REDUCING SURFACE IRRIGATION WATER LOSSES IN THE NILE DELTA

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ABSTRACT

Due to the serious water shortages the saving of irrigation water is very important, particularly in countries with limited water like as Egypt. A field experiment was conduct during the summer season of 2012 at El-Karada Water Research Station, Water Management and Irrigation Systems Research Institute, Kafr El-Sheikh, Egypt. This research aims to study the effect of new method of mulching on water saving and yield of maize. Four treatments were tested : no mulch (control) (A); straw mulch (B); 30 % plastic mulch (C), and 60 % plastic mulch (D). Mulching was performed with 30 and 60 % furrows preimeter, along 50 % furrows length. Applied irrigation water (AIW), water advance time (WAT), soil moisture content (SMC), water use efficiency (WUE), application water efficiency (E_a), ground water level (GWL), and grain yield (GY) were computed.

Results showed that both treatments D and C decreased AIW about of 24.65 % and 21.65 %, while straw mulch treatment increased AIW about of 3.37 % compared with control treatment. Both treatments of C and D reduced (WAT) with 20.9 and 21.3 %, while treament of B increased it with 19.1 % compared with control treatment. Plastic mulch had siginficantly effect on SMC which the minimum values were recorded under treatments of D and C, respectively. On the other hand, highest values of SMC were obtained under straw mulch treatment. It was observed that WUE had the highest value under treatments C and D, respectively. While, the lowest value was obtained under straw mulch treatment. Application water efficiency invistegated the highest values under treatment of C and B, respectively. But, it had the lowest values under control treatment. Results of GWL indicated that the highest values were obtained under treatments D, A, B and C, respectively. Mulching affected grain yield non-significantly, but the highest grain production was observed in treatment of C (3034.2 Kg/fed.), and minimum in

treatment of B (2401.1Kg/fed.). It was concluded that plastic mulch is the best method to save water under surface irrigation system.

INTRODUCTION

Nile River is the main source of fresh water in Egypt. It supplies 55.5 BCM/yr of freshwater every year, which represents 97% of all renewable water resources in Egypt ***(Minsitry of Water Resources and Irrigation, 2005).*** One of the main objective of the Egyption sustainable agriculture development is increasing crop productivity per unit of water use and to improve on farm irrigation effciency. Recent studies indicate that, by year 2025, severe water scarcity will effect one-third of the population in development countries as there will be insufficient water resources to cover agriculture, domestic, indusrtial and environmental needs. Surface irrigation is the traditional method (about 80% of the irrigated area in Egypt), and it generally has a lower application efficiency (about 50 %) than other method mainly because of water loss due to deep percolation, which lead to rising ground water tables and leaching of nutrients **(Swelam and Atta, 2009).** Consequently, deep percolaction has a negative effect on crop yield, fertilizer requitrements and efficient water use ***(Donahue et al. 1977)***. Farmers commonly over-irrigate their fields, with greater losses. Therefore, the compination among mulching, cutting-off , and irrigation scheduling methods is one optimal method to save water and allivate water scarcity. The practice of spreading plastic sheet or any other material like straw on the soil surface to reduce water losses is called mulching. Furrow irrigation in combination with plastic mulch is a highly efficient water-saving irrigation technology **(*Chen and Feng, 2013)***. Soil mulching with plastic film, which results in reduced water loss and more even regulation of soil temperature, has been widely used in agriculture ***(Zhang et al., 2005)***. While, ***Rathore et al. (1998)*** reported that more water conserve in the soil profile during the early growth period with straw mulch than without it. Morever, straw mulching (SM) systems can conserve soil water and reduce temperature because they reduce soil disturbance and increase residue accumulation at the soil surface ***(Baumhardt and Jones, 2002; Zhang et al., 2009)*.** Irrigation scheduling minimizes water-logging problems by reducing the drianage

requirements and control root zone salinity problems through controlled leaching. Enviromental irrigation benefits of irrigation scheduling e.g. reduced losses of fertilizers resulting from a decrease in seepage increase in the soil ***(Mao, 1996);*** Nevertheless, in recent years there has been a wide range of proposed novel approaches to irrigation scheduling which have not yet been widely adopted; many of these are based on sensing the plant reponse to water dificits rather than sensing the soil mositure status directly ***(Jones, 1990)***.Optimal length of irrigation run at which watering should be stopped instead of irrigation till the tail end of the furrows . Such procedure resulting in reducing amounts of water pathways and the advancement movement of the accumulated water after stopping irrigation used in watering the remaining un-irrigated area. ***Soares et al. (2000)*** declared that for continuous and cutting-back irrigation, the application efficiency increased with the discharge, reaching a maximum value and decreased thereafter, the runoff loss increased and the deep percolation loss decreased as the discharge increased. ***Puustinen et al. (2005)*** found that mulching contributes to decrease runoff flow and enhance infiltration. While, ***García-Orenes et al. (2009)*** observed that time to ponding was delayed after straw mulching treatment respect to other types of management, as systemic herbicide or ploughing. Under field conditions, water is generally supplied to individuals furrows via siphon tubes or gated pipes, with the intent being to set inflow rates uniformly on a set of equal length furrows. ***Trout and Mackey (1988)*** measured inflow rate variability of 15%for siphon tube, 25% for gated pipe, and 29% for feed ditch water application techniques. Mulches improve both irrigation efficiences of water use and water application. ***Deng et al. (2006)*** reported that mulching with crop residues improve WUE by 10-20% where straw mulching increased WUE of maize from 1.55 to 1.84 $Kg.m^{-3}$. Which, ***Awan and Ali (1988)*** evaluated that application efficiency at farmers' field and reported that the application efficiency ranged from 34 to 95 percent.

MATERIALS AND METHODS

1- Location and soil analysis

Field study was conducted during Summer season of 2012 at El-Karada Water Research Station, Water Management and Irrigation Systems

Research Institute, Kafr El-Sheikh, Egypt which located at Latitude of 31°03'N and Longitude of 30°57' E. The soil was totally clay, with physical and chemical properties as shown in table (1).

2- Experimental Design

Experimental field consistes of four treatments as follow:

(1) No mulch (control) (A)

(2) Straw mulch (B)

(3) 30 % plastic mulch (C)

(4) 60 % plastic mulch (D)

Table (1) Some soil physical and chemical properties:

Depth (cm)	Sand %	Silt %	Clay %	Texture	Bulk density (g cm^{-3})	Field Capacity (%)	Wilting point (%)	Avaliable water (%)	E.C (dS.m^{-1})	pH
00 - 20	16.50	23.60	59.90	Caly	1.19	38.00	18.00	20.00	1.75	7.80
20 - 40	10.00	25.00	65.00		1.29	39.54	19.00	20.54	1.88	8.00
40 - 60	10.00	20.00	70.00		1.31	40.50	20.50	20.00	2.20	7.90
60 - 80	09.00	24.00	67.00		1.36	41.00	21.00	20.00	2.23	8.10
Average	11.38	23.15	65.48		1.29	39.76	19.63	20.14	2.02	7.95

Each treatment contains of four furrows. The length of furrows was 60 m with spacing 0.70 m as shown in Fig. (1). Mulching was performed in the cross sectional of furrow channle (furrow perimeter) along 50 % of furrows length. Two different materials were used under experimental treatments; rice straw and plastic sheet. Rice straw was added with a rate of 50 gram.m^{-1} of furrow. On the other hand, plastic sheet (PS) was applied with different dimintions under two treatments were C and D as shown in table (2).

