International Journal of Vegetable Science

ISSN: 1931-5260 (Print) 1931-5279 (Online) Journal homepage: https://www.tandfonline.com/loi/wijv20

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INTERNATIONAL JOURNAL OF VEGETABLE SCIENCE
https://doi.org/10.1080/19315260.2018.1547344

Impact of surface drip irrigation manners and allowed moisture depletion percent on potato growth and yield

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ABSTRACT

Water deficit in semiarid areas limits potato (*Solanum tuberosum* L.) production and quality. Suitable water regimes to store moisture may help overcome drought. The cv. Ravera was planted on 15 September 2016 in a silty loam soil in a field to study the influence of surface drip irrigation methods and allowed depletion percent (25% and 50%) on soil porosity, bulk density, potato growth indicators, and yield of potato. There were differences in averages of soil bulk density, and porosity which were 1.25 Mg·m^{-3}, 52.47% and 1.41 Mg·m^{-3}, 46.39%, when partial soil surface drying drip irrigation was used compared with 1.36 Mg·m^{-3}, 48.48%, and 1.49 Mg·m^{-3}, 43.54%, for full drip irrigation. The allowed depletion percent influenced soil bulk density and porosity which were 1.27 Mg·m^{-3}, 51.71%, and 1.42 Mg·m^{-3}, 46.20%, for soil available water depletion percent of 25% compared with 1.34 Mg·m^{-3}, 49.24%, and 1.48 Mg·m^{-3}, 43.73%, when soil available water allowed depletion percent was 50% for the 0–20- and 20–40 cm soil depths, respectively. Stem diameter, stem length, plant shoot dry weight, leaf area, root length, and mass were respectively 1.06 cm, 76.65 cm, 75.66 g/plant, 65.12 dm^2, 28.88 cm, and 2.26 g/plant when partial soil surface drying was used compared to 0.84 cm, 70.75 cm, 64.02 g/plant, 56.78 dm^2, 32.55 cm, and 1.30 g/plant when full drip irrigation was used. The same parameters reached 1.02 cm, 75.65 cm, 73.83 g/plant, 63.77 dm^2, 29.78 cm, and 2.04 g/plant when the soil available water depletion was 25% compared with 0.90 cm, 71.75 cm, 65.86 g/plant, 58.13 dm^2, 31.65 cm, and 1.26 g/plant when soil available water depletion was 50%. Average single plant and total yield were 955 g/plant and 23,875 kg·ha^{-1} when the partial soil surface drying drip irrigation method used compared with 795 g/plant and 19,875 kg·ha^{-1} for the full drip irrigation method. The same plant yield parameters were 925 g/plant and 23,125 kg·ha^{-1} when depletion was 25% and reached 825 g/plant and 20,625 kg·ha^{-1} for 50% allowed soil available water depletion. Use of surface drip irrigation at partial soil surface drying drip irrigation and soil available water depletion percent (25% and 50%) reduced water waste and improved water-use efficiency without damage to potato growth and yield.

KEYWORDS
Solanum tuberosum; water consumption use; water-use efficiency; water stress; yield

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Water is the most required resource for agriculture, but the freshwater supply is in competition for agricultural, industrial, and domestic purposes. Climate change accelerates desertification and drought which leads to decreased available planted areas and deceased agricultural production (Tignino, 2010). Water unit productivity (water-use efficiency) is the amount of production for each water unit. Improved water-use efficiency will conserve water for other uses (Kirda, 2002). Increasing irrigation interval reduces nutrient uptake, plant cell growth and extension, plant leaf area, and carbon synthesis impacting plant growth (Akinci and Losel, 2012). A shortage in available water resources for agricultural purposes has led to new concepts, technologies, and methods to minimize irrigation water amount, including partial drying of the root zone, to increase application efficiency while maintaining production levels (Kirda et al., 2005).

Most surface water resources in Iraq come from other countries, and there are obstacles to obtain enough water due to constraints of international water resource sharing agreements. Use of modern irrigation technologies, including drip irrigation, can conserve water (Al-Hadithi and Yassin, 2000). Agricultural research has been focused in increasing productivity regardless of amount of applied water, but new avenues are examining production factors and amount of irrigation water regardless of planted area. Choices and practices dealing with water shortage include planting a part of the field with full irrigation amount, or planting the whole field with less irrigation water using modern irrigation methods (English et al., 2002).

