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Utilization of Soil Mulching Practices to Improve Drought Management in Arid Region

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Abstract

The main objective of this study was to evaluate the effect of deficit irrigation and mulching practices on yield and water use efficiency of corn, some soil physical properties. The experiment was conducted in Soil and Water Resource Research Station at Baghdad 33º.14 (North) and 44º.4 (East). Randomized Complete Block Design (RCBD) with three replicates was used. Corn was cultivated in fall season 2015 under four treatment were investigated, Full irrigation (***I1*** *) and deficit irrigation (reduction 30% from irrigation requirement) (* ***I2*** *) without mulching application (* ***M0*** *) and with mulching application (* ***M1*** *).Amounts and timing of applied irrigation water were estimated based on measurement of soil water content by using soil moisture sensor type Diviner-2000. Applied irrigation water measured at each irrigation for the whole growing season .Actual evapotranspiration (ET_a) was estimated by measuring the volumetric soil water content at each irrigation and before the next irrigation.* ***(****Actual water requirement****,*** *water use efficiency , grain yield, Hydraulic conductivity, Percent of soil stable aggregates, soil organic carbon, Bulk density****)*** *were estimated. The results showed that: were :* ***(i)*** *Deficit irrigation (reduction 30% from irrigation requirement) (****I2****) caused decreasing in irrigation water amount with 1600 m^3. $ha^{-1}season^{-1}$ (26 %) as compared with full irrigation (****I1****) (6200 m^3. $ha^{-1}season^{-1}$) and does not cause moral shortage in grain yield about 14 %.* ***(ii)*** *Full irrigation (* ***I1*** *) caused increasing in grain yield with 14.1 % compared with deficit irrigation (* ***I2*** *).* ***(iii)*** *Mulching application (* ***M1*** *) caused increasing in grain yield and water use efficiency with 22.5% and 21.8 % ,respectively, compared without mulching application (* ***M0*** *).* ***(iv)*** *The mean maximum value grain yield with 7710 kg ha^{-1} were observed in treatment combination I1 M1 and minimum value 5420 kg ha^{-1} were observed in treatment combination I2M0.* ***(v)*** *Full irrigation (* ***I2*** *) caused increasing in hydraulic conductivity , Percent of soil stable aggregates and soil organic carbon with 24.1% , 19.4 % and 9.5 % , respectively compared deficit irrigation (reduction 30% from irrigation requirement) (* ***I2*** *).****(vi)*** *Mulching application (* ***M1*** *) caused increasing in hydraulic conductivity , Percent of soil stable aggregates and soil organic carbon with 61.5 , 57.1 and 30.3 % respectively, compared without mulching application (****M0*** *).On the other hand* ***(vii)*** *Mulching application (* ***M1*** *) caused decreasing in Bulk density with 7.8 % compared without mulching application (* ***M0*** *).* ***(viii)*** *The mean maximum value saturated hydraulic conductivity, soil percent of stable aggregate and soil organic carbon with 27.6 mm hr^{-1}, 28.7% and 2.75 g kg^{-1} respectively were observed in treatment combination* ***I1M1*** *and minimum value 13.2 mm hr^{-1}, 14.9% and 1.91 g kg^{-1} respectively, were observed in treatment combination* ***I2M0****.* ***(viiii)*** *Maximum value of soil bulk density 1.42 μg m^{-3} was observed in case of treatment combination* ***I2M0*** *and minimum value of soil bulk density 1.27 μg m^{-3} was observed in case of* ***I1M1*** *combination*

Keywords: *Irrigation, Mulches, Diviner 2000, Soil physical properties.*

Introduction

Irrigation water is one of the main determinants of agricultural production, especially in arid and semi – arid region, Agricultural sector is being the greatest consumer of fresh water, which occupies about 90% of the available water in Arab countries. Enhancement of agriculture development is surely depending and relating to the quantity and quality of the fresh water available for irrigation practices. Scarce water resources and growing competition for water will reduce its availability for irrigation.