Table (2) Calculation of Total applied plastic sheet for experimental treatments:

Treatments	Furrow perimeter (m)	mulched percentage of furrow perimeter (%)	Mulched furrow length (m)	Total amount of PS (m^2.furrow^{-1})
30 % plastic mulch (C)	0.7	30	30	6.3
60 % plastic mulch (D)	0.7	60	30	12.6

3- Irrigation scheduling

3-1- Applied Irrigation Water (AIW)

Irrigation water was applied using for each treatment with a spile. Actual applied irrigation water was calculated by the following equation (Eid, 1998).

$$Q = q \times t \times n \quad \text{(1)}$$

Q = Applied irrigation water, m^3/fed

q = Discharge m^3/min,

t = Total irrigation time, min/fed, and

n Number of irrigation per season.

The gross irrigation water depth was estimated for each treatment and was calculated by the following equation (Brouwer et al 1989).

$$d_g = \frac{d_n}{E_i(1\text{-}LR)} \quad \text{(2)}$$

Where:

d_g = Gross irrigation depth, cm

d_n = Net application depth, cm

E_i = Irrigation water efficiency, %

LR = Leaching requirements, %

3-2- Irrigation intervals

Tensiometers were used to schedule irrigation at three depths 10, 20 and 40cm for each treatment. Irrigation water was supplied when management allowable depletion (MAD) approached 50 %. Maximum depth of maize root zone was 0.70 m. Tensiometers on depths 10 and 20 cm were installed in intial stage, while, the other depth 40 cm was installed in the mid season stage.

4- Advance time and cut off

Water advance time (WAT) was measured at each treatment every 10 m along furrows length. On the other cutting off was perfomed when water reaches 85 % of furrow length.

5- Soil Mositure Content (SMC)

Soil moisture content (SMC) was measured for each treatment at depths 0 – 20, 20 – 40, 40 – 60cm and 60 -80 cm using gravimetric method**.** It

was measured at three locations X, Y and Z along cross sectional of furrow channel as shown in Fig. (2).

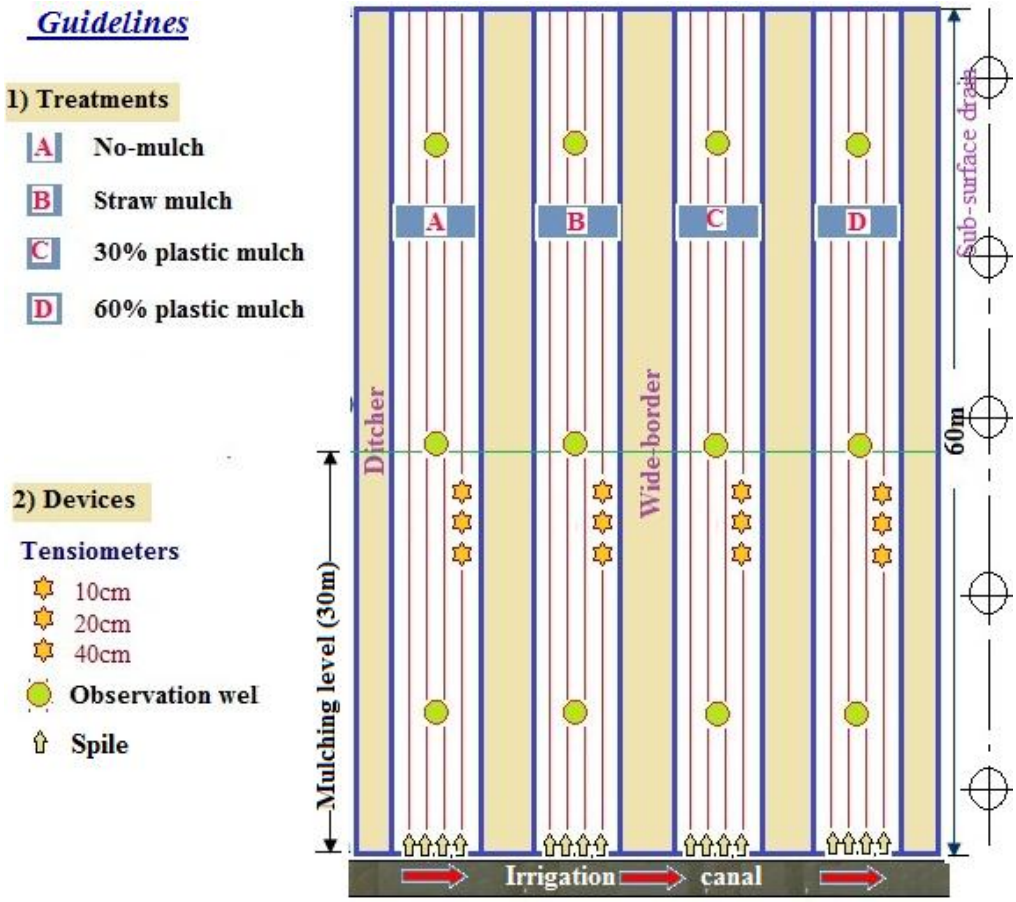

Fig. (1) Schematic diagram of experimental field treatments in detail.

6- Irrigation water efficiencies

6-1- Water Use Efficiency (WUE)

Water use efficiency was calculated for different treatments after crop harvest according to Eq. (3) *(Jensen, 1983).*

$$WUE = \frac{\text{Grain yield (kg fed}^{-1})}{\text{Water applied (m}^3\text{ fed}^{-1})} \quad \text{.....(3)}$$

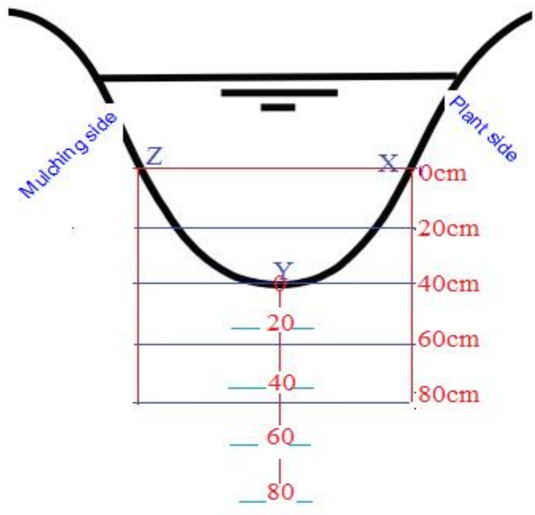

Fig. (2) Locations of measuring moisture content.

6-2- Water application efficiency

It was *calculated* according to Eq. (4).

$E_a = (cu/W_a)\times100$……………………..…………………………….(4)

Where:

E_a = Water application efficiency (%)

cu = Irrigation water stored in the root zone (mm)

W_a = Irrigation water delivered to the farm or field (mm).

