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Full Length Article

Potato Cultivar Marfuna Yield and Water Use Efficiency Responses to Early-Season Water Stress

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ABSTRACT

The present study was conducted to investigate the influence of early-season water stress on yield and water use efficiency (WUE) in potato cv. Marfuna. There were four levels for the fourth irrigation events at the 36 (control), 44 (W1), 51 (W2) and 59 (W3) days after planting date for three consecutive years at the Ekbatan, Iran. Initial vegetative stage is not sensitive to early-season water stress, therefore W2 produced the highest yield of 30.28 t and extra-application of water caused a decrease in yield. Consequently, control condition produced the lowest yield. Applying fourth irrigation at the 51 (W2) and 59 (W3) days after sowing, respectively resulted in yield increase as 11.28 (the highest) and 2.50% (the lowest) relative to that of 36 (W1) days after sowing. To relate tuber yield to water applied, a water production function was developed by multiple regressions analysis. Also, applying fourth event at the 51 (W2) and 36 days after sowing produced the highest (2.79 kg m^{-3}) and the lowest (2.24 kg m^{-3}) WUE for three cropping years. The highest increase in WUE (21.15 %) relative to control condition was shown by W2. Based on water use efficiency values, it is recommended that potato cv. Marfuna should be irrigated with 59 days after sowing (W3) to achieve the optimum water use efficiency.

Key Words: Early-season water stress; Irrigation scheduling; Potato cv. Marfuna yield; Water use efficiency

INTRODUCTION

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 & 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; Kiziloglu *et al.,* 2006). Thornton (2002) and 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. On the other hand, 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.

Water use efficiency (WUE) is defined as the tuber yield obtained per unit of water consumed as evapo-transpiration (ET) by the potato (Doorenbos & Pruitt, 1977). Nagaz *et al.* (2007) concluded that WUE varied around 8-9, 6-8 and 11-14 kg m^{-3} for autumn, winter and spring planted potato, respectively. Wright and Stark (1990) reported that the WUEs for conditions favoring maximum yields range from approximately 50 to 100 kg ha^{-1} per mm. Rashidi and Gholami (2008) reported that WUE of potato in Iran ranged from 1.92 to 5.25 kg m^{-3}.

Hamedan, Iran is located in arid and semiarid region. Consequently, sufficient water is not available to irrigate the cultivated crops farms. While some crops such as wheat and barley could be irrigated by using saved water from potato farms. The potato cv. Marfuna is extensively cultivated in Hemedan. But the effect of water stress on yield of this cultivar has not been investigated. Therefore, the main objective of the present study was to investigate effects of early-season water stress on yield and water use efficiency of potato cultivar Marfuna in order to develop the crop water production function.

MATERIALS AND METHODS

Potato (*Solanum tuberosum* L.) cultivar Marfuna was used as experimental material during 2004, 2005 and 2006 from June to October at the Agricultural Research Station of

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Table I. Potato yield (t) from water stress treatments in cropping years

	2004	2005	2006	Average
Control	23.47±0.87a	28.05±0.48a	28.89±0.86a	26.81±2.61
W1	25.00±1.44ab	29.31±0.24a	30.83±0.41b	28.38±2.73
W2	26.11±1.20b	31.39±1.34b	33.33±1.10c	30.28±3.40
W3	23.71±0.68a	29.03±1.05a	29.86±0.64ab	27.53±2.97
Mean	24.75±1.45*	29.44±1.48	30.73±1.85	28.25±5.77

*Figures in the Table are mean± standard deviation

Table II. Potato water use efficiency (kg m^{-3}) under water stress condition in cropping years

	2004	2005	2006
Control	1.96±0.07a	2.21±0.03a	2.54±0.08a
W1	2.14±0.12b	2.46±0.02b	2.89±0.03b
W2	2.35±0.11c	2.83±0.12c	3.40±0.11c
W3	2.26±0.07bc	2.82±0.10c	3.31±0.07c
Mean	2.18±0.17*	2.58±0.28	3.03±0.36