At same time, The need to meet the growing demand for food will require increased crop production by less water. Achieving greater efficiency of water use will be a primary challenge for the near future and will include the employment of techniques and practices that deliver a more accurate supply of water to crops. In this context, deficit irrigation can play an important role in increasing

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water use efficiency (WUE). The concept of deficit irrigation (given the amount of water less than the actual water needs of the crop) is an important way in water management leads to improved irrigation and investment optimization water, particularly in countries with limited water. Usually the purpose of irrigation scheduling is to attain an optimum water supply for productivity, with soil water content being controlled near field capacity. Irrigation scheduling is the decision to maximize profit in order to, when and how much water applied to a field. Its aim is to maximize irrigation efficiencies by the application of exact amount of water needed to refill the soil water to the appropriate level, thus save water. Water requirement for maize is 600-700 mm for optimum growth and yield depending on the climatic conditions (Reddy,2006).Moreover, application of only deficit or limited irrigation does not gives positive results regarding crop production or soil quality and under such crucial condition mulching may be one of the suitable alternatives to maintain optimum moisture and thermal environment in soil, increases water use efficiency through reduction in evaporation and subsequently higher grain yield (Chakra borty *et al.* 2008). Wheat straw is considered one of the most important plant waste problems. Most farmers left behind the wheat straw. Wheat straw can be used as mulch. In addition, wheat straw is very cheap source of mulching material and can be economically utilized. Moreover, Liu *et al.* (2014) showed that soil mulching is used to increase soil water storage in the soil profile compared and eliminate weeds competition for water and nutrients. Zhang *et al.* (2005) and Vial *et al.*(2015) found that mulching with straw reduced soil evaporation loss. Moreover, it improves water infiltration (Faber *et al.*, 2001; Ji and Unger 2001 and Laila and Ali 2011) . (Liu *et al.*, 2009 : Pandey *et al.*, 2013 and Saikia *et al.*, 2014) pointed that Straw mulching reduced water requirement of crop plants and increased water use efficiency), In addition, straw mulching saved 30% of irrigation water and increased water use efficiency (Chaudhry *et al.*, 2004;). The objective of this study was to evaluate the effect of deficit irrigation and mulching practices on some soil physical properties.

Material and Methods

Field experiment was conducted during the summer season of the year 2015 to evaluate the effect of sustained regulated deficit irrigation and mulching on yield and water use efficiency of corn, some soil physical properties at soil and water recourses center station in middle of Iraq. (33.14^0 N 44.4^0) 34 m above sea level. The soil has silty clay loam texture and classified as (fine loam, mixed, hypothermic, typic, terrified events), Relevant soil physical and chemical properties were determined according to standard methods (Black,1965, page et-al,1982,Richarads , 1931). Table (1). The field was divided by three equally blocks with interval distance 3m between the blocks , each block was divided into four experimented unit each of 6X6 size 2m apart of each. Randomized completed block design (R.C.B.D) with three replicates was used. Four treatments randomly applied to each block were:

1. Full irrigation without mulches (**I1M0**).
2. Full irrigation with mulches (**I1M1**).
3. Deficit irrigation (reduction 30% from irrigation requirement) without mulches (**I2M0**).
4. Deficit irrigation (reduction 30% from irrigation requirement) with mulches (**I2M1**).

I1= Full irrigation
I2= Deficit irrigation (reduction 30% from irrigation requirement).
M0=Without mulches.
M1=With mulches (wheat straw).

Table 1: Relevant physical and chemical properties to the soil studied

Properties	Unit	Value
Sand	$g.Kg^{-1}$	**257**
Silt		**408**
Clay		**335**
Texture		Silty Clay Loam
Bulk density	$\mu g.m^{-3}$	**1.36**
Percent of soil stable aggregates	%	9.2
Organic carbon	$G\ Kg^{-1}$	1.8
Volumetric moisture content at 33 Kpa	$cm^{-3}.cm^{-3}$	**0.3**4
Volumetric moisture content at 1500 Kpa	$cm^{-3}.cm^{-3}$	**0.1**4
Available water	$cm^{-3}.cm^{-3}$	**0.20**
ECe	$dS.m^{-1}$	3.4

Fertilization was applied as urea (46% N) at a rate 400 $kg.ha^{-1}$ on two batches: the first with 260 $kg.ha^{-1}$ from T.S.P at before planting. The second was added after five weeks after planting. Potassium fertilizer was applied at rate of 200 $kg.ha^{-1}$ as K_2SO_4.Corn seeds were sown on 18/7/2015 in rows of 0.75m apart of each and 0.25 between plants. Amounts of irrigation water required was estimated based on measurement of soil water content using Diviner-2000 sensor for soil depth 0-0.8m depending on particular calibration equation for the soil (Fig.1).

