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Effects of Water Deficit and Potassium Humate on Tuber Yield and Yield Component of Potato Cultivars in Ardabil Region, Iran

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Abstract: This experiment carried out on three potato cultivar [Agria (susceptible), Satina (semi-tolerant) and Ceaser (tolerant to water deficit)] and four irrigation regimes (after 30 mm evaporation from basin class A; after 30 mm evaporation from basin class A with spraying by potassium humate; after 60 mm evaporation with spraying by potassium humate and after 60 mm evaporation from basin class A) for three locations of Ardabil (Alarog, Hassanbarog and Khoshkeroud) in Northwestern Iran, for two years (2007-2008). Experimental design was split plot with three replications. Potassium humate sprayed (250 mL ha^{-1}) in the three stage of emergence, before tuberization and during tuberization period. The highest total and marketable tuber yield, plant height, tuber number and weight per plant had the lowest amount under stress conditions and the highest under normal and normal with spraying by potassium humate conditions. Use of potassium humate in water deficit condition increased tuber yield more than 0.93 and 9.63 t ha^{-1} under normal and stress conditions, respectively. Caesar cultivar had the highest total and marketable tuber yield, plant height, tuber weight per plant and dry matter percent under normal with spraying by potassium humate, stress with spraying by potassium humate and stress conditions and Agria cultivar under normal condition. Khoshkeroud and Alarog locations were produced the highest total and marketable tuber yield, plant height, tuber number and weight per plant.

Key words: Stress, potassium humate, potato, irrigation

INTRODUCTION

Water deficit is a common stress in potato production, which leads to yield and tuber quality decreasing. Because of potato susceptibility to drought (Hassanpanah *et al*., 2008), preparing sufficient water is very important for increasing potato quality and quantity. It is necessary to study about tolerance of different potato cultivars against water deficit stress and determination of potato water consumption in Ardabil, Iran. There is a water deficit problem in this region. Climatic changes occurred in this region at the recent years. These changes caused differences in precipitation dispersion, river flowing and wells water. Therefore, we have to identify agronomic characters and water need of new potato cultivars and more improvement of their quality and quantity.

Water deficit decreased number of leaves, plant water potentials (Frensch, 1997), leaf area, stem height, ground coverage, tuber number, growth and yield, canopy radiation interception and only to a lesser extent by effects on radiation use efficiency, harvest index and tuber dry matter concentration (Schittenhelma *et al*., 2006) and nitrate reductase (Misra *et al*., 2002) and increased reducing sugar content in the stem, tuber cracking and malformation, surface abrasions, hollow heart, brown center, internal brown spot, vascular discoloration or bruise, degradation of starch in the tuber stem end and total glycoalkaloids concentration (Papathanasiou *et al*., 1999). Reflectance indices were used to measure biomass and drought stress, changes in leaf water content (Francois and De Proft, 2005) and

water stress (Bahrun *et al*., 2003). A set of drought tolerance genes previously found to be up-regulated in tolerant potato under drought (Schafleitner *et al*., 2007) was assayed for expression changes in potato under drought.

Potassium humate is a material with natural origin that extracts from plants and animal remains exist in the bottom of marshes. This material is formed from N, P, K and microelements namely Mo, Cu, Zn, B, Co, Mg (Gadimov *et al*., 2007). Using of potassium humate increased tuber yield about 11.01 t ha^{-1} under water stress condition (Hassanpanah *et al*., 2008), root number (Baraldi *et al*., 1991) and pea numbers and weight under saline stress condition and decreased nitrate amounts in leaves and roots (Gadimov *et al*., 2007) and decreased nitrate accumulation in potato tubers (Hassanpanah *et al*., 2007).

The objectives of this study were to interpret G×E interaction obtained of yield and yield component of potato cultivars and treatments of irrigation in three locations and two years, effects of water deficit and potassium humate on tuber yield and yield component of potato cultivars.

