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PRODUCTION AND WATER USE OF POTATO UNDER REGULATED DEFICIT IRRIGATION TREATMENTS

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ABSTRACT

Field experiments were carried out for two consecutive seasons at the Agricultural Research Station of Abu-Graib, Baghdad – Iraq to study the yield of potato (Solanum *tuberosum L.*), under regular deficit irrigation. Soil moisture content with depth, potato yield, crop evapotranspiration (ET), water use efficiency (WUE) and crop water productivity (CWP) were measured. The irrigation treatments were, irrigate reestablishing field capacity when 60% of the available water was depleted (control), T1 was no irrigation during vegetative growth stage, T2 was no irrigation during tuberigation stage, and T3 was no irrigation during bulking and tuber enlargement.

Results showed that the yield of potato were 34.5, 34.3, 28.2 and 30.2 $T.ha^{-1}$ for control treatment, T1, T2 and T3, respectively for the first season, while in the second one equaled 36.7, 36.2, 30.0 and 31.2 $T.ha^{-1}$. Values of cumulative ETa were 441-391 mm and 428.7-373.7 mm for the two seasons, respectively. The corresponding WUE were highest 8.33 and 9.21 $kg.m^{-3}$ under T1 treatment at vegetative growth stage of the two seasons. References ET were 494 and 472 mm for the two years based on Penman-Montieth equation.

INTRODUCTION

Water is one of the most limiting factors affecting crop production in semiarid environment. Where irrigation has supplemented rainfall for crop production, competition from urban water users has created a need for better understanding of crop water requirements and yield relationships.

Water use efficiency (WUE) is defined as the tuber yield obtained per unit of water consumed as evapotranspiration (ET) by the potato **(Doorenbos and Pruitt, 1977)**.While the term crop water productivity (CWP) is defined as the physical mass of production or the economic value of production measured against gross inflows, net inflow, depleted water, process depleted water, or available water **(Molden, 1997 and Molden** and **Sakthivadivel, 1999)**. The four physical levels of crop water productivity defined are expressed by the following equations **(Molden, 1997 and Ahmad *et al* 2004)**:

$$CWP_{Y-I_g} = C\frac{Y}{I_g} \quad (1)$$

$$CWP_{Y-I_{rr}} = C\frac{Y}{I_{rr}} \quad (2)$$

$$CWP_{Y-ET_{act}} = C\frac{Y}{ET_{act}} \quad (3)$$

$$CWP_{Y-T_a} = C\frac{Y}{T_a} \quad (4)$$

Where CWP is the crop water productivity (kg m^{-3}), Y the actual yield (kg ha^{-1}), Ig the difference of gross inflow and storage in the water balance equation (mm), Irr the irrigation requirements water (mm), ETact the actual evapotranspiration (mm), Ta the transpiration alone (mm) and C is the conversion factor, 0.10 (ha mm m^{-3}).

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In arid and semiarid regions, potato is sensitive to water stress and irrigation has become an essential component of potato production in comparison with the other crops **(Wright and Stark, 1990)**. Potato may be quite sensitive to drought **(Van Loon, 1981)** as it needs frequent irrigation for suitable growth and optimum yield **(Yuan *et al* 2003 and Kiziloglu *et al* 2006)**. **Shock (2004)** found that all growing stages of potato, especially tuber formation stage, are very sensitive to water deficit stress. In contrast, **Wright and Stark (1990)** reported some stress can be tolerated during early vegetative growth and late tuber bulking under water deficit conditions. **Doorenbos and Kassam (1979)** have reported that initial vegetative stage is not sensitive to water stress. Water supply and scheduling have important impacts on tuber quality – frequent irrigation reduces the occurrence of tuber malformation. Water deficit in the early phase of yield formation increases the occurrence of spindled tubers. Using good agricultural practices, including irrigation when necessary, a crop of about 120 days in temperate and subtropical climates can yield 25 to 40 tones of fresh tubers per hectare **(International Year of the Potato, 2008)**.