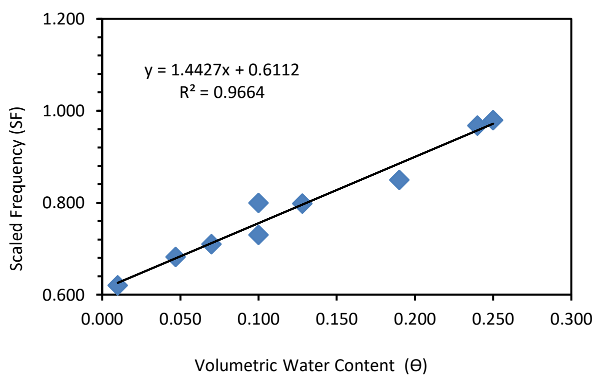


Figure 1: Diviner-2000 calibration equation for (Si.C.L.) soil

Linear correlation with r =0.966 was found between Volumetric water content (ϴ) and scaled frequency (S.F.).

$$SF = 1.443\Theta + 0.611 \quad (1)$$

$$SF = \frac{FA - Fs}{FA - Fw} \quad (2)$$

Where:

F_A =Diviner count in air.
Fs = Diviner count in soil.
Fw = Diviner count in water.
to moistening the 0-0.3m during growing season after irrigated and before next irrigation using equation (Kovda, et.al , 1973)

$$d = (\theta_{fc} - \theta_{bi}) * D \quad (3)$$

Where:

d= depth of water applied (m)
θ_{fc}=Volumetric moisture content at field capacity ($m^3.m^{-3}$)
θ_{bi}=Volumetric moisture content before irrigation($m^3.m^{-3}$)
D= soil depth (m).

Results and Discussion

Actual water requirement at season

Figure 2 shows that deficit irrigation practices, (reduction 30% from irrigation requirement) (**I2**) caused decreasing in irrigation water amount with 1600 m^3. $ha^{-1}season^{-1}$ (26 %) as compared irrigation full irrigation (**I1**) (6200 m^3. $ha^{-1}season^{-1}$). Increasing the water stress during certain stages of growth does not cause moral shortage in grain yield about 14 %, this way you can save the amount water can be use for the exploited purposes of agricultural expulsion, or in other areas. These results were also obtained by Falih *et al* 2017. The concept of deficit irrigation (given the amount of water less than the actual water needs of the crop) as an important way in water management leads to improved irrigation and investment optimization water (Smith and Kivumbi.2014).

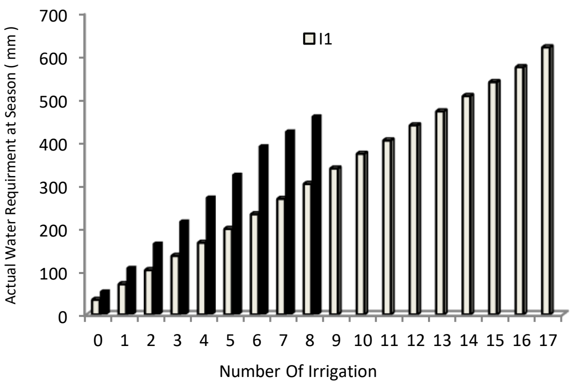


Figure 2: Actual Water Requirement and number of irrigation at Season (mm)

Effect of irrigation and mulch on grain yield (Kg ha^{-1}) of Corn

Fig. 3 shows that irrigation and mulch had significant effect on grain yield of maize crop. Regarding the irrigation effect on grain yield, the mean maximum value (6975 Kg ha^{-1}) of grain yield was recorded in case of treatment I1 and minimum (5995 Kg ha^{-1}) was found in treatment I2. In case of mulch, the mean maximum value (7140 Kg ha^{-1}) of grain yield was observed in treatment M1 and minimum (5830 Kg ha^{-1}) was found in case of treatment M0. The interactive effects between irrigation and mulch was significant. mean maximum value of grain yield 7710 Kg ha^{-1} was observed with treatment combination I1 M1. Next to this, treatment combinations I2M1, I1M0 and I2M0 showed grain yields of 6570, 6240 and 5420 Kg ha^{-1}, respectively.

