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Responses of potato genotypes to limited irrigation

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Abstract

In order to evaluate the responses of potato genotypes to different irrigation treatments, an experiment was carried out as split-plot based on randomized complete block design with three replications at the Research Center of Ardabil Agricultural and Natural Resources, Ardabil, Iran in 2013. Irrigation treatments were assigned to main plots and three Potato genotypes were allocated to the sub plots. The potato genotypes traits such as tuber yield, relative water content, starch content, chlorophyll (a), chlorophyll (b), chlorophyll (a+b), and carotenoid were assessed under both well-watered and deficit irrigation conditions. Results showed that limited irrigation reduced plant tuber yield to17.7% compared with common cultivar. The Clone 97-2 gave the highest tuber yield, chlorophyll (a+b) and carrotenoid content at 80% irrigation treatment. Therefore, some genotypes of potato are more suited for planting in Ardabil region. It was concluded that using clone 97-2 genotype in this region would be an advantage for farmers.

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Introduction

Potato (*Solanum tuberosum* L.) is grown and eaten in many countries more than some other crops (Stephen, 1999). It is a crop that grows mainly in climates with cool temperate and full sunlight, moderate daily temperatures and cool nights. Short days generally induce tubers in potatoes, although, many modern cultivars can initiate tuberization in the long days of North regions temperate (Tarn *et al.*, 1992). The potato is a starchy, tuberous crop from the perennial Solanum tuberosum of the Solanaceae family (also known as the nightshades). Potatoes are the world's fourth largest food crop, following rice, wheat, and maize. The United Nations FAO reports that the world production of potatoes in 2009 was 315 million tonnes. (FAO, 2010). Potato is one of the main crops in Iran where it's production is about 5.6 million tons, harvested from 186000 ha (FAO, 2010). Iran is the 12th potato producer in the world and the third biggest producer in Asia, after China and India (FAO, 2008). Water is the most important compounds in an active plant and constitutes more than 80% of the growing tissue. Because it is essential for most plant functions, the amount of water applied during irrigation, the time and method of water application are important in plant health and yield (Ati *et al.*, 2012). Early studies have shown that water deficit is a very important limiting factor for potato production, which reduced tuber quality and yield. Because of potato susceptibility to drought (Hassanpanah *et al.*, 2008) preparing sufficient water is very important for increasing potato quality and quantity and it is possible to increase production levels by well-scheduled irrigation programs throughout the growing season (Deblonde & Ledent, 2001, Faberio *et al.*, 2001, Ferreira & Carr, 2002, Kashyap & Panda, 2003, Onder *et al.*, 2005, Erdem *et al.*, 2006). Potato has a relatively shallow root zone and a lower tolerance for water stress than most other crops. Therefore Potato is sensitive to water deficit in soil and precise irrigation management is necessary to obtain optimum yield and quality. Irrigation scheduling involves determining the correct timing and amount of water necessary to maintain root zone moisture within the optimal range for crop growth. Irrigation uniformity is related to how evenly water is distributed over the field area (Stark *et al.*, 2006). Furrow irrigation method is the most common in Iran. Potato needs frequent-irrigation for a good growth and yield. Yield is considerably affected by storage quality, disease resistance, and the time, amount and frequency of irrigation (Bartoszuk, 1987). Irrigation regimens influenced tuber yield ($P < 0.05$), and the highest tuber yield was registered for 30% irrigation regimen, reaching 35.13 t ha^{-1} in 2003, and 44.56 t ha-1 in 2005 (Erdem *et al*; 2006). Heuer and Nadler (1995) reported that plant height, leaf area and fresh weight accumulation were significantly affected by the salinity and moisture treatments. Water deficit decreased number of leaves, leaf area, plant height, tuber number, growth and yield, canopy radiation interception, harvest index, root, leaf weight, root number, root dry weight (Donnelly *et al.*, 2003) and tuber yield (Hassanpanah, 2009). The extent of the damage to tuber yield and quality will depend upon the severity, timing, and duration of water stress during the growing season. Several studies have shown that water stress during the tuber set and early bulking growth stages causes the greatest reductions in tuber yield and quality relative to other growth stages. Water deficits spread over the latter part of the growing season generally have less impact on tuber yield and quality than an equivalent reduction in crop water use over a shorter period of time. If possible, potatoes should be grown on fields that have the greatest potential for maintaining adequate soil moisture under deficit irrigation management. Coarse-textured soils such as sands and sandy loams have low water-holding capacities and will lead to rapid development of water stress under deficit irrigation. In comparison, soils with relatively high water-holding capacities, such as loams and silt loams, allow water stress to develop at a slower rate, reducing its impact on yield and quality. Variety choice can be an important tool in order to avoidance or tolerance of drought stress. Potato varieties vary widely in maturity and in ability to withstand water stress. Planting an early maturing variety can help a grower avoid crop damage resulting from a late-season loss of water supply (Stark *et al.,* 2006).

