Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 8(10) pp. 300-310, November, 2019 Issue.
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Full Length Research Paper

Soil Management Practices to Improve Irrigation Performance and Eggplant Water Use Efficiency in A Cracked Soil

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Accepted 19 October, 2019

Vertisols cover extensive areas in the intermountain valleys of Iraq. These soils crack upon soil moisture loss and the formed cracks facilitate rapid transport of surface water into the subsoil via preferential flow. A large volume of water can be saved by practicing proper soil management practices. Sequential experimental were conducted encompassing laboratory, preliminary and field experiments. The field experiments were conducted over a cracked soil at a research farm located in the outskirt of Sulaimani city during the summer seasons of 2017 and 2018. The objectives were to improve the performance of a furrow irrigation and water use efficiency of eggplant under different treatments. The treatments encompassed: control, cultivation, puddling and application of wheat straw. Preliminary tests unveiled that volume of water required to fill the cracks constitutes a major component of the total depth of infiltrated water. The performance of various management practices in term of irrigation efficiencies, fruit yield and water use efficiency of eggplant followed the order of straw>puddling> cultivation control> control. The results also displayed a declining trend in water irrigation efficiencies, fruit yield and water use efficiency of eggplant with increasing length of furrow from 30 m to 70 m.

Keywords: Cracked soils, soil management practices, eggplant, irrigation efficiencies, water use efficiency

INTRODUCTION

The national economic of Iraq can be raised by bringing more lands under irrigation. The expansion of irrigated lands without appropriate water management will notensure crop production demands (Yigezu et al., 2016).

Furrow irrigation is one of the most popular methods of surface irrigation in different parts of Iraq. (Kumar and Singh 2003) reported that proper management is of urgent need in view of increasing water demands, limited resources and groundwater contamination. It is observed that the main constraints on furrow irrigation are considerable loss of water through runoff and deep percolation (Reddy and Clyma 1981). The problem of

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water loss via deep percolation is more profound or more problematic inVertisoils. These groups of soils represent a vast crop production resource and account for a considerable portion of the intermountain valleys and the Mosul-Erbil-Kirkuk plains of Iraq (Muhaimeed et al., 2014).

These soils crack upon soil moisture loss and the formed cracks facilitate rapidtransport of surface water into the subsoil via preferential flow (Dinka and Lascano 2012).

Different approaches to improve the on-farm application efficiency of surface irrigation practices can be broadly categorized according to whether they modify the soil, water (application/scheduling) or design parameters (Raine et al., 1996 Yahya Sh and Abdul-Razaq 2017; Mandal et al., 2004; Masood 2015; Al-Omran et al., 2010). Revealed that the performance of surface irrigation systems is a function of field design, infiltration characteristics of the soil, and the irrigation management practices.

(Islam et al., 2004), reported that among nine soils management practices the hand hoe operation offered a better performance than trampling to reduce cracks with a width of 10mm. The findings of (Wopereis et al., 1994), revealed that puddlingcan reduce the non-capillary pore spacing, resulting in a closer packing of soil particles. Plant roots can perform various tasks to reduce cracking intensity via forcing the soil to be coherent and acts as a single mass when the soil starts to fail (Abernethy and Rutherfurd 2001). Furthermore, (Wopereis et al., 1994), have noticed that shallow tillage reduced the preferential flow or crack bypass flow in undisturbed cores by (45-60%). The findings of (Mousavi et al., 2011), elucidated that application of organic materials in soil could delay crack formation and its intensity.

Eggplant *(Solanummelongena* L.) is one of the Solanaceae plants and considered as one of the cultivated vegetable crops in many regions of the world including the Middle East Region (33).Additionally, it has a high nutritional value (Abu-Alaees and AlBaity 2017). In order to achieve high eggplant yield, an adequate water supply is required during the growing season (28). Accordingly, the current study was conducted with main objective of improving irrigation performance and yield and water use efficiency of eggplant grown in a cracked soil inSulaimani Province via implementing some selected soil management practices.

2. MATERIAL AND METHODS

2.1. Study Site Description

The field experiments were conducted at the research farm of the Directorate Agriculture Research–Sulaimani, Iraq. It is located about 20km northeast of theSulaimani city center.The geoposition of the experimental site is 35°22′4.75″N and is 45° 37′47.45″E, lying 548 m a.s.l.

On the basis of aridity index (AI) defined as the ratio of mean annual precipitation to potential evapotranspiration, the climate regime can be classified as semiarid (0.2> AI <0.5) (35).The aridity index according this scheme is 0.23. Further, it can be classified as a temperate, dry summer, hot summer (Csa) according to the scheme proposed by Koppen.

According to soil taxonomy Soil Survey Staff, (34), the soil at the experimental site is categorized as: fine clay, active, mixed, thermic, Typic Chromoxerets. The soil of the site is nearly free of rocks (clay = 40.17%, silt = 52.62%, sand = 7.21%, ECe = 0.57 dSm^{-1}). Furthermore, the soil has relatively a high potential to volume change, which is manifested by wide and deep crakes during the summer season.

2.2. Preliminary Tests

Prior to conducting field experiments on a large scale, several sets of potexperiments were conducted to determine the potential of the investigated soil to volume change and cracking. Another test was also carried out to determine the percent of linear shrinkage of investigated soil according to (BSI 1990).

Additionally, a plot experiment was conducted to evaluate the performance of some selected management practices (control, cultivation, puddling and wheat straw application) on reducing cracking index using small plots (2 m x 2m) before extrapolatingthem to the field via implementing large scale experiments.

2.3. Field Experimental Layout

The experiment was laid out in a completely randomized block design with three replications.Four treatments were applied with a total number of 12 experimental units or with 36 furrows. Each furrow of experiment 1 had a length of 30 m with an average depth of 0.25 m. The top width was 0.55 m, while the side slope was 1:1. Further, the longitudinal slope was 0.015 m / m. unless otherwise stated, the experiment furrows were blocked on the downstream ends.