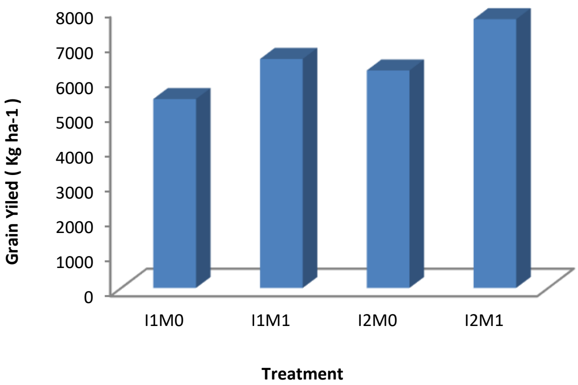


Figure 3: Effect of irrigation and mulch on grain yield (Kg ha^{-1}) of corn

These results were in agreement with Khurshid *et al*, 2006 who reported that grain yield were significantly affected by the irrigation levels and mulching.. Liu *et al*,2002 reported that the addition of mulch resulted in significant increase in soil water contents and reduced runoff , the increase in soil water was effective in ensuring better germination and higher yield. Nutrients were available to plant roots in presence of moisture, leading to higher grain yield. Wajid, 1990 who reported that

Effect of irrigation and mulch on water use efficiency (kg m^{-3})

The effect of irrigation and mulch on water use efficiency are given in Fig. 4, irrigation and mulch had significant effect on water use efficiency of maize crop. As regard irrigation treatments, the mean maximum value of 1.31 Kg m^{-3} water use efficiency was recorded in deficit irrigation treatment (I2) and minimum of 1.13 Kg m^{-3} was in full irrigation treatment (I1) These results were also obtained by Falih *et al* 2017 and. Tawfeeq *et al* 2017 . In case mulch, the mean maximum value of 1.34 Kg m^{-3} was measured in mulching applied treatment (M1) and minimum of 1.10 Kg m^{-3} was noted in treatment M0 (without mulching). The interactive effects between irrigation and mulch was significant treatment combination I1 M1 showed mean maximum value of water use efficiency 1.43 Kg m^{-3}. Followed by 1.24 Kg m^{-3} in case of I2M1 and minimum value (1.01 Kg m^{-3}) was observed in I2M0 combination.

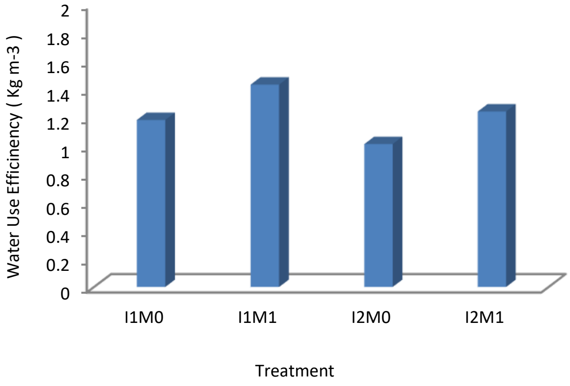
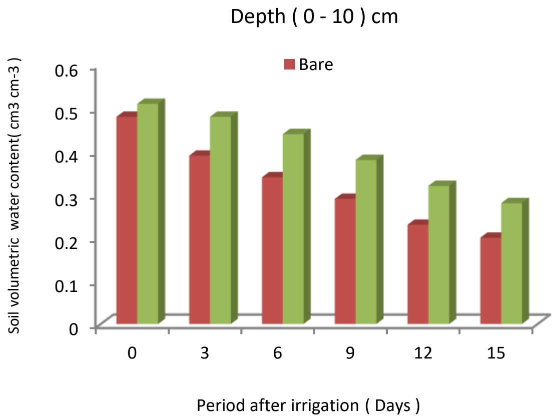


Figure 4: Effect of irrigation and mulch on water use efficiency (kg m^{-3}) in corn

The mulching applied on the soil surface act as a shade, serve as a barrier against moisture loss from the soil. By reducing the irrigation depth and application of mulch, the evaporation losses reduced so that WUE was increased. These results were in agreement with Oweis *et al*,1998 and Khurshid *et al*, 2006 they reported that the mulching reduced soil evaporation for maize and WUE was improved. These results indicate that the water use efficiency increased with the decrease in irrigation depth applied.

Soil water holding capacity

Fig.5 Showed that implementation of mulching practices caused to increase soil water holding capacity and causing less water evaporation from soil surface. Increasing reaches to 6.3 – 40 % to the layer 0-10 cm and 18.2-31.3 % to the layer 10-20 cm to the period from 0 to 15 days after irrigation. These results were in agreement with (Vial *et al* , 2015) and (Liu *et al* , 2014) reported that mulching reduced soil water evaporation and increases soil water storage in the top soil.