7- Ground Water Level (GWL)

It measured at each treatments at three location as shown in Fig. (1) . The locations were X,Y, and Z . It located on 12, 30, and 48m along treatments length respectively.

8- Grain yield (GY)

Three plants within three replications at each treatment were randomly selected. Total grain yield was calculated using multiplied by a number of the plants in feddan (24000 plant/fed).

RESULTS AND DISCUSSION

1- Irrigation scheduling

1-1- Applied irrigation water

Results in table (3) showed that the highest amount of applied irrigation water was obtained under treatments of B, A, C and D, respectively. It

was observed that both treatments of D and C reduced irrigation water with about of 24.65 % and 21.65 % compared to the treatment of A, respectively. On the other hand, the treatment of B increased the applied irrigation water with about of 3.37 % than the treatment of A, as shown in Fig.(3).

1-2- Irrigation intervals

Results of soil water potential (SWP) were obtained as shown in the following figures 4, 5, 6 and 7. Results showed that five irrigation applications were added to the field. It was observed that SWP was significantly affected by mulching under depths 10 and 20 cm because most of maize roots concentrate under this layer which leads to increase Evapotranspiration and increase infiltration. On the other hand, SWP had non-significantly changes under depth of 40 cm due to the rising of ground water tables which leads to increase soil water content under this layer.

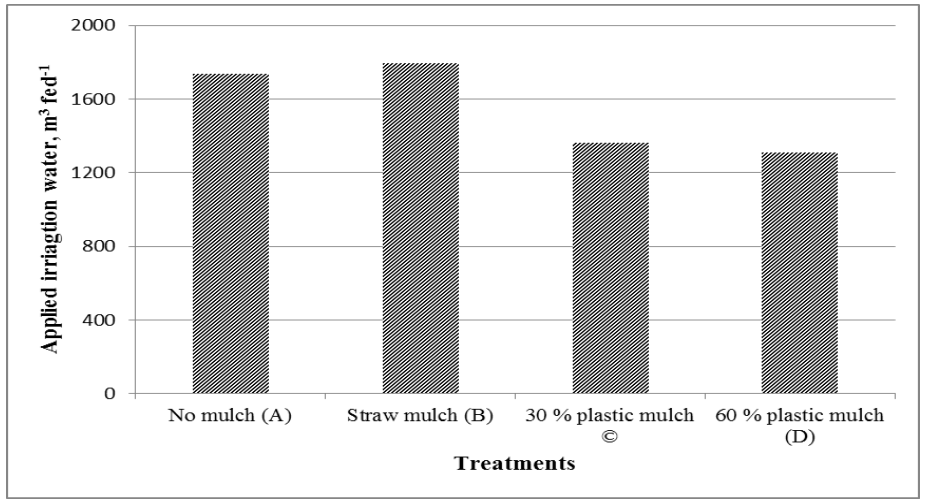

Fig. (3) Diagram showing percentages of applied irrigation water to main experimental field.

As can be seen in the following figures 4, 5, 6 and 7 that highest values of SWT at 10 and 20 cm depths were obtained under treatments of A, D, B and C, respectively. While, the highest values of SWT at 40cm depth were obtained under C, A, B and D, respectively.

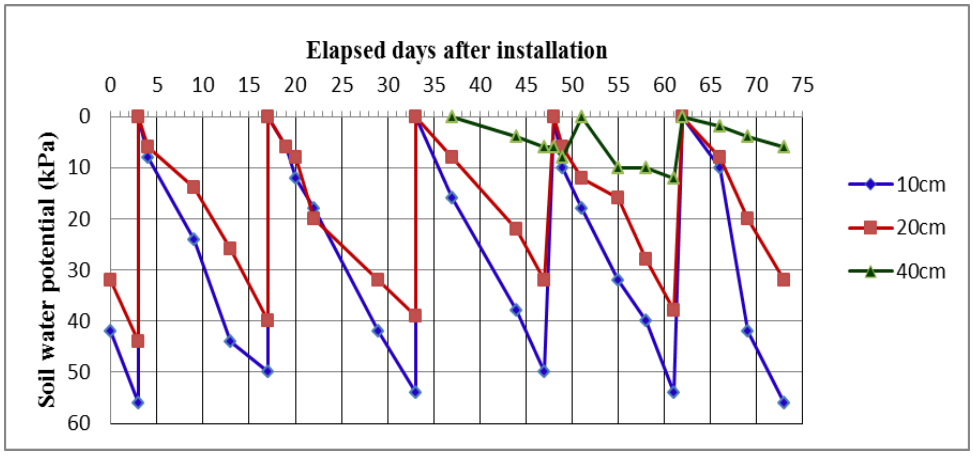

Fig. (4) Soil water potential under treatment of no mulch (A).

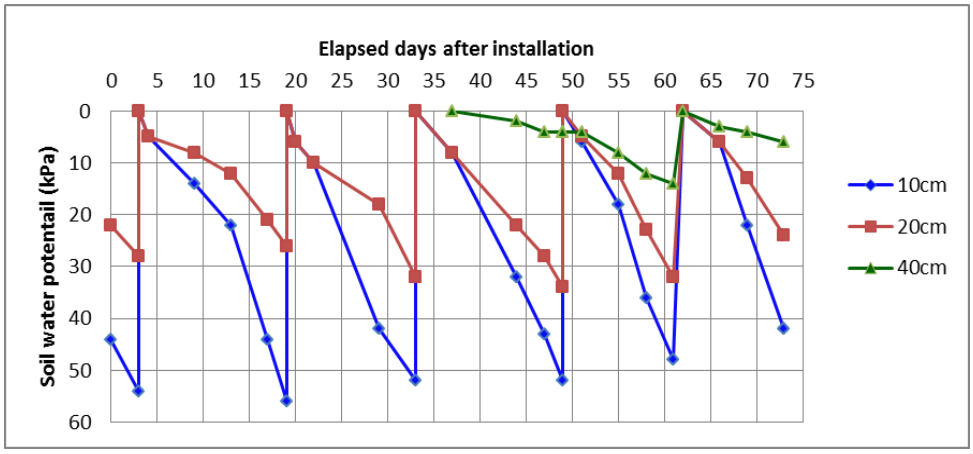

Fig. (5) Soil water potential under treatment of of straw mulch (B).

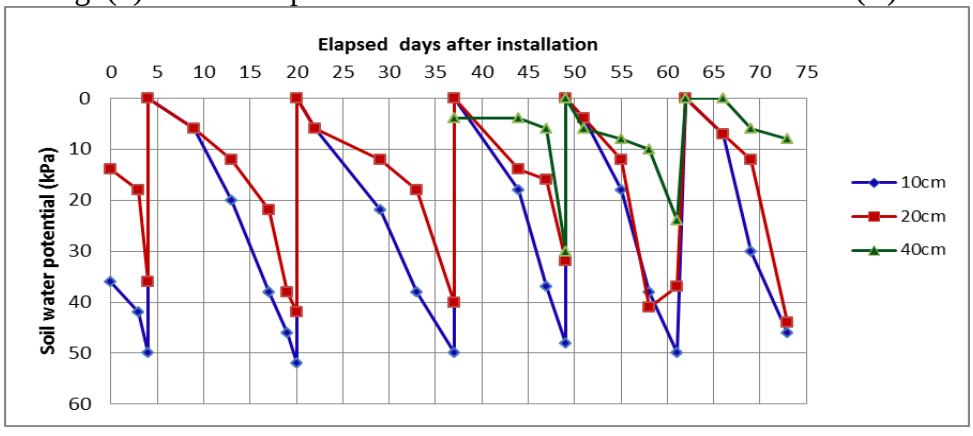

Fig. (6) Soil water potential under treatment of 30 % plastic mulch (C).

