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Optimum Irrigation Events for Potato Cultivar Agria

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ABSTRACT

This research was conducted to find optimum irrigation events for potato (cv. Agria) based on potato yield and water use efficiency (WUE) under Ekbatan, Iran, climate condition with a mean annual relative humidity of 51% and rainfall of 200 mm. Results revealed that the highest (28.47±3.58 t) and lowest (24.58±2.05 t) yields were produced by partial with 16 and full irrigation with 18 events, respectively. These originated from insensitiveness of initial vegetative stage of potato to partial irrigation. On the other hand by 18 events with 13408±58 m^3 ha^{-1} water was applied to the experimental plots. While water requirement of potato is 6640 m^3 ha^{-1} and it seems extra application of water caused a decrease in yield. It was found that the highest (2.36±0.35 kg m^{-3}) and lowest (1.84±0.18 kg m^{-3}) WUE produced by partial with 16 and full irrigation with 18 events, as well. Since initial vegetative stage of potato is not sensitive to water deficit, partial irrigation did not cause a decrease in yield but also increased WUE relative to full irrigation. To relate crop yield to water applied, a water production function was developed by multiple regressions analysis. Applying 16 irrigation events caused a yield increase as 13.21±4.05% and water saving up to 9.88±2.35% relative to 18 irrigation events. Therefore, it is recommended that potato cultivar Agria should be irrigated with 16 irrigation events to achieve the optimum yield and WUE.

Key Words: Irrigation scheduling; Irrigation events; Potato (cv. Agria) yield; Water use efficiency

INTRODUCTION

Potato (*Solanum tuberosum* L.) is produced about 321 million t over the world (FAO, 2007). Iran is the third biggest potato producer in Asia, where the production is about 5.2 million t with average of 25 t ha^{-1} in 2007 (FAO, 2007). In comparison with the other crops, potato is sensitive to water stress at some growth stages and irrigation has become an essential component of potato production in arid and semiarid regions (Wright & Stark, 1990). Yuan *et al.* (2003) and Kiziloglu *et al.* (2006) reported that potato for suitable growth and optimum yield needs frequent irrigation. For potato production in Hamedan, Iran irrigation is needed, because occurred rainfall during growing season and stored soil moisture are insufficient to provide potato water requirement to acquire the optimum yield. Van Loon (1981) concluded that potato is quite sensitive to drought. Wright and Stark (1990) reported that some stress can be tolerated during early vegetative growth and late tuber bulking under water deficit condition. Thornton (2002) and Shock (2004) found that all growing stages of potato, especially tuber formation stage are very sensitive to water deficit stress. However, Doorenbos and Kassam (1979) reported that initial vegetative stage is not sensitive to water stress. Hassan *et al.* (2002) concluded that the stolonization and tuberization stages were more sensitive than bulking and tuber enlargement stages. Also, Shock *et al.* (1992) reported that potato can tolerate water deficit before tuber set without reduction in tuber quality in some conditions. However, Shock and Feibert (2002) concluded that a short period of water stress following tuber set reduces tuber yield and quality. Under deficit irrigation conditions, potato yield and grade responded linearly to applied water (Shock & Feibert, 2002).

Water use efficiency (WUE) is defined as the tuber yield obtained per unit of water consumed as evapotranspiration (ET) by the potato (Doorenbos & Pruitt, 1977). Hassan *et al.* (2002) reported that WUE of potato ranged from 0.69 to 2.33 t $ha^{-1}cm^{-1}$ which the highest WUE was obtained from treatments include continuous stress at all stages of potato. Kiziloglu *et al.* (2006) found that WUE changed between 63.4 to 44.1 kg ha^{-1} mm^{-1} which the highest one was for plots with irrigation treatments of 20% useable soil water. Nagaz *et al*. (2007) concluded that WUE varied around 8-9, 6-8 and 11-14 kg m^{-3}, respectively for autumn, winter and spring. They also found that the lowest WUE obtained from full irrigation with daily application. The aims of the current study were to find optimum irrigation events for potato cultivar Agria based on yield and water use efficiency and to develop the crop water production function for potato yield as a function of irrigation water.

