal expansion in agriculture.

From Table (3), it is clear that after stop irrigation, the advancement of water front still going on towards the lower end of the cultivated border. The extra wetted length is in the opposite trend with the degree of cut off. Meaningfully, 9-10 m was wetted under treatment E of 80% SL cut off, while it was 2.5 m for the 95% SL cut off (Trt. B). This is the advantage of using such technique of cut off watering to save irrigation water.

Therefore, by irrigating 90% from the border length instead of the traditional watering till the end of the strip (Trt. A), the remaining dry length of 7.0 m^2 could be wetted by the accumulated water of the irrigated area of 90% S.L. Moreover, saving water could be attained (9.5%) along with less water could be underneath drained.

These findings are agreeded with those obtained with Emara and Ibrahim (2004) who found that irrigating beet crop to 90% of furrow length almost 9.97% saving water

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	12-14 min.
C = 90% of SL	7.0 m	= 7.0 m	20-22 min.
D = 85% of SL	10.5 m	~ 10.5 m	30-34 min.
E = 80% of SL	14.0 m	~ 10 m	30-34 min.

b. Advance, recession curves and opportunity time:

The direction of both curves, of advance and recession, are almost parallel for all treatments (Figs.1 through 5). The opportunity time, which equaled the consumed time needed to infiltrate the accumulated water at each station from the soil surface to inside soil, is clearly affected by the cut-off treatments. The opportunity time has the adverse direction with the level of cut-off. In 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 (less opportunity time) 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 saved water, and

(ii) Crop yield along with productivity of unit applied water.

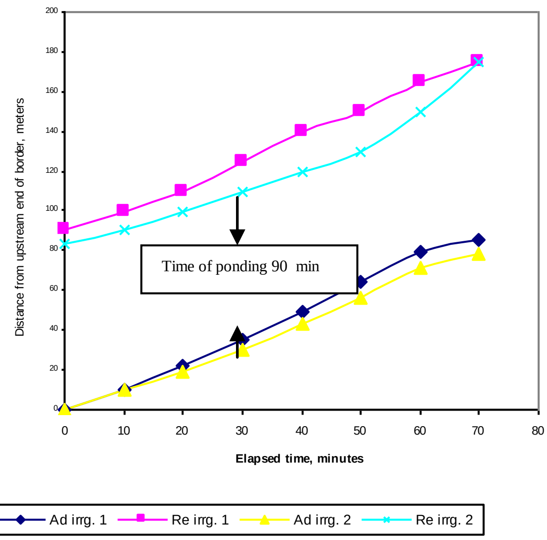

Fig. 2. Irrigated length and elapsed time for B treatment.

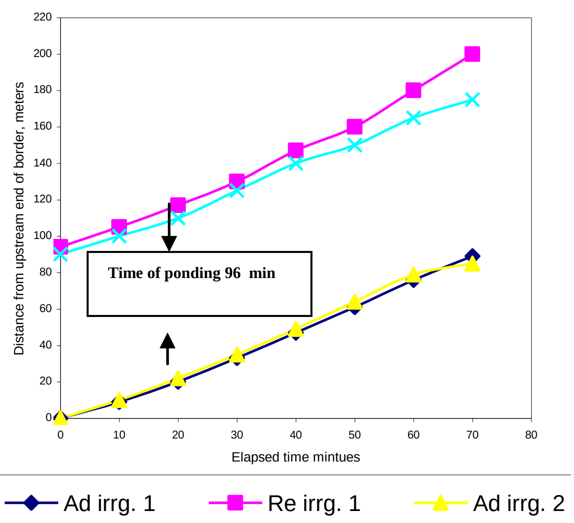

Fig. 1. Irrigated length and elapsed time for A treatment (control). (Time of ponding = Infiltration opportunity time)