Iraq is located in arid and semiarid region. Consequently, sufficient water is not available to irrigate the cultivated crop farms. The potato is extensively cultivated in large area of Iraq; but the effect of water stress on yield of this cultivar has not been investigated. Therefore, the main purpose of this study was to evaluate water stress effects during various stages of potato growth on yield, water use efficiency of potato in order to develop the crop water production function.

MATERIALS AND METHODS

Experimental site and climate: The experiment was carried out during spring seasons of 2008 and 2009 at the Agricultural Research Station of Abu-Graib- Baghdad, Iraq (33° 20′ N, 44° 12′ E; elev. 34.1 m). Potato (*Solanum tuberosum* L.) was planted on soil of silt clay loam texture (Sand=150 g kg^{-1}, Silt=570 g kg^{-1} and Clay=284 g kg^{-1}) with average bulk density of 1.44 $Mg.m^{-3}$ and soil content moisture 0.304 $cm^3\ cm^{-3}$ at field capacity and wilting point equal 0.164 $cm^3\ cm^{-3}$. During the cultivation seasons; the mean relative humidity were 46 and 45% and mean rainfall were 6.3 and 18.17 mm during potato growing season, respectively. The total soil water, calculated between field capacity and wilting point for an assumed potato root extracting depth from 0.15 to o.45 m.

Crop management and experimental design: planting took place on 7 February during two seasons using seeding rate of 2000 kg ha^{-1} in 75 cm spaced rows with net plot size of 10 m × 4.5 m, in a randomized complete block design with three replicates. Each experimental unit consisted of 5 rows. All plots were irrigated with river water an ECi = 1.1 $dS.m^{-1}$. Irrigation were scheduled when soil water content in the root zone was depleted by the crop to specific fraction of available water (irrigation was imposed at 60% depletion of available water). The soil depth of the effective root zone is increased from 0.15 m at planting to 0.45 m in bulking and tuber enlargement stages. Measured amount of water were delivered to the furrows using water meter. Soil water content was measured gravimetrically. The sum of differences in soil water and applied irrigation water plus rainfall were calculated as ETa using water balance equation, assuming negligible deep percolation, groundwater contribution and runoff.

The growth cycle of the potato was divided into three stages: stolonization (vegetative growth) 48 days; tuberization stages 12 days; bulking and tuber enlargement stages 49 days. Water stress treatment combinations comprised four treatments; full irrigation (control), irrigation was imposed at 60% depletion of available water. The non complete irrigation omitting one irrigation at vegetative, tuberization and bulking and tuber enlargement stage. The treatments were plants watered (W) and not watered (D) during the growth stages, which will be referred to as treatment:

	Growth stages		
Treatment	vegetative	tuberization	bulking and tuber enlargement
Control	W	W	W
T1	D	W	W
T2	W	D	W
T3	W	W	D

Reference evapotranspiration ET_0 was calculated using Penman-Montieth modified equation **(Allen *et al* 1998)**. Crop coefficient was calculated as the ratio between ETa and ET_0 **(Doorenbos and Pruitt, 1977)**.

Measurement and water use efficiency: potato was harvested on 1 June, 2008 and 26 May, 2009. Ten plants per row within each plot were collected to determine potato yield, tuber number m^{-2} and tuber weight.

Water – Use Efficiency (WUE) calculated as fallows:

$$W.U.E\left(kg.m^{-3}\right)=\frac{Yield\left(kg \quad ha^{-1}\right)}{total \quad water \quad applied \quad m^{-3}} \quad (5)$$

Statistical analysis: analysis of variance was performed to evaluate the statistical effect of irrigation treatment on potato yield, yield components, WUE and CWP using **SAS Analysis (2002)**.LSD test was used to find any significant difference between treatment means.

