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Determining effects of irrigation stress on growth and yield of potato cultivars in Ardabil cold region

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Abstract

To determine effects of irrigation stress on growth and yield of experimental potato cultivars, 6 potato cultivars were studied in Ardabil Agricultural Research Station. To perform test, split plot statistical design based on Completely Randomized design was used in three replicates. In this test, water stress was applied with increasing irrigation distance during growth of the plant. Factor of irrigation interval with three levels i.e. stress-free (irrigation every 6 days), medium stress (irrigation every 12 days), and high stress (irrigation every 18 days) was included in main plots and factor of potato cultivars was included in 6 levels in subplots. In this research, traits of the number of day until emergency, the number of day until tuberization, the number of day until flowering, height of plant, number of main stem, diameter of main stem, number of tuber per plant, weight of tuber per plant and yield of the plant were studied. Results of ANOVA showed that there was significant difference among all of the studied traits but number of day until tuberization in terms of irrigation levels and cultivars. Serenade and agria cultivars produced the highest mean yields of tuber with 28.78 and 28.28 tons per hectare and draga cultivar produced the lowest mean yields of tuber with 24.41 tons per hectare. Potato cultivars with different irrigation periods in terms of plant height, number of man stem, and number of tuber per plant, weight of tuber per plant and yield of tuber showed interaction. This shows that difference of cultivars in different irrigation periods was not equal.

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Introduction

Considering growing increase of population and need for food on the one hand and necessity of maximum utilization of the limited production sources on the other hand requires extensive and multilateral studies on all crops particularly the crops which play more role in fulfillment of this food requirement (Khajepour, 1994 and Babaei, 1996). Potato is also one of the important crops which have been recognized as a main and valuable food like wheat, rice and corn and plays important role in human nutrition in terms of food security of the country (Babaei, 1996 and Karimian *et al*, 1994). This plant is one of the strategic products and is of special importance in protein of tubers, having necessary amino acids in protein, vitamins and minerals (Khodadadi and Masiha, 1996 and Malakoti and Tabatabaei, 1998). Potato is in the fourth place after wheat, rice and corn in terms of cultivated surface and production in the world. This crop is widely distributed in the world after corn and about 140 countries of the world are cultivated (Khodadadi and Masiha, 1996 and Rezai and Soltani, 1996).

Cultivated surface of potato in the world is about 19 million hectares and its global production is more than 300 million tons. Average production in surface unit (hectare) is about 16 tons. The reason for low global average production rate of this crop in the countries of tropical regions is undesirable climate and low technology in which yield of potato is low. The most important countries which produce potato in terms of production rate are china, India , the Netherlands, Belgium , America, Germany, Denmark, and England (FAO, 2011). Production rate of potato in the country has been estimated to be about 4.02 million tons . Ardabil Province with more than 800000 tons of potato has gained the second rank. Six provinces of Hamedan, Ardabil, Kordestan, Isfahan, Zanjan and East Azarbayejan have gained totally 69.91% of potato production rate in the county. Irrigation is one of the most important ways of increasing quality yield of vegetables which is not only important in arid and semiarid regions but also for humid regions. Generally, the vegetables which are cultivated due to their branch and leaf need a uniform humidity during their growth while those which are cultured due to their fruit and seed need high water amount at time of formation and growth of fruit (Mobli and Piraste, 1998). It is not possible to achieve suitable yield and use other inputs optimally such as machinery, fertilizer, poisons and all agricultural operations which play role in production without providing enough humidity (Akbari and Mortazavi, 1998). Since most points of our country are located in arid and semiarid regions and have limited water resources, water is the first and the most important factor of limitation in increase of agricultural products particularly in potato. It is also predicted that climate changes will heat the air in future and as a result, water need if plants increases and use of water resources is limited more (Farshi, 1995). Water shortage is one of the most common types of stress in potato agriculture (Mosavi Fazl, 1998) and is one of the important factors of decreasing yield. Since potato is sensitive to water stress (Foti *et al*, 1995; Harris, 1987 and Harris, 1992). Provision of enough irrigation water is regarded as one of the important ways of increasing quality and quantity of potato. Based on research by Harris (1992) and Struik and Voorst (1986), soil water content should not be less than 50% of maximum accessible water in the root to obtain high yield in potato. Provision of enough water after formation of tuber increases tuber size per plant (Harris, 1987). Water stress during germination decreases yield (Babaei and Ghafari, 1994; Akbari and Mortazavi, 1998 and Steyn *et al*, 1993) and number of tuber in plant of some cultivars (Struik and Voorst, 1986). Intensive drought stress along with high temperature particularly in early tuber growth period when soil is not covered with branch and leaf can cause secondary growth (Rezai and Soltani, 1996). Drought stress reduces area of leaf and average weight of tuber (Fasan and Havekort, 1991). Researches by Shock *et al*, (1992) show that if plants are exposed to hydraulic stress condition before tuberization, their quality will