*Figures in the Table are mean± standard deviation

Table III. Increase in water use efficiency (%) from water stress condition in cropping years

	2004	2005	2006
W1	8.31±3.60 a	10.28±1.23a	11.99±2.16a
W2	16.66±2.72b	21.78±4.51b	25.02±1.03b
W3	13.40±2.07ab	21.45±3.87b	22.99±1.39b
Mean	12.79±4.41	17.83±6.43	19.99±6.23

Ekbatan, Iran (34º 52´ N, 48º 32´ E; elev. 1730 m). Experimental soil was loam with average bulk density of 1.49 g cm^{-3} and moisture at filed capacity and wilting point were 21 and 9.6%, respectively. In year 2004, 2005 and 2006; the mean air temperature were 20, 20.5 and 21°C, mean relative humidity were 43, 41 and 38% and mean rainfall were 90, 31 and 17 mm during potato growing season, respectively. Cumulative evapo-transpiration (ET) and irrigation water requirement (IWR) of potato during growing season from 20 April to 12 October for long-term period were respectively 716 and 664 mm for Ekbatan climate condition (Farshi *et al.*, 1997).

Experiment was planted on April 30 during all the three years using seeding rate of 2000 kg ha^{-1} in 75 cm spaced rows with net plot size of 6 m× 4.5 m Fertilizers N, P and K were applied at 400 kg ha^{-1}each. To prevent any possible water deficit stress during the vegetative stage, irrigation was applied at 12, 21 and 29 days after sowing. The first, second and third irrigation were applied at 12, 21 and 29 days after sowing. Early-season water stress treatment combinations comprised four levels for the fourth irrigation events at 36 (control which was 7 days after third irrigation), 44 (W1), 51 (W2) and 59 (W3) days after sowing. After fourth irrigation, all plots were irrigated at 7 days interval. Irrigation scheduling is given in Fig. 1. Amount of irrigation water was measured at the entrance of each furrow by a connected-flow-meter to a siphon and at the end of furrow by Washington State College (WSC) flume. At maturity, potato was harvested for tuber yield.

Potato water use efficiency (kg m^{-3}) was estimated as tuber yield per total water applied. Similarly, WUE increase (WUEI) in percent from plots under stress relative to control condition was estimated as:

$$WUEI\ (\%) = 100\ (1-(WUET/WUEF)) \quad (1)$$

Where, WUET and WUEF are potato water use efficiency from plots under stress and from control plot in kg m^{-3}, respectively.

The experimental data were analyzed statistically by analysis of variance techniques and the means were compared by Duncan's multiple range tests. The least squares procedure was applied for develop the crop water production function.

RESULTS AND DISCUSSION

Analysis of meteorological factors. Meteorological factors including air temperature, rainfall and relative humidity over three years of 2004, 2005 and 2006 were shown in Fig. 2. Range of air temperature was from 16 (May) to 24°C (July), rainfall was from 2.2 (September) to 21.1 mm (May) and relative humidity was from 37.7 (July) to 46.8% (May) over three years.

Early-season water stress effects on potato yield. The effect of early-season water stress on potato yield was significant in the three consecutive years ($p \leq 0.05$). In general, W2 and control treatments produced the highest and lowest treatments in all the three years (Table I). The highest yield was obtained from W2 treatments during all the years (Fig. 3). It seems the initial vegetative stage is not sensitive to water stress. This finding is in accordance with Doorenbos and Kassam (1979) and Wright and Stark (1990) who reported that water stress can be tolerated during early vegetative growth stage. The control condition produced the lowest yield with average of 26.80 t in all the three years (Fig. 3). It seems that excessive water application of water decreased the tuber yield (Wright & Stark, 1990).

Results also indicated that yield by W3 and W1 was similar (Fig. 3). In other words, application of fourth irrigation at the 44 and 59 days after sowing produced statistically identical yield.

