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Increasing water use efficiency of potato through irrigation scheduling and sensor based irrigation.

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ABSTRACT

Field experiment was conducted in research Station of irrigation technology, soil water resources center, Ministry of science and technology, which was located in Tuwaitha. The objective of the study was to test the role of irrigation scheduling and irrigation management through using soil moisture sensors type Diviner- 2000 on water use efficiency of potato crop. The experiment involved 4 irrigation treatments, I_1 control (Full irrigation after 10% depletion of available water), I_2 irrigation cutting between two irrigations, I_3 and I_4 (irrigation after depletion of 30 and 60% of available water respectively) . Randomized complete block design with 3 replicates was applied. Soil moisture sensor Diviner – 2000 was used to monitor soil water content during the growing season to determine when to irrigate and how much water to apply. Results Shows that irrigation treatment I_3 achieved a highest water use efficiency which were 7.8 and 8.1 Kg m^{-3} for both field and crop water use efficienes respectively . As well as the actual evapotranspiration rate reaches to 441.3 mm whereas456.7mm irrigation water applied during the whole growing season.

Keywords: Diviner- 2000, water use efficiency, potato, water consumptive.

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INTRODUCTION

Water resources take a special importance in human life and environment resources. Irrigation water abundance is a restricted factor for agricultural production around the world especially in areas which was suffering for water resources shortage. Irrigation practices is one of priority factors which affect the quality and quantity of crop production. So determining crop consumptive water use and increasing irrigation water use efficiency is very essential in agricultural sector and crop production development. Ximing et al., (2011) reported that irrigation scheduling and accurate crop water consumptive determination were very essential to improve and increase crop water use efficiency. Irrigation scheduling mainly depends on monitoring and determination of soil moisture content (Allen et al., 1994). Deficit irrigation practice which means giving irrigation water amounts less than water consumptive in a certain growth stages or in the whole growing season (Annandale et al., 2000). So deficit irrigation implementation may cause crop productivity decreasing comparing with full irrigation, on other hand water saving can be achieved which was very important in those areas suffering from water scarcity in arid and semi- arid regions. Soil moisture sensors such as Diviner-2000 is one of the recent technology to monitor soil moisture content in the root zone, due to it is accuracy, easy and fast determination of soil water content in the field which enable to irrigate directly by application of sensor based irrigation phenomena.(Fares and Aliva, 2000).

MATERIALS AND METHODS

Field experiment was executed during fall season 2013 in irrigation technology station , soil and water resources center, 33^0.21 north altitude and $44^0.52^-$ east longitude. Potato crop was cultivated as indicator crop and to determine it's water consumptive in silty clay loam soil by using soil moisture sensor type Diviner-2000 .Table 1shows some physical and chemical characteristics of the soil which were determined according to standard methods mentioned in Dane Top(2002) and page et al.,(1982).Four irrigation treatments were examined I_1 control (full irrigation after 10% depletion of available water) ,I_2 (irrigation cutting between two irrigation), I_3 and I_4 (irrigation after depletion of 30 and 60% of available water used respectively) .Randomized complete block design was used with 3 replicates, the experimental plots were 9m^2 area (3*3m). Potato crop Desirey species was cultivated in 20 August 2013. Triple super phosphate was applied in rate 120 kg ha^{-1} as a source for phosphorus , as well as urea (46%N) was applied in rate 240 kg ha^{-1}as a source for nitrogen .potato tubers were collected at the end of the growing season in 10/1/2014.

Table 1: Some soil physical and chemical characteristics.

characteristics	unit	value
sand	gkg^{-1}	191.76
silt		422.39
clay		385.85
Texture		
Bulk density	Mgm^{-3}	1.37
Volumetric moisture content at 33k$_{pa}$	cm^{3}cm^{-3}	0.388
Volumetric moisture content at 1500k$_{pa}$	cm^{3}cm-^{3}	0.182
Available water	cm^{3}cm-^{3}	0.206
ECe	dsm^{-1}	4.00
pH		7.2

irrigation scheduling

Irrigation was done depending on available water depletion depth from soil profile up to 0-0.3m for each specific treatment .Timing and how much of irrigation water application to each treatment was adjusted by using Diviner -2000 as a soil moisture sensor during the whole growing season . Diviner -2000 access tubes were installed in middle of each experimental plot to insert the probe of the instrument to take the readings of volumetric soil moisture content . calibration equation for Diviner-2000 was estimated (Fares and Aliva, 2000) :

$$S.F. = (F_A - F_s) / (F_A - F_W) \text{ -------- } (1)$$

Where :

S.F. = Scaled frequency
F_A = Reading in air (160000 counts in 100% dry air)
F_s = Reading in soil (160000 – 120000 counts depending on soil moisture content)
F_w = Reading in water (120000 counts)

Figure 1 shows the relation between scaled frequency and soil volumetric water content , linear correlation was found with R^2 = 0.943 for silty clay loam soil.

