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Determination of Yield Stability in Advanced Potato Cultivars as Affected by Water Deficit and Potassium Humate in Ardabil Region, Iran

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Abstract: This experiment was done on the three potato cultivars [Agria (susceptible), Satina (semi-tolerant) and Ceaser (tolerant to water deficit)] and three irrigation treatments (after 30 mm evaporation from basin class A, after 60 mm evaporation+spraying by Potassium Humate, and after 60 mm evaporation from basin class A) for two locations in 2007. Experimental design was Split Plot with three replications. Potassium Humate spraying (250 mL ha^{-1}) were done in three stages of emergence, before tuberization and during tuberization period. Combined analysis of variance showed that there were significant differences between locations, cultivars, irrigation treatments and location×cultivars interaction as effect on tuber yield. Comparison of means for irrigation treatments showed that spraying by Potassium Humate in stress condition induced increasing of tuber yield. Spraying by Potassium Humate in water deficit condition increased tuber yield up to 11.01 ton ha^{-1}. Ceaser had the highest tuber yield. It had higher tolerance to water deficit as well. Ceaser had a high potential in control and severe stress. Decrease in yield of Ceaser after 60 mm evaporation+spraying by Potassium Humate and after 60 mm evaporation from basin class A, relative to control (after 30 mm evaporation from basin class A) was 1.03 and 13.08 ton ha^{-1} but for Satina was 7.83 and 16.61 ton ha^{-1}, respectively. Satina had the lowest Environmental Variance, Environmental Variance Coefficient, Finlay and Wilkinson's and Eberhart and Russell's model and was the most stable cultivar. Lin and Binns parameter showed that Ceaser and Satina were the most stable cultivars. Results of GMP, STI and MSTI were very considerable and Ceaser and Satina had a high yield in water stress and control conditions.

Key words: Potassium humate, potato, stability parameters, water deficit

INTRODUCTION

Water stress is a common stress in potato production areas, which lead to yield and tuber quality decreasing. Because of potato susceptibility to drought (Foti *et al*., 1995), preparing sufficient water is very important for increasing potato quality and quantity. It is very necessary to study about tolerance of different potato cultivars against water deficit stress and determination of potato water consumption in Ardabil. There is a water deficit problem in this region. Climatic changes were occurred in Ardabil 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.

Humates are widespread carbonic matters being formed in the processes of biological and chemical decomposition of plant and animal residues. Humates present the complex of high molecular polyfunctional nitrogenic organic compounds with cyclic structure and specific physical, chemical and biological characteristics (Lopez-Fernandez *et al*., 1992). Humic acid causes to increase yield in watermelon and cabbage and potatoes (Salman *et al*., 2005). Humic acid is used to remove or decrease the negative effects of chemical fertilizers and some chemicals from the soil. The major effect of humic acid on plant growth has long been reported (Lee and Bartlette, 1976; Linchan, 1978; Pal and Sengupta, 1985; Hartwigson and Evans, 2000).

Potassium Humate is an active hormone with natural origin that extracts from plants and animals remains existed in the bottom of marshes. This material

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are formed from N, P, K and microelements namely Mo, Cu, Zn, B, Co, Mg (Gadimov *et al*., 2007). Potassium humate causes increased accumulation of chlorophyll, sugar, amino acids and improves the efficiency of nitrogen utilization, allowing for reduced fertilizer rates, the plant's ability to withstand the stresses of heat, drought, cold, disease, insect and other types of environmental or cultural pressures and also increases general plant productivity, in terms of yield, as well as plant stem strength (Anonymous, 2008). Using of potassium Humate increased root system, tuber yield, tuber number per plant in potato (Anonymous, 2007) and pea numbers from 14.4 to 52.6 and its weight from 12-36 g in condition of saline stress with application of 250 mL ha^{-1} Potassium Humate at 3-6 weeks after planting as spraying and decreased nitrate amounts in leaves and roots of pea (Gadimov *et al*., 2007) and also decreased nitrate accumulation in potato tubers (Hassanpanah *et al*., 2007).