Climatic changes were occurred in Ardabil region at the recent years and there is water deficit problem in this region. These changes caused differences in precipitation dispersion, river flowing and wells water. It is very necessary to study about tolerance of different potato cultivars against water deficit stress and determination of potato water consumption in Ardabil. Therefore, we have to identify agronomic characters of new potato cultivars and more improvement of their quality and quantity. This study was conducted to evaluate the different potato genotypes responses to water deficit to introduce the cultivar for the regions with water deficit.

Materials and methods

Site description and experimental design

This research was conducted in Research Center of Ardabil Agricultural and Natural Resources where located in the north-west of Iran (Lat 38°, 15' W; Long 48°, 15' E and elevation 1352 m) in 2013. Mean 30-year rainfall average is 275 mm and 14.6°C temperature. Some climatic parameters of the experimental region during growth period are presented in table1. According to table1, average temperature and total rainfall values during growth period (April-September) were 15° and 139.2 mm, respectively. According to soil analysis carried out prior to sowing, the soil texture was a clay-loam with field capacity (FC) = 29.1%, permanent wilting point (PWP)= 14.6%, electrical conductivity (EC) = 1.2 ds/m, pH = 7.8, organic carbon (O.C) (%) = 0.803, soil P2O5= 14 ppm, K2O= 540 ppm N = 0.1, and the volume weight of the soil was 1.29 g/cm3. Selected, pre-sprouted potato tubers were transplanted manually, at a depth of 10-12 cm on April 10, 2013, and harvested on August 15, 2013. Fertilizer applications were based on soil test data, including 60 kg ha-1 N and 50 kg ha-1 P2O5 was utilized. Herbicides and insecticides were applied to each plot when necessary. The preceding crop was wheat last year. The experiment was carried out in a split-plot design arrangement based on complete block design, with three replications. Three furrow irrigation regimes was as main plots (I_1=full irrigation, I_2= 0.8 I_1 and I_3= 0.6 I_1) and three Potato genotypes as subplots (B_1= Clone 82-10, B_2= Clone 97-2 and B_3= Agria cultivar). Therefore I_2 and I_3 have been considered as moderate and severe stress respectively. Water applied by fallow equation:

I_1= 0.8x (EP) x (A) Which:

A: Plot area (m^2)

EP: Evaporation from evaporation pan (mm).

When evaporation was received 28 mm via evaporation pan, it was irrigation time. Agria cultivar is a common genotype in Ardabil region and other studied genotypes have not been identified as cultivar and research programs are continuing yet. Water requirement was supplied by a counter which set in the field (Figure 1). Experimental plots measured 20 m^2 (4 × 5) and contained 120 plants spaced 0.75 × 0.25. Plots were separated 3 m from each other.