MATERIALS AND METHODS

This experiment were conducted with three cultivars of potato [Agria (susceptible), Satina (semi-tolerant) and Caesar (tolerant to water deficit)] and four irrigation regimes (after 30 mm evaporation from basin class A; after 30 mm evaporation from basin class A with spraying by potassium humate; after 60 mm evaporation with spraying by potassium humate and after 60 mm evaporation from basin class A) for three locations of Ardabil (Alarog, Hassanbarog and Khoshkeroud) in Northwestern Iran, for two years (2007-2008). Experimental design was split plot design with two factors based on randomized complete blocks in three replications. Factor A was four irrigation regimes and factor B was three cultivars. Plot sizes were 9 m^2 with four rows that each of them had 3 m length, 25 cm distance between plants and 75 cm distance between rows. Distances between plots were 1.5 m. The first irrigation was general, but the following irrigation time was determined as described above. Applied water amount was calculated according to the collected evaporation of A class basin every time and following equation:

$$IW/CPE = 0.8$$

Where:
IW = Irrigation water amount irrigation
CPE = Collected evaporation ratio calculated from evaporation basin

The amount of irrigation regimes water was measured by water meter. The start of irrigation was base on 30 mm evaporation from A class evaporation basin. Amount of precipitation was measured by udometer and daily evaporation by A class evaporation basin.

Potassium humate sprayed (250 mL ha^{-1}) in the three stages of emergence, before tuberization and during tuberization period. In the growth period and after harvesting, the traits such as main stem number, plant height, tuber number and weight per plant, total and marketable tuber yield and dry matter percent were measured. The application of fertilizer was 350 kg N (Oreh) ha^{-1} at three stage (150 kg ha^{-1} at planting, 100 kg ha^{-1} at germination and 100 kg ha^{-1} at before tuberizatioin) and 150 kg P_2O_5 ha^{-1} at one stage (planting time). The harvested plot's size was 3.75 m^2 (two rows at the center of each plot having 2.5 m length). Combined analysis of variances were performed and comparison of means were done by LSD test. Correlation coefficients were calculated between different traits in irrigation regimes and potato cultivars in two years and three locations (2007-2008) by MSTATC software. Physical and chemical characteristics of soil and parameters of climatology of locations are showed in Table 1, 2.

Table 1: Physical and chemical characteristics locations soil

Locations	OC (%)	N (%)	P (ppm)	K (ppm)	Cu (ppm)	Mn (ppm)	SP (%)	Ec (mmohs cm^{-1})	pH	TNV (%)	Tex.
Alarogh	0.64	0.06	17.90	433	6.68	6.59	51	1.084	7.80	8.95	Clay loam
Hassanbarog	0.86	0.10	9.20	460	78.80	8.30	46	0.520	7.60	17.00	Sand loam
Khoshkeroud	1.45	0.14	19.40	478	-	-	51	0.867	8.00	6.33	Loam

Table 2: Parameters of climatology of locations (1998-2008)

	Amount of precipitation (mm)			Relative humidity (%)			Temperature (°C)		
Month	Alarog	Hassanbarog	Khoshkeroud	Alarog	Hassanbarog	Khoshkeroud	Alarog	Hassanbarog	Khoshkeroud
January	19.70	40.17	38.62	77.00	76.30	85.35	-4.51	0.20	-10.80
February	50.40	37.60	33.46	60.00	81.50	77.71	-2.88	1.10	-4.90
March	15.40	50.52	46.03	76.50	85.10	60.03	6.11	3.10	5.20
April	5.70	51.29	58.96	76.80	83.50	63.93	11.10	8.00	11.70
May	1.90	51.86	57.13	77.60	73.50	75.12	14.90	14.70	13.60
June	0.30	14.27	20.53	73.90	77.83	75.63	18.50	17.40	15.10
July	18.40	12.96	15.96	76.60	79.00	71.70	18.50	18.70	19.10
August	87.70	14.22	13.85	68.10	73.35	80.00	21.70	19.60	19.05
September	35.90	20.38	25.72	77.70	73.00	83.00	15.90	17.20	17.95
October	21.70	41.35	34.47	79.70	73.55	75.30	14.10	12.90	13.50
November	20.60	42.11	39.32	77.80	69.19	76.20	3.90	6.80	2.60
December	33.00	36.90	37.83	83.60	77.44	78.56	-2.60	1.10	-4.06
Sum	310.90	408.90	421.90						
Latitude	37° 15′	38° 12′	38° 16′						
Longitude	48° 11′	48° 05′	48° 08′						
Altitude	1332	1350	1510						

Table 3: Analysis of variance of different traits on irrigation regimes and potato cultivars in three locations and two years