be improved at time of harvesting and low tubers with end of dark brown stem will be observed.

Reduction of yield caused by water stress is affected by genotype, intensity of stress and germination stage of plant. Generally, the cultivars which have lower compatibility with water stress and produce higher yield under desirable condition are intensively damaged under different stresses. Therefore, effect of water shortage on growth of different parts of potato plants which play role in formation of yield should be specified in regions such as Ardabil where water stress is high during growth period due to shortage of agricultural water and compulsory application of water stress on the plant to use some cultivars which are more stable during high productivity and can keep their high quality and quantity when confronting with water stress. Cultivation of such cultivars is the guaranteed cultivar for farmer to obtain more reliable crop when confronting with water stress.

Considering the above facts, goal of this research is to study effect of irrigation stress on growth and yield of potato cultivars.

Materials and methods

Location of testing

The study was carried out in Ardabil Agricultural Research Station located at Alaroq a village at 12 km south of Ardabil. The location was a semi-arid and cold climate that in winter is often below zero. Region has a long dry season, especially in summer. Altitude is reported 1350 m, latitude and longitude, respectively 20' 48 ° and 15' 38°, the mean minimum, and maximum temperatures were 1.98, 15.8 and 21.58 ° C and the precipitation annual average is 310.9 mm.

Herbal material

In this study, six potato varieties with medium to late maturity were used. Agria and Draga as the control varieties of the region with Diament, Cosima, Serenad and Asterix, which had nearly the same growth period were evaluated in this experiment. The varieties l was prepared from agricultural research station of Ardabil.

How to perform the experiment

This test was performed to study indices of drought toleration in cultivars as split plots test based on Completely Randomized blocks in three replicates. In this research, main factor of irrigation interval (A1: every 6 days and A2: every 12 days and A3: every 18 days) was included in main plots and sub factor of potato cultivars was included in six levels in subplots. Cultivation was performed on the ground which was in fallow in the previous year. To prepare the desired ground, subsoil was performed in fall and 110 kg/hectare of the phosphorous fertilizer and 55 kg/hectare of potas fertilizer were mixed with soil. In April, furrows were created with furrower and half of the nitrogen fertilizer i.e. 55 kg/hectare was tested as topdress fertilizer concurrently with cultivation in 3 May after surface and ground leveling. Area of each plot was 15 m^2 and each plot included 4 rows of cultivation with length of 5 m, distance of rows was 75 cm and distance between tubers on cultivation rows was 25 cm. To start germination after cultivation, all plots were irrigated. It is necessary to note that fertilization rate was determined according to the procedure and based on soil tests in the station. After cultivation during agricultural season, the grasses were removed manually in four intervals. Earthling up operations was performed concurrently with weeds control. When height of plant reached 20 cm (45 days after cultivation), another half of chemical fertilizer which is 55 kg/hectare was given to the ground. Plots were irrigated equally to hot spot of water. In this research, traits of the number of day until emergency, the number of day until tuberization, the number of day until flowering, height of plant, number of main stem, diameter of main stem, number of tuber per plant, weight of tuber per plant and yield of the plant were studied.