Measurement of traits

The traits such as tuber yield, starch content (%), chlorophyll (a), chlorophyll (b), chlorophyll (a.b), and carrotenoid were measured (figure 2). Chlorophyll and carrotenoid were determined as followed (Arnon, 1994):

Cchlo. (a) = 0.0127xA_{663} – 0.00269A_{645}

Cchlo. (b) = 0.0229xA_{645} - 0.00468xA_{663}

Cchlo(a+b) = 0.0202xA_{645}+0.00802xA_{663}

Ccarrotenoid (mg/g.f.w) = 0.0076xA_{480}-0.00149xA_{510}

Where: A_{663}= light absorption of sample at 663n.m length wave

C chlo. = chlorophyll concentration (mg/g.f.w)

Statistical analysis

Statistical analysis of the data based on split-plot design was performed using MSTAT-C software. Least significant differences test was applied to compare means of each trait at the 1% probability level.

Results and discussion

According to the results showed, irrigation treatments significantly affected tuber yield, relative water content(RWC), chlorophyll (a), chlorophyll (a+b) and carotenoid at 1% probability level and starch content (%) and chlorophyll (b) at 5% probability level. High significant genotypic differences were observed in tuber yield, starch content (%), chlorophyll (a) and chlorophyll (a+b), but genotypes had no effect on relative water content, chlorophyll (b) and carotenoid. Interaction between Irrigation and genotypes affected tuber yield, starch content, relative water content (RWC), chlorophyll (a) and carotenoid, but chlorophyll (b) and chlorophyll (a+b) did not affect significantly by interaction A×B (table 2).

Table 1. Some climatic parameters of the experimental region.

Parameters	April	Months May	June	July	August	September
Rainfall (mm)	10.7	48.1	57.3	0.7	16.0	6.4
Mean Temperature(°c)	9.6	11.2	16.1	17.5	17.3	18.3
Humidity (%)	64	66	67	64	71	68
Sum of sunlight (hr)	214.5	247	280.1	346.9	253.9	275.0

Table 2. Analysis of variance for selected parameters of potato affected by different irrigation and genotypes treatments.

S.V	d.f	M.S Yield	RWC	Starch	Chlrophyll (a)	Chlrophyll (b)	Chlrophyll(a+b)	Carrotenoid
Replication	2	1022.26	3.529	1.21	0.001	0.005	0.007	0.000
Factor A	2	52121.17 **	412.0 **	3.34 *	0.115 **	0.060 *	0.339 **	0.048 **
Error	4	477.28	0.847	0.42	0.000	0.005	0.006	0.001
Factor B	2	47117.19 **	8.69 n.s	7.35 **	0.008 **	0.001 ns	0.013 **	0.000 ns
AB	4	5166.30 *	22.31 **	2.20 **	0.002 **	0.003 ns	0.005 ns	0.001 *
Error	12	1205.07	4.184	0.240	0.001	0.003	0.002	0.0001

Ns: Non significant; ** and *: significant at 0.01 and 0.05 probability level, respectively.

Table 3. Effects of different irrigation treatments and genotypes on selected parameters of potato.

		Yield (gr)	*RWC (%)*	*Starch (%)*	*Chlrophyll(a)*	*Chlrophyll(b)*	*Chlrophyll(a+b)*	*Carrotenoid*
Irrigation	A_1	754.3 A	82.45 A	17.43 B	0.919 B	0.350 A	1.268 A	0.461 B
	A_2	737.4 A	79.99 A	17.58 B	0.949 A	0.336 A	1.285 A	0.501 A
	A_3	640.8 B	69.70 B	18.56 A	0.739 C	0.202 B	0.941 B	0.359 C
Genotype	82-10 (B_1)	682.9 B	75.63 A	18.53 A	0.834 B	0.286 A	1.12 B	0.434 A
	97-2 (B_2)	845.7 A	78.03 A	18.22 A	0.892 A	0.297 A	1.189 A	0.442 A
	Agria (B_3)	603.9 B	75.74 A	16.83 B	0.880 A	0.305 A	1.185 A	0.447 A

Numbers in the columns followed by the same letters are not significantly different at $P < 0.01$ or 0.05.