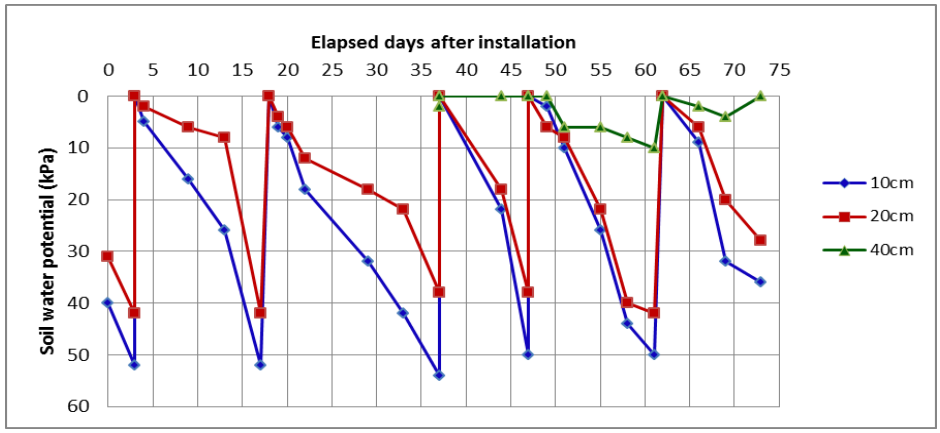

Fig. (7) Soil water potential under treatment of 60 % plastic mulch (D).

1-3- Relationship between estimated and actual applied irrigation water

Applied irrigation water (AIW) was estimated from irrigation scheduling data, and also actual AIW was measured with a spile. Results indicated that there is a big difference between estimated and actual values of applied irrigation water as shown in Fig. (8). It was observed that treatments A and B invistigated the highest values of actual AIW, but lower than values of estimated AIW under the same treatments due to the performance of cutting off. On the other hand, treatments C and D invistigated the lowest values of actual AIW due to the performance of cutting off and plastic sheet leads to prevent water to infiltrate into soil.

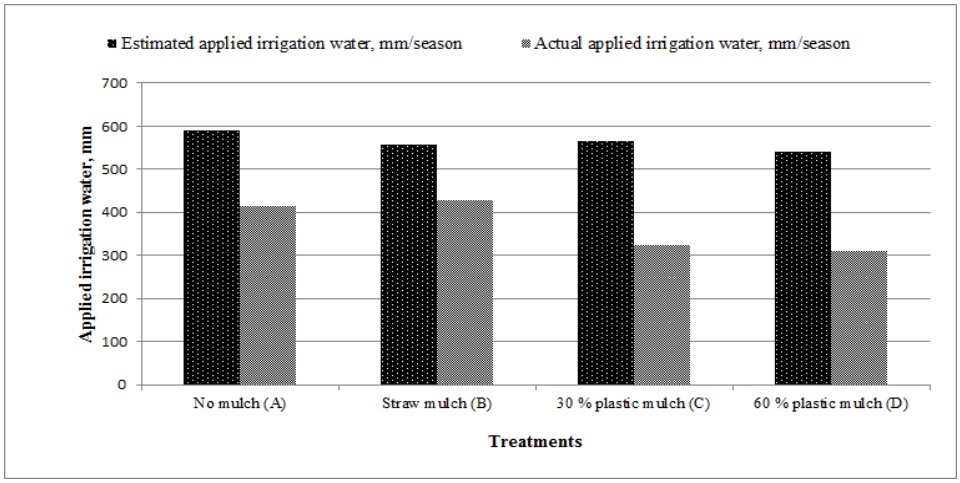

Fig. (8) Relationship between estimated and actual applied irrigation water

2- Advance time

Results indicate that both treatments 30 and 60 % plastic mulch reduced advance time with 20.9 and 21.3 % compared to control treatment, respectively. While, the treatment of straw mulch increased the advance time with 19.1 % compared to control treatment as shown in figures (9,10,11 and 12). This is in agreement with other findings reported by several authors. *Puustinen et al. (2005)* found that mulching contributes to decrease runoff flow and enhance infiltration. *García-Orenes et al. (2009)* observed that time to ponding was delayed after straw mulching treatment respect to other types of management, as systemic herbicide or ploughing.