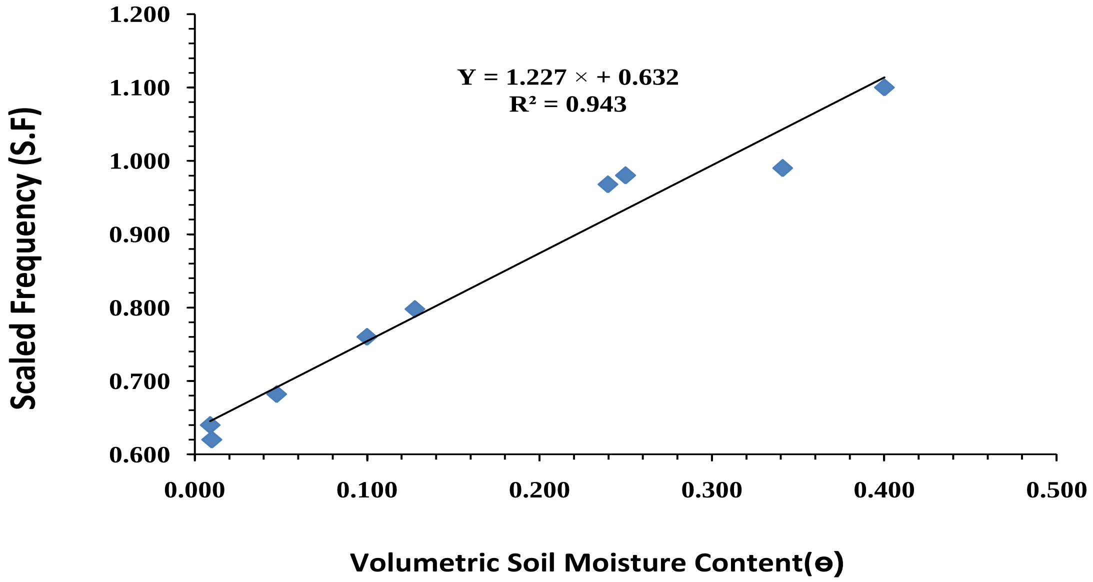

Figure (1) calibration equation of Diviner -2000 for silty clay loam soil

the depth of irrigation water applied to reparation soil available water depleted by plant consumptive and evapotranspiration using equation 2 and 3(kovda et al. ,1973):

$$A_w = \theta_{F.c} - \theta_{wp} \text{ ------------ } (2)$$

Where :
A_w = Applied water .
$\theta_{f.c}$ = Soil volumetric water content at field capacity(33kp$_a$) .
θ_{wp} = Soil volumetric water content at welting point(1500kp$_a$) .

$$d = (\theta_{F.c} - \theta_{irri.})D \text{ ---------- } (3)$$

Where:
d : depth of applied irrigation water (m).
$\theta_{F.c}$: Soil volumetric water content at field capacity .
$\theta_{irri.}$: soil volumetric water content at irrigation .
D : soil depth (m) .

Potato crop consumptive use was calculated by using water balance equation .(Allen, 1994).

$$\pm \Delta s = (I+P+C)-(ET_a + D + R) \text{-------------} (4)$$

Where:
± Δs: changing in soil moisture storage during whole growing season
I: amounts of irrigation water applied (m^3).
P: precipitation during whole growing season (m).
C: capillary ground water sharing.
ET_a: Actual evapotranspiration (crop water consumptive use)(m).
D= water deep percolation (m^3).
R= water runoff (m^3).

Both field and crop water use efficiencies were calculated by using following equations (Demir et al. , 2006) (Goksoy et al., 2004):

$$WUE_f = \frac{\text{Yield}}{\text{water applied}} \text{-------- ------(5)}$$

$$WUE_c = \frac{\text{Yield}}{\text{ETa}} \text{-----------------------(6)}$$

Where:
WUE_f = field water use efficiency (kg m^{-3})
WUE_c = crop water use efficiency (kg m^{-3})
ET_a= actual evapotranspiration (m)

RESULTS AND DISCUSSION

Depth of irrigation water Applied

Table 2 shows depth of irrigation water applied, number of irrigation and actual evapotranspiration for the four irrigation treatments. Results indicated that full irrigation treatment (I_1) had highest irrigation water application during the whole growing season comparing with the other irrigation treatment I_2, I_3, and I_4. The most lowest irrigation water application was observed in I_2 treatment 251.7mm season^{-1} as compared with I_1, I_3 and I_4 treatments 352.8, 308.9 and 300.1 mm season^{-1} respectively. Decreasing the number of irrigation (table 2) for I_2 and I_4 treatments during the whole growing season leads to occurrence of water stress on potato plants which this leads decreasing in tubers yield. Thornton,(2002) and shock, (2004) founds that potato plant is very sensitive to water stress during whole growing season. While I_3 irrigation treatment (30% depletion of available water) had less applied irrigation water compared with I_1 treatment with a short interval period between two irrigation. This agrees with Goldberg etal., 1971 who indicates that water application to the soil with less amount and short interval period between irrigations leads to small differences in soil moisture content in the root zone.