To reduce the complications that the G×E interaction creates when selecting superior genotypes, many attempts have been made to (i) understand the environmental components causing the G×E interaction (Epinat-Le Signor *et al*., 2001), (ii) to examine the G×E interaction biometrically (Lin *et al*., 1986; Finlay and Wilkinson, 1963; Yan *et al*., 2001) and (iii) to develop selection strategies that involve a stability parameter (Magari and Kang, 1993).

There are two major stability measures that can be ascribed to the static, type I stability concept (Lin *et al*., 1986; Becker and Leon, 1988).

- The environmental variance (S^2), i.e., the variance of genotype yields recorded across test or selection environments (i.e., individual trials). For the genotype i:

$$S_i^2 = \Sigma (R_{ij} - m_i)^2/(e-1)$$

Where:

R_{ij} = Observed genotype yield response in the environment j (the m_{ij} notation may also be appropriate, since values are averaged across experiment replicates)

m_i = Genotype mean yield across environments and

e = No. of environments

Greatest stability is S^2 = 0. Derived stability measures include the square root value (S) and its coefficient of variation.

- The regression coefficient of genotype yield in individual environments as a function of the environment mean yield (m_j), adopting Finlay and Wilkinson's b coefficient (1963).

The modeled genotype response:

$$R_{ij} = a_i + b_i m_j$$

where, a_i = intercept value, is analogous to equation reported for joint regression analysis of adaptation, but genotype responses to environments (rather than to locations) are of concern here. Greatest stability is b = 0.

Lin *et al.* (1986), while ascribing this measure to a type III stability concept, interpreted it as an indicator of the goodness of fit of the regression model for describing the stability response.

Lin and Binns (1988) type IV stability concept relates to stability only in time (i.e., across test years or crop cycles), averaged across test locations, rather than stability also in space (as implied by stability analysis across environments).

Finally, Lin and Binns (1991) resulted that parameters type I (Environmental variance; Environmental variance coefficient) and IV (Lin and Binns within location variance) were heritable and proper for selection; but parameters type II (Finlay and Wilkinson) and III (Eberhart and Russell) were not heritable and proper for selection.

MATERIALS AND METHODS

This experiment was conducted on the three potato cultivars [Agria (susceptible), Satina (semi-tolerant) and Ceaser (tolerant to water deficit)] and three irrigation treatments (after 30 mm evaporation from basin class A, after 60 mm evaporation+spraying by Potassium Humate and after 60 mm evaporation from basin class A) for two locations in 2007. Experimental design was Split Plot with three replications. 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, some of characters were measured such as main stem number, plant height, tuber number and weight per plant, total tuber yield, marketable tuber yield, dry matter percent and marketable tuber number and weight per plant. Combined analysis of variances were done and comparison of means made by LSD. Cultivars were evaluated by stability parameters as below:

- Environmental variance

$$S_i^2 = \sum_{j=1}^{q}(x_{ij} - \bar{x}_i.)^2/(q-1)$$

- Environmental variance coefficient

$$CV_i = S_i / \bar{x}.. \times 100$$

- Finlay and Wilkinson (1963)

$$b_i = \sum(x_{ij} - \bar{x}_i.)(\bar{x}._j - \bar{x}..)/\sum_{j=1}^{q}(\bar{x}._j - \bar{x}..)^2$$

- Eberhart and Russell (1966)

$$s^2d_i = \left\{\sum_{i=1}^{p} x_{ij} - x_i.)^2 - b_i \sum_{j=1}^{q}(\bar{x}.1 - \bar{x}..)^2\right\}/q-2$$

Where:

$$b_i = \sum(x_{ij} - \bar{x}_i.)(\bar{x}._j - \bar{x}..)/\sum_{j=1}^{q}(\bar{x}._j - \bar{x}..)^2$$

$$SSGE = \sum\sum(x_{ij} - \bar{x}_i. - \bar{x}._j + \bar{x}..)^2$$

x_{ij} = Mean of genotype i, (i = 1,2,...,p) at environment j, (j = 1,2,...,q)
$(\bar{x}.j)$ = Mean of environment j
$\bar{x}_i.$ = Mean of genotype i in all of environments
$\bar{x}..$ = Total mean
q = Number of environments
p = Number of genotypes
Si = Environmental variances