Decreasing irrigation interval has led to improved plant shoot growth and yield compared to increasing irrigation interval due to good soil moisture conditions in the root zone (Al-Jeboori et al., 2017). Using alternative partial irrigation increased water-use efficiency for potato (*Solanum tuberosum* L.) which reached 0.0696 $Mt{\cdot}mm^{-1}{\cdot}ha^{-1}$ compared with 0.0461 $Mt{\cdot}mm^{-1}{\cdot}ha^{-1}$ for full irrigation (Al-Ashwal and Almangathy, 2017). This project was undertaken to determine if reduced irrigation could be used to overcome negative effects of water deficit.

Materials and methods

A field experiment was carried out from 15 September to 23 December 2016 in a field located northeast of Ramdi, Iraq. (latitude 33°27′49″ North, longitude 43°21′25.5″ E, altitude 48 m) to study the impact of surface drip irrigation at 2 soil moisture depletion percent on potato growth and yield. A representative sample of the silty loam soil of the field was taken before planting from 0 to 30 cm and passed through a 2 mm sieve. Bulk density was 1.25 $Mmg{\cdot}m^{-3}$, particle density was 2.63 $Mmg{\cdot}m^{-3}$, porosity was 52.47%, soil moisture at 1/3 bar was 33.04%, soil moisture at 15 bar was 10.22%, available water was 22.82%, $pH_{1:1}$ was 7.21, $CaCO_3$ was Ca^{2+} 6.76 meq L^{-1}, Mg^{+2} was

4.55 meq L^{-1}, K^+ was 0.11 meq L^{-1}, Na^+ ws 2.58 meq L^{-1}, Cl^- was 0.12 meq L^{-1}, SO_4^{-2} was 12.28 meq L^{-1}, CO_3^{-2} was almost nonexistent, HCO_3^- was 1.6 meq L^{-1}, and $EC_{1:1}$ was 1.4 $dS{\cdot}m^{-1}$ determined according to Klute et al. (1986) and Page et al. (1982). The field soil was plowed and leveled and divided into three blocks. Plant spacing was 1 m between rows and 0.5 m between plants, with a density of 25,000 $plants{\cdot}ha^{-1}$.

Tubers of potato, cv. Revira, were planted in 8–10 cm deep holes on 15 September 2017. A factorial experiment in a randomized complete block design was used. The number of experimental units for two levels of drip irrigation, two levels of moisture depletion, and three replicates was 12 (Al-Rawi and Khalaf, 2000). Potato pieces were soaked using the fungicide Revanol® at 100 mL/100 L water, for 15 min before planting to protect tubers against fungal infection (Al-Juhairi, 2011). Potato pieces, weighing 56 g, with three eyes, were planted in between two lateral drip irrigation lines 30 cm apart to be used for partial drying and on one side of a lateral line for full surface drip irrigation. After planting the insecticides, Flash® and Comdoro® were applied according to AL-Mehmdy (2011). Fertilization was with urea (46% N), tri-superphosphate (45% P_2O_5), and K_2SO_4 (41.5% K) as sources of nitrogen, phosphorus, and potassium at 240, 120, and 400 $kg{\cdot}ha^{-1}$, respectively. At 1 month after emergence, all the potassium and the rest of the nitrogen was added. Urea fertilizer (46% N) and Magnum® as a source of nitrogen and high phosphorus fertilizer (17% N and 44% P) and potassium (47% K), was applied to foliage (3 N, 1.5 P and 6 K $g{\cdot}L^{-1}$) of each treatment at 10 days after emergence. Further application was at a 10-day interval (Al-Fadlly, 2006).