Actual evapotrarspiration (ETa):

Table (2)Amount of applied irrigation water and ET_a for potato at different irrigation treatments

Irrigation treatment	Number of irrigation	Depth of water added(mm season^{-1})		ET_a (mm season^{-1})
		Irrigation water	Rain water	
I_1	9	352.8	147.8	495.6
I_2	6	251.7	147.8	379.8
I_3	8	308.9	147.8	441.3
I_4	7	300.1	147.8	404.9

Table 2 shows the actual evapotranspiration values for potato crop during the whole growing season for the different irrigation treatments. Maximum actual evapotranspiration was observed in I_1 (full irrigation) treatment (495.6 mm), then the values of ET_a were decreased by imposing deficit irrigation treatment I_2, I_3, and I_4. There were a relation between the amounts of applied irrigation water and ET_a, the values of ET_a were decreased when the irrigation water applied decreases for I_2, I_3 and I_4 compared with I_1 (full irrigation).

This decreasing in ET_a values for I_2, I_3 and I_4 treatments due to decreasing in plant transpiration rate with decreasing available soil moisture to plant as well as water evaporation from soil (Hill, 1990).

Field and crop water use efficiencies

Difference in both field and crop water use efficiencies were observed between irrigation treatment I_1, I_2, I_3 and I_4 (fig. 2). Highest field and crop water use efficiency were noticed in I_3 irrigation treatment (30% available water depletion) 7.81 and 8.10 Kg m^{-3} respectively. I_3 irrigation treatment exceeded in field water use efficiency with 6.8, 18.7 and 10.9% and with 9.3, 19. 1 and 1.4% for crop water use efficiency as compared with I_1, I_2 and I_4 irrigation treatments respectively. This increasing in water use efficiency for potato crop in I_3 treatment due to decreasing in applied irrigation water as compared with I_1 treatment and potato tubers yield were highest as compared with I_2 and I_4 treatments, these results were agreed with (Amanullah et al., 2010 and Fouda et al., 2012).

Minimum field and crop water use efficiencies were observed in I_2 irrigation treatment (irrigation cutting between two irrigations) decreasing percentage in field water use efficiency reaches 9.9, 15.7 and 6.5% and for crop water use efficiency reaches 8.2, 16.1 and 14.9% for I_1, $I_3$and I_4 treatments respectively. The reason for this decreasing in crop and field water use efficiency for I_2 treatment due to reduction in potato tubers yield because of water stress condition because of long interval period between two irrigation and had less number of irrigations during the whole growing season (Singh et al., 2012).