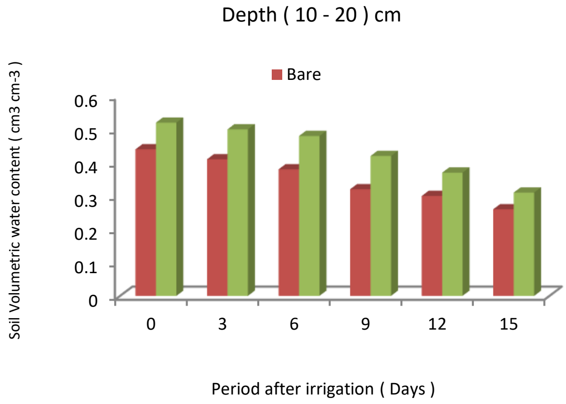


Figure 5: Effect of mulching on soil volumetric water content (cm^3 cm^{-3})

Effect of irrigation and mulch on saturated hydraulic conductivity (mm hr^{-1})

Fig. 6.showed that both irrigation and mulch had significant effect on saturated hydraulic conductivity. Deficit irrigation (reduction 30% from irrigation requirement) I_2 caused significant decreased in soil hydraulic conductivity with 24% compare with full irrigation (I_1) , when mulching applied (M_1) led to significant improvement in soil saturated hydraulic conductivity reached 61% compare with without mulching (Mo).The interactive effects between irrigation and mulch have significant effect on hydraulic conductivity. Minimum value was found (13.2 mm hr^{-1}) when deficit irrigation without mulching were applied (I_2 Mo) followed by 16.4 mm hr^{-1} in case full irrigation without mulching (I_1Mo) , these maximized to 20.1 and 27.6 mm hr^{-1} , respectively by mulching application at same treatment.

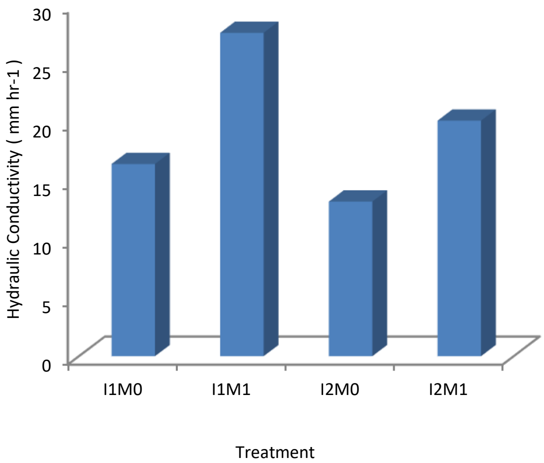


Figure 6: Effect of irrigation and mulch on field saturated hydraulic conductivity (mm hr^{-1})

These results confirm the findings of Gurpeet *et al*,2007 who reported that increased carbon content of the soil due to mulching increased the aggregation status, infiltration rate and hydraulic conductivity of soil. Moreover, mulches increased infiltration rate and water in the rhizosphere, improved macro-porosity and structure of soil along with reducing runoff and evaporation losses. These results corroborate the findings of Canqui and Lal ,2007 who reported that mulching significantly impacted hydraulic conductivity properties of soil.

Effect of irrigation and mulch on soil organic carbon (g kg^{-1})

Effect of irrigation and mulch on soil organic carbon concentration is given in Fig.7 Irrigation had non-significant effect on soil organic carbon concentration, maximum value was 2.43 g kg^{-1} in (I_1) treatment and minimum value 2.20 g kg^{-1} was observed with (I_2) treatment. Mulching applied (M_1) led to significant increasing in soil organic carbon concentration reached 30.3% compare with without mulching (M0).The interactive effect between irrigation and mulch have significant effect at 0 – 10 cm death from surface soil. Maximum value 2.75 g kg^{-1} was found in I_1M_1 treatment while I_2M_1 2.48 g kg^{-1} as second best treatment. Minimum value of soil organic carbon concentration of 1.91 g kg^{-1} was observed in I_2 Mo treatment.

