ISSN NO. 2320-5407

*Journal homepage: http://www.journalijar.com*

*INTERNATIONAL JOURNAL OF ADVANCED RESEARCH*

**RESEARCH ARTICLE**

# Effect of tillage system and deficit irrigation on consumptive use, some soil physical properties, growth and yield of potato *Solanum tuberosum* L.

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## *Manuscript Info*

***Manuscript History:***

Received: 11 February 2014
Final Accepted: 19 March 2014
Published Online: 22 April 2014

***Key words:***
water use efficiency, deficit irrigation, soil physical properties, potato.

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## *Abstract*

The experiment was conducted to estimate the crop water requirement and water use efficiency of potato under complete and deficit irrigation with two tillage systems. The study was carried out in field of Agricultural Collage-University of Baghdad during spring season 2013. Split plot design under Randomized Complete Block Design with three replicates was used in this study. The first factor Tillage systems included Mold Board Plow and Chisel Plow. Whereas the second one was irrigation treatments included (full irrigation $T_0$), irrigation imposed at 35% depletion of available water, the deficit irrigation (cutting one irrigation) in differ stage of plant growth include: no irrigation during vegetative growth stage ($T_1$), no irrigation during tuberigation stage ($T_2$), no irrigation during bulking and tuber enlargement ($T_3$). All agricultural processes for crop management were used according to Ministry of Agriculture recommendation. Actual evapotranspiration was estimate using water balance equation. Some soil physical properties determine after a month of Agriculture, mid-season and after harvest included soil bulk density, saturated hydraulic conductivity and mean weight diameter. Also some plant properties measured included: high of plant (cm), number stems/plant, leaf area ($cm^2$/plant), number of tubers per plant and potato yield (kg. $h^{-1}$). The actual evapotranspiration ($ET_a$) values of complete irrigation were 400 and 436 mm for Mold board plow treatment and Chisel plow treatment, respectively. The highest $WUE_f$ value was obtained from $T_1$ treatment (deficit irrigation at vegetative stages) with average of 11.6 and 8.8 kg $m^{-3}$ for mold board plow and chisel plow, respectively**.** The value of high plant, number stems/plant, leaf area, number of tubers per plant and potato yield recorder 62.45;43.05 cm, 4.41;3.89 stems/plant, 8850;6046 $cm^2$/plant, 6.74;4.58 tubers per plant and 2896;2496 kg. $h^{-1}$ for mold board plow and chisel plow treatment, respectively



## 1. Introduction

The management of soil tillage, irrigation and other agricultural processes effect on growth and production of crops. Because of the differences in properties and soil conditions, the degree of positive or negative effect of management processes differ from soil to another (Baver et al., 1977). Tillage play important role to improve properties of the soil and the quality of plowing in order to prepare appropriate birthplace of seeds and provide conditions for germination by optimizing the physical characteristics of the soil and give the appearance of good plowing and roughness. Choose any suitable tractor and tillage equipment lead to reduce the negative influence of soil degradation aggregate stability, crust, soil resistance penetration and the movement of water in soil, and

increase the production of machine, plant and improve soil physical properties (Jasim, 1983). Al- Ani et al. (2000) and Al-Ajeli (2008) found that the tillage with mold board plow and chisel plow improving physical characteristics of soil such as increase hydraulic conductivity, mean weight diameter and decreased soil bulk density.

A lot of studies confirm the need to determine crop water requirement especially in arid and semi-arid region, because the main water factors for production, and water consumption of the plant were affected by tillage systems, moisture content of the soil, plant coverage and fertilization, as well as weather conditions (Al-Ani et al., 2000 and Al-Zubaidi, 2004). The concept of deficit irrigation in the agricultural process, which includes deleted a number of irrigations during the growth stages, most bearable of shortage water to important management irrigation and increase efficiency use. The use of deficit irrigation at specific stages growth may lead to reduce the yield at limited degree and is not significant (Kirda et al., 1996), in this way can provide the amount of water to be exploited for purposes of agricultural expansion. Using best irrigation method is not necessarily to give highest production but lead to higher water use efficiency (get higher production per unit water irrigation added) by reducing the irrigations number and have little effect on plant productivity (Kirda, 2000). 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 tons of fresh tubers per hectare (International Year of the Potato, 2008).