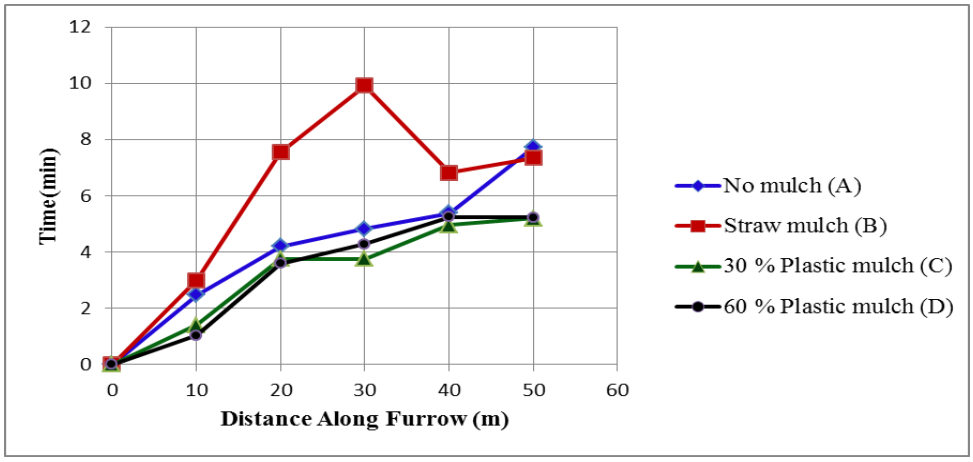

Fig. (9) Effect of mulching on advance time during first irrigation

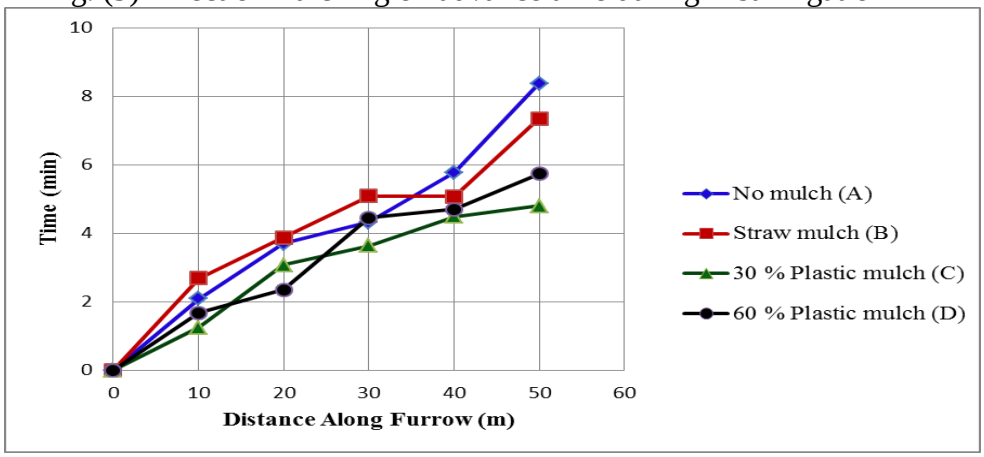

Fig. (10) Effect of mulching on advance time during second irrigation

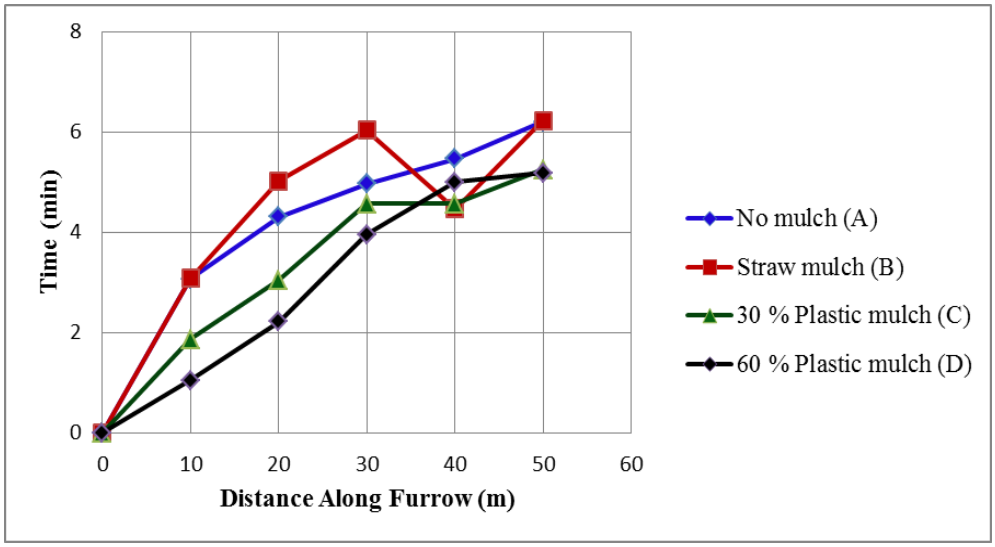

Fig. (11) Effect of mulching on advance time during third irrigation

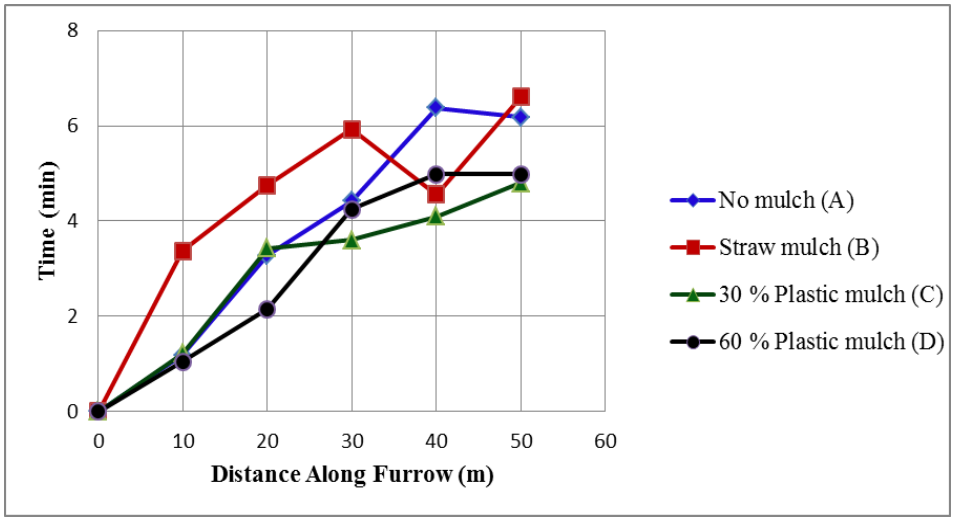

Fig. (12) Effect of mulching on advance time during fourth irrigation

3- Soil Mositure ontent (SMC)

Results in Fig. (13) showed that both treatments D and C reduced SMC at locations Y and Z, while, the highest values of SMC were obtained under straw mulch treatment. These results agree with the findings of several authors, for example, *Ji and Unger (2001)* reported increases in soil moisture storage by using straw mulch.

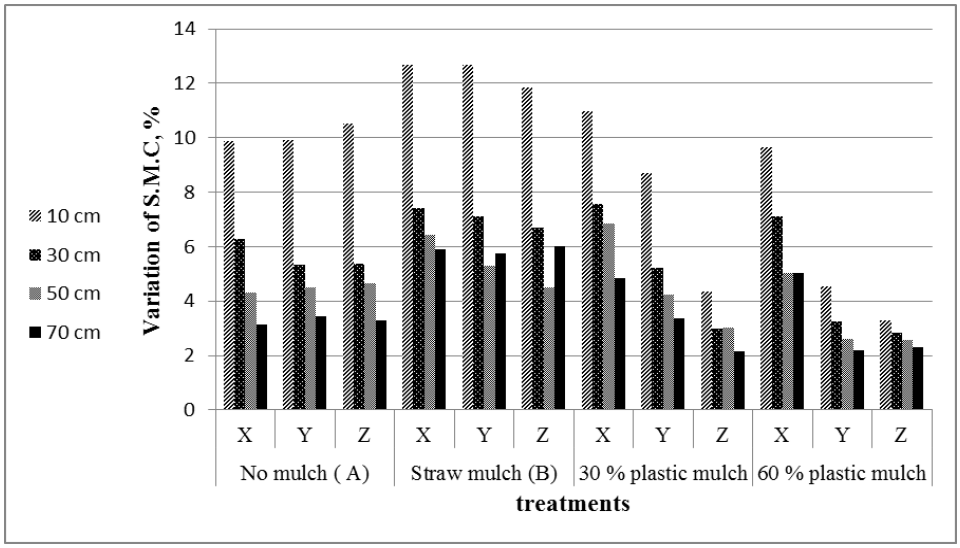

Fig. (13) Effect of mulching on mositure content variation before and after irrigation.

4- Irrigation efficiencies

4-1- Water Use Efficiency (WUE)

Water use efficiency investigated significantly differences among whole experimental treatments. Value of WUE were (2.23, 2.09, 1.69 and 1.34 Kg. Fed^{-1}) under treatments of C, D, A and B, respectively as shown in Fig. (14). Straw mulch treatment had the lowest value of WUE due to the increasment of ground water table which rises upward and compine with rice straw. Basically, straw is an organic matter which absorbed irrigation water under the rooting system of maize which leads to reduce plant transpiration.