Each experimental unit was composed of three adjacent furrows. The treatments encompassed:

T1 = Control

T2= Application of chopped wheat straw at a rate of 0.6 kg m^{-2} buried at a depth of 5 cm below the furrow bed surface

T3= Hoeing (Shallow tillage of the furrow bed or cultivation)

T4= Puddling during irrigation

2.4. Planting and other Cultural Practices

Prior to transplanting, seeds of eggplant plant cultivar (Species: MELANZANA, Varity: VIOLETTA) were sown in a nearby nursery in form of four plots, each having an area of 5 m^2 (2 m x 2. 5 m)on February 20, 2017.Subsequently, the seedlings were transplanted into the furrows on May

27th in 2017. The seedlings were transplanted at the furrow crest at spacing of 0.60 m on both sides of the ridges. The ridge top center spacing was 0.75 m. The eggplant received a basal application of 25 kg N and 225 kg P in form of urea and single superphosphate, respectively. Weeds were removed manually three times in the season and irrigation water was applied during the growing season based on the proposed irrigation schedule.

It is commendable to mention that the experiment was repeated during the summer season of 2018. It was similar to those of 2017 except that the furrow length was 70 m instead of 30 m. Further, the transplanting date was 25May 2018 instead of 27 May 2017.

2.5. Irrigation Schedule

The eggplant was irrigated whenever time 40% of available water was depleted. The soil moisture content was monitored gravimetrically by using a small worm type auger and the leaf appearance was used as an indicator for the time of irrigation. The source of irrigation was a nearby stream with an average EC of 0.85 dSm^{-1}.

2.6. Advance Time Measurement

The central furrow under each treatment was divided into a number of stations having equal distances between them by driving metal pegs into the soil at 3 m interval along its length. In order to maintain a constant flow of water into the head of the furrow during the test period, a free flow V-notch weir was installed to supply water at a rate of 0.4 L s^{-1}. As the irrigation water was advanced down the furrow arrival times were recorded at the end of each rich using a stopwatch. The advance time was measured during the applied irrigation events.

2.7. Performance Indictors

The performance of different management practices and irrigation techniques were evaluated by using: the irrigation adequacy (Amer and Daim 2011), irrigation application efficiency (Zerihun et al., 1997) and distribution efficiency (Holzapfel et al., 1985).

2.7. Crop Yield and Field Water Efficiency

The eggplant fruit were picked every 5-7 days and the total marketable yield was assessed.Additionally the following formula was used to calculate the field water efficiency (James 1988).

$$WUE = \frac{Y}{d} \times 1000$$

Where: Y = Crop marketable yield (t ha^{-1})
d = Volume of applied water (m^3ha^{-1}) WUE= Field water use efficiency (kg m^{-3})

3. RESULTS AND DISCUSSION

3.1. General Aspects about the Cracking Characteristics of the Soil at Experimental Site along with the Specification of Furrow Irrigation System across the Region

Visual field observations indicated that summer shrinkage and subsequent winter swelling in the soil of the experimental site is a perennial process. The swell-shrink potential is manifested in form of cracking during the dry season. Soil cracking is a striking morphological feature of Vertisols. Constitute a considerable portion of the total geographical area of Iraqi Kurdistan region.

On average the cracks were 6.58 ± 0.55 cm wide and 80 ± 7 cm deep. The cracks fall in the deep class (Ahmad and Mermut 1996). Among many criteria that are available to identify and characterize the potential capacity of the soil to volume change; percent of linear shrinkage was used as a criterion for this purpose. Laboratory tests indicated the percent of linear shrinkage is in the range of 10 to 12% It appears that the study soil is characterized by having of a considerable proportion of highly active clay minerals of the montmorillonite group which are responsible for its pronounced capability to volume change.

Albeit, there was no standard identification and classification of shrinkage and swelling potential of soils (Nelson and Miller 1992), the study soil fell in the critical class (PLS > 8%) according to the classification scheme proposed by (Altmeyer 1955).

The results also indicated that the cracking index for the experimental site varies from as low as 0.4 m to as high 1.2 m with an average value of 0.65 m. It is evident from the above results that the volume of water required to fill the cracks constitutes a major component of the total depth of infiltrated water.

These results emphasize on the fact that the soil of experimental site has a high capacity to recharge the soil profile and water table during water application from irrigation and rain. Additionally, the high surface area facilitates the water loss from the soil profile through evaporation (Ritchie and Adams 1974).

This type of data can be considered as prerequisite information for selecting the appropriate management practices for sustainable agricultural production with minimum environmental degradation in highly cracked soil.

Although the furrow system is used for a variety of row crops, at present its use is confined mainly to vegetable crops like tomato, eggplant, lady finger, squash, cucumber, cowpea and melon, etc. The furrow length across the upper part of Iraq hardly exceeds 50 m. In the view of the authors, the factors posing restrictions on furrow length are: fragmented sizes of farmer's land, small stream sizes, manual (none mechanized) farming and rocky soils, Further, The practice of tail water recycling is absent. This means that blocked end furrows are the dominant type.

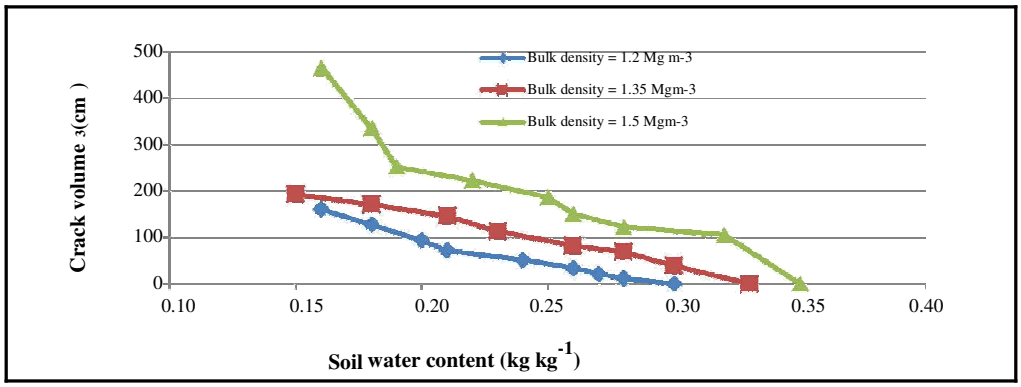


Figure1. Variation of crack volume with soil moisture loss under different degree of soil compaction

Table 1.Effect of type of management on the component of infiltration rate

Treatment	f_o	f_c	$f_{average}$	Equation
Control	76.713	8.494	16.8	$D=104.69+2.247\ T^{0.569}$
Straw	40.309	2.219	5.83	$D=89.13+1.782T^{0.377}$
Puddling	43.430	1.564	4.55	$D=80.64+2.074T^{0.349}$
Cultivation	40.352	7.613	12.98	$D=94.79+1.019T^{0.660}$

However, short furrows require a lot of attention, but water can be used efficiently.