Ati et al. (2010) found that the water consumption of potato were 441 mm, 429 mm for the agricultural season 2008 and 2009, respectively. Results showed by Ati and Nafaou (2012) that highest production of potato was at treatment depletion 50% of available water (30.26 t. $ha^{-1}$) compared to the treatment depletion 75% of available water (25.66 t. $ha^{-1}$). Potato (*Solanum tuberosum* L.) is considered as one of the most important vegetable crops all over the world. Production of potato takes a very important place in world agriculture, with a production potential of about 327 million tons harvested and 18.6 million hectares planted area (Bowen, 2003 and FAO, 2006). Potato is usually grown in Iraq during autumn and spring seasons. The successful irrigation of potato requires knowledge of both irrigation and scheduling methods. The present study was conducted to evaluate the effect of tillage systems and shortage moisture (deficit irrigation) on consumptive use, water use efficiency, growth and yield potato.

## 2. Materials and Methods

**Experimental site and climate:** The experiment was carried out during spring seasons of 2013 in field of Agricultural Collage- University of Baghdad /Abu-Graib- Baghdad, Iraq (33º 20´ N, 44º 12´ E; elev. 34.1 m). Potato (*Solanum tuberosum* L.) was planted on soil of $EC_e$ (4.25 $dS.m^{-1}$), pH (7.32), organic matter (11.6 g $kg^{-1}$), silt clay texture (Sand=107 g $kg^{-1}$, Silt=452 g $kg^{-1}$ and Clay=441 g $kg^{-1}$) with average bulk density of 1.44 $Mg.m^{-3}$ and soil content moisture 0.342 $cm^3cm^{-3}$ at field capacity and wilting point equal 0.154 $cm^3cm^{-3}$. Averages of annual temperature, relative humidity, wind speed, and total annual precipitation are presented in Table 1.

**TAB. 1- Some climatic parameters of region for the experimental year**

| Month | Month length (days) | Temperature ($^0$C) | | Total amount of rainfall (mm) | Relative humidity (%) | | wind speed (km/day) |
|---|---|---|---|---|---|---|---|
| | | Maximum | Minimum | | Maximum | Minimum | |
| January | 31 | 16.43 | 5.29 | 75.8 | 86.78 | 44.68 | 6.04 |
| February | 28 | 19.49 | 8.13 | 8.5 | 89.54 | 38.13 | 5.19 |
| March | 31 | 24.39 | 9.88 | 0.2 | 73.60 | 21.99 | 5.76 |
| April | 30 | 30.68 | 14.03 | 0.0 | 64.46 | 15.76 | 5.30 |
| May | 31 | 27.45 | 11.23 | 11.25 | 66.78 | 17.23 | 5.45 |

**Crop management and experimental design:** Potato tubers (*Solanum tuberosum* L.) were transplanted manually, at a depth of 10-12 cm on January10, 2013, and harvested on May 22, 2013. Fertilizer applications were composed fertilizer including (200, 240 and 600 kg/ha for $K_2SO_4$, $P_2O_5$ and Urea, respectively). The experiment was arranged in a split-plot design, with two tillage treatments as main plots and four irrigation treatment subplots. Experimental plots measurement 30.0 $m^2$ (5.00 × 6.00 m) and plants spaced were 0.70 × 0.30 m. Plots were separated 3 m from each other. The treatment was:

**(I) Tillage Treatment as follows:**

1. Mold Board Plow (18 cm depth).
2. Chisel Plow (18 cm depth).

**(II) Irrigation Treatment as follows:**

1. Full irrigation (control), irrigation was imposed at 35% depletion of available water ($T_0$).
2. Non complete irrigation cutting one irrigation at vegetative stages ($T_1$).
3. Non complete irrigation cutting one irrigation at tuberization stages ($T_2$).
4. Non complete irrigation cutting one irrigation at bulking and tuber enlargement stages ($T_3$).

All plots were irrigated with river water an ECi = 1.17 $dS.m^{-1}$. 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 35% 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 $ET_a$ using water balance equation, assuming negligible deep percolation, groundwater contribution and runoff. Evapotranspiration ($ET_a$) was calculated using the soil water balance method (Allen et al., 1998).

$$I + P = ET_a + D + \Delta S \ldots\ldots\ldots\ldots (1)$$

Where P is the rainfall (mm); I is the irrigation applied to individual plots (mm); D is the deep percolation; and Δs is the change in water storage of the soil profile (mm). Since the amount of irrigation water was only sufficient to bring the water deficit to field capacity, deep percolation was ignored.