- Lin and Binns within location variance (1988)
- Within location variance coefficient

Indices used for evaluation of advanced potato cultivars were Fischer and Maurer stress index (SSI), Fernandez tolerance index (STI), Rosielle and Hamblin tolerance index (TOL), Baron geometric index (GMP) and Modified tolerance index (MSTI) as below (Fischer and Maurer, 1978; Frenandez, 1992; Rosielle and Hamblin, 1980; Naderi *et al.*, 1999):

- Stress Susceptibility Index (SSI):

$$SSI = (1-(Ys_i/Yp_i))/SI$$

Where:
Ys_i = Yield of cultivar in stress condition
Yp_i = Yield of cultivar in normal condition

$$SI = 1-(Ys/Yp)$$

Where:
Ys = Total yield mean in stress condition
Yp = Total yield mean in normal condition

- Stress Tolerance Index (STI):

$$STI = (Yp_i \times Ys_i)/Yp^2$$

- Tolerance Index (TOL):

$$TOL = Yp_i - Ys_i$$

- Geometric Mean Index (GMP):

$$GMP = \sqrt{Yp_i \times Ys_i}$$

- Mean Productivity (MP):

$$MP = (Yp_i + Ys_i)/2$$

- Modified Stress Tolerance Index (MSTI):

$$MSTI = K(Yp_i \times Ys_i / Yp^2)$$

Where:
$K = Ys_i^{\,2}/Ys^2$

RESULTS AND DISCUSSION

Combined analysis of variance showed that there were significant differences between locations, cultivars, irrigation treatments and location×cultivars interaction on tuber yield. Comparison of means for irrigation treatments showed that spraying Potassium Humate in stress condition induced increasing of tuber yield. Spraying by Potassium Humate in water deficit condition increased tuber yield up to 11.01 ton ha^{-1}. Ceaser had the highest tuber yield. It had as well as tolerance to water deficit. There was a high potential in control and severe stress for Ceaser. Decreasing yield of Ceaser after 60 mm evaporation+ spraying by Potassium Humate and after 60 mm evaporation from basin class A, relative to control (after 30 mm evaporation from basin class A) was 1.03 and 13.08 ton ha^{-1} but for Satina was 7.83 and 16.61 ton ha^{-1}, respectively (Table 1).

Because of location×cultivars interaction significant differences for tuber yield, the below mentioned parameters were used to estimate the highest stable cultivars.

Table 1: Mean of tuber yield and decreasing yield for potato cultivars under normal, stress and stress+spraying by Potassium Humate

Cultivars	Normal	Stress + spraying by Potassium Humate	Stress	Decreasing yield relative to Normal: Stress + spraying by Potassium Humate	Decreasing yield relative to Normal: Stress
Ceaser	36.08	35.05	23.00	1.03	13.08
Agria	33.93	33.42	22.23	0.51	11.70
Satina	39.27	31.44	22.66	7.83	16.61
Mean	36.43	33.30	22.63	3.13	13.80

Table 2: Estimates of stability parameters for potato cultivars

Cultivar	Variance	Variance coefficient	Eberhart and Russell's	Finlay and Wilkinson's	Lin and Biuns	Environmental variance coefficient
Ceaser	30.47	14.96	30.47	0.0208	10.16	8.60
Agria	30.47	15.60	30.47	-0.0203	10.16	9.01
Satina	25.60	13.98	25.60	-0.0005	08.53	8.07

Satina had the less variance among the environments and was the most stable cultivar (Table 2).

Francis and Kannenberg's (1978) variance of a genotype across environments (Si^2) and the coefficient of variability of each genotype: These authors used both statistics as stability parameters and proposed the classification of genotypes based on yield and environmental variance coefficient. In our experiment Satina with the least environmental variance coefficient and higher yield than total mean was stable cultivar (Table 2).