Experimental factors included moisture depletion (D) at $D_{0.25}$ and $D_{0.5}$ for 25% and 50% to preserve plant growth and water saving, soil available moisture depletion, and drip irrigation method (I), I_f for full surface drip irrigation and I_p for partial drying surface drip irrigation (0–30 cm soil depth). Irrigation was applied according to American evaporation pan class A for all plant growth stages except before emergence which was applied according to the gravitational method due to not knowing a crop factor which is not available for this stage at 25% or 50% depleted soil available moisture (no rainfall in the season). Emitter discharge was 4 $L{\cdot}hr^{-1}$ at 0.5 bar pressure (Abood, 2012). Soil bulk and particle density was determined using the core sample method of Klute et al. (1986), and soil particle density determined using the pycnometer method and soil porosity calculated. Half of the irrigation was applied to one side of plants at the middle duration of irrigation interval and half applied to the other side of the plant at the plant growth stages.

Plant stem diameter was measured on five randomly selected plants and plant height measured from the root collar to the shoot apex. Plant leaf area was determined from five leaves from each of five randomly selected plants. For leaf area, a sample was taken using a known area pipe with 1 cm diameter and plant leaf area calculated according to the formula of Wein (1997) and dried by oven (convection) at 65°C for 72 h. each and weighed. Plant roots were washed under a water stream. Root length (plant roots were washed using a water stream after harvest and root length determined). Roots dry weights were determined (Al-Shaabani, 2017). Plant shoot dry weight was determined at the end of season for five randomly chosen plants after drying in an oven (convection) at 65°C for 72 h (Al-Sahaf, 1989). Data were subjected to analysis of variance using Genstat (ver. 9.1, VSN International Ltd., Hemel Hempstead, UK). If interactions were significant, they were used to explain results. If interactions were not significant means were separated with LSD.

Results and discussion

Drip irrigation method and allowed depletion percent affected all measured responses, except for stem diameter which was not affected by depletion percent (Table 1). There were differences in porosity when partial drying method was used for irrigation compared with full irrigation at the 0–20 and 20–40 cm depth. The highest bulk density was recorded at 0–20 cm and 20–40 cm for the full irrigation compared to partial irrigation (Table 2). This may be due to wetting the soil after drying which degraded soil aggregates and caused soil compaction and this confirms that drought, rapid wetting, and soil swelling lead to soil degradation and porosity (Abood, 2012; AL-Nagem, 2013).

Drip irrigation method affected some plant growth parameters and yield (Table 3). The succession for partial drying treatments produced the widest stems, tallest plants, heaviest shoot dry weight, most leaf area, greatest root mass, highest yield per plant (as fresh weight of tubers), and highest total yield compared with full irrigation. This could be due to maintenance of soil moisture allowing continued nutrient uptake (Al-Jeboori et al., 2017). Plants irrigated at the full level produced the longest roots compared with partial drying.

The amount of depletion affected soil porosity and bulk density at the 0–20 and 20–40 cm depth with the 25% depletion percent compared with the 50% depletion percent (Table 4). This may due to wetting the soil after drying degrading soil aggregates and the drying–wetting cycles causing soil compaction (AL-Kateeb and AL-Najm, 2015; AL-Nagem, 2013; Al-Shaabani, 2017).

The tallest plants, highest shoot dry weight, greatest leaf area, highest root mass, most yield per plant, and total yield was for the 25% soil moisture depletion (Table 5). This could be due to decreasing soil moisture associated with increasing water deficit which could decrease photosynthesis in plants sensitive to water deficit. This was likely due to full irrigation providing a consistent supply of water to the entire root area so that drench and dry-out conditions are minimized. Most morphological, physiological, and biochemical processes associated with plant development are compromised during water

Table 1. Analysis of variance for main effects of surface drip irrigation methods and allowed depletion percent on soil porosity, bulk density, and potato growth indicators and total yield and single plant.