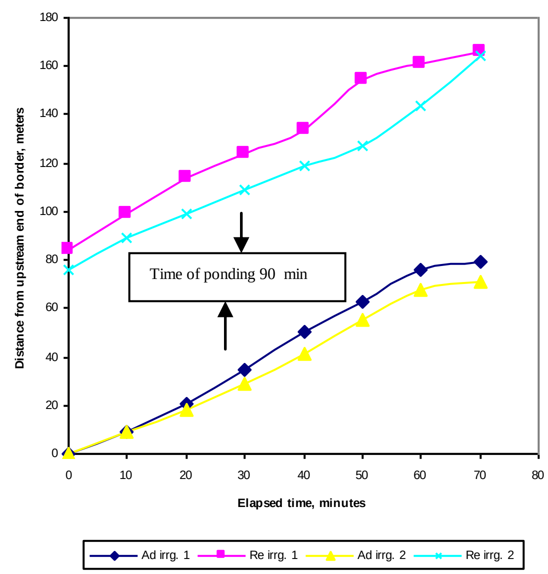

Fig. 3. Irrigated length and elapsed time for C treatment

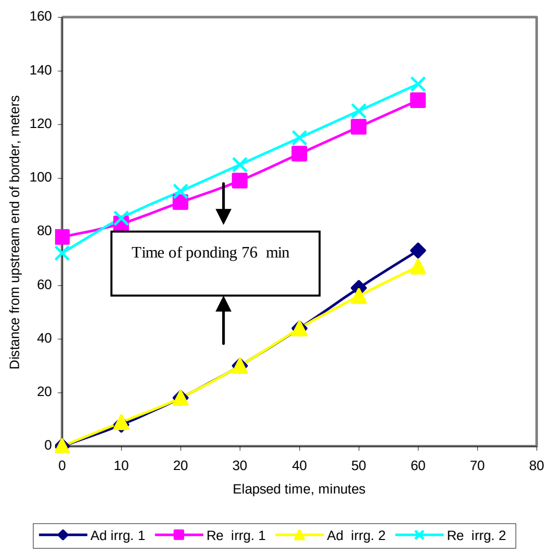

Fig. 4. Irrigated length and elapsed time for D treatment

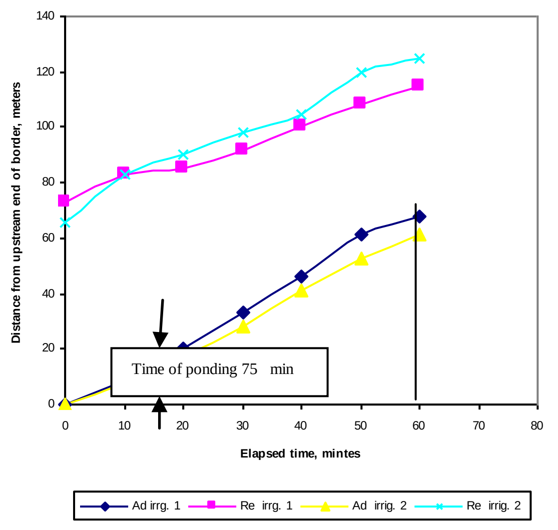

Fig. 5. Irrigated length and elapsed time for E treatment

Crop Consumptive Use (ETc):

Crop water consumptive use (CU) or crop evapotranspiration (ETc) has the same trend as that of the applied irrigation water. Consumptive use is a direct function of the soil water status which already affected by the amount of applied water. The overall average values of seasonal consumptive use for wheat, in the two growing seasons (Table 2), were A (45.46) > B (43.35) > C (41.27) > D (40.01) > E (37.98) cm. It is obvious, therefore, that CU was the highest 45.46 cm for 100% S.L (Trt. A), which resulted from irrigation till the end of the cultivated border. This is due to the highest water delivered to treatment A. On the other hand, the lowest value (37.98cm) was resulted in the 80% (Trt. E). The average values of seasonal rate of CU for the treatments had the same trend. (2.7, 2.6, 2.4, 2.5 and 2.2 mm day^{-1}, respectively). These results are similar with those reported by Metwally et. al (1984), Shahin and Mosa (1994).