3.2. Preliminary Tests

Before initiating the main field experiments, a laboratory experiment was conducted to study the response of crack volume to soil compaction and soil moisture content of the soil of the experimental site (Figure1). It was revealed that irrespective of degree of compaction the crack volume starts to stabilize at a soil water content of about 15%, which is close to the permanent wilting point of the investigated soil. It can also be observed that the water content at which cracks start to generate is soil bulk density dependent. The higher the soil bulk density the higher will be the soil water content at which cracks start to generate. Overall, crack starts to generate at a soil water content that exceeds the field capacity of soil (FC= 25.5%).

Based on the obtained data of Figure 1 and from management point of view, it is recommended to avoid soil compaction on one hand and not allow the soil water content to drop substantially below the field capacity on the other hand. This implies by growing crops with small depletion fractions. Under these conditions, the risk of groundwater pollution can be largely avoided. It is commendable to indicate the data of Figure 1 were obtained from a soil column experiment conducted in the laboratory exposed to open air.

Table1.depicts the parameters of the infiltration under different soil management practices during the plot experiment and prior to conducting the main field experiments. As can be noticed in Table 1 that the applied treatments were effective in reducing the intercept of the infiltration model in the following order: Puddling > Straw > Shallow tillage (hoeing) > Control.

It is worth mentioning that the intercept of the equations is representing the cracking index or the depth of water that must be applied before ponding initiation. The results also showed that, compared to the control, the percent of reduction in cracking index under puddling, straw, shallow tillage or cultivation treatments were 22.98, 14.86 and 9.46% respectively. The same conclusions were drawn when the three parameters of model were taken into consideration collectively. It is commendable to indicate that the cumulative infiltration at a given time does not

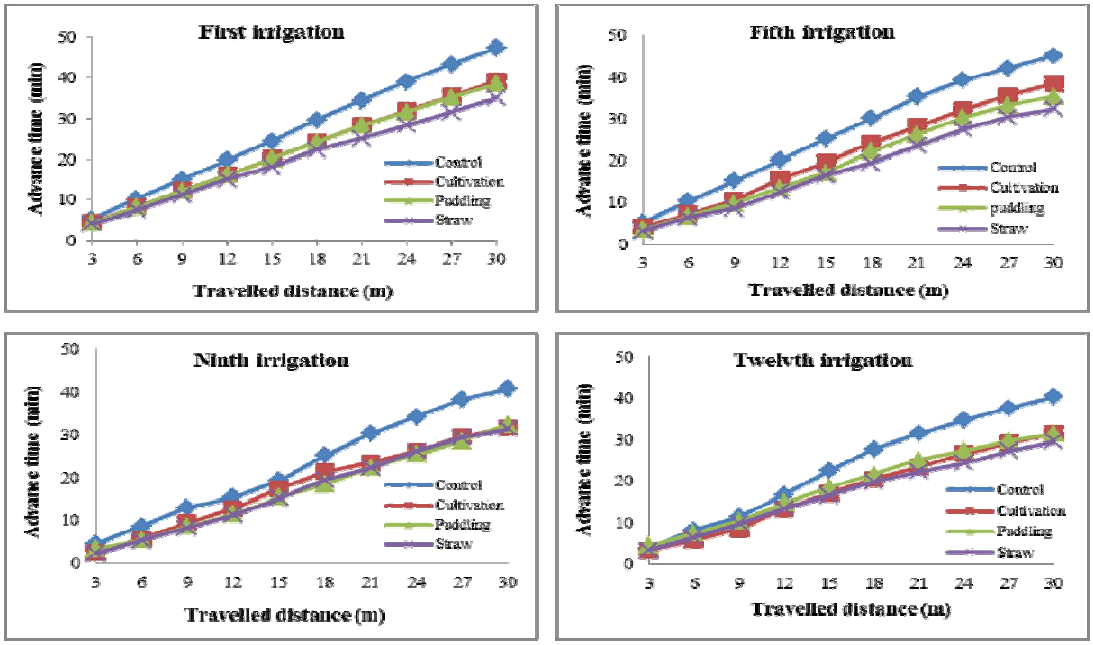


Figure 2. Advance time versus elapsed time for the different management for 30 m length

depend only on the intercept, but also on the model coefficient and its exponent collectively.

It is obvious from the above results that the applied treatments were effective in reducing the cumulative depth of infiltrated water in general and, in particular, under the puddling and straw treatments. It is of vital importance to take benefit from these soil management practices to lower the risk of groundwater pollution.

3.3. Advance Time as Influenced by Different Soil Management Practices

By plotting the time water arrives at various distances down the furrow against the distance under different soil management practices, advance curves were developed to describe the rate at which water moves down the furrow having a length of 30 m (Figure 2). The average surface irrigation water flow advanced faster and less time was needed under all the applied treatments compared to the control. It was also noticed that the advance trajectories of the three treatments did not differ much from each other. The fastest advance time to reach the end of the furrow was observed for the straw treatment and the puddling the next fastest.

Although, successive irrigations presumably act to consolidate the soil, reducing impedance and increasing the rate of irrigation advance, but this effect was not profound during successive irrigation

Figures 2. Indicate that wave-front advance along the furrows is quasi-linear under straw, puddling and shallow tillage. On the other hand, the advance curve of the control treatment can be described by a power function model.

Overall, water front under the control treatment reached the end of the furrows in about 50 minutes, while, less than this amount was needed for water front to reach the end under treatments respectively. The time required for water to advance down the control furrow was about 1.5 times longer than the time required under the rest of the treatments.. However, for efficient irrigation, advance must be rapid throughout the length. Generally, slower advance times can be observed during the late stage of water advance. When water advances through the furrow some of it infiltrates into it. This causes both flow rate and flow velocity to decrease, so the closer the water front gets to the end of the field, the longer it takes to cover a unit of distance.

Additionally, the results indicated the advance curves exhibited similar trends in the field experiment in which the length of the furrows was 70 m (Figure 3). The exception is the time required for water to advance down the control furrow was about 2 times longer than the time for the remaining treatments.

These outcomes indicate that applied treatments under the conditions that prevail in the study region lead to a shorter advance time in comparison to control treatment.

Results of the study showed that the with 30 m furrow length, the highest application efficiency of 76.13% was obtained under straw treatment, whereas the lowest application efficiency of 70.45% was obtained with control treatment (Figure 4). A none-significant difference observed among straw, puddling and cultivation practices.