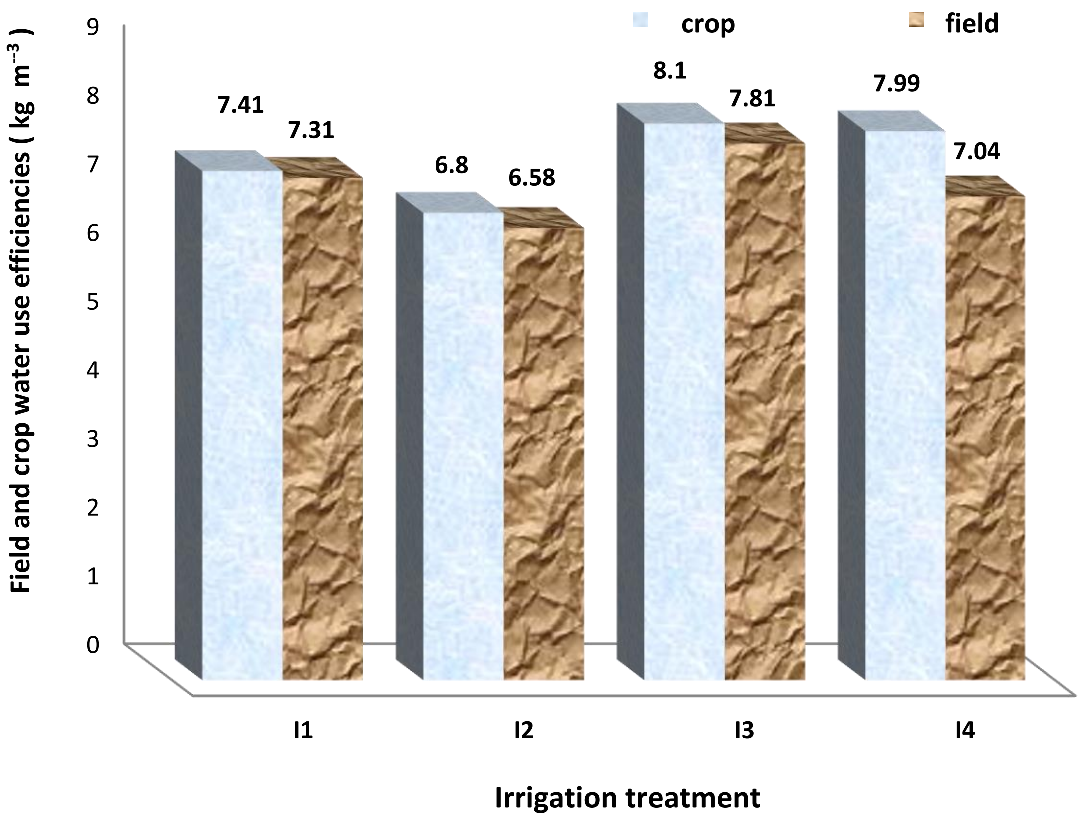

Figure 2: Field and crop water use efficiencies for irrigation treatments

REFERENCES

[1] Allen, R. G, M. Smith, A. Perrier, and L. S. Perira. 1994. An update for the definition of reference evapotranspiration. ICID, Bull. 43: 1 – 34.

[2] Amanullah, A. S. M., S.U. Talukder., A.A. Sarkar., and A.S.M. Ahsanullah., 2010. Yield and Water Use Efficiency of four Potato Varieties under Different Irrigation Regimes. Bangladesh Res.Publication J.4(3):154-264.

[3] Annandale, J. G., G. S. Campbell, F. C. Olivier, N. Z. Jovanovic .2000. predicting crop water uptake under full and deficit irrigation: An example using pea (*pisum sativum sativum* L.c.v. Puget) Irrig. Sci. 19: 65 - 72.

[4] Dane, j. H and G. C. Topp. 2002. Methods soil Analysis. Part 4. Physical Methods. Soil sci. of America, Iic. Madison,Wisconsin. USA.

[5] Demir, A.O., A. T. Goksoy, H. Buyukcangaz, Z. M. Turan and E. S. Koksal. 2006. Deficit irrigation of sunflower (*Helianthus annuus* L.) in a sub-humid climate. Irrig. Sci. 24: 279-289.

[6] Fares, A. and A. K. Aliva, 2000. Soil water Components based on capacitance probes in a sandy soil. Soil. Sci. Soc. Am. J. 64: 302-310.

[7] Fouda, T. A. ELmaetwalli., and E. Ali., 2012. Response of potato to nitrogen and water deficit under sprinkler irrigation . Scientific papers Series Management , Economic Engineering in Agriculture and Rural Development . 12 :77 - 82.

[8] Goksoy, A. T., A. O. Demir, Z. M. Turan and N. Dagustu. 2004. Responses of sunflower (*Helianthus annuus* L.) to full and limited irrigation at different growth stages. Field Crops Research. 87: 167 -178.

[9] Goldberg, S. D., M. Rinot, and N. Karu. 1971. Effect of trickle irrigation intervals on distribution and utilization of soil moisture in a vinegard. Soil Sci. Soc. Am. Proc. 35: 127 – 130 .

[10] Hill, R. L. 1990. Long – term conventional and no – tillage effects on selected soil physical properties. Soil Sci. Soc. Am. J. 54: 161 –166.

[11] Kovda, V. A., C. Vanden Berg, and R. M. Hangun. 1973. Irrigation, Drainage and Salinity.

[12] -Page, A. L., R. H. miller and D. R. Keeney. 1982. Methods of Soil Analysis. Part2. chemical and Microbiological properties. 2nd edition. Am. Soc. Agron. Inc. publisher, Madison, Wisconsin, USA.

[13] Shock, C. C. 2004. Effect of Irrigation Scheduling Malheur Experiment station, Oregon state university, Oregon, USA.

[14] Singh, A., Aggarwal. G. S. Aulakh. and R. K. Hundal. 2012 . Ways to maximize the water use efficiency in field crops - Areview. Greener. J. of Agric. Sci. 2 (4) : 129-188. www. g journals.

[15] Thornton, M. K. 2002. Effect of heat and water stress on the physiology of potato . Idaho potato. Conference, Idaho.

[16] Ximing, C. M. A., I. Mohamad., A. M. A. Hejazi. And W. Dingbao. 2011. Value of probabilistic weather forecasts . Assessment by real –time optimization of irrigation scheduling. J. of Water Planning and management. ASCE /September. 391.