4-2- Application water efficiency (E_a)

Mean values of application water efficiency were estimated for whole applications of irrigation. Results indicated that values of E_a were (63.62, 59.15, 56.10 and 53.10 %) under treatments C, D, A and B, respectively as shown in Fig. (15). These results agree with the findings of *Wolters and Berisavljevic (1991),* reported that field application efficiency is influenced by factors such as soil type, irrigation application method. Values of application efficiency are mostly similar to results were obtained by *Awan and Ali (1988)* who evaluated application efficiency at

farmers' field and reported that the application efficiency ranged from 34 % to 95 %.

5- Ground water level (GWL)

Ground water level was measured at three locations per treatment X, Y and Z for both of two stages (experimental test and main experimental field).

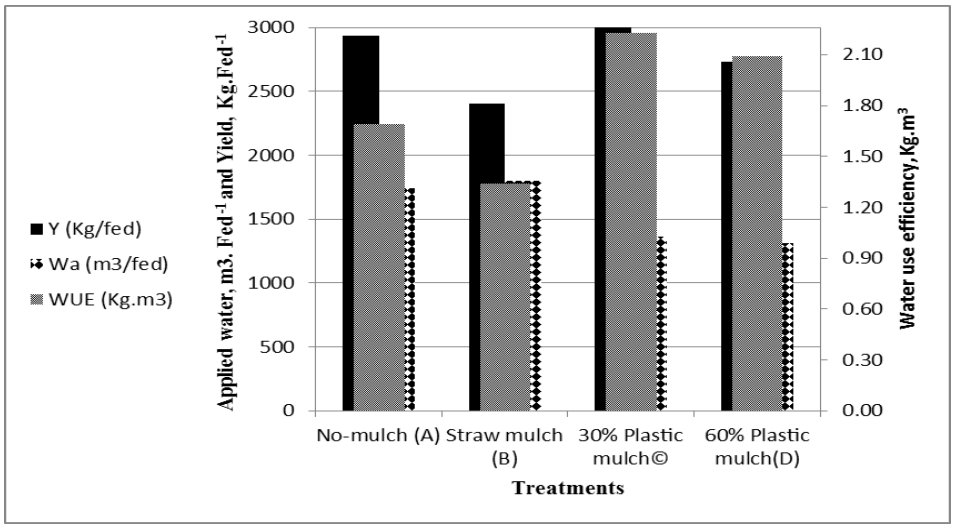

Fig. (14) Effect of mulching on water use efficiency of maize.

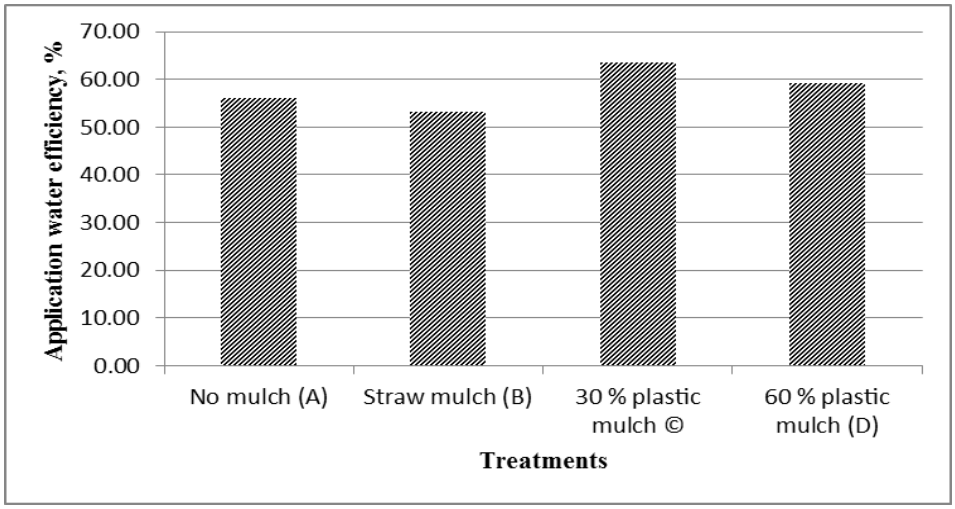

Fig. (15) Effect of mulching on application irrigation water efficiency of maize.

According to location X, it was observed that GWL investigated the highest values under treatments of A, D, and B, respectively. On the other hand, the lowest values were obtained under the treatment of C, as shown in Fig. (4.16).

According to location Y, in experimental test (before sowing), the highest values of GWL were obtained under treatments of B, A, D, and C, respectively. During intial and mid stages, GWL invistigated the highest values under treatments of A, B, D and C, repectively. Moreover, in late stage, the highest values of GWL were obtained under treatments of A, D, C, and B, respecively, as shown in Fig. (4.17).

According to location Z, values of ground water level during (experimental test, intial and mid stages) were the highest under treatments D, C, B, and A, respectively. On the other hand, in late stage, the highest values of GWL were obtained under treatments of D, A, C, and B, respectively, as shown in Fig. (4.18).

6- Grain yield (GY)

Mulching affected grain yield non-significantly as shown in table (3). Highest value of grain yield production was observed in treatment of C (3034.2 Kg/fed.), while, the lowest value was obtained under treatment of B (2401.1 Kg/fed.). This is due to increase soil water storage under straw mulch treatment to trigger the accumulation of salts in root zone with negative effects on crop productivity.

Table (3) Effect of mulching methods on maize grain yield.

Treatment	Grain yield (Kg/fed.)
No mulch (A)	2936.7
Straw mulch (B)	2401.1
30%plastic mulch (C)	3034.2
60% plastic mulch (D)	2733.9