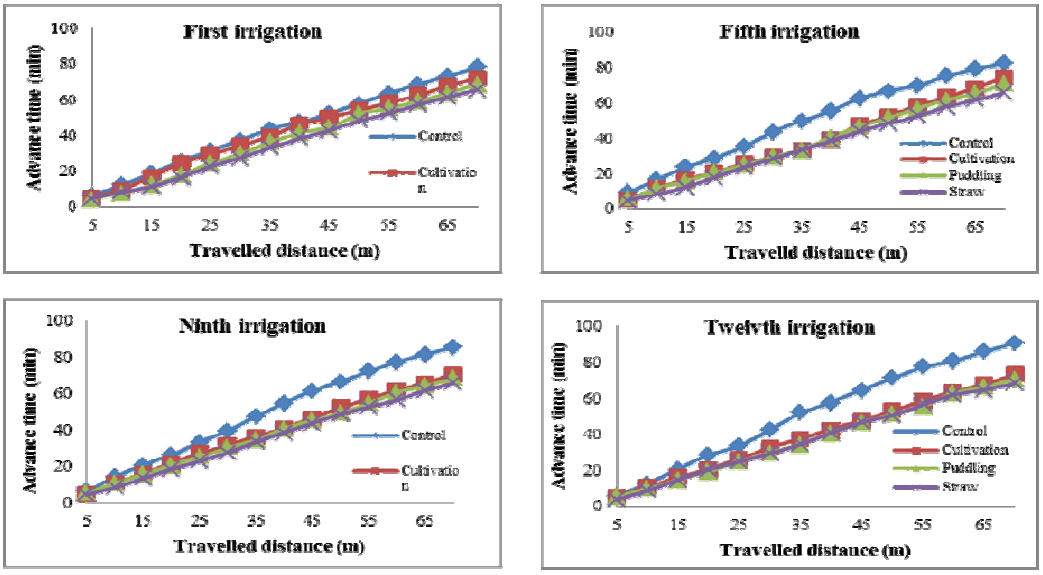


Figure3. Advance time versus Elapsed time for the different management for 70 m length 3.4. Irrigation Efficiencies

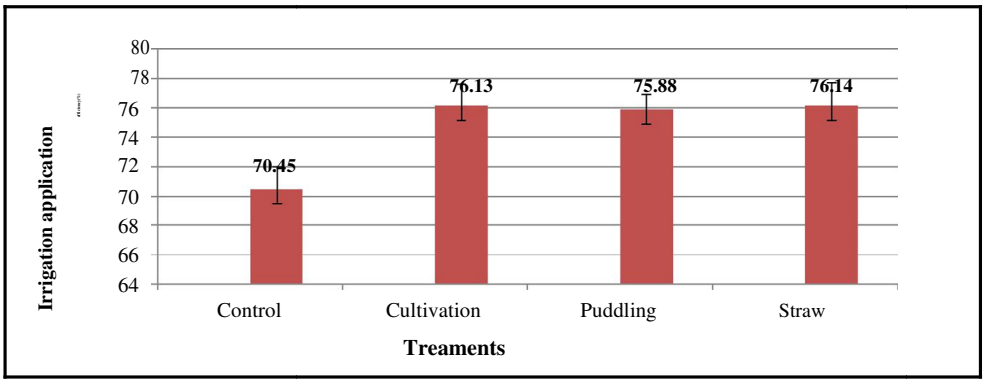


Figure 4. Irrigation application efficiency as influenced by different soil treatments when the furrow length is 30 m

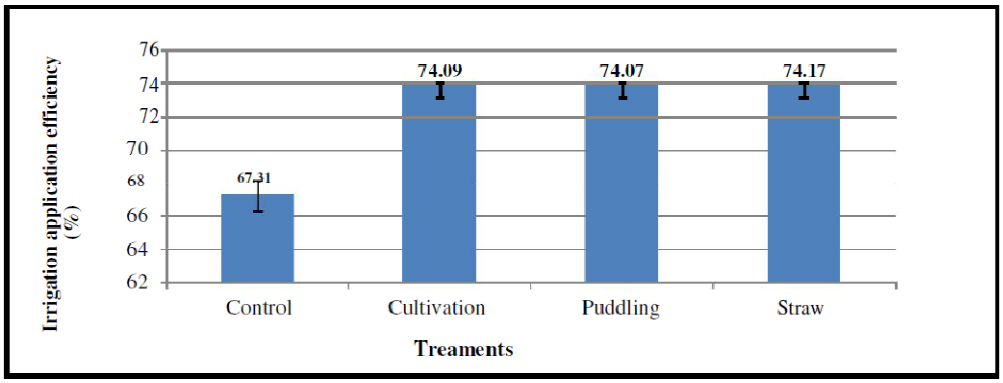


Figure 5. Irrigation application efficiency as influenced by different soil treatments when the furrow length is 70 m

Dunnett's–test indicated that with no exception the application efficiency all the applied treatment differed high significantly (P□ 0.01) from that under control treatment.

It was also noticed in Figure 5 that the applied treatment in the experiment with 70 m furrow length exhibited similar trends. The highest Ea of 74.17 % was obtained with the

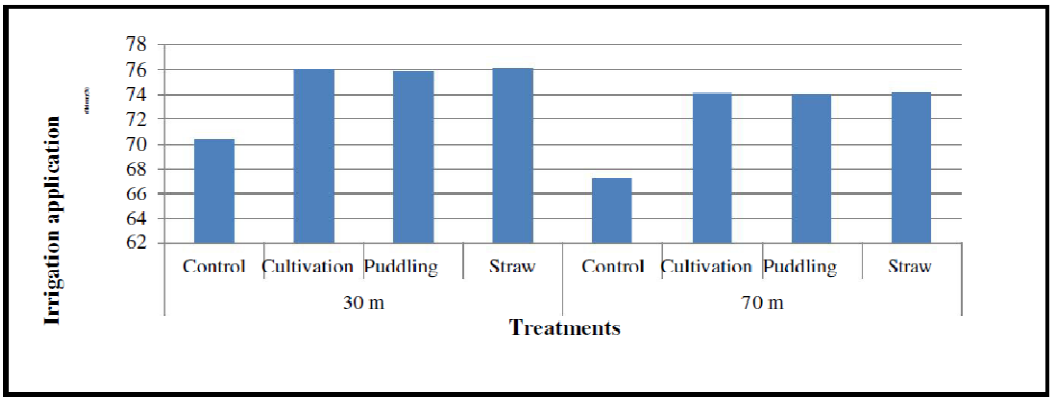


Figure 6. Irrigation application efficiency as influenced by different soil managements and furrow length