SOV	df	Total yield (t ha^{-1})	Marketable tuber yield (t ha^{-1})	Plant height (cm)	No. of main stem	Tuber weight per plant (g)	Tuber No. per plant	Dry matter percent
Year (Y)	1	31.3922**	2657.800**	5144.50**	29.400**	1012657.09**	11.50	64.99**
Location (L)	2	16622.9100**	12236.890**	3261.85**	1.880	5831226.80**	1669.50**	74.35**
Y×L	2	52.3600	59.980	494.87**	4.270*	33619.09 *	45.89**	29.43*
R(LY)	12	68.1300	72.103	88.58	0.624	23851.04	18.34	7.39
Irrigation regimes (A)	3	5189.8800**	5002.070**	231.49*	4.761**	1775369.46**	45.85**	17.43
Y×A	3	78.3200*	148.920*	127.63	11.500**	19990.36**	21.49**	21.90+
L×A	6	643.9800**	558.580**	245.02**	2.190+	236229.50**	15.89*	19.78+
Y×L×A	6	136.8500**	182.120**	184.70*	1.550	55774.75**	5.90	8.14
Error a	36	21.6300	58.069	75.37	1.030	6886.97**	4.85	9.34
Cultivar (B)	2	135.8000**	229.730**	136.86*	0.612	54632.14**	14.42**	25.31+
Y×B	2	6.8070	10.202	70.74	0.679	1858.74	0.666	14.31
L×B	4	44.0060**	146.680*	96.33	2.664**	14741.44**	27.0**	41.57**
Y×L×B	4	31.0320*	81.380	65.35	3.774**	10870.25*	3.443	10.32
A×B	6	95.6000**	102.840*	63.28	1.010*	29518.80**	5.298*	8.90
Y×A×B	6	29.0050*	55.790	48.85	0.318	9682.36*	2.017	20.64*
L×A×B	12	34.5200**	65.450	31.60	1.100**	13432.92**	4.855	7.55
Y×L×A×B	12	8.6540	45.740	32.17	0.579	3548.67	1.799	12.58
Error b	96	11.5700	42.550	45.81	0.445	3533.009	2.318	9.83
CV (%)	-	9.9400	21.470	12.96	18.790	9.25	14.98	14.66

+, *and **: Significant at 10, 5 and 1% level of probability, respectively

RESULTS AND DISCUSSION

Combined analysis of variance showed that were significant differences between year (Y), location (L), irrigation regimes (A) and cultivar (B) and their interaction (Y×A, L×A, L×Y×A, L×B and A×B) on total and marketable tuber yield, plant height, tuber weight per plant, interaction L×Y×B and L×A×B on tuber yield, number of main stem and tuber weight per plant, interaction Y×A×B on tuber yield, tuber weight per plant and dry matter percent (Table 3).

Table 4: Mean of different traits in irrigation regimes

Irrigation treatments	Total tuber yield (t ha^{-1})	Marketable tuber yield (t ha^{-1})	Plant height (cm)	Main stem No.	Tuber weight per plant (g)	Tuber No. per plant	Dry matter percent
Normal	41.54^{a}	38.33^{a}	54.00^{a}	3.84^{a}	775.20^{a}	10.260^{b}	20.90^{b}
Normal+Humate	42.47^{a}	37.35^{a}	54.01^{a}	3.50^{ab}	796.40^{a}	11.260^{a}	21.36^{ab}
Stress+Humate	31.28^{b}	28.17^{b}	50.73^{ab}	3.70^{a}	589.30^{b}	10.120^{b}	22.19^{a}
Stress	21.65^{c}	17.68^{c}	51.15^{b}	3.16^{b}	409.00^{c}	9.001^{c}	21.11^{ab}
Mean	34.24	30.38	52.48	3.55	642.48	10.160	21.39

Mean with the same letters in each column does not have significant difference at the 5% level of probability to according to value of LSD; Normal: After 30 mm evaporation from class A basin; Normal+Humate: After 30 mm evaporation from classabasin with spraying by potassium humate (250 mL ha^{-1}) in the three stage of emergence, before tuberization and during tuberization period; Stress with Humate: After 60 mm evaporation with spraying by potassium humate (250 mL ha^{-1}) in the three stage of emergence, before tuberization and during tuberization period; Stress: After 60 mm evaporation from classabasin

Table 5: Mean of different traits on potato cultivars

Cultivars	Total tuber yield (t ha^{-1})	Marketable tuber yield (t ha^{-1})	Plant height (cm)	Main stem No.	Tuber weight per plant (g)	Tuber No. per plant	Dry matter percent
Caesar	35.81^{a}	32.22^{a}	53.29^{a}	3.56^{a}	673.9^{a}	9.84^{b}	22.00^{a}
Satina	33.59^{b}	30.28^{a}	52.71^{ab}	3.64^{a}	631.2^{b}	9.97^{b}	20.82^{b}
Agria	33.30^{b}	28.65^{a}	50.66^{b}	3.45^{a}	622.4^{b}	10.67^{a}	21.35^{ab}
Mean	34.23	30.38	52.22	3.55	642.5	10.16	21.39