RESULTS AND DISCUSSION

Yield and its components

To investigate the effect of irrigation water stress on the final yield, two criteria were retained: tuber yield and tuber weight. Data concerning, the two considered parameters, for all irrigation scheduling, are presented in **Table (1)**. In general, control, T_1 and T_2 treatments produced the highest and lowest values in the two seasons. The highest yield was obtained from control and T_1 treatments during the two seasons. For example T_1 treatment was higher by 21.6% and 13.3% for T_2 and T_3, respectively during the first year. The same tendency was found during the second year with an increase of 20.9 and 16.3 % for T_2 and T_3. It seems the initial vegetative stage is not sensitive to water stress. This finding is in accordance with the finding of **Doorenbos & Kassam (1979) and Wright & Stark (1990)** who reported that water stress can be tolerated during early vegetative growth stage. The T_2 and T_3 treatment produced the lowest yield with average 29.08, 30.71ton.h^{-1} in two seasons 2008 and 2009, respectively. In general, water deficits in the middle to late part of the growing period – during stolonization and tuber initiation and bulking – tend to reduce yield, while the crop is less sensitive during early vegetative growth (**International Year of the Potato, 2008**).

The tuber weight were significantly ($p<0.05$) affected by irrigation scheduling. The reduction in tuber yield was mainly attributed to reduction in tubers weight

Water Use Efficiency

Table (2) shows the amounts of applied irrigation water under different treatments during the growth period for two years. Total water supply were 435, 410; 405, 375; 395, 370 and 385, 355 mm for control, T1, T2 and T3 treatments in year 2008 and 2009, respectively. The amounts of irrigation water in control treatment were similar to those reported by **Onder *et al* (2005) and Erdem *et al* (2006)** where experiment carried out near the area of this study.

The cumulative ETa under different water treatments are also presented in **Table (2)**. The highest ET_0 measured during the year was 441 mm for control and the lowest was 391 mm for T_3 treatment a saving of almost 11.3% of irrigation water. In the second year the highest a measured was 428.7 mm and lowest value was 373.7 mm for T_3 treatment a saving of 12.8% of irrigation water.

Water use efficiency for irrigation water (IWUE) and for the total water input of irrigation and rainfall (TWUE) expressed as the ratio of potato yield to water supply from planting to harvest varied typically comparable to those obtained in other field studies (**Fabeiro *et al* 2001; Bowen, 2003 and Kiziloglu *et al* 2006**), who reported that range of WUE was from 7 to 14 kg m^{-3}. The highest WUE value was obtained from T_1 treatment with average of 9.07 and 8.77 kg m^{-3} for IWUE and TWUE, respectively for two seasons.

The net saving in irrigation water with irrigation scheduling average between 6.9 to 11.3 % when compared with full irrigation treatment (control) **(Table 2)**.

Crop coefficients (Kc) for potato calculated as the ratio of ETa/ETo were similar between the two years for all treatments **(Table 2)**. The maximum value of Kc were 0.91 and 0.98 for control treatments of first and second year, respectively receiving maximum irrigation cumulative ETo calculated from Penman-Monteith modified equation totaled 493 and 472 mm for the two years, respectively which are close to the ETa (441, 429 mm) proved the validity of this equation for estimating the water requirements of potato within the context of the region.

Crop Water Productivity (CWP)

CWP of potato were ranged between 7.08 and 9.43 kg m^{-3} **(Table 3). Yaghmaei (1987)** reported the maximum values exceed 5.43 kg m^{-3} in experiment, which potato twelve varieties were planted in furrows and compared together. **Soltani *et al* (1998)** found the highest yield value of 39060 kg ha^{-1} in a field trial with deficit irrigation, while seasonal ETa was relatively low with 765 mm. Beside it; **Soltani *et al* (1998)** reported the minimum value of CWP of 1.25 kg m^{-3} with 19560 kg ha^{-1} yield and 1560 mm seasonal ETa under surface

Table 1. Potato yield (t) and tuber weight (g) from water stress treatments in cropping years

Treatment	Yield components			
	Fresh tuber yields ($T.ha^{-1}$)	Tubers weight (g)	Fresh tuber yields ($T.ha^{-1}$)	Tubers weight (g)
	2008		2009	
Control	34.526	106.40	36.691	111.34
T1	34.272	105.93	36.257	110.29
T2	28.184	90.62	29.982	93.17
T3	30.253	96.27	31.174	98.77
LSD (5%)	2.64	7.23	3.37	8.41

