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Maximizing Irrigation Water Productivity for Corn (Zea Mays) by using Deficit Irrigation

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Abstract:

The objective of the study was to increase productivity of irrigation water for corn under deficit irrigation practices at middle part of Iraq climatic conditions. The experiment was conducted in soil and water resources research station at Hilla 33^0.59 (North) and 44^0.30 (East). Randomized complete block design (RCBD) with three replicates was used. Corn was cultivated in fall season 2013 under five irrigation treatment were investigated, full irrigation (control) (C) and four deficit irrigation (reduction 40% from amount of applied water in control treatment) at different growth Stages seedling, vegetative, flowering and maturity. 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 was 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. Applied water productivity (AWP), grain yield and response factor (K_y) were estimated.

Both Applied water productivity (AWP), reduction percent of applied water results have highest value when deficit irrigation was *imposed at flowering growth stage (F) which was 1037kg m^{-3}and reduction percent for applied water was 17%.*

As well as corn grain yield which was forms about 97% from the yield in full irrigated treatment, when deficit irrigation was imposed in flowering growth stage. This reduction in grain yield was not significant.

Key words: Corn, deficit irrigation, Diviner - 2000

INTRODUCTION:

When irrigation water resources and its supplies becomes rare and limited the farmers' goal, there should be a special practices to maximize net income (productivity) per unit water used. Recently more emphasis has been placed on the concept of water productivity (WP) (Sam and Raes, 2009) water productivity can be defined as the yield or net income per unit of water used in evapotranspiration (ET) (Mao et.al., 2003). Experimentally for many crops water productivity increases under deficit irrigation practices relatively to its value under full irrigation When yield reaches its maximum value, any additional amounts of irrigation do not increase it any further. The amount of water needed to ensure maximum water productivity depends on the uniformity of irrigations (Cohen and Bresler, 1967). Crop Water productivity is also affected by the yield response to deficit irrigation. Deficit irrigation imposing program must be based on knowledge on when and how much soil moisture depletion reaches. Deficit irrigation program must be designed to manage the stress, so the yield decline is minimized. Water productivity can be maximized when the yield decline, in relative terms is less than evapotranspiration decrease. Smith, (2004) reported that seasonal drought is the most affecting factor that limits corn grain yield production in the world.

The objectives of this study are (i) maximizing water productivity through deficit irrigation imposing at different growth stages (ii) determination of the most sensitive corn growth stage for deficit irrigation.

MATERIALS AND METHODS:

The study was conducted during the Fall season of 2013 at Hill research station, soil and water resources center, Agricultural research Directorate, Iraq. The experimental treatments were arranged in randomized complete block design (RCBD) with three replicates. Plot area was 16m^2 (4X4m), Corn (Zea Mays L.) variety Bohoth 106were planted on 15 th July and harvested at the end of growing season on 26th November. The soil at the site is clay and classified as fine loam, mixed, hypothermic, typic, torrifluevent. Some soil physical and chemical characteristics were determined according to standard methods (page, 1982 and Dane and Topp, 2002) table1. Triple super phosphate (260 kg. ha^{-1} , 48% $p_2 o_5$) was added, in addition to urea (200kg. ha^{-1} , 46% N) at planting, The second portion of urea 200kg. ha^{-1} was added after 5 weeks of plantation. Five irrigation treatments were investigated, full irrigation.

characteristics	Unit	Value
Sand	gKg^{-1}	266.0
Silt		320.0
Clay		413.5
Texture		Clay
Bulk density	Mgm^3	1.36
Volumetric moisture content at 33 K_{pa}	cm^{3}cm^3	0.34
Volumetric moisture content at 1500 K_{pa}	cm^{3}cm^3	0.14
Available water	cm^{3}cm^3	0.20
ECe	dSm^1	3.4
pH		7.6

Table 1: Some soil physical and chemical characteristics.

(C, control) for whole growing season andfour deficit irrigation treatments (40% reduction from the full irrigation) at different growth stages, seedling (S), vegetative (V), flowering (F) and maturity (M). Diviner- 2000 as soil moisture sensor was used to determine timing and amounts of irrigation water through determining soil moisture content before and after each irrigation. Irrigations were done by using plastic pipes (1.0˝) supplied with meter to control the amount of irrigation water.Irrigation amounts were calculated depending on soil moisture depletion for depth 0-0.2m from planting until the end of vegetative growth stage. This depth was increased to 0-0.4m form Flowering stage up to the end of growing season. Irrigation water depth was calculated according to (Kovda et.al., 1973).

$$d= (\theta_{F.C.} - \theta_{bi})\ D \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

d: Irrigation water depth (mm)
$\theta_{F.C}$= Soil volumetric water contentwhen to irrigate (cm^3cm^{-3})
θ_{bi}= Soil volumetric water content before irrigation (cm^3cm^{-3})
D= Soil depth (mm)

Actual evapotranspiration (ETa) Was estimated using water balance equation (Doge, 1960).

$$\pm \Delta S= (I + P+ C) - (ETa +D + R) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:
ΔS: Soil water content changes (mm)
I: Irrigation (mm)
P: precipitation (mm)
C: Ground waterinput (mm)
ETa: Actual evapotranspiration (mm)
D: water deep percolation (mm)
R: water runoff (mm)

Crop yield response factor (K_y) was calculated according to (Stewart et.al., 1977).