Early-season water stress effects on Potato water use efficiencies. Water use efficiency of potato cv. Marfuna was affected by Early-season stress and non-stress conditions in all and over the three consecutive years ($p \leq 0.01$). The average of WUE was 2.60 kg m^{-3} and the range going from 1.96 to 3.40 kg m^{-3} were obtained from applying control treatment in 2004 and applying W2 in 2006, respectively (Table II). This finding is inconsistent with those of Kiziloglu *et al.* (2006) and Nagaz *et al.* (2007), who reported that the range of WUE was from 44.1 to 63.4 kg ha^{-1} mm^{-1} and from 8 to 14 kg m^{-3}, respectively. The highest WUE value was obtained from W2 treatment with average of 2.79 kg m^{-3} for three years (Fig. 4).

Fig. 1. Irrigation events for experimental plots based on days after sowing

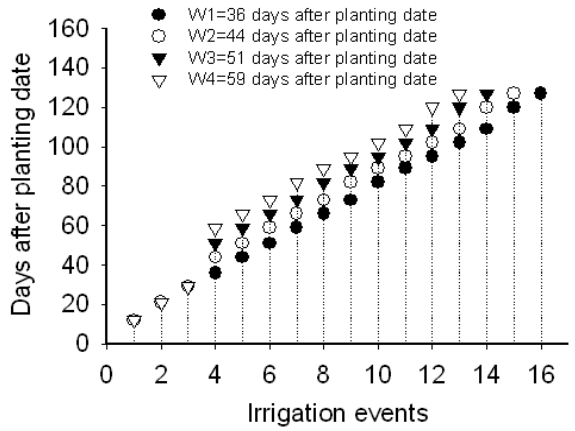
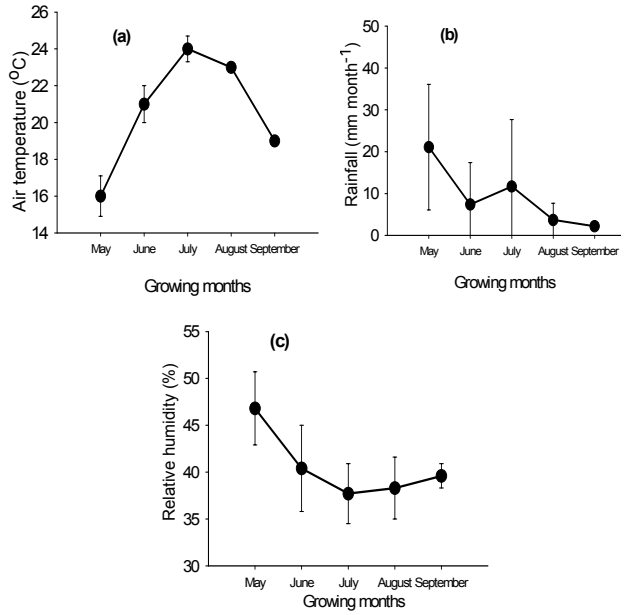


Fig. 2. Air temperature (a), rainfall (b) and relative humidity (c) over years of 2004, 2005 and 2006 as mean± standard deviation



In general, application of fourth irrigation at the 36 days after sowing produced the lowest WUE with average 2.24 kg m^{-3} for three cropping years (Fig. 4). Since initial vegetative stage of potato cv. Marfuna was not sensitive to water deficit stress, it did not decrease in potato yield. Therefore, applying decreased-water in the W2 plots increased water use efficiency. Also, control treatment decreased in WUE. Over the three cropping years, produced-WUE by applying irrigation after 51 and 59 days after sowing, were statistically identical (Fig. 4).