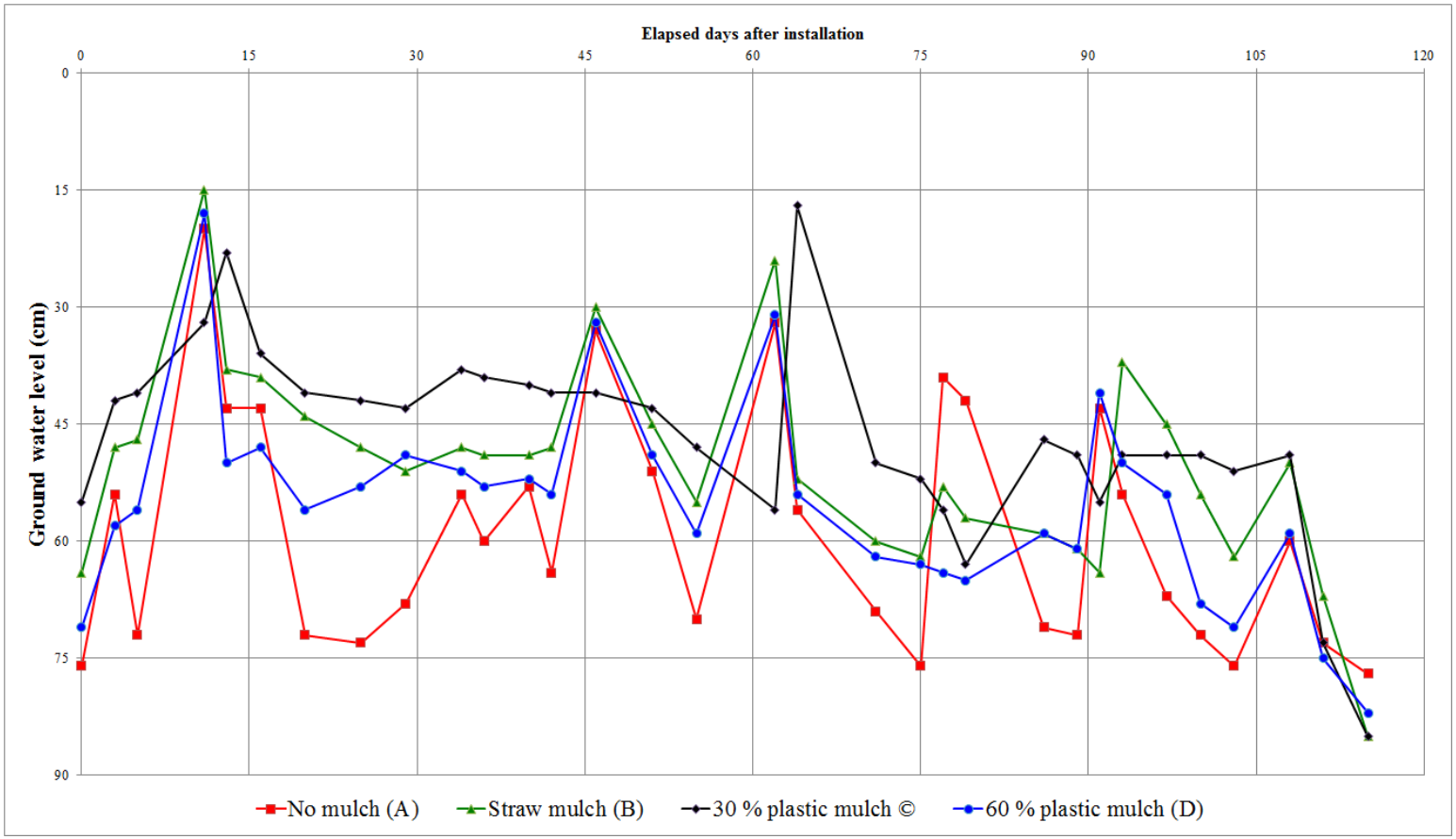

Fig. (16) Effect of mulching method on ground water level at location X

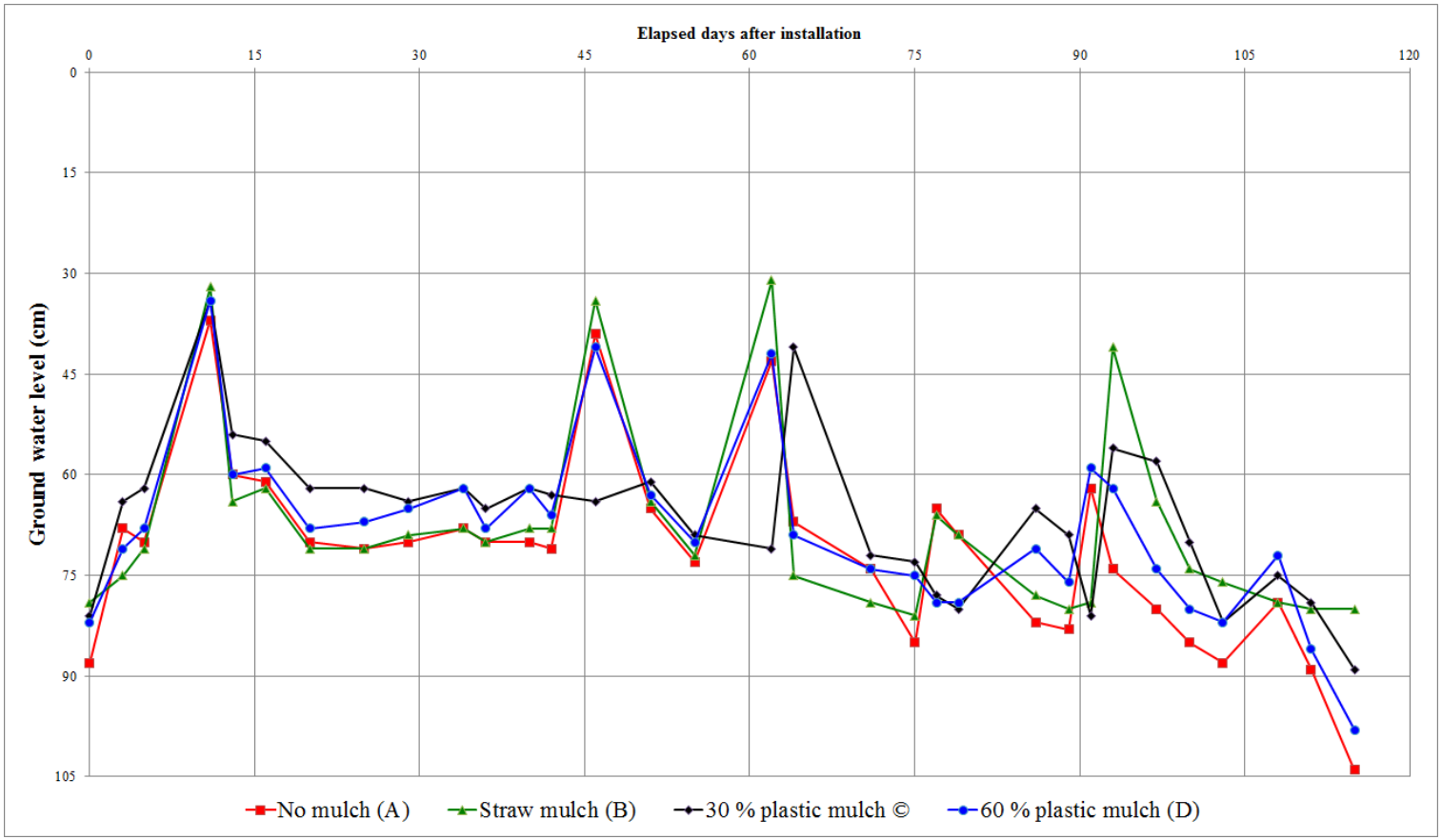

Fig. (17) Effect of mulching method on ground water level at location Y

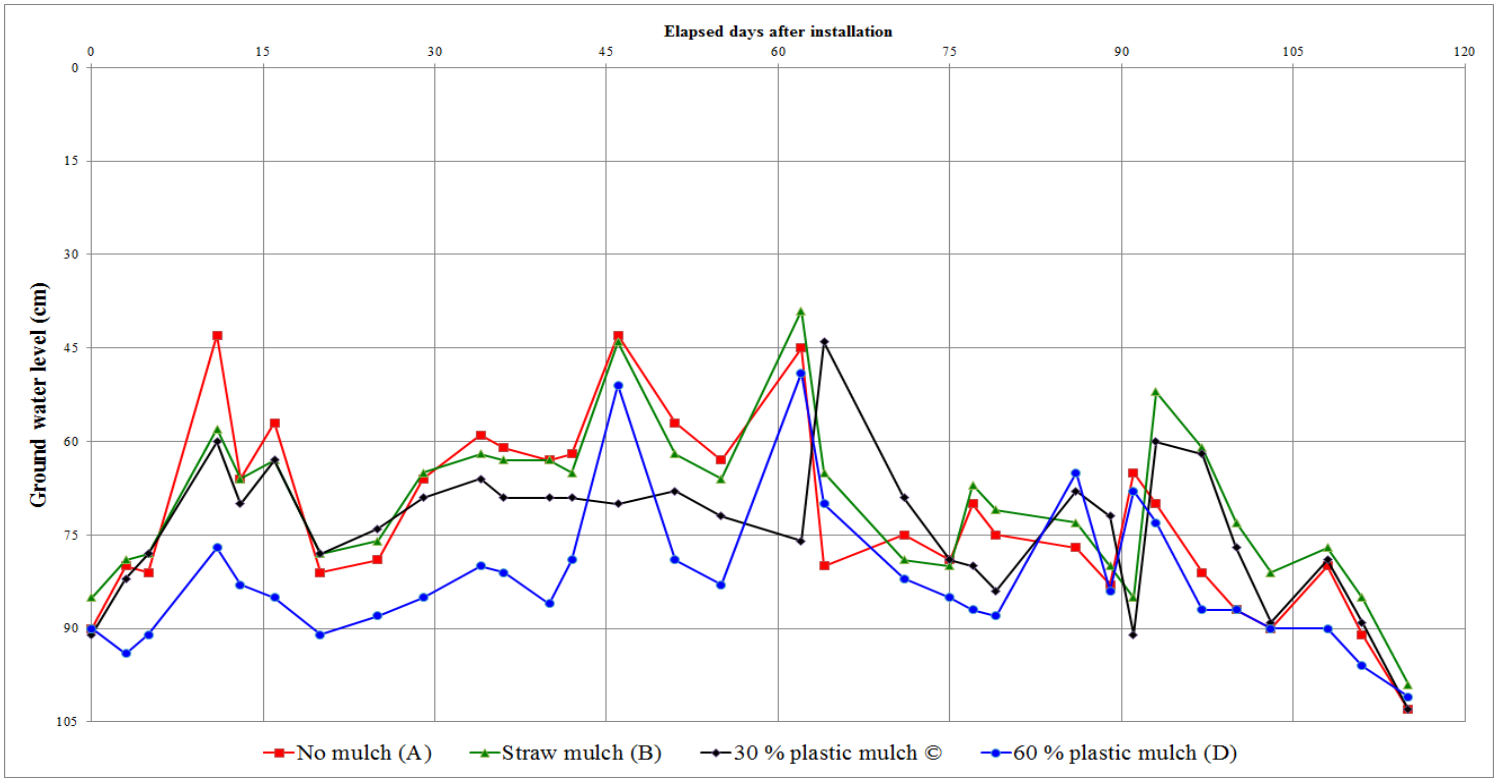

Fig. (18) Effect of mulching method on ground water level at location Y

CONCLUTION

Plastic mulch is effective method on irrigation water saving. It can be control weeds as observed during the experimental test. It saves the applied irrigation water and control erosion. It conserves soil moisture content within soil profile. It controls ground water table so reduces soil salinity. It improves both irrigation water use and application efficiencies. Also, it increases grain yield production of maize.

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الملخص العربى

تقليل فواقد مياه الرى السطحى فى دلتا النيل

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يعتبر الرى السطحى من أكثر نظم الرى الطرق انتشاراً فى مصر بل وفى كل أنحاء العالم. نظراً لكمية الفواقد المائية العالية الناتجة عن استخدام هذا النظام ، تم تنفيذ تجربة حقلية خلال صيف ٢٠١٢ بمحطة المقننات المائية بالقرضا – معهد بحوث إدارة المياه – كفر الشيخ – مصر. كان الهدف من هذه التجربة هو دراسة تأثير طريقة جديدة من طرق التغطية على توفير مياه الرى و انتاجية محصول الحبوب لمحصول الذرة الشامية. تتكون التجربة الحقلية من أربع معاملات رئيسية وهى

١- الكنترول (بدون تغطية)
٢- التغطية بالقش
٣- ٣٠ % تغطية بالمشمع
٤- ٦٠ % تغطية بالمشمع.

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٣. باحث أول / معهد بحوث إدارة المياه / المركز القومى لبحوث المياه
٤. مهندس زراعى