Before two weeks of harvest time, ten plants was taken from each unit experiment were measure the high of plant (cm), number stems/plant, leaf area ($cm^2$/plant), number of tubers per plant and potato yield (kg. $h^{-1}$). Field water use efficiency ($WUE_f$) calculated (Pene and Edi, 1996) as follows:

$$WUE_f = \frac{\text{Yield}(\text{kg})}{\text{Total water applied}(\text{m}^3)} \ldots\ldots\ldots\ldots (2)$$

Soil samples were taken from each experimental unit of depth 0-0.15 m and 0.15-0.40 m after a month of Agriculture, mid-season and after harvest, to determine soil bulk density using core sample method (Blacke, 1965) and the same samples measured saturated hydraulic conductivity according to (Klute, 1986) and calculated mean weight diameter (MWD) (Yoder,1936). Analysis of variance (ANOVA) was conducted to evaluate the effects of the treatments on the yield and water use efficiency. Least significant differences method (L.S.D) was used to differentiate means at the 0.05 level (SAS, 2010).

## 3. Result and Discussion

Table (2) shows the amounts of applied water irrigation and cumulative $ET_a$ of different irrigation treatments during the growth period. Total water supply were 305, 341; 270, 305; 255, 290 and 245, 277 mm for control, $T_1$, $T_2$ and $T_3$ treatments under mold board plow and chisel plow treatment, respectively. The highest $ET_a$ measured during the season was 400, 436 mm for control irrigation under mold board plow and chisel plow, respectively. The amounts of irrigation water in control treatment were similar to those reported by Ati et al. (2012) (432 mm) and Ati and Nafaou (2012) (423 mm) where experiment carried out in center of Iraq, and experiment carried out near the area of this study (Onder et al., 2005 and Erdem et al., 2006).

**TAB. 2- Factors the water balance for irrigation treatments (complete and deficit) for potato crop**

| Tillage | Irrigation | Number of Irrigation | Irrigation (mm) | Rain fall (mm) | (ETa) (mm) | Fresh tuber yield ($t.kg^{-1}$) | $WUE_f$ $kg.m^{-3}$ | Irrigation water saving (%) |
|---|---|---|---|---|---|---|---|---|
| | control | 13 | 305 | 95 | 400 | $32700_a$ | 10.7 | - |
| Mold | T1 | 12 | 270 | 95 | 365 | $31420_a$ | 11.6 | 13.0 |
| Board | T2 | 12 | 255 | 95 | 350 | $26680_b$ | 10.5 | 20.0 |
| Plow | T3 | 12 | 245 | 95 | 340 | $25070_b$ | 10.2 | 28.2 |
| | control | 13 | 341 | 95 | 436 | $28780_{ab}$ | 8.40 | - |
| Chisel | T1 | 12 | 305 | 95 | 400 | 26980b | 8.80 | 11.8 |
| Plow | T2 | 12 | 290 | 95 | 385 | $22450_c$ | 7.70 | 17.6 |
| | T3 | 12 | 277 | 95 | 372 | $21630_c$ | 7.80 | 23.1 |

The resulted from treatment deficit irrigation to reduce evapotranspiration actual at rates differ according to the stages of plant growth, which showed a difference comparison with control treatment , under mold board plow or chisel plow treatment, this due to the fact that amounts of irrigation water are added to the control treatment was higher than the deficit irrigation treatment, lead to increased processes transpiration by plant and evaporation from the soil surface, as well increase in water consumption for control treatment compared tension water (deficit irrigation) back to the soil moisture near from field capacity.

Water use efficiency ($WUE_f$) expressed as the ratio of potato yield to water supply from planting to harvest (Table 2). The highest $WUE_f$ value was obtained from $T_1$ treatment (deficit irrigation at vegetative stages) with average of 11.6 and 8.8 kg $m^{-3}$ for mold board plow and chisel plow, respectively compare with control, $T_2$ and $T_3$. The percentage increase in water use efficiency ($WUE_f$) 7.7, 9.5 and 12.1% with mold board plow treatment and 4.5, 12.5 and 11.4 with chisel plow treatment. This increase is due to higher production of tubers to this treatment, which did not differ significantly from control treatment (full irrigation) on one hand, and lower the amount of irrigation water additive to the field. This finding is in accordance with the finding of Doorenbos and Kassam (1979) and Wright and Stark (1990) who reported that water stress can be afford during early vegetative growth stage.

Results of data in Table 2 show the use mold board plow reduce the irrigation water amount (saving irrigation water with irrigation scheduling) by 13.0, 20.0 and 28.16% at vegetative, tuberization and bulking, tuber enlargement stages, respectively. While the percentage decreases in the same treatment when using chisel plow 11.8, 17.6 and 23.1%, respectively. This due to an increase soil moisture retention when tillage with mold board plow compared chisel plow and reduced rates of evapotranspiration (Jasim et al, 2008), as well as increase aggregate stability and hydraulic conductivity (Table 3).