Increase in water use efficiency (%) was estimated by Eq. 1 for all plots (Table III). In general, increase in WUE averaged 16.87% over three years. The highest and lowest increase in WUE was produced by the application of W2

Fig. 3. Tuber yield ± standard deviation from water stress treatments over three years

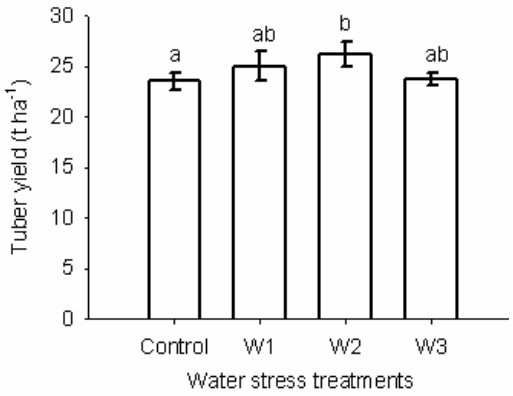
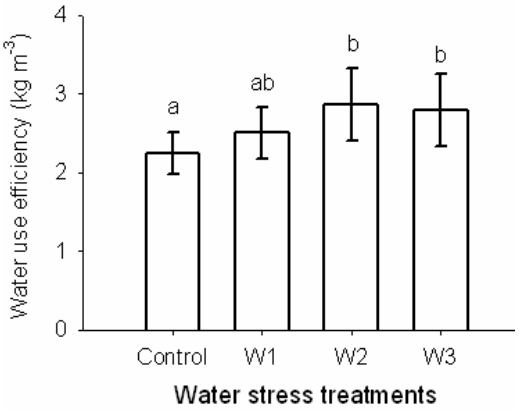


Fig. 4. Water use efficiency ± standard deviation under water stress condition over three years



and W1 treatments, respectively (Fig. 5). The produced values by W2 and W3 were statistically similar at the 95% confidence level. Therefore, based on water use efficiency values, it is recommended that potato cv. Marfuna should be irrigated within 59 days after sowing to achieve the optimum water use efficiency.

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

$$PMY=6.46\ (\pm 0.95)\ AW-0.0003\ (\pm 0.00008)\ AW^2 \quad n=12 \quad R^2=0.99 \qquad (2)$$

The fitted model explains about 99% of the variability in the yield by applied water. This model is quadratic, which not being consistence with those of Shock and Feibert (2002), who reported that yield linearly varied with applied water under deficit irrigation condition. The highest yield (=29700 kg) was obtained with the application of water @ 9031 m^3. The measured and predicted yields with upper and lower limits for predictions at the 95% confidence level are shown in Fig. 6 being good agreements between them.

Fig. 5. Increase in Water use efficiency (%) from water stress relative to control condition over three years

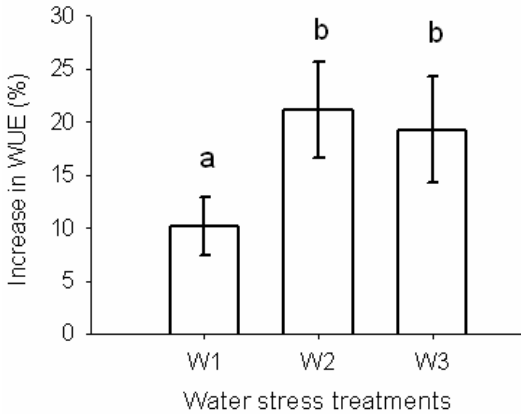
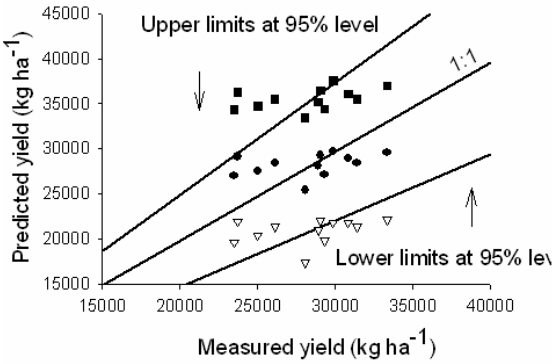


Fig. 6. Measured and predicted yield of potato cv. Marfuna



CONCLUSION

Over-irrigation with water decreases yield. To relate tuber yield to water applied, a water production function was developed by multiple regression analysis. Based on water use efficiency values, it is recommended that potato cv. Marfuna should be irrigated 59 days after sowing to achieve the optimum water use efficiency.

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