تم تنفيذ التغطية فى محيط الابتلال لخطوط الرى من الجهة المقابلة للنباتات وعلى امتداد ٥٠ % من أطوال خطوط الرى . تم قياس كل من المتغيرات التالية وهى كميات مياه الرى المضافة، زمن التقدم، المحتوى الرطوبى للتربة، كفاءة استعمال المياه، كفاءة استخدام المياه، منسوب الماء الأرضى و إنتاجية المحصول من الحبوب.

أوضحت النتائج أن كلتا المعاملتين ٦٠ % و ٣٠ % تغطية بالمشمع خفضت كميات مياه الرى المضافة بنسبة ٢٤,٦٥ % و ٢١,٦٥ % ، على التوالى. بينما زادت معاملة التغطية بالقش كميات الرى المضافة بنسبة ٣,٣٧ % مقارنة بالمعاملة الكنترول. أثبتت النتائج أيضاً أن كلتا ٣٠% و ٦٠ % تغطية بالمشمع خفضت زمن التقدم بنسبة ٢٠,٩ % و ٢١,٣ % على الترتيب مقارنة بالمعاملة الكنترول. كان لاستخدام المشمع أثراً معنوياً على المحتوى الرطوبى للتربة حيث تم الحصول على أقل القيم من خلال المعاملتين ٦٠ % و ٣٠ % تغطية بالمشمع ، على التوالى. ومن ناحية أخرى، تم الحصول على أعلى القيم له من خلال معاملة التغطية بالقش. لوحظ أن أعلى كفاءة لاستعمال المياه كانت من خلال المعاملتين ٣٠ % و ٦٠ % تغطية بالمشمع على التوالى، بينما أقل قيمة لها كانت من خلال معاملة التغطية بالقش. كما حققت كفاة اضافة المياه أعلى القيم لها تحت كل من المعاملات ٣٠ % تغطية بالمشمع ثم التغطية بالقش ثم ٦٠ % تعطية بالمشمع ثم الكنترول. أشارت النتائج إلى أن أعلى قيم لمنسوب الماء الأرضى كانت من خلال المعاملات وهم ٦٠ % تغطية بالمشمع ثم الكنترول ثم التغطية بالقش ثم ٣٠ % تغطية بالمشمع. لقد أثرت التغطية تأثيراً غير معنوى على محصول الحبوب من الذرة الشامية و بالرغم من ذلك تم الحصول على أعلى انتاجية من محصول الحبوب خلال المعاملة ٣٠ % تغطية بالمشمع (٣٠٣٤,٢ كجم / فدان) وأقل انتاجية خلال معاملة التغطية بالقش (٢٤٠١,١ كجم /فدان). استنتج من خلال هذه الدراسة أن التغطية باستخدام المشمع هى أفضل الطرق العملية لتقليل فواقد مياه الرى السطحى فى منطقة الدلتا.