Mean with the same letters in each column does not have significant difference at the 5% level of probability to according to value of LSD

Table 6: Mean of different traits on irrigation regimes for potato cultivars

Irrigation treatments	Cultivars	Total tuber yield (t ha^{-1})	Marketable tuber yield (t ha^{-1})	Plant height (cm)	Main stem No.	Tuber weight	Tuber No.	Dry matter percent
Normal	Caesar	41.93^{a}	38.69^{abc}	56.04a	4.17^{a}	788.1^{ab}	9.97^{cd}	21.00^{ab}
	Satina	38.93^{a}	35.71^{bc}	55.25^{ab}	3.71^{abc}	727.4^{c}	10.45^{cd}	20.00^{b}
	Agria	43.76^{a}	40.61^{a}	50.71^{bc}	3.63^{bcd}	810.0^{ab}	10.38^{cd}	21.69^{ab}
Normal+	Caesar	43.79^{a}	40.24^{ab}	55.67^{ab}	3.61^{bcd}	825.7^{a}	11.61^{ab}	21.98^{ab}
Humate	Satina	40.29^{a}	37.46^{abc}	52.61^{abc}	3.50^{bcd}	767.8^{b}	10.34^{cd}	20.83^{ab}
	Agria	42.70^{a}	34.33^{cd}	53.75^{abc}	3.40^{cd}	795.8^{ab}	11.83^{a}	21.26^{ab}
Stress+	Caesar	33.58^{b}	30.46^{de}	49.40^{c}	3.54^{bcd}	632.7^{d}	9.45^{de}	22.71^{a}
Humate	Satina	32.16b^{c}	29.31^{f}	53.13^{abc}	3.96^{ab}	605.9^{d}	10.26^{cd}	22.46^{a}
	Agria	28.10^{cd}	24.74^{f}	49.67^{c}	3.62^{bcd}	529.5^{e}	10.64^{bc}	21.41^{ab}
Stress	Caesar	23.94^{de}	19.48^{g}	52.05^{abc}	2.91^{e}	449.0^{f}	8.33^{f}	22.31^{ab}
	Satina	22.35^{ef}	18.65^{gh}	49.86^{c}	3.38^{cd}	423.8^{f}	8.85^{ef}	19.98^{b}
	Agria	18.66^{f}	14.92^{h}	48.53^{c}	3.18^{de}	354.2^{g}	9.85^{cde}	21.04^{ab}

Mean with the same letters in each column does not have significant difference at the 5% level of probability to according to value of LSD

The highest total and marketable tuber yield, plant height, number of main stem, number and weight of tubers per plant were produced in 2007. Result of decrease value of these traits was relative to decrease of amount of precipitation and increase of drought and heat stress on tuberization stage in 2008.

The traits of total and marketable tuber yield, plant height, tuber number and weight per plant had the lowest under stress conditions and the highest under normal and normal with spraying by potassium humate conditions and the trait of dry matter had the lowest under normal and normal with spraying by potassium humate and the highest under stress conditions. Spraying by potassium humate in water deficit condition increased tuber yield more than 0.93 and 9.63 t ha^{-1} under normal and stress conditions, respectively (Table 4). Hassanpanah *et al.* (2008) reported potassium humate increased tuber yield about 11.01 t ha^{-1} under water stress condition.

Caesar had the highest total and marketable tuber yield, plant height, tuber weight per plant and dry matter and Agria the lowest (Table 5).

The highest total and marketable tuber yield, plant height, tuber number and weight per plant and dry matter were produced in Caesar cultivar under normal with spraying by potassium humate, stress with spraying by potassium humate and stress conditions and Agria cultivar under normal

Table 7: Mean of tuber yield, increasing and decreasing of yield for potato cultivars

					Yield decreasing and increasing relative to normal condition		
Cultivar	Normal	Normal+ Humate	Stress + Humate	Stress	Normal+ Humate	Stress + Humate	Stress
Caesar	41.93	43.79	33.58	23.94	1.86+	-8.350	-17.99
Agria	38.93	40.29	32.16	22.35	1.36+	-6.787	-16.58
Satina	43.76	42.70	28.10	18.66	1.06-	-15.660	-25.10
Mean	41.54	42.26	31.28	21.65	0.72	-10.260	-19.89