Statistical calculations

For analysis of variance of the measured traits, mean of the data obtained from each plot was used and comparisons of mean irrigation interval were made

based on LSD test and there was comparison between mean cultivars and interaction of irrigation interval ×cultivars based on Duncan test. To perform statistical computations, MSTATC, SPSS-18 and Excel computer software was used to draw diagrams and tables.

Results and discussion

ANOVA of the studied traits showed that there was significant difference among all of the studied traits but number of day to tuberization in terms of different irrigation levels and cultivars. Interaction of cultivars × irrigation interval was observed only in terms of traits of plant height , number of main stem, diameter of main stem, number of tuber per plant , weight of tuber per plant and yield of the plant were studied. This showed that difference of cultivars was equal in different irrigation intervals.

Number of day to flowering

Mean of different irrigation levels (Table 2) is suspended every 18 days compared with irrigation evrry 6 days for 4.2 days of flowering in potato cultivars. Suspension of flowerring in potato cultivars due to water stress can be related to lack of timely growing season. This result is in line with findings of Necas (1962). Comparison of mean cultivars showed that (Table 3) Serenade and agria cultivars had the highest number of day and Asterix and Cosima cultivars had the lowest number to flowering.

Plant height

ANOVA of plant height shows that effect of different levels of irrigation on plant height is significant in probability level of 1% (Table 1) and plant height was reduced with increasing irrigation stress so that plant height was 53.1 cm every 6 days in irrigation and it reached 43.9 cm through irrigation every 18 days (Table 2). Potato cultivars had significant difference in plant height in probability level of 1% (Table 1). Table of mean plant height (Table 3) shows that the highest plant height is related to Cosima cultivar (55.9 cm) and the lowest plant height is related to Draga cultivar (42.8cm). Interaction of irrigation interval × cultivars on plant height is shown in Diagram 1. As you see, plant height is the highest in stress-free condition and the lowest in medium and high stress condition. In general, growth of all the studied cultivars was reduced in terms of plant height due to water stress but plant height in Agria cultivar has no significant difference every 6 and 12 days. In Cosima cultivar, there is no significant difference between irrigation every 12 days and every 18 days.

Main stem number

Effect of different irrigation levels on main stem number is significant in probability level of 1% (Table 1) and main stem number was reduced with increasing irrigation stress so that mean of main stem number was 5.39 in irrigation every 6 days which reached 4.96 by applying water stress in irrigation interval every 12 days and 4.54 in irrigation every 18 days (Table 2). Karafylidis *et al*, (1996) declared that water stress in the early growth period decreased main stem number in plant, which is in line with results of this test. Potato cultivars had significant difference in terms of plant height in probability level of 1 % (Table 1). This result is similar to results of research by Adeli (1998). Table of mean plant height (Table 3) shows that Asterix and Cosima cultivars produced the highest main stem number (6.3, 5.6 and 5.2) and Diamante, Draga and Serenade cultivars produced the lowest main stem number (3.7, 4.5 and 4.6). As shown in diagram of interaction of irrigation interval ×cultivars (main stem number (Diagram 2). All cultivars reacted to water stress in terms of man stem number in plant so that main stem number has been reduced with increasing irrigation interval.

Main stem diameter

Main stem diameter is 9.848 mm in irrigation every 6 days, 9.632 mm in irrigation every 12 days and 8.824 mm in irrigation every 18 days (Table 2). Therefore, stress reduces main stem diameter. Serenade and Diamante cultivars have higher main stem diameter with inclusion in class A and Asterix, Cosima, Draga and Agria cultivars have lower main stem diameter with inclusion in class B (Table 3).