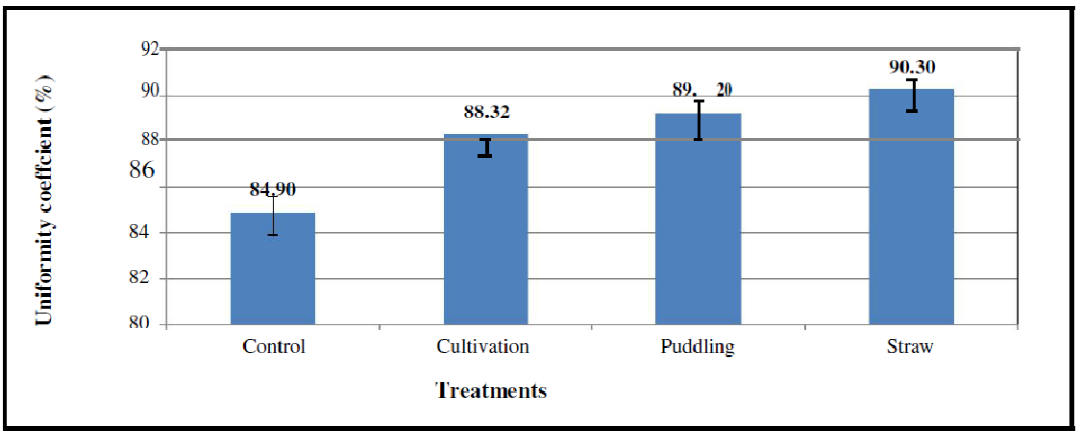


Figure 7. Uniformity coefficient as influenced by different soil treatment for furrows having lengths of 30 m.

straw treatment followed by cultivation, puddling and control. Additionally, it can also be observed that the percent of increase in Ea due to implementation of any of these three management practices were about 10 and 8% for furrows with lengths of 30 and 70 m respectively.

Comparison of irrigation efficiency under different management practices indicated that reducing field lengthis an effective measure for improving irrigation efficiency and for reducing percolation rate below the root zone (Figure 6). Studies have shown that shortening the field length by one-half can reduce percolation by at least 50 percent (Bali et al., 2010). This in not consistent with (Yigezu et al., 2016), who reported that the efficiency of irrigation for open ended furrows efficiency increased from 24.6 to 34% when the furrow length increased from 16 to 48 m. They also noticed that open ended short furrows were the major source of water loss through surface runoff.

Figure 7 depicts the effect of different management practices over 12 successive irrigations on coefficient of uniformity when the length of the furrows was 30 m. As can be seen in Fig.8, Straw treatment recorded the highest coefficient of uniformity of 90.3%%, whereas control treatment registered the lowest value of 84.90%. The Coefficient of uniformity decreased in the order straw >puddling> cultivation > control. Dunnett's-test unveiled that each of applied three treatments differed high significantly (P□ 0.01) from the control treatment.

By contrast, there was no significant difference in coefficient of uniformity between these three treatments.

It is noteworthy that the applied treatments with 70 m length followed a pattern similar to those with 30 m length in term of coefficient of uniformity (Figure 8). For instance, the straw and control treatments offered the highest and lowest values for Cu respectively. In the meantime, the

effect of the applied treatment on increasing Cu is less profound with 70 m furrow length compared to 30 m furrow length.

Similar to Ea, values of Cu decreased with an increase in furrow length under all the treatments (Figure 9). Irrigation runs that are too long result in overwatering at the top of the furrow (36).It seems from these experiments that significant improvements in irrigation performance could be

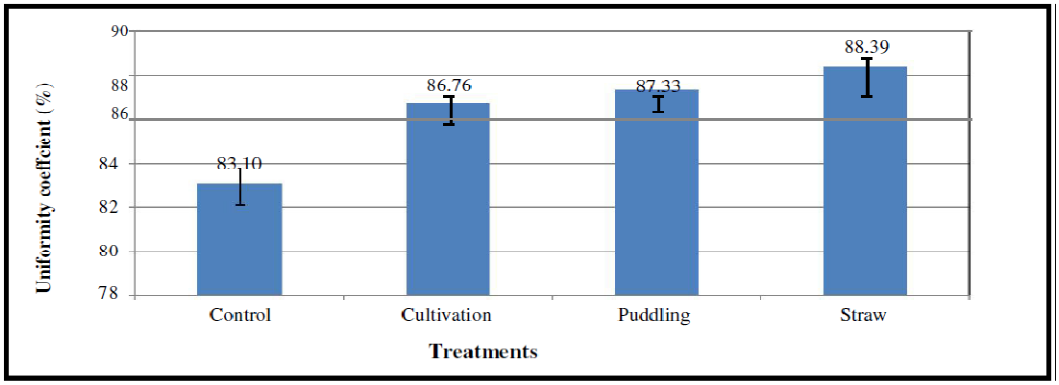
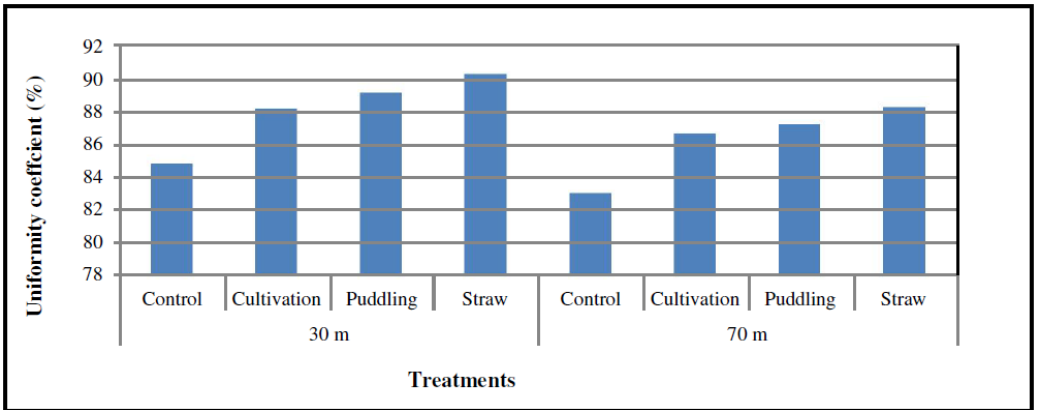