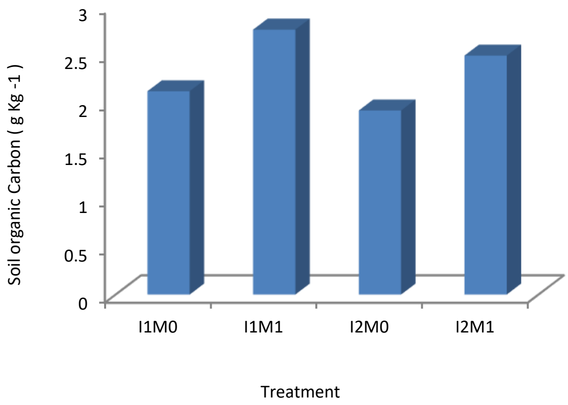


Figure 7: Effect of irrigation and mulch on soil organic carbon g kg^{-1}

Saroa and Lal ,2003 conducted a study to assess the role of aggregation to enhancing soil organic carbon concentration for different mulch rates. Their results showed that mulch rates significantly increased the soil organic carbon concentration in the 0-5 cm soil layer only. Pervaiz *et al*,2009 also concluded that mulch increased moisture contents and soil organic matter but decreased soil strength and bulk density compared to control.

Effect of irrigation and mulch on soil percent of stable aggregate (%)

Effect irrigation and mulch on percent of sable aggregate of soil is given in Fig.8. Percent of sable aggregate decreased in significantly by 19.4% when deficit irrigation was application (I_2) compare with full irrigation (I_1) , on the other hand, mulching applied (M_1) caused significant increased in percent of stable aggregate of soil by 57.1% compare with without mulching (Mo). The interactive effect between irrigation and mulch have significant effect on soil percent of stable aggregate. Minimum value was 14.89% when implementing of deficit irrigation without mulching (I_2Mo). While 17.62% in full irrigation without mulching (I_1Mo). This increasing to 22.46 and 28.72% respectively, by mulching application at same treatment.

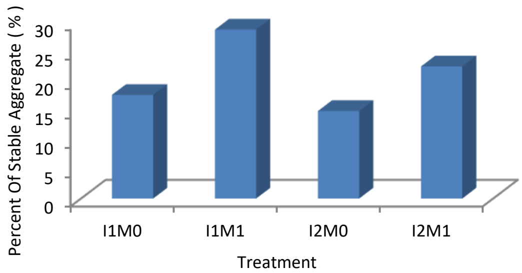


Figure 8: Effect of irrigation and mulch on percent of sable aggregate (%)

Wang *et al* , 2016 and Gurpeet *et al*,2007found that increased carbon content of the soil due to mulching increased the aggregate stability of soil . Poloma *et al*, (2016) pointed that soil aggregate stability , the percentage of stable aggregate has increased slightly in all the treatments in relation to control , specifically, the differences were recorded in the fraction of macro aggregate. The largest increases have been associated with straw mulching, pinups mulch and sludge.

Effect of irrigation and mulch on soil bulk density (μg m^{-3})

Fig.9 showed that irrigation treatment had non-significant effect on soil bulk density, but mulch had significant effect. maximum value 1.41 **μg** m^{-3} was observed in (Mo) and 1.30 Mg m^{-1} was noted in (M1) as decreased equivalent 7.8 % compare with (M0).The interactive effect between irrigation and mulch had significant on soil bulk density.

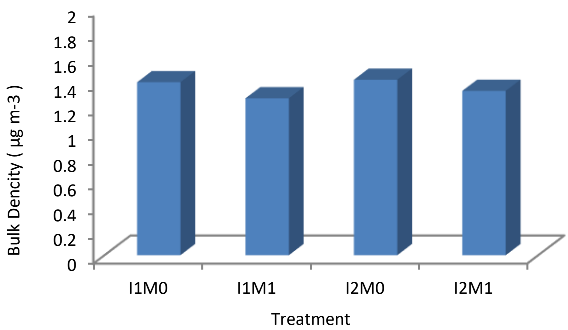


Figure 9 Effect of irrigation and mulch on soil bulk density (**μg** m^{-3})

Maximum value of soil bulk density 1.42 μg m^{-3} was observed in I2 x M0 , this minimized to 1.33 μg m^{-3} by mulching application at same treatment (I2M1). Minimum value of soil bulk density 1.27 μg m^{-3} when full irrigation with mulching application (I1M1).

Ghuman and Sur,2001 concluded that mulching decreases bulk density of the surface soil. Pervaiz *et al*,2009 also concluded that mulch increased moisture contents and soil organic matter but decreased soil strength and bulk density compared to control.

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