Yield of tuber

Effect of different irrigation levels on yield of tuber was significant in probability level of 1% (Table 1). Mean yield of tuber in cultivars was the highest during irrigation every 6 days and the lowest during irrigation every 18 days (Table 2). Mean yields of tuber in potato cultivars were 24.24, 25.63 and 18.22 tons /hectare in stress free, medium stress and high stress conditions (Table 2). Considering the above results, it is observed that irrigation stress reduced crop by 8.61 tons/hectare in medium stress condition compared with stress-free condition and 16.02 tons/hectare in high stress condition compared with stress-free condition and this figure considerably decreased. The obtained results in this research are in line with results of research by Martin *et al*, (1992), Babaei and Ghafari (1994), Akbari and Motazavi (1998) and Jefferies and Mackenson (1987). Serenade and Agria cultivars with tuber mean yields of 28.78 and 28.28 tons/hectare are among the productive cultivars and Draga cultivar with tuber mean yield of 24.41 tons/hectare is among the less productive cultivars (Table 3).

As shown in Diagram 3, all the studied potato cultivars have higher tuber yield in stress-free condition than medium and high stress condition. With increasing stress, tuber yield is reduced more in Agria and Diamante cultivars by 10.52 and 14.17 tons/hectare so that agria and Diamante cultivars had reduced yield by 10.52 and 14.17 tons/hectare during irrigation every 12 days compared with the control treatment (every 6 days) and with increasing stress during irrigation every 18 days, this reduced yield reached 19.6 and 18.63 tons/hectare. While yield of Asterix cultivar was reduced to 9.14 tons/ hectare in the same condition. Therefore, considering the obtained results, it can be mentioned that Asterix cultivar shows lower sensitivity compared with other cultivars and where we face water shortage; we should not use Agria and Diamante cultivars because their yield is considerably reduced due to water shortage.

Tuber number per plant

Means of tuber number per plant in irrigation levels every 6 days, every 12 days and every 18 days are 12.24, 11.11 and 10.41, respectively (Table 2). Therefore, it can be concluded that water stress reduces tuber number per plant. Akbari and Mortazavi (1998) and Struik and Voorst (1986) also achieved similar results in this field. Considering Table 3, Serenade, Cosima and Asterix cultivars with 12.44, 12.32 and 12.24 tubers had the highest mean number of tuber and Draga cultivar with 9.31 tubers had the lowest mean number of tuber per plant. Considering diagram of interaction of irrigation interval (Diagram 4) every 6 days, all cultivars had higher tuber number per plant. The studied cultivars during irrigation interval every 12 days produced more tubers compared with irrigation interval every 18 days but Draga cultivar didn't show significant difference in medium and high stresses in terms of tuber number per plant.

Tuber weight per plant

Effect of different irrigation level on tuber weight per plant is significant in probability level of 1% (Table 1). Mean weight of tuber per plant was considerably reduced during irrigation every 18 days and every 12 days compared with irrigation every 6 days (Table 2) and these values were 182.6 and 369.6 grams, respectively and these values are considerable. Mean weight of tuber per plant under irrigation condition every 6 days was 801.2 grams. Shock *et al*, (1992) and Miller and Martin (1984) also achieved such results. Agria and Serenade cultivars with tuber weights of 659.3 and 642.4 grams had the highest values and Draga and Cosima cultivars with 583.1 and 583.6 grams had the lowest values (Table 3). All of the studied cultivars had reduced weight of tuber due to application of irrigation stress but this problem was less significant in Asterix cultivar so that tuber weight was reduced only by 169.6 grams every 18 days compared with irrigation every 6 days but it reached the maximum value i.e. 471 grams in Agria cultivar (Diagram 5).