Means Comparison showed that limited irrigation (60% full irrigation) reduced plant tuber yield from 754.3 to 640.8 gr (17.7%). Losses in potato yield in response to limited irrigation were in agreement with Cappaert *et al.* (1992), Donnelly *et al.* (2003), Eldredge *et al.* (1992), Tourneux *et al.* (2003), Stark and McCann (1992) and Hassanpanah (2009). Although water stress reduced tuber yield, but there is not significant differrence between 20 % water stress (0.8 irrigation) and full Irrigation. Therefor moderate water sress can be useful for potato production without yield losses. Eskandari *et al.* (2011) reported that agria cultivar can tolerate water deficit (0.7 full irrigaion) without yield losses before tuber initiation. Clone 97-2 had the highest tuber yield among genoypes. Potato genotypes significantly differ in tolerance to water deficit and 97-2 clone had the highest tuber yield (table 2). Jefferies (1993) reported that potato genotypes have different tolerance to water stress. There was no significant difference between Agria and 82-10 genotype for tuber yield. Relative water content decreased by water stress. full irrigation and Moderate water stress afected RWC samely but severe water stress (40% stress) decreased

RWC from 82.4 to 69.7%. There was no significant diferrneces for RWC, chlorophyll (b) and carrotenoid amoung genotypes. Tuber starch content (%) increased by water deficit. There was no significant difference between A_1 and A_2 irrigation regimes. Among genotypes, two advanced clones had higher starch content compared with agria cultivar. Chlorophyll content (mg/g.f.w) decreased at 60% irrigation (40% stress) and the highest level observed in 97-2 clone (figure 3). The highest carrotenoid content belongs to 80% applied water and it is decreased significantly at 60% applied water (table 3). Interaction effect of irrigation and genotypes showed that the highest tuber yield obtained by 97-2 clone at full irrigation. Jefferies and MacKerron (1993) have found strong potato-genotype × water-stress interactions. The highest starch content obtained with 82-10 and 97-2 clones at 60% full irrigation. Agria cultivar had the lowest starch content under 60% irrigation. Clone 97-2 had the highest chlorophyll (a), chlorophyll (b), chlorophyll (a+b) and carotenoid content at 80% full irrigation (table 4). In other hand, clone 97-2 had an advantage in all studied adjectives. Therefore it is necessary to study ecological and agronomic requirements of 97-2 clone as new cultivar in Ardabil region.

Table 4. Interaction effect of irrigation and genotypes on selected parameters of potato.

		Yield (gr)	*RWC (%)*	*Starch (%)*	*Chlrophyll(a)*	*Chlrophyll(b)*	*Chlrophyll(a+b)*	*Carrotenoid*
A_1	82-10 (B_1)	629.1 ^{E}	82.64 ^{A}	17.70 ^{B}	0.894 ^{B}	0.333 ^{ABC}	1.226 ^{C}	0.464 ^{B}
	97-2 (B_2)	957.9 ^{A}	82.65 ^{A}	17.69 ^{B}	0.922 ^{AB}	0.327 ^{ABC}	1.249 ^{C}	0.450 ^{B}
	Agria (B_3)	675.8 ^{DE}	82.06 ^{AB}	16.91 ^{BC}	0.940 ^{AB}	0.389 ^{A}	1.329 ^{AB}	0.470 ^{B}
A_2	82-10 (B_1)	787.1 ^{C}	80.02 ^{BC}	17.93 ^{B}	0.929 ^{AB}	0.309 ^{ABCD}	1.1.238 ^{C}	0.472 ^{B}
	97-2 (B_2)	855.0 ^{B}	78.65 ^{C}	17.65 ^{B}	0.985 ^{A}	0.365 ^{A}	1.350 ^{A}	0.524 ^{A}
	Agria (B_3)	570.0 ^{F}	81.29 ^{AB}	17.17 ^{BC}	0.931 ^{AB}	0.336 ^{AB}	1.267 ^{BC}	0.507 ^{A}
A_3	82-10 (B_1)	632.5 ^{E}	68.57 ^{E}	19.95 ^{A}	0.680 ^{C}	0.217 ^{BCD}	0.896 ^{D}	0.365 ^{C}
	97-2 (B_2)	724.2 ^{D}	74.13 ^{D}	19.31 ^{A}	0.769 ^{C}	0.198 ^{CD}	0.967 ^{D}	0.351 ^{C}
	Agria (B_3)	565.8 ^{F}	66.39 ^{E}	16.41 ^{C}	0.769 ^{C}	0.190 ^{D}	0.959 ^{D}	0.363 ^{C}