Figure 8. Uniformity coefficient as influenced by different soil treatment for furrows having lengths of 70 m



9. Uniformity coefficient as influenced by different soil treatment and furrows length.

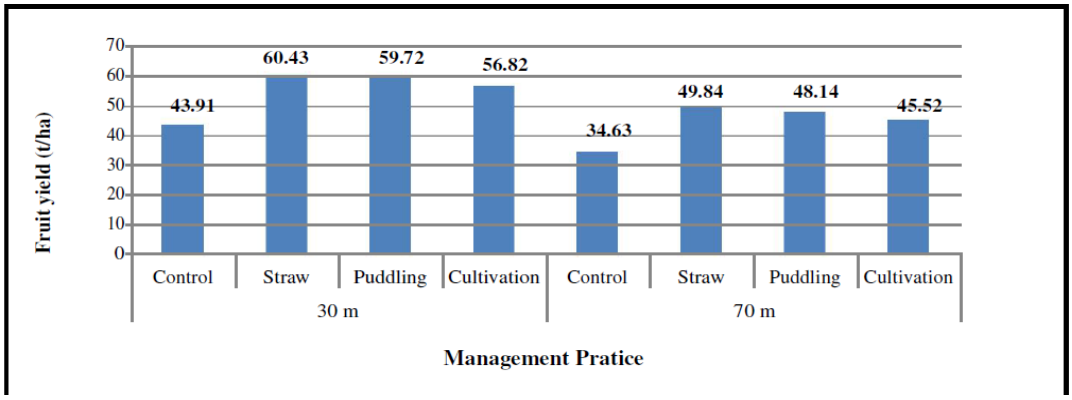


Figure 10. Total fruit of eggplant as influenced by different soil management practices and furrow length

obtained via the adoption management practices that are suitable to the farm's environmental and management constraints. Overall, the results indicated that the irrigation adequacy more than 70 % in most cases.

Comparison of average fruit yields under different management practices with a 30 m furrow length indicated that the straw treatment offered the highest fruit yield (60.43 t ha^{-1})and the control has the lowest fruit yield (43.91 t ha^{-1}) (Figure10).Residue incorporation results in more microbial activity and more water availability than its removal. Accordingly, if residues are managed properly, it

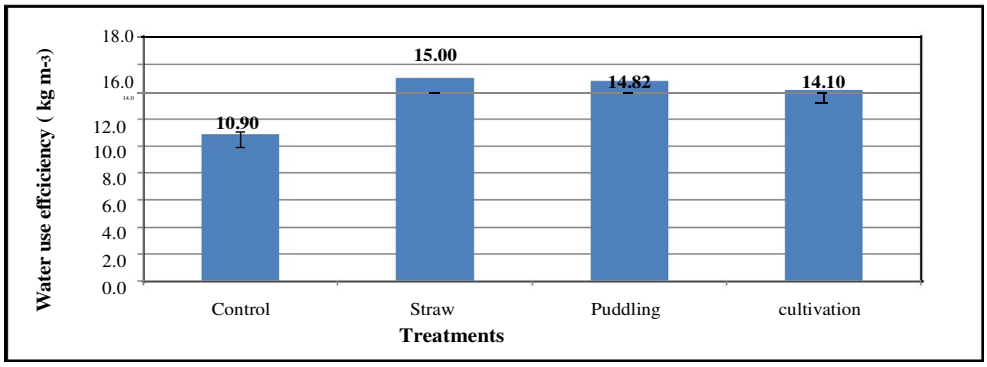


Figure 11. Eggplant water use efficiency as influenced by soil management practices with furrow length of 30 m.

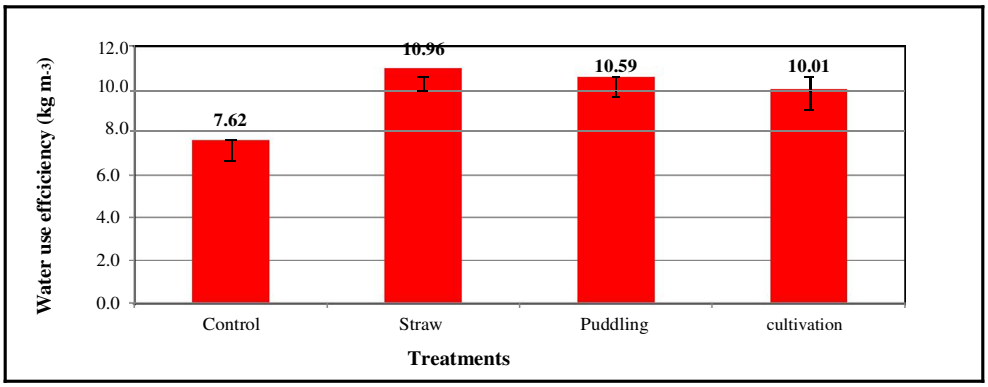


Figure 12. Eggplant water use efficiency as influenced by soil management practices with furrow length of 70 m.

can warrant improvements in soil properties and sustainability in crop productivity (Mandal et al., 2004).

Albeit, the three treatments did not differed from each other significantly, each differed high significantly (P 0.01) from the control treatment. There were significant increases in marketable yield of over 38, 36 and 29% by adopting straw, puddling and cultivation practices respectively as against the control treatment irrigation when the furrow length was 30 m.

Similarly, it was observed thatthe fruit yield under the straw treatment and with 70 m furrow length was superior to those under the other practices as it resulted in a yield of 49.84 t/ ha compared to the control treatment Figure 10. The increase in yield was associated with increased soil moisture content. The improved soil water availability resulted in greater plant growth and crop yield (Ne Smith et al., 1987).

These results confirms the previous the findings Ayas (8), who observed that the eggplant yield varied between 18 to 62 t ha^{-1}. In another study by (Çolak et al., 2015), it was observed that full irrigation treatment with 3-day interval under surface drip irrigation produced the highest yield (78.5 t ha^{-1}) and the lowest yield was obtained with 6-day interval under subsurface drip irrigation (40.9 t ha^{-1}). Similar yielding data were reported by (Maghfoer et al., 2014), who have noticed that cultivation of eggplant with 3 main branches has resulted better growth and fruit yield than 1 and 2 main branches, 50.85, 47.91 and 30.79 t ha^{-1} respectively, In contrast, They are inconsistent with the findings of (Rahman et al., 2011), who observed that the highest yield per hectare (29.84 t ha^{-1}) was recorded in the cultivar Nayantara and the lowest yield (10.50 t ha^{-1}) was recorded in the cultivar Dhundhul.