Table 1. ANOVA of the studied traits in different potato cultivars

S.O.V	df	Mean of Square			
		number of day to tuberization	Number of day to flowering	plant height	Main stem number
Rep	2	0.001^{ns}	0.667 ^{ns}	0.503 ^{ns}	0.014 *
irrigation interval (a)	2	50^{ns}	80.889 **	381.22 **	3.251 *
Error 1	4	0.001	0.889	1.085	0.002
Genotype (b)	5	68.4^{ns}	187.28 **	174.68 **	7.458 **
a × b	10	0.8^{ns}	1.933 ^{ns}	4.6 **	0.053 **
Error 2	30	0.001	1.815	0.851	0.006
C.V.%		1.12	1.88	1.91	1.62

* and ** Significantly at p < 0.05 and < 0.01, respectively.

Continue Table 1.

S.O.V	df	Mean of Square			
		Main stem diameter	yield of tuber	Tuber number per plant	Tuber weight per plant
Rep	2	0.442 ^{ns}	6.935 ^{ns}	0.106 ns	1113.57 ^{ns}
irrigation interval (a)	2	5.237 **	1157.42 **	15.408 **	614786.06 **
Error 1	4	0.069	4.506	0.104	2698.36
Genotype (b)	5	2.388 **	34.375 **	14.657 **	9257.82 **
a × b	10	0.579 ^{ns}	15.434 **	0.294 **	9238.54 **
Error 2	30	0.421	4.912	0.079	1621.34
C.V.%		6.88	8.51	2.49	6.52

* and ** Significantly at p < 0.05 and < 0.01, respectively.

Table 2. Mean of the evaluated traits of potato cultivars in different irrigation levels

irrigation levels	Traits													
	Number of day to flowering		plant height (cm)		Main stem number		Main stem diameter		yield of tuber (t/ha)		Tuber number per plant		Tuber weight per plant (gr)	
every 6 days	69.5	c	67.7	a	5.39	a	9.748	a	34.24	a	12.24	a	801.2	a
every 12 days	71.9	b	71.9	b	4.96	b	9.632	a	25.63	b	11.11	b	618.6	b
every 18 days	73.7	a	73.7	c	4.54	c	8.824	b	18.22	c	10.41	c	431.6	c

Differences between averages of each column which have common characters are not significant at probability level of 5%.

Table 3. Mean of the evaluated traits of potato cultivars

Genotype	Traits													
	Number of day to flowering		plant height		Main stem number		Main stem diameter		yield of tuber (t/ha)		Tuber number per plant		Tuber weight per plant (gr)	
Agria	75.9	b	49.1	b	5.2	c	9.28	b	28.28	a	10.5	b	659.3	a
Asterix	67.3	e	47.9	c	6.3	a	8.98	b	25	b	12.2	a	602.3	bc
Serenad	77.7	a	48.2	c	4.5	d	10.09	a	28.78	a	12.4	a	642.4	ab
Draga	72.8	c	42.8	e	4.5	d	9.16	b	24.41	b	9.3	c	583.1	c
Diamant	70.3	d	45.5	d	3.7	e	10.08	a	24.73	b	10.7	b	631.9	ab
Cosima	66.3	e	55.9	a	5.6	b	9.02	b	24.99	b	12.3	a	583.6	c

Differences between averages of each column which have common characters are not significant at probability level of 5%.

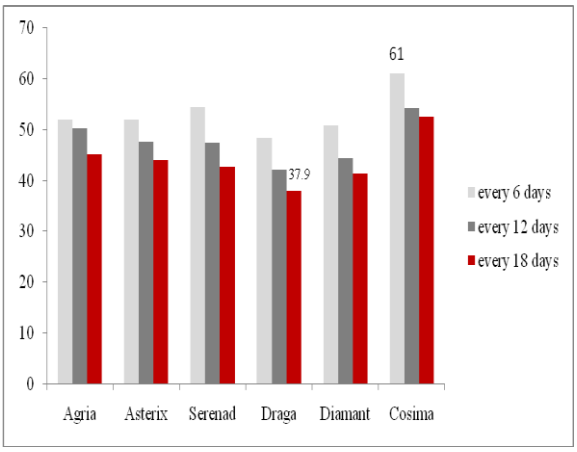

Diagram 1. Comparing mean plant height of potato cultivars in interaction of irrigation interval × cultivar