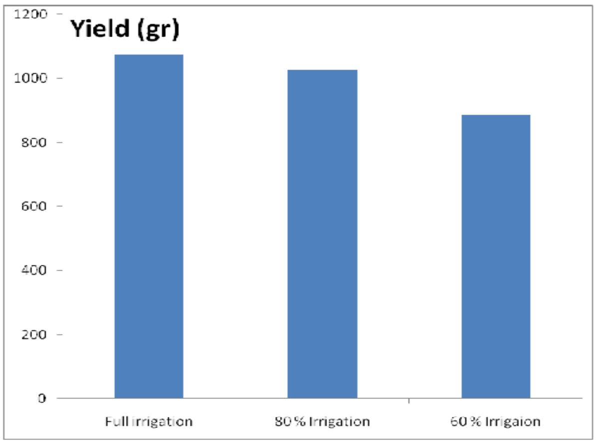
Numbers in the columns followed by the same letters are not significantly different at $P < 0.01$ or 0.05.

Table 5. Correlation coefficients between selected parameters of potato affected by irrigation and genotype treatments.

	Yield	*Chlorophyll(a)*	*Chlorophyll(b)*	*Chlorophyll(a+b)*	*Carrotenoid*
Yield	1.00				
Chlorophyll(a)	0.585**	1.00			
Chlorophyll(b)	0.495*	0.706**	1.00		
Chlorophyll(a+b)	0.588**	0.934**	0.912**	1.00	
Carrotenoid	0.491*	0.879**	0.754**	0.888**	1.00

Fig. 1. Counter and Siphons in the field.

Fig. 2. Leaf extract for chlorophyll and carotenoid measurement.



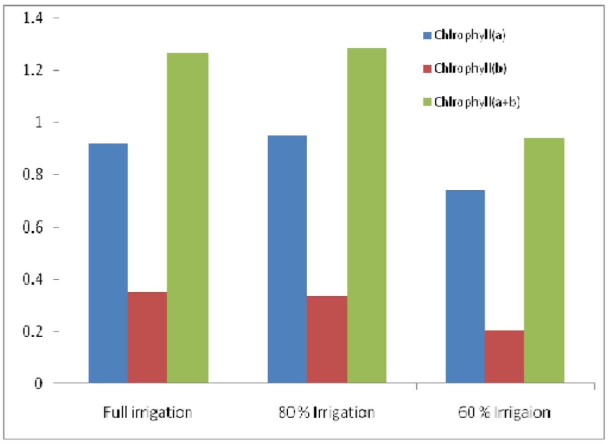


Fig. 3. Effect of different irrigation treatments on Chlorophyll content of potato.

Correlation coefficients are presented in table 5. According to table5, there were positive relationship between yield and chlorophyll-carrotenoid. The highest correlation with yield related to chlorophyll (a+b) and carrotenoid had the lowest correlation with yield.

Conclusions

Although severe water stress (0.6 irrigation) reduced significantly tuber yield and amounts of other physiological traits, but effect of moderate stress (0.8 Irrigation) on physiological traits that strongly correlated with plant productions, such as RWC, chlorophyll(a), chlorophyll (a+b) and tuber yield , was not significant. Therefore it is recommend to study the ecological and agronomic requirements of 97-2 clone as a new cultivar in Ardabil regions and similar climates.

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