Factors like variety, degree of maturity, climate, protection and management factors are affecting variability in eggplant fruit yield. For instance (Adamczewska-Sowiska and Krygier 2013), reported that an eggplant is a thermophilic plant and thermal conditions favored eggplant growth. Yields can reach 3.5–4.5 kg m^{-2} for short cycle and 11.5–13.0 kg m^{-2} for long cycle in greenhouse cultivation (FAO 2017). However, the performance of various management practices with both furrow lengths followed the order of straw>puddling> cultivation> control..

It can also be noticed from Figure10 that fruit yield under the same management tended to decrease with an increase in furrow length due to decreased water availability with an increase in furrow length.

On average, the crop consumed 504 and 568 mm during the whole growing seasons for the experiments where the furrow length was 30 and 70 m respectively. No rainfall was received during these periods. These results are in accordance with the amount of irrigation water applied from

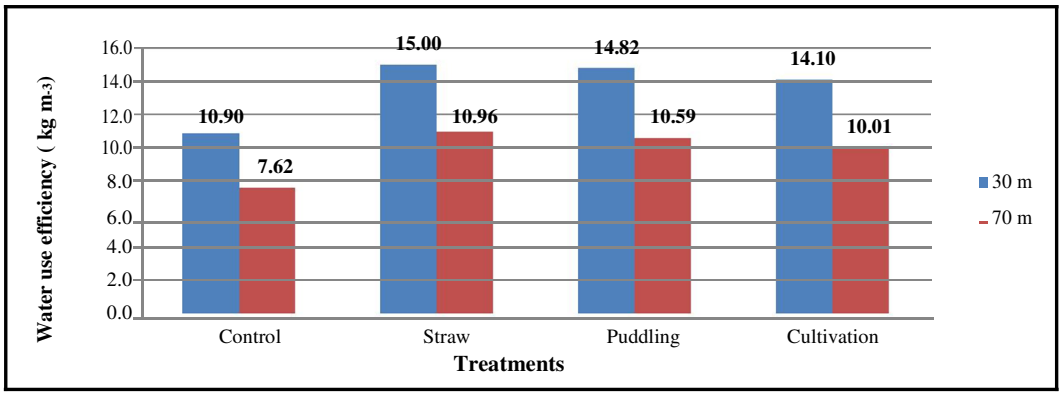


Figure 13. Eggplant water use efficiency as influenced by soil management practices and furrow length

Table 2. Summary of Dunnetts test and percent of increase in water use efficiency of eggplant due to different treatments over control in the field experiment

Furrow length (m)	Treatment (Ti)	Average water use efficiency (kgm^{-3})	Absolute difference |Ti-T1|	Percent of increase with respect to control = [100 |T1-Ti|] /T1]
30	Control(T1)	10.90	0.00	0.00
	Straw(T2)	15.00	4.10	37.62
	Puddling(T3)	14.82	3.92	35.99
	Cultivation(T4)	14.10	3.20	29.39
	Dunnett D(0.05)	0.70		
	Dunnett D(0.01)	0.97		
70	Control(T1)	7.62	0.00	0.00
	Straw(T2)	10.96	2.25	25.89
	Puddling(T3)	10.59	1.88	21.59
	Cultivation(T4)	10.01	1.30	14.97
	Dunnett D(0.05)	0.80		
	Dunnett D(0.01)	1.12		

previous studies. (Ertek et al.,2002), reported that irrigation water applied to eggplants varied between 452 and 696 mm. By contrast, (Kirnak et al., 2002), observed the applied water to eggplant were in between 905 and 1373 mm in southeastern part of Turkey.

As can be seen in Figure 11 and 12, the average water use efficiency (WUE) was highest under straw treatment (15 kg m^{-3}) when the furrow length was 30 m, which was significantly superior to the other three treatments. This statement is also true for experiment with a furrow length of 70 m. In this experiment, the straw treatment resulted in maximum water efficiency treatment (10.96 kg m^{-3}).

When the results concerning WUE are compared with the findings of other researchers, on can conclude that they are consistent with most of them. For instance, (Ayas 2017), obtained a value of 13.14 kg m^{-3} for WUE under full irrigation of eggplant. Further, he demonstrated that the values of WUE are affected by a host of factors, including, climate, variety choice, soil structure, efficient use of water, etc.

The results presented in Table 2 also revealed that water use efficiency under straw, puddling and cultivation treatmentswas increased by37.62, 35.99 and 29.39%as compared with control when the furrow length was 30 m. concomitantly, the percent of increase in water use efficiency was 25.89, 21.59 and 14.97% as compared with control when the furrow length was 70 m.

The results displayed in Figure.13 revealed a declining trend in water WUEwith increasing length of furrow from 30 m to 70 m. Further, Dunnett's test indicated that there is a

high significant difference between control and straw as well as between control and each of puddling and cultivation (Table 2).

It is of vital importance to take benefit from the applied soil management practices, in general and applying straw in particular, to improve eggplant yield, its water efficiency and to reduce the risk of groundwater pollution in cracking soils. Further, it can also be concluded that reducing field length is an effective measure for improving irrigation efficiency, eggplant yield and its water use efficiency.

REFERENCES

Abernethy B, Rutherfurd ID (2001). The distribution and strength of riparian tree roots in relation to riverbank reinforcement. Hydrological processes, 15(1): 63-79

Abu-Alaees SRM, AlBaity SQS (2017). The role of sustainable agriculture on the growth and yield of eggplant. The Iraqi Journal of Agricultural Sciences – 47(3): 738-748.

Adamczewska-Sowiska K, Krygier MM (2013). Yield quantity and quality of field cultivated eggplant in relation to its cultivor and the degree of food maturity. Acta Sci. Pol., HortorumCultus12(2): 13-23

Ahmad N, Mermut A (1996). Vertisols and technologies for their management (Vol.24). Elsevier.

Al-Omran AM, Al-Harbi AR, Wahb-Allah MA, Nadeem M, Al-Eter A (2010). Impact of irrigation water quality, irrigation systems, irrigation rates and soil amendments on tomato production in sandy calcareous soil. Turkish Journal of Agriculture and Forestry, 34(1):59-73.