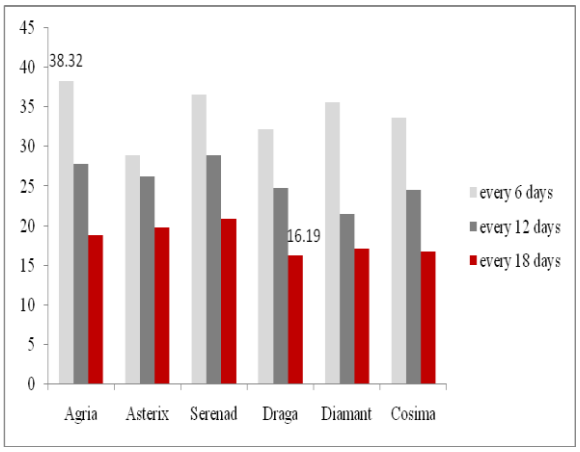

Diagram 3. Comparing mean yield of tuber in potato cultivars in interaction of irrigation interval × cultivar

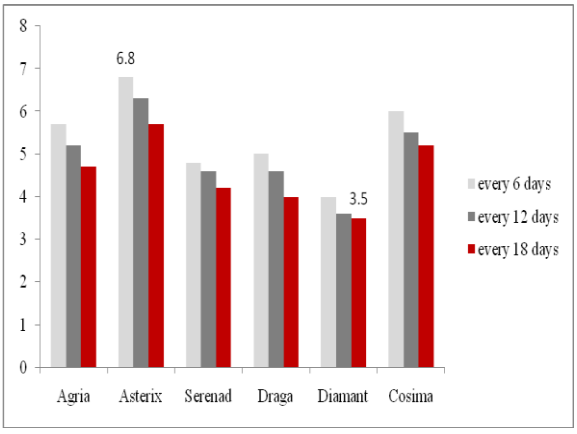

Diagram 2. Comparing mean number of main stem of potato cultivars in interaction of irrigation interval × cultivar

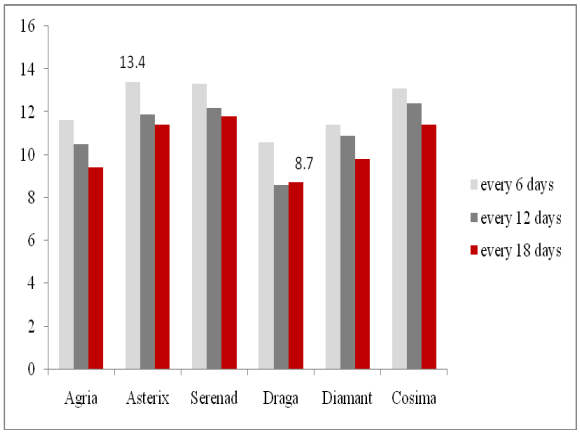

Diagram 4. Comparing mean number of tuber in potato cultivars in interaction of irrigation interval × cultivar

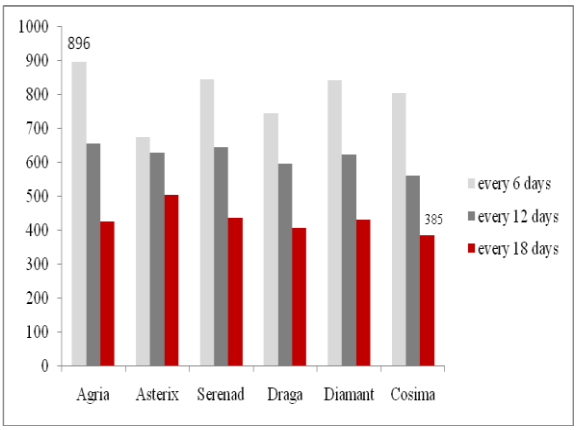

Diagram 5. Comparing mean weight of tuber in potato cultivars in interaction of irrigation interval × cultivar

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