Table 8: Mean of different traits in three locations

Locations	Total tuber yield (t ha^{-1})	Marketable tuber yield (t ha^{-1})	Plant height (cm)	Main stem No.	Tuber weight per plant (g)	Tuber No. per plant	Dry matter percent
Alarog	40.55^{a}	37.49^{a}	51.83^{b}	3.73^{a}	754.70^{b}	8.97^{b}	21.11^{b}
Hassanbarog	16.90^{b}	15.34^{b}	45.69^{c}	3.49^{ab}	318.90^{c}	6.05^{c}	20.54^{b}
Khoshkeroud	45.25^{a}	38.32^{a}	59.14^{a}	3.42^{b}	853.80^{a}	15.46^{a}	22.52^{a}
Mean	34.23	30.38	52.22	3.55	642.47	10.16	21.39

Mean with the same letter(s) in each column does not have significant difference at the 5% level of probability to according to value of LSD

Table 9: Linear correlation coefficients between different traits on potato cultivars and irrigation regimes

Correlation coefficient	Total tuber yield	Marketable tuber yield	Tuber No.	Tuber weight	No. of main stem	Plant weight	Dry matter percent
Total tuber yield	1						
Marketable tuber yield	0.97**	1					
Tuber No.	0.65**	0.54**	1				
Tuber weight	0.99**	0.96**	0.66**	1			
Main stem No.	0.33**	0.35**	0.14	0.33**	1		
Plant weight	0.64**	0.59**	0.56**	0.64**	0.34**	1	
Dry matter percent	0.29*	0.25**	0.42**	0.30*	0.16	0.42**	1

*and **: Significant at probability levels of 5 and 1%, respectively

condition (Table 6). Decreasing yield of Caesar under stress with spraying by potassium humate and stress conditions, relative to normal conditions (after 30 mm evaporation from basin class A) was 8.35 and 17.99 t ha^{-1} but for Satina was 15.66 and 25.1 and for Agria 6.79 and 16.58 t ha^{-1}, respectively (Table 7).

Lynch and Tai (1989) showed genotypes were very sensitive to moisture stress at both tuber initiation and at the tuber sizing growth stages, the greatest variability amongst genotypes in response to stress occurred at tuber sizing.

Khoshkeroud and Alarog locations had the highest total and marketable tuber yield, plant height, tuber number and weight per plant and dry matter percent were produced toward Hassanbarog location (Table 8). Result of increase value of these traits was relative to increase of amount of precipitation (Table 2) and high quality soil (Table 1).

The total and marketable tuber yield, plant height and tuber weight per plant had high in 2007 year and tuber number per plant and dry matter percent under normal and normal with spraying by potassium humate conditions in 2008, in Khoshkeroud and Alarog locations, respectively and the lowest under stress condition in Hassanbarog location in 2008.

This study, dry matter percent of Agria cultivar were the highest than Satina and Caesar cultivars, therefore Agria cultivar is recommended for chips. Satina and Caesar cultivars had a lower dry matter, but are considered for fresh potato consumption (Table 5). Hassanpanah *et al.* (2006) reported Agria cultivar is recommended for chips and Satina and Caesar cultivars for fresh potato consumption.

If it is possible to prevent cold sweetening, they will loose less dry matter because of reduced respiration and it may even be possible to avoid the use of germination inhibitors. Lower sugars cause less wastage in chips production from dark chips (Hassanpanah *et al.*, 2006).

There were significant and positive correlation between total tuber yield with marketable tuber yield, tuber weight per plant, main stem number and plant height and dry matter percent and marketable tuber yield with tuber number and weight per plant, main stem number, plant height and dry matter percent (Table 9). The results are according to Hassanpanah *et al.* (2008) report.

Total tuber yield and marketable tuber yield with main stem number had significant and positive correlation (Table 9). The main stem number per plant is one of the important traits for potato. As a general, if the stem number in potato becomes less, decrease tuber weight and finally tuber yield.

Marketable tuber yield with tuber number and weight per plant had significant and positive correlation. This means that although the tuber number has so effect on yield but this effect is by the tuber weight.

CONCLUSION

Comparison of irrigation regimes showed that spraying potassium humate under normal and stress condition induced increasing of tuber yield and yield components. Spraying by potassium humate in water deficit condition increased tuber yield about 0.93 and 9.63 t ha^{-1} under normal and stress conditions, respectively. Caesar had the highest tuber yield.

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