MATERIALS AND METHODS

The experiments were carried out on potato (*Solanum tuberosum* L.) in 2004, 2005 and 2006 during the growing season of June to October at the Agricultural Research Station of Ekbatan, Iran (34º 52′ N, 48º 32′ E; elev. 1730 m), with a mean annual relative humidity of 51% and rainfall of 200 mm. On 30 April every year potato cv. Agria was sown on six rows 6 m long and 75 cm apart (6×4.5 m^2 plots) at seeding rate of 2000 kg ha^{-1}. Field soil was loam with average bulk density of 1.49 g cm^{-3} and moisture at filed capacity and wilting point as 21 and 9.6%, respectively. The sown site were irrigated for three events (to 6 June) to prevent any possible water deficit stress during the vegetative stage of potato. The Fertilizers with rates of 400 kg N ha^{-1}, 400 kg P ha^{-1} and 400 kg K ha^{-1} were applied according to potato requirement. Treatment combinations comprised four levels for irrigation events during potato growth stages viz. full irrigation with 18 events (control), 17 events (I1), 16 events (I2) and 15 events (I3). Reduced events were after third irrigation. Fig. 1 shows irrigation dates and events no for experimental treatments. The irrigation waters volume was measured at the entrance of each furrow by a connected-flow-meter to a siphon and at the end of furrow by WSC flume (Type V). After maturity, plots on 22 October every year were harvested for yield. In the present study, the calculation of the WUE was modified by taking in to account the total amount of water applied and calculated as potato yield per total water applied, in which WUE, yield and total water applied are in kg m^{-3}, kg ha^{-1} and m^3 ha^{-1}, respectively. Evapotranspiration (ET) and irrigation water requirement (IWR) of potato for Ekbatan climate condition were presented in Fig. 2 (Farshi *et al*., 1997). Cumulative ET and IWR during growing season from 20 April to 12 October were 716 and 664 mm, respectively.

Yield increase (YI) (%) from plots with irrigation events relative to control plot with 18 events were estimated from the fallowing relation:

$$YI\ (\%) = 100\ (1-(PYT/PYF)) \qquad (1)$$

Where, PYT and PYF are potato yield from plots with different irrigation events and from control plot in ton.

Similarly, applied water saving (WS) (%) for treatment plots relative to full irrigation condition were estimated as fallows:

$$WS\ (\%) = 100\ (1-(WT/WF)) \qquad (2)$$

Where, WT and WF are applied water for plots with different irrigation regimes and for full irrigation condition in m^3.

Fig. 1. Irrigation events no applying for experimental treatments

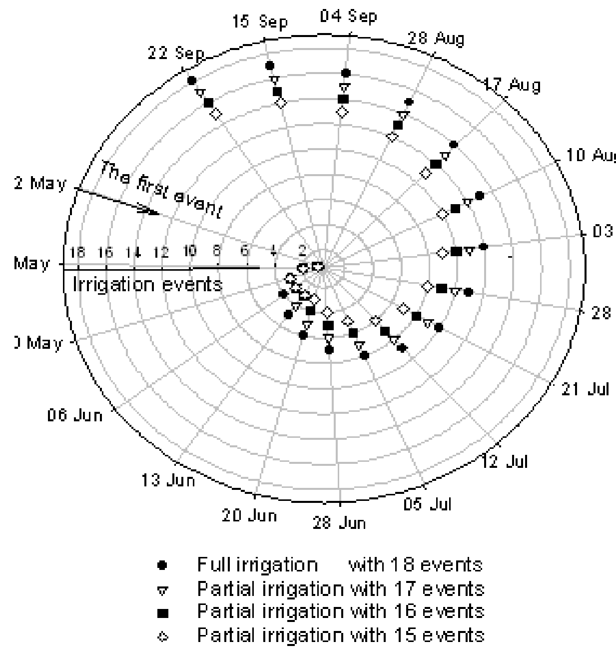
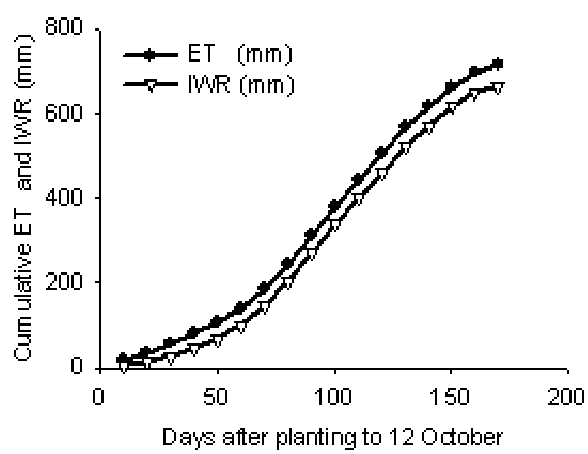


Fig. 2. Evapotranspiration (ET) and irrigation water requirement (IWR) of potato under Ekbatan climate condition (Farshi *et al.*, 1997)



Yield increase (%) was related to the water saving (%) from treatment plots as:

$$YI = k\ WS \qquad (3)$$

In which k is effective factor of saving water in yield production.