$$K_y = [\, 1 - (y_a / ym)] / [\, 1 - (ET_a / ET_m)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

Where:
K_y: crop yield response
Y_a: Actual yield for deficit irrigation treatment (Kg)
Y_m: Maximum yield (Kg)
ET_a: Actual evapotranspiration for deficit irrigation treatment (mm).
ET_m: Maximum evapotranspiration (mm).

$$AWP = Aw / Gy \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where :
AWP : Applied water productivity (K m^{-3})
AW = Applied water for unit area (m^3 ha^{-1})
G_y = Total grain yield (Kg ha^{-1})

Soil moisture sensor Diviner – 2000 calibration :

Diviner – 2000 as a soil moisture sensor need tobe calibrated to our specific soil. The soil under investigation was clayey (Table 1). A linear correlation with r^2=0.943was found between S.F.(scaled frequency) and soil volumetric water content (θ) (Fig 1).

$$S.F. = 1.443\,\theta + 0.611 \ldots\ldots\ldots\ldots.(5)$$

$$S.F. = \frac{Fa - Fs}{Fa - Fw} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Where:
S.F: Scaled frequency
F_a: Diviner counts in air
F_s: Diviner counts in soil
F_w: Diviner counts in water

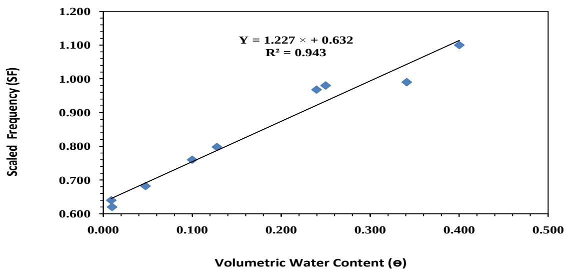

Fig 1: Diviner -2000 calibration equation for Clay soil

RESULTS AND DISCUSSION:

Total Actual evapotranspiration (ET_a) values which were collected during the whole growing season was effected by imposing deficit irrigation at different growth stages (Fig.2).

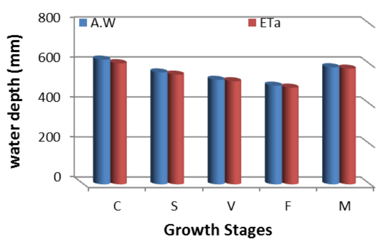

Fig 2: Total actual evapotranspiration (ETa) and total applied water during growth stages

Both actual evapotranspiration and applied irrigation water have maximum values in full irrigation treatment (control). Whilst minimum values for both total actual evopotranspiration and total irrigation water applied were remarked when deficit irrigation was imposed at flowering growth stage. Annandale et. al., (2000). Recorded that actual evapotranspiration values increases by increasing of irrigation water application. The reduction percent for the total amount of applied irrigation water reached its maximum value table2when deficit irrigation was imposed in flowering growth stage. Regarding to the grain yield, highest grain yield production was found in full irrigation treatment (control), but irrigation water saving can be reached between 6.1- 20.9% when deficit irrigation practice imposed at different growth stages through the whole growing season (Table 2).

Treatment	Grain Yield (ton ha $^{-1}$)	Percent of water reduction (%)
C	7520	-
S	7121	10.3
V	5300	16.2
F	7325	20.9
M	7401	6.1

Table: (2) Corn Grain yield and reduction percent of applied irrigation water

Maximum reduction in irrigation water 20.9% was found in T4 treatment (deficit irrigation at flowering growth stage), While grain yield decreased slightly this treatment (Table 2) as compared with full irrigation treatment.(Mao et.al,.2003).Fig –3 shows water applied productivity (WAP), highest value was observed at T4 treatment (imposing deficit irrigation at flowering growth stage). Using deficit irrigation at flowering growth stage did not affect the grain yield but decreased the amount of applied irrigation water this lead to get highest water applied productivity 1.49 kgm^{-3} (Singh et al.2012).

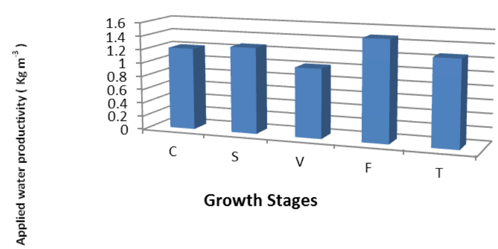

Fig 3: Applied water productivity during different growth stages

On the other hand minimum value was observed at T3 treatment (imposing deficit irrigation at vegetative growth stage). Smith (2004) found that irrigation water stress causing decreasing in vegetative corn growth on certain growth stages. This means that vegetative growth stage is the most sensitive growth stage for deficit irrigation and reducing irrigations. Fig - 4 shows yield response factor (K_y), this factor was varied regarding to imposing deficit irrigation at the different growth stages through the whole growing season. The K_y values takes the sequence 0.13< 0.36< 0.56<1.98for Flowering, maturity, seedling and vegetative growth stages respectively.

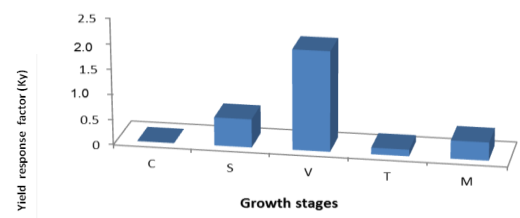

Fig 4 : Yield response factor at different growth stages

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