Grain Yield (kg. fed^{-1}):

Length of irrigation run had a significant effect on grain yield over both seasons (Table 4). The highest yield of 2984.75 kg fed^{-1}. (19.90 ardab fed^{-1}.) was obtained from the 90% control (Trt. C),. On the other hand, the lowest yield of 2259.16 kg/fed. (15.06 ardab fed^{-1}.) was recorded for 80% of irrigation border length (Trt. E). This finding might be attributed to that, under treatment C (90% cut off), wetting front following stop irrigation almost reached the end of strip. On the other hand, irrigation till the end of the wheat cultivated strip of Trt. A, resulted in excess water more than the actual needs of the growing plants. Both excess and/or less water leads to reduction in grain yield. Similar results were obtained by Abd El-Mottaleb (1978), Shahin and Mosa (1994) and Abo-Warda (2002), who reported that yield of wheat and its components increased significantly as the availability of soil moisture increased.

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 relates yield to the water applied, and water use efficiency (WUsE) which relates yield to water consumed. Regarding water utilization efficiency (WUtE), mean values of the two seasons for treatments A, B, C, D and E were 1.16, 1.23, 1.61, 1.53 and 1.34 kg m^{-3}, respectively (Table 2). Therefore, treatment C (90% S.L) showed the highest average of W.Ut.E of 1.61 kg m^{-3}, while the lowest value 1.16 kg m^{-3} was associated A (0% cut-off).

Concerning, water use efficiency (WUsE), values for treatments A, B, C, D and E were 1.27 1.35, 1.73, 1.62 and 1.42 kg m^{-3}, respectively (Table 2). The highest value of 1.73 kg m^{-3} was recorded for treatment C (90% S.L), while the lowest 1.27 kg m^{-3} resulted from treatment A (100% S.L.). Therefore, one kg grain bread wheat needs 666.7 L of consumed water in the Middle North Nile Delta region. These findings are in a good agreement with those obtained by Shahin and Mosa (1994) and Abo-Warda (2002).

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. Table (2) showed that the highest value of Ecu was 94.30% (85% S.L., Trt. C.). Therefore, by decreasing the applied water, higher amounts of irrigation water could be beneficially used by the growing plants which results in minimizing water losses.

Straw Yield:

Length of irrigation run had a significant effect on straw yield over both seasons. The highest mean value of 6089.16 kg fed^{-1}. was obtained from irrigation till 85% of S.L (Trt. D). On the other hand, the lowest mean value of 4303.34 kg fed^{-1}. was recorded from 80% of S.L. (Trt. E) Table (4).

Biological Yield:

Biological yield was significantly affected by length of irrigation run (Table 4). The highest mean value of 9024.75 kg fed^{-1}. was obtained from irrigation till 90% of S.L. (Trt. C). On the other hand, the lowest mean values of 6562.5 kg fed^{-1}. was recorded for irrigation 80% S.L. (Trt. E).

Harvesting Index:

Length of irrigation run had a significant effect on harvesting index over both seasons. The highest mean value of 34.44% was obtained from irrigation till 80% of S.L (Trt. E). while, the lowest mean value of 30.91% was recorded for 85% of S.L (Trt. D,Table 4)

1000-Grain Weight (gm):

Weight of 1000 grain was significantly affected by length of irrigation run. Table (4) The highest mean value 53.03 gm was obtained for irrigation to 90% of S.L (Trt. C), while, the lowest mean value 50.91 gm was obtained from irrigation to 100% of S.L (Trt. A).