The experimental data were analyzed statistically by analysis of variance techniques and the treatment means were compared by Duncan's multiple range tests. The least squares procedure was applied for developing regression models.

Table I. Potato yield (t) from applying different irrigation events

	2004	2005	2006	Over 3 years
Full irrigation (18)	22.09 a	25.28 a	26.39 a	24.58±2.05 a
I1 (17)	23.05 ab	27.22 ab	29.03 b	26.43±2.85 ab
I2 (16)	24.03 b	29.72 b	31.67 c	28.47±3.58 b
I3 (15)	22.78 a	26.53 a	28.33 ab	25.88±2.63 ab
Mean	22.98±0.87*	27.19±2.04	28.85±2.21	26.34±3.06

*Figures in the Table are mean± standard deviation

Table II. Potato water use efficiency (kg m^{-3}) from different irrigation events

Irrigation events	Year 1	Year 2	Year 3	Over 3 years
Full irrigation (18)	1.70 a	1.77 a	2.09 a	1.84±0.16 a
I1 (17)	1.82 b	2.10 b	2.37 b	2.07±0.25 ab
I2 (16)	1.99 c	2.34 c	2.77 c	2.36±0.35 c
I3 (15)	1.98 c	2.23 c	2.66 c	2.29±0.31 bc
Mean	1.87±0.13*	2.10±0.24	2.46±0.31	2.14±0.34

*Figures in the Table are mean± standard deviation

Table III. Potato yield increase (%), water saving and effective factor (k) from different irrigation events

	Yield increase (%)	Water saving (%)	k
2004			
I1 (17)	4.14±1.97*	2.31	1.79±0.85
I2 (16)	8.07±1.05	6.76	1.19±0.15
I3 (15)	3.01±1.07	11.53	0.26±0.09
2005			
I1 (17)	7.07±1.02	5.60	1.26±0.35
I2 (16)	14.93±1.18	11.20	1.33±0.11
I3 (15)	4.65±0.25	16.80	0.28±0.15
2006			
I1 (17)	9.08±1.07	5.32	1.71±0.11
I2 (16)	16.62±1.25	11.69	1.42±0.11
I3 (15)	6.83±1.51	17.82	0.38±0.08
Over three years			
I1 (17)	6.76±2.56	4.41±2.92	1.59±0.53
I2 (16)	13.21±4.05	9.88±2.35	1.32±0.14
I3 (15)	4.83±2.26	15.38±1.58	0.31±0.11

*Figures in the Table are mean± standard deviation

RESULTS AND DISCUSSION

Meteorological factors variations. Analysis of variance (Tables were not shown) showed that there are no statistically difference between air temperature, pan evaporation, rainfall, relative humidity and wind speed during three years at the 90% confidence level. Average meteorological factors during growing season over three cropping years were displayed by Fig. 3. Air temperature ranged from 16±1.1 (May) to 24±0.7 (July), pan evaporation ranged from 229.7±56.1 (May) to 312.3±15.1 mm month^{-1} (July), rainfall were from 2.2 (September) to 21.1±15 mm (May), relative humidity were from 37.7±3.2 (July) to 46.8±3.9% (May) and wind speed ranged from 1.1±0.5 (September) to 3.0±0.7 ms^{-1} (May).