Altmeyer WT (1955). Disc. On rep. 516 Proc. ASCE, 85.

Amer M, Daim TU (2011). Selection of renewable energy technologies for a developing county: a case of Pakistan. Energy for Sustainable Development, 15(4):420-435.

Ayas S (2017). The effect of irrigation regimes on the yield and water use of eggplant (Solanummelongena L.). Toprak, S.D.6(2):49-58

Bali KM, Hanson BR, Sanden BL (2010). Improving flood irrigation management in alfalfa.https://www.researchgate.net/publication/228842024

British Standards Institution (1990). British Standards, BS. 1377

Çolak, Y.B., A.Yazar, İ. Çolak, H. Akçaand G. Duraktekin. 2015. Evaluation of crop water stress index (CWSI) for eggplant under varying irrigation regimes using surface and subsurface drip systems. Agriculture and agricultural science procedia, 4, 372-382.

Dinka TM, Lascano RJ (2012). “A Technical Note: Orientation of Cracks and Hydrology in a Shrink-Swell Soil”, Open Journal of Soil Science, 2, 91-94.

Ertek A, Sensoy S, Yildezand M, Kabay T (2002). Crop water consumption for eggplant.

FAO (2017). Good agricultural practicesfor greenhouse vegetable production in the south east European countries. FAO. Plant Production and Protection Paper 230.

Holzapfel EA, Marino MA, Chavez-Morales J (1985). 'Performance irrigation parameters and their relationship to surface-irrigation design variables and yield', Agricultural Water Management, 10(2):159-74.

Islam MJ, Mowla G, Parul SS, ZAlamand MM, Islam S (2004). Management of Cracking Puddle Soils and Its Impact on Infiltration. J. Biological Sci., 4: 21-26.

James LG (1988). Principles of farm irrigation systemdesign.John Wiley& Sons(Ed.), New York, pp.543.

Kirnak H, Ismail T, Cengiz K, David H (2002). Effects of deficit irrigation on growth, yield and yield quality of eggplant under semiarid conitions. Aus.Jour,ofAgri.Res. 53(12):1367-1373.

KSU.J. Science and Engineering 5(2):57-67.

Kumar R, Singh J (2003). Regional water management modelling for decision support in irrigated agriculture. J. Irrig. Drain. Eng. ASCE 129:432-439.

Maghfoer MD, Soelistyono R, Herlina N (2014). Growth and yield of eggplant (Solanummelongena L.) on various combinations of N-source and number of branch.Agrivita. Volume 36, No.3

Mandal KG, Misraand AK, Mohanty M (2004). Rice residue-management options and effects on soil properties and crop productivity. Food, Agriculture & Environment 2(1): 224-231.

Masood TK (2015). Irrigation methods and anti-transpiration as related to wheat and waterproductivity. The Iraqi J. Agric. Sci. 46(6):1016-1022.

Masood TK (2017). Effect of irrigation methods and water content distribution, water and corn productivity. The Iraqi Journal of Agricultural Sciences – 48(1): 178-184.

Mousavi ME, Irish JL, Frey AE, Oliveraand F, Edge BL (2011). Global warming and hurricanes: the potential impact of hurricane intensification and sea level rise on coastal flooding. Climatic Change, 104(3-4):575-597.

Muhaimeed AS, Saloom AJ, Saliem KA, Alaniand KA, Muklef WM (2014). Classification and distribution of Iraqi soils. International Journal of Agriculture Innovations and Research, 2(6):997-1002.

Nelson JD, Miller DJ (1992). Expansive soils problems and practice in foundation and pavement engineering. John Wiley and Sons, NY.

NeSmith DS, Hargrove WL, Radcliffe DE, Tollner EW, Arioglu H (1987). Tillage and residue management effects on properties of an Ultisol and double-cropped soybean production. Agron. J. 79:570-576.

Pirboneh H, Ghasemi M, Abdzad GA, Bahari B, Babaei BZ (2012). Effect of irrigation and straw mulch on yield and yield components of eggplant (Solanummelongena L.). International Journal of Basic and Applied Sciences, 3:46-51.

Rahman MA, Ali F, Hossain KMA (2011). Shoot and Root Growth and Yield of Eggplant Cultivars as Affected by Wilt Disease. Journal of Experimental Sciences 2(1):11-15

Raine A, Teichmann S, Ben-Tovim L, Nietlispach D, Broadhurst RW, Terada T, Kelly M, Oschkinat H, Shibata T, Smith BO, Ito Y (1996). An approach to global fold determination using limited NMR data from larger proteins selectively protonated at specific residue types. Journal of biomolecular NMR, 8(3):360-368.

Reddy JM, Clyma W (1981). Optimal design of furrow irrigation systems. Transactions of the ASAE, 24(3):617-0623.

Ritchie JT, Adams JE (1974). Field measurement of evaporation from soil shrinkage cracks. Soil Science Society of America Journal, 38(1):131-134

Sarhan H (2011). Energy efficient control of three-phase induction motor drive. Energy and Power Engineering, 3(2):107.

Soil Survey Staff (1999). Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd ed. USDA Agric. Handb. 436. U.S. Gov. Print. Office, Washington, DC.

United Nations Educational, Scientific and Cultural Organization (UNESCO). (1979). Map of the world distribution of arid regions: Map at scale 1:25,000,000 with explanatory note. MAB Technical Notes 7, Paris

Waskom RM (1994). Best management practices for irrigation management. Bulletin #XCM-173 Colorado State University Cooperative Extension in cooperation with Colorado Department of Agriculture.

Wopereis MCS, Bouman BAM, Kropff MT, Ten Berge HFM, Maligaya AR (1994). Water use efficiency of flooded rice fields I. Validation of the soil-water balance model SAWAH. Agricultural Water Management, 26(4):77-289.

Yahya Sh H, Abdul-Razaq MMA (2017). Effect of irrigation methods and magnetization on quality of sunflower and water use efficiency. The Iraqi Journal of Agricultural Sciences –48(6):

Yigezu TT, Narayanan K, Hordof T (2016). Effect of Furrow Length and Flow Rate on Irrigation Performances and Yield of Maize. International Journal of Engineering Research, 5(4)

Zerihun D, Wang Z, Rimal S, Feyen J (1997). Analysis of surface irrigation performance terms and indices. Agricultural Water Management 34: 25-46.