CONCLUSION AND REMARKS

It might be concluded that irrigation wheat, in North Nile Delta area, as 90% of strip length (Trt. C) show the following achievements: (i)Highest grain yield, biological yield, 1000-grain weight, (ii)Moderate amount of applied and consumed water in comparison with 100% irrigation of strip length, (iii) Saving irrigation water with an amount of about 238 m^3/fed, i.e. 9.5% which equaled more than a half mil. cubic metre at the national level, and (iv)Highest values of crop-water functions. i.e. WUtE (1.61 kg m^{-3}) and WUsE (1.73 kg m^{-3}).

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الملخص العربي

تحديد طول جبهة الرى كطريقة فعالة لترشيد رى القمح

ماهر محمد كساب , محمد عبد الفتاح محمد إبراهيم

أقيمت تجربتان حقليتان خلال موسمى 2005/2004م ، 2006/2005م لمعرفة التأثير الرئيسى لطول شريحة الرى الواجب إيقاف الرى عندها وكذلك تعظيم الوحدة من الماء المضاف وإنتاج محصول القمح وكانت المعاملات الري الى 100% (معاملة أ) ، 95% (معاملة ب) ، 90% (معاملة جـ) ، 85% (معاملة د) ، 80% (معاملة هـ) من طول الشريحة.

وتوضح النتائج أنه قد تراوح المتوسط الموسمى للماء المضاف ما بين 2111.5م^3/فدان (50.27سم) إلى 2516.6م^3/فدان (59.92سم). حيث يمكن ترتيب كميات مياه الري المضافة الكلية تنازليا: 2516.6 > 2412.24 > 2278.06 > 2201.26 > 2111.51م^3/فدان للمعاملات أ ، ب ، جـ ، د ، هـ على الترتيب. وفر فى كمية المياه بما قيمته حوالى 238م^3/فدان لأحسن معاملة جـ أى 90% من طول الشريحة بالمقارنة بالمعاملة أ 100% من طول الشريحة. كما أوضحت البيانات أنه يمكن ترتيب قيم الاستهلاك المائى تنازليا كالآتى: 45.46 > 43.35 > 41.27 > 40.01 > 37.98سم للمعاملات أ ، ب ، جـ ، د ، هـ أما معدل الاستهلاك اليومى فقد بلغ 0.27 > 0.26 > 0.24 > 0.23 > 0.22 مم /يوم لنفس المعاملات. وكان متوسط قيم كفاءة استهلاك المياه فقد تراوحت ما بين 91% إلى 94% للمعاملات من أ الى هـ . كما تشير البيانات أن هناك اختلافات معنوية بين المعاملات المدروسة لكل من محصول الحبوب والقش و(الحبوب + القش) كذلك معامل المحصول 1000 حبه. وكانت أعلى قيمة لمحصول القمح (2984.75كجم/فدان) أى 7.1 طن/هكتار سجلت تحت الظروف المعتدلة من الرطوبة للمعاملة 90% من طول الشريحة. سجل أعلى متوسط لكفاءة استخدام المياه لمحصول القمح 1.61 كجم/م^3 والذى نتج من المعاملة "جـ" (90% من طول الشريحة) بينما سجل أقل متوسط لكفاءة استخدام المياه 1.16كجم/م^3 تحت المعاملة أ (100% من طول الشريحة). نفس النتائج حصلت عليها بالنسبه لكفاءة استعمال المياه والقيم المماثلة هى 1.73 ، 1.27كجم/م^3.

وعليه فتوصي الدراسة بري القمح الى 90% فقط من طول الشريحة بدلا من الري الى نهايتها. حيث تتحقق الميزات التالية:

1. وفر في كمية مياه الري بحوالي 238 م^3/فدان أي بما قيمته 9.5%.
2. أعلى عائد محصولي 2984.75 كجم/فدان مقارنة بـ 2421.41كجم/فدان في حالة الري الى نهاية الشريحة.
3. أعلى عائد محصولي لوحدة المياه سواء المضافة (1.16كجم/م^3) أو المستهلكة (1.73 كجم/م^3)