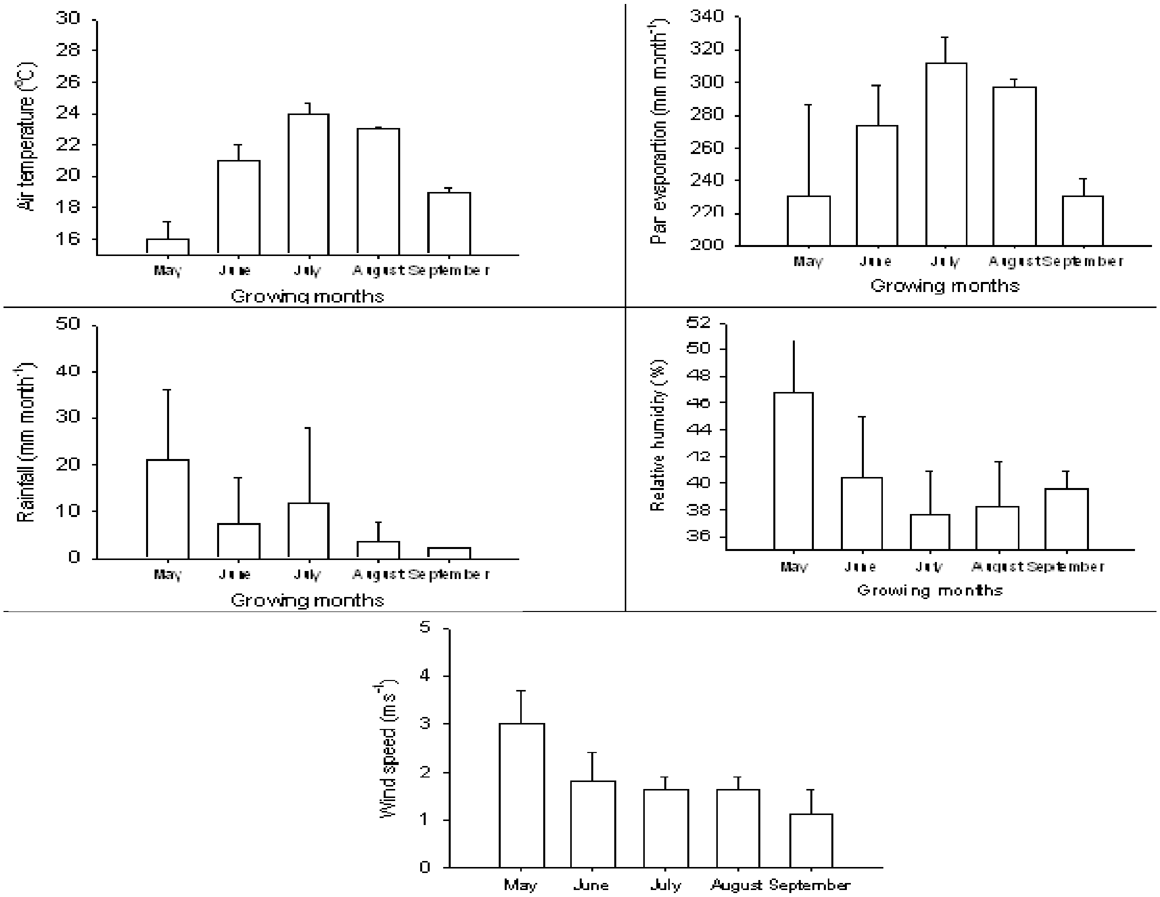
Irrigation events effects on yield. The effect of irrigation events on potato yield was statistically significant in the three consecutive years and over years ($p \leq 0.05$). The highest yield acquired from plots with 16 events with yield of 28.47±3.58 t over three cropping years (Table I). It seems the initial vegetative stage is not sensitive to water stress. This finding is in accordance with Doorenbos and Kassam (1979). Full irrigation with 18 events produced the lowest yield with average of 24.58±2.05 t for three cropping years (Table I). By 18 events 13408±58 m^3 ha^{-1} water was applied to the experimental plots. While water requirement of potato is 6640 m^3 ha^{-1} and it seems extra application of water caused a decrease in yield in addition to water application efficiency. This finding is accordance with those reported by Wright and Stark (1990) concluding that over irrigation reduce marketable yields. Note that, over-irrigation can be increased fertilizer requirement, pumping energy costs, watse water and grundwater contamination.

Results revealed that the highest (28.47±3.58 t & 2.36±0.35 kg m^{-3}) and lowest (24.58±2.05 t & 1.84±0.16 kg m^{-3}) yields and water use efficiencies were respectively produced by applying 16 and 18 irrigation events. Since water requirement (IWR) of potato is 6640 m^3 ha^{-1} and it seems extra application of water was two times of IWR by 18 events causing a decrease in yield. Over-irrigation can increase fertilizer requirement, pumping energy costs, waste water and groundwater contamination. Partial irrigation did not cause a decrease in yield but caused an increase in WUE relative to full irrigation with 18 events. Applying irrigation with 16 events caused a yield increase as 13.21% and water saving as 9.88% relative to 18 events. Therefore, it is found that 16 irrigation events as optimum events for potato cultivar Agria to achieve the optimum yield, WUE and water saving. Also, to relate potato yield to applied water, a water production function was worked out by multiple regressions analysis.