Source	df	Bulk density 0–20	Bulk density 20–40	Porosity 0–20	Porosity 20–40	Stem diameter	Plant height	Shoot dry weight	Leaf area	Root length	Root mass	Plant yield	Total yield
Block	2	0.0039	0.0015	5.632	2.280	0.0271	0.430	3.99	1.038	2.56	0.10	154	274
Irrigation (I)	1	0.0330*	0.0168*	47.760*	24.396*	0.1656*	104.4*	406.8*	208.4*	40.51*	2.76*	768*	136*
Depletion (*D*)	1	0.0126	0.0126*	18.303*	18.278*	0.0396	45.63*	190.3*	95.59*	10.54*	0.78*	300*	534*
$I \times D$	1	0.0000ns	0.0090ns	0.108ns	13.125ns	0.0036ns	4.320ns	0.357ns	0.594ns	1.172ns	0.03ns	300ns	546ns
Error	6	0.0021	0.0020	3.032	2.954	0.0129	2.973	1.009	0.372	1.153	0.03	740	132
Corrected Total	11												

ns: not significant;*significant at 0.05 level, ANOVA.

Table 2. Effect of surface drip irrigation methods on soil bulk density and porosity for the 0–40 cm soil depth.

Drip irrigation method	0–20 cm depth Bulk density ($g \cdot cm^{-3}$)	Porosity (%)	20–40 cm depth Bulk density ($g \cdot cm^{-3}$)	Porosity (%)
Partial drying	1.25	52.47	1.41	46.39
Full irrigation	1.36	48.48	1.49	43.54
LSD	0.0647	2.460	0.0638	2.428

Table 3. Influence of drip irrigation method on stem diameter, plant height, shoot dry weight, leaf area, root length, root mass, plant yield, and total yield potato.

Drip irrigation method	Stem diameter (cm)	Plant height (cm)	Shoot dry weight (g)	Leaf area (cm^2)	Root length (cm)	Root mass (g)	Plant yield (g)	Total yield ($kg \cdot ha^{-1}$)
Partial drying	1.76	76.65	75.66	65.12	28.88	2.26	955	23875
Full irrigation	0.84	70.75	64.02	56.78	32.55	1.30	795	19875
LSD	0.1605	2.43	1.419	0.862	1.517	0.2642	38.44	514.2

Table 4. Effect of surface drip irrigation methods on soil bulk density and porosity for the 0–40 cm soil depth.

Soil moisture depletion (%)	0–20 cm depth Bulk density ($g \cdot cm^{-3}$)	Porosity (%)	20–40 cm depth Bulk density ($g \cdot cm^{-3}$)	Porosity (%)
25	1.27	51.71	1.42	46.20
50	1.34	49.24	1.48	43.73
LSD	0.0647	2.460	0.0638	2.428

Table 5. Influence of depletion percentages on plant height, shoot dry weight, leaf area, root length, root mass, plant yield, and total yield of potato.

Soil moisture depletion (%)	Plant height (cm)	Shoot dryweight (g)	Leaf area (cm^2)	Root length (cm)	Root mass (g)	Plant yield (g)	Total yield ($kg \cdot ha^{-1}$)
25	75.65	73.83	63.77	29.78	2.04	925	23,125
50	71.75	65.86	58.13	31.65	1.53	825	20,625
LSD	2.436	1.419	0.862	1.517	0.2642	38.44	514.2

deficit, respiration, and nutrient metabolism (Al-Jeboori et al., 2017; AL-Kateeb et al., 2016; AL-Mehmdy, 2011). The longest roots was due to 50% soil moisture depletion. Use of partial drying irrigation increased productivity of potato.

References

Abood, M.A. 2012. Effect of drip irrigation, organic manure and mulching on growth and yield of potato. College of Agriculture, University of Baghdad. Baghdad. Iraq, PhD Dissertation.

Akinci, S., and D.M. Losel. 2012. Plant water-stress. Tech for Publishing, Rijeka, Croatia.

Al-Ashwal, H.H.A., and B.M.A. Almangathy. 2017. Effect of partial root - zone drying and ridge height on water use efficiency of potato (*Solanum tuberosum* L.) in Maareb Province, Yemen. Syrian J. Agric. Res. 4(2):1–14.

Al-Fadlly, J.T.M. 2006. Effect of NPK Addition and foliar application on growth, yield and components of Potato plants tubers (*Solanum tuberosum* L.). Dept. of Soil and Water Sci., Coll. of Agric., Univ. of Baghdad, Baghdad, Iraq, MS Thesis.