**TAB. 3- Values of bulk density ($\mu g.m^{-3}$), hydraulic conductivity ($cm.h^{-1}$) and mean weight diameter (mm)**

| | | After month of planting | | | Middle season | | | After harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Tillage | Depth (m) | Bulk Density ($\mu g.m^{-3}$) | Hydraulic conductivity ($cm.h^{-1}$) | MWD (mm) | Bulk Density ($\mu g.m^{-3}$) | Hydraulic conductivity ($cm.h^{-1}$) | MWD (mm) | Bulk Density ($\mu g.m^{-3}$) | Hydraulic conductivity ($cm.h^{-1}$) | MWD (mm) |
| Mold board plow | 0.00.15 | 1.26 | 8.21 | 1.23 | 1.32 | 7.45 | 0.92 | 1.37 | 6.86 | 0.81 |
| | 0.150.40 | 1.37 | 6.34 | 0.82 | 1.40 | 5.16 | 0.76 | 1.44 | 4.23 | 0.72 |
| Chisel plow | 0.0-0.15 | 1.24 | 8.05 | 1.18 | 1.31 | 7.54 | 0.95 | 1.36 | 6.92 | 0.84 |
| | 0.150.40 | 1.36 | 6.47 | 0.84 | 1.40 | 5.22 | 0.76 | 1.43 | 4.67 | 0.71 |

LSD (0.05) Bulk Density = 0.01
LSD (0.05) Hydraulic Conductivity = 1.11
LSD (0.05) Mean Weight Diameter = 0.72

The results of Table 4 indicate significant differences of tillage treatment in each of the high of plant (cm), number stems/plant, leaf area ($cm^2$/plant), number of tubers per plant and potato yield (kg. $h^{-1}$) recorder 62.45;43.05 cm, 4.41;3.89 stems/plant, 8850;6046 $cm^2$/plant, 6.74;4.58 tubers per plant and 2896;2496 kg. $h^{-1}$ for mold board plow and chisel plow treatment, respectively. We note from the results mentioned above different significant between treatment tillage (mold board plow and chisel plow) for all vegetative growth and production properties, this due the process tillage generally lead to breaking compaction layer and then increase the exploitation of plant to the water, as well as improved soil physical properties (decrease soil bulk density and increase aggregate stability, hydraulic conductivity (Table 3). Improving the soil physical properties and moisture lead to increased size, stretch the root system and increase efficiency absorption nutrients and improve the properties of the vegetative growth, the process of photosynthesis and productivity.

**TAB. 4- Values of high of plant (cm), number of stems/plant and leaf area ($cm^2$/plant), number tubers / plant and Tuber yield ($kg.h^{-1}$)**

| Tillage | Irrigation | high of plant (cm) | number stems/plant | leaf area ($cm^2$/plant) | number tubers / plant | Tuber yield ($kg.h^{-1}$) |
|---|---|---|---|---|---|---|
| Moldboard Plow | control | 68.37 | 4.99 | 9721 | 6.88 | 32700 |
| | T1 | 63.16 | 4.49 | 8908 | 7.05 | 31420 |
| | T2 | 60.16 | 4.27 | 8393 | 6.63 | 26680 |
| | T3 | 58.11 | 3.88 | 8381 | 6.38 | 25070 |
| Mean | | 62.45 | 4.41 | 8850 | 6.74 | 2896 |
| Chisel Plow | Control | 43.84 | 4.39 | 7064 | 5.00 | 28780 |
| | T1 | 43.49 | 3.83 | 6131 | 4.78 | 26980 |
| | T2 | 42.94 | 3.77 | 5653 | 4.40 | 22450 |
| | T3 | 41.94 | 3.60 | 5336 | 4.15 | 21630 |
| Mean | | 43.05 | 3.89 | 6046 | 4.58 | 2496 |
| LSD (0.05) | | 1.68 | 0.51 | 1207 | 0.74 | 510 |

## 4. 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) was highest for potato plants not-watered during the vegetative growth ($T_1$). This experiment results showed that the use of mold board plow caused reduction irrigation water amount (saving irrigation water with irrigation scheduling) by 13.0, 20.0 and 28.16% at vegetative, tuberization and bulking, tuber enlargement stages, respectively. More study are needed to investigate the benefits of further mold board plow tillage using for potatoes grown in the different soil textures under arid conditions of Iraq.

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