Results also indicated that produced yield by 15 and 18 irrigation events were in similar class (Table I). Note that, both over- (18 events) and under-irrigation (15 events) produced reduced-yield. Consequently, to achieve the relative highest yield, it is recommended irrigation with 16 events.

Water use efficiency response to irrigation events. Water use efficiency of potato was significantly affected by irrigation events in and over the three consecutive years ($p \leq 0.01$). The average of WUE was 2.14±0.34 kg m^{-3} and the range going from 1.70 to 2.77 kg m^{-3} achieved from 18 events in the first year and applying 16 events in the third year, respectively. This finding is inconsistence with those reported by Kiziloglu *et al.* (2006) and Nagaz *et al.* (2007) reporting the range of WUE from 44.1 to 63.4 kg ha^{-1} mm^{-1} and from 8 to 14 kg m^{-3}, respectively. The highest WUE value obtained from plots with 16 events with average of 2.36±0.35 kg m^{-3} for three years (Table II). In general, applying 18 events produced the lowest WUE with average 1.84±0.16 kg m^{-3} for three cropping years. Because of insensitiveness of initial vegetative stage to water deficit or partial irrigation, it did not cause a decrease in potato yield. Therefore, applying decreased water with 16 events caused an increase in water use efficiency. Also, full irrigation with 18 events caused decrease in WUE.

Fig. 3. Meteorological factors over three cropping years (mean ± standard deviation)



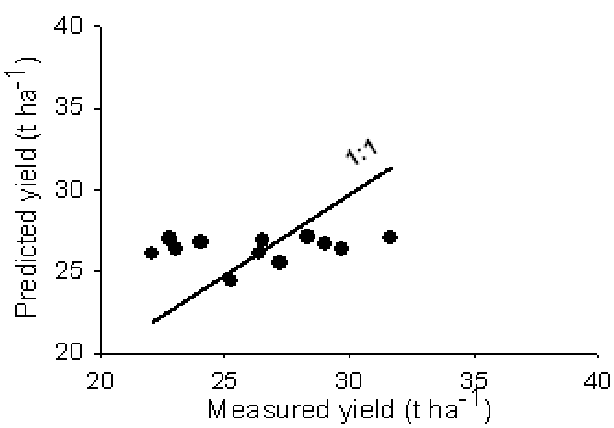
Water-yield production function. By multiple regression analysis and the least squares procedure (Kohler, 2002) a polynomial model was developed for describing yield (Y) of potato cultivar Agria over three cropping years in kg as a function of water applied (W) in m^3 as follows:

$$Y=4.99\ (\pm 0.957)W-0.00023\ (\pm 0.00008)\ W^2 \qquad n = 12 \qquad R^2= 0.988 \qquad (1)$$

The fitted model explains about 99% of the variability in the yield by applied water. This model is quadratic not being consistence with those reported by Shock and Feibert (2002) concluding that yield was linearly varied with applied water under partial irrigation condition. The highest yield (=31.67 t) obtained with applying water as 11445 m^3. The measured and predicted yields were shown in Fig. 4 being good agreements between them.

Yield increase and water saving responses to irrigation events. Yield increase (%) and water saving (%) from affected plots by different irrigation events relative to that from 18 events were respectively estimated by Eqs. (1) and (2) (Table III). The effect of irrigation events on yield increase ($p \leq 0.05$), water saving ($p \leq 0.05$) and effective factor ($p \leq 0.01$) were significant. But the mean of yield increase from 17 events (6.76±2.56%) and 15 events (4.83±2.26%) were statistically similar at the 95% confidence level. Applying irrigation with 16 events produced the highest yield increase (13.21±0.14%). The mean of water saving were respectively 4.41±2.92, 9.88±2.35 and 15.38±1.58% for irrigation with events of 17, 16 and 15 events. Applying irrigation with 15 events produced the highest water saving

Fig. 4. Measured and predicted yield of potato cv. Agria



percent. The mean of k factor from 17 (1.59±0.53) and 16 events (1.32±0.14) were statistically similar at the 95% confidence level. In general, irrigation with 17 events produced the highest effective factor, k, (=1.59±0.53) for three cropping years and 15 events in irrigation produced the lowest k (=0.31±0.11). The highest value of k mainly resulted from the highest yield increase. Applying 16 events caused a yield increase as 13.2% and water saving as 9.9% relative to irrigation with 18 events.

CONCLUSION

It is recommended that potato cultivar Agria should be irrigated with 16 events to achieve the optimum effective factor.

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