Al-Hadithi, E.K.H., and M.F. Yassin. 2000. Scientific styles in dealing with the deficit in water consumption for agricultural purposes in desert conditions. Iraqi Western Desert: (model for study). J. Agric. Water. 1:99–106.

Al-Jeboori, K.D., M.Z.K. Al-Mharib., A.Q. Hamdan, and A.H. Mahmood. 2017. Effect of irrigation intervals and foliar of salicylic acid on growth and yield of potato. Iraqi J. Agric. Sci. 48(1):242–247.

Al-Juhairi, H.Y.A. 2011. Effect of fertilizer sources level, irrigation methods, growth and yield of Potato (*Solanum tuberosum* L.). Dept. of Soil and Water Sci., Coll. of Agric., Univ. of Baghdad, Baghdad, Iraq, PhD Dissertation.

AL-Kateeb, B.A., and H.J.M. AL-Najm. 2015. The impact of irrigation water salinity, water magnetization and soil available moisture depletion percent on potato yield and growth. Anbar J. Agric. Sci. 13(2):49–60.

AL-Kateeb, B.A., B.M. Youssef, and W.F. Abad AL-Rahman. 2016. Measurement of water consumptive use, growth and yield potato (*Solanum tuberosum* L.) under drip irrigation system. Anbar J. Agric. Sci. 14(2):36–52.

AL-Mehmdy, SH.M.H. 2011. Effect of emitters, discharge and irrigation water salinity on some physical properties of soil, salt distribution, growth and potato yield. Dept. of Soil Sci. and Water Resources., Coll. of Agric., Univ. of Anbar, Anbar, Iraq, PhD Dissertation.

AL-Nagem, H.J.M. . 2013. The impact of irrigation water salinity, water magnetization and soil available moisture depletion percent on some soil physical and potato yield and growth of Potato. Dept. of Soil Sci and Water Resources., Coll. of Agric., Univ. of Anbar, Anbar, Iraq, PhD Dissertation.

Al-Rawi, K.M., and A.I. Khalaf. 2000. Design and analyses of agriculture experiments. Ministry of Higher Education and Scientific Research. Univ. of Mosul., Coll. of Agric and Forestry, Ninawa Governorate, Mosul, Iraq.

Al-Sahaf, F.H. 1989. Applied plant nutrition. Ministry of Higher Education and Scientific Research. Univ. of Baghdad, Baghdad, Iraq.

Al-Shaabani, E.M.H. 2017. Effect of water stress and dividing irrigation by stable surface drip in some soil physical properties and Potato growth and yield. Department of Soil Sci. and Water Resources., Coll. of Agric., Univ. of Anbar, Anbar, Iraq, MS Thesis.

English, M.J., K.H. Solomon, and G.J. Hoffman. 2002. A paradigm shift in irrigation management. J. Irrig. Drain. Eng. 128:267–277. doi: 10.1061/(ASCE)0733-9437(2002)128:5(267).

Kirda, C. 2002. Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Deficit irrigation practices, Food and Agriculture Organization, Rome. doi:10.1044/1059-0889(2002/er01).

Kirda, C., K. Stops, H. Kaman., A.C. Ulger, A. Yazici., M. Cetin, and M.R. Derici. 2005. Grain yield response and N-fertilizer recovery of maize under deficit irrigation. Field Crops Res. 93:132–141. doi: 10.1016/j.fcr.2004.09.015.

Klute, A., R.C. Dinauer, D.R. Buxton, and J.J. Mortvedt. 1986. Methods of soil analysis. Amer, Soc. Agron., Crop Sci. Soc. America, Madison, WI, 9 (Part 1).

Page, A.I., R.H. Miller, and D.R. Keeney. 1982. Methods of soil analysis. Part 2, Chemical and microbiological. Properties. 2nd ed. Agronomy 9. Am. Soc. Agron., Soil Sci. Soc. Am. Inv., Madison, WI.

Tignino, M. 2010. Water, international peace, and security. Int. Rev. Red Cross 92 (879):647–674. doi: 10.1017/S181638311000055X.

Wein, H.C. 1997. The physiology of vegetable crops. CAB International, New York.