These authors had regression means yields of the i^{th} genotype at the j^{th} environment (X_{ij}) on the environmental means. According to Finlay and Wilkinson (1963), cultivars with b-values around 1 have average stability. When average stability is associated with high yield, varieties are specifically adapted to high-fertile environments while accompanied low yield, then these varieties were adapted to low-fertile environments. b-values >1 implies high sensitivity (below average stability) and adaptability to high-fertile environments. b-values <1 implies greater resistance to environmental changes and adaptation to low-fertile environments. From this view of point, Satina with $b_i = 1$ was the most stable cultivar (Table 2).

Eberhart and Russell (1966) had regression mean yields (X_{ij}) on environmental indices. They identified an ideal variety as one which had high mean yield, b_i=1 and σ_{ij}=0. They and other authors noted that varieties with b_i<1 produced yields which lower than the grand mean of the experiment, while other researchers found no correlation between yield and b-values. Cultivars like Agria with b_i>1, had lower stability but Satina with b_i<1, had higher stability. Eberhart and Russell (1969) noted that genotypes are suitable for large fields which increasing environment fertility lead to yield increasing. Because this, Satina is suitable for Ardabil region (Table 2).

Lin and Binns (1989) gave types IV of stability. According to them a variety is stable where:

- Its among-environmental variance is small (SS of Years)
- It has average slope (~1) (SS of Years×Locations)
- Its standard deviations from regression mean square are small (SS of Years×Cultivars)
- It has small among-years mean square (SS of Years×Locations×Year).

From this view of point, Ceaser and Satina were the most stable cultivars (Table 2).

Analyzing of tolerance and sensitivity evaluation indices to environmental stress conditions showed that efficiency of these indices modify with genotypes yield variation and aims assessment.

Fischer and Maurer index classified genotypes as tolerant or sensitive. This index can recognize genotypes as tolerant or sensitive, be regardless to their yield and have a good efficiency for finding genotypes with resistance genes. TOL has a conditional efficiency, but after classifying genotypes to equal TOL, we can select resistant genotypes with MP. Finding equal TOL in different groups is very hard. With regard to role of TOL and MP, genotype with high MP may not be exists in the least TOL groups and selecting superior genotypes may be difficult. Frenandez index uses stress and non-stress yield and geometric mean. There is a problem and it is geometric equation of coupling data that have natural difference. Environmental changes in all of the Iran provinces are visible. MSTI index with calculating KSTI for suitable and unsuitable conditions is useful for selecting superior genotypes for each region. MSTI results are very notable.

Yield decreasing in mild drought (SI = 0.09) and severe drought (SI = 0.38) relative to control was 9 and 38%, respectively (Table 3, 4).

MP, GMP, STI and MSTI selected Ceaser; and TOL and SSI selected Agria as better cultivar under mild stress condition (Table 3). SSI, STI and MSTI selected Ceaser and Agria; and MP, GMP and TOL selected Ceaser and Satina as stable cultivars under severe

Table 3: Estimates of water stress indices for potato cultivars under mild stress

Cultivars	Yp	Ys	SSI	GMP	MP	TOL	STI	MSTI
Ceaser	36.08	35.05	0.08	35.56	35.00	1.03	0.97	2.33
Agria	33.93	33.42	0.04	33.67	33.00	0.51	0.98	2.15
Satina	39.27	31.44	0.52	35.14	35.00	7.83	0.80	1.55

(SI = 0.09); Yp = Mean of tuber yield in normal condition; Ys = Mean of tuber yield in stress condition

Table 4: Estimates of water stress indices for potato cultivars under severe stress

Cultivars	Yp	Ys	SSI	GMP	MP	TOL	STI	MSTI
Ceaser	36.08	23.00	0.95	28.81	29.54	71.46	0.64	0.66
Agria	33.93	22.23	0.91	27.46	28.08	79.38	0.66	0.63
Satina	39.27	22.66	1.11	29.83	30.97	66.16	0.58	0.58

(SI = 0.38)

stress condition (Table 4). Phenologic investigation of Ceaser and Satina in susceptible periods can lead to understanding strategic methods in agronomy and breeding practices.

CONCLUSION

Spraying by Potassium Humate in water deficit condition increased tuber yield. Ceaser and Satina had the highest tuber yield and were tolerant to water deficit. They were the stable cultivars in Ardabil condition.

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