Table 2. Actual evapotranspiration (ETa) (mm) and water use efficiency (WUE) ($kg\ m^{-3}$) from water stress treatments in cropping years

year	Treatment	Irrigation (I) mm	Rain fall (R) mm	(ETa) Actual evapotran-spiration mm	Kc	IWUE	TWUE	Irrigation water saving (%)
2008	control	435	6.3	441	0.98	7.94	7.83	-
	T1	405	6.3	411	0.83	8.46	8.33	6.9
	T2	395	6.3	401	0.81	7.14	7.02	9.1
	T3	385	6.3	391	0.79	7.86	7.73	11.3
2009	control	410	18.71	429	0.91	8.95	8.56	-
	T1	375	18.71	394	0.83	9.67	9.21	8.2
	T2	370	18.71	389	0.82	8.10	7.71	9.3
	T3	355	18.71	374	0.79	8.78	8.34	12.8

Table 3. Crop Water Productivity (CWP) analysis

Year	Treatment	CWP ($kg\ m^{-3}$) Equ. 2	CWP ($kg\ m^{-3}$) Equ. 3	Mean
2008	Control	7.937	7.829	7.883
	T1	8.462	8.338	8.40
	T2	7.135	7.028	7.082
	T3	7.857	7.737	7.797
2009	Control	9.949	8.552	8.750
	T1	9.668	9.202	9.435
	T2	8.103	7.707	7.905
	T3	8.781	8.335	8.558

irrigation method. It is necessary to explain that from the standpoint of maximizing CWP, evaporation should be minimized by maximizing T, which implies intensification of farming. **Keller and Seckler (2005)** conclude that CWP is maximized by full irrigation of a smaller area rather than by deficit irrigation of a larger area with the same volume of water.

Conclusion

The potential of irrigation scheduling to improve yield and to save water has been demonstrated in this work, obtained under actual farming condition, support the practicality and usefulness of using the Soil Water Balance (SWB) scheduling method by FAO to optimize irrigation in arid regions. Water use efficiency (WUE) and crop water production (CWP) was highest for potato plants not-watered during the vegetative growth (T_1). This experiment results showed that a saving 6.9-8.2% of irrigation water can be achieved with a corresponding increase in yield up to 20.9-21.6% under T_1 treatment.

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حوليـات العلـوم الزراعية
جامعة عين شمس ، القاهرة
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أنتاجيــة وكفــاءة إستخدام المياه للبطاطا تحت معاملات الري الناقص

[١٠]

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الموجــــز

نفذت تجربة حقلية ولموسمين زراعيين في حقول كلية الزراعة/جامعة بغداد - ابو غريـب- العـراق لدراسة حاصل البطاطا (*Solanum tuberosum L.*) تحت تأثير نقص الري. قـيس المحتـوى الرطـوبي للتربة مع العمق، حاصل البطاطا، التبخر-نتح الفعلي، كفاءة استخدام الماءوكفاءة انتاجية الميـاه. تـضمنت المعاملات معاملة المقارنة (الري عند اسـتنفاد ٦٠% من الماء الجاهز) ومعاملة T1, T2, T3 المتمثلة بقطع رية واحدة عند مرحلة النمو الخضري، نشوء الدرنات وكبر وتكوين وكبر الدرنات، على التوالي.

بينت النتائج ان انتاجيـة البطاطـا كانـت 34.5 و34.5 و 28.2 و 30.2 طن هكتار$^{-1}$ لمعاملة المقارنة ومعاملة T1, T2, T3، على التوالي في السنة الاولــى للبحث بينما كانت في الـسنة الثانيـة 36.7 و 36.2 و30.0 و 31.12 طن هكتار$^{-1}$ ولـنفس المعــاملات. وكانت قيم التبخر -نتح التجميعي تتراوح بين ٣٩١-٤٤١ مم و٣٧٤-٤٢٨ مم للموســميين الــزراعيين، على التوالي. تحققت اعلى كفاءة لاستخدام المياه عند المعاملــة T1 قــدرها 8.33 و 9.21 كغــم. م$^{-3}$ وللموسميين الزراعيين. فيما سجلت قيم التبخر -نتح المرجعي المحسوبة من معادلة Penman-Montieth ٤٩٤ و ٤٧٢ مم وللموسمين الزراعيين.

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