GENOTYPE × ENVIRONMENT INTERACTION AND STABILITY ANALYSES CONCERNING THE YIELD AND QUALITY CHARACTERISTICS OF PROMISING POTATO (*SOLANUM TUBEROSUM*) GENOTYPES

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Abstract. This experiment was carried out in three different locations with different environmental characteristics such as altitude, soil structure and precipitation in the Central Black Sea Region in Turkey between 2017-2018. The aim of this study was to investigate performance, dry matter ratio and total tuber yield of 15 different promising potato clones and five different potato commercial cultivars in various environments. The average tuber yields across the environments was 32.44 ton/ha while the average of standard cultivars was 35.13 ton/ha and average of advanced clones was 31.54 ton/ha. The mean dry matter ratio was 19.64%, which was 20.22% for commercial varieties and 20.03% for advanced clones. In terms of the stability and genotype × environment interaction for tuber yield, regression coefficients varied from βi = 0.10 to 3.39. PAI-8-857, PAI-8-3-15, PAI-8-6-35 and PAI-8-5-34 were closest to βi = 1 in all environments in respect of the general average and regression coefficient. PAI-8-857 and GOU 6/28 were better suited to grow in all environments. The dry matter values were also subjected to stability and genotype × interaction analyses. The regression coefficients varied from βi = 0.06 to 2.76. PAI-8-8-57 clone had higher dry matter content than other genotypes under suitable conditions.
Keywords: *adaptation, altitude, clones, dry matter content, regression coefficient, tuber yield*

Introduction

Potato, *Solanum tuberosum*, is estimated to have been cultured by selection from wild species found in the Andes in South America about 10,000 years ago. It is the third most important food crop (FAO, 2018). Potato is cultivated in more than 125 countries. Almost 52% of the total cultivation area lies in the temperate region in Europe, 34% of Asia, and 14% of Africa. The total world potato production was at 368.2 million tons in 2018 (FAO, 2018). Turkey is one of the lowland tropics, and the nineteenth largest producer of potato in the World. Turkey is Middle East’s largest producer after Iran, with a production of almost 4.6 million tons in 2018 (FAO, 2018).

Potatoes are cultivated in various environments (Haverkort, 1990). Potatoes are grown in a wide area from the sea level up to elevations of 4000 m. The maximum capacity and genuine tuber dry matter contents and tuber yield are acquired in areas with mild climates (Van der Zaag, 1984; Stol et al., 1991). The dry matter content of potato tubers ranges from 18 and 28% depending on the genotype and environment (Er and Uranbey, 1998).

Genotype and environment interactions are correlated with the performance of genotypes that indicate stability when planted in various environments. Ruswandi et al. (2008) reported selection of high-efficiency and quality genotypes based on multi environment testing.

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According to Roostaei et al. (2014), the Genotype and environment interactions factor is a major issue faced by plant breeders in plant breeding programs. GEI is essential for the acquirement of new and superior breeding lines as reported by many research results (Niringiye et al., 2014; Hongyu et al., 2014). Important features of an optimal variety include high yield stability under adverse environmental conditions. Furthermore, advanced crop cultivars need to have higher yield levels as well as in other features and this superiority should be expressed in the primary areas where the crop is cultivated (Martin et al., 1988).

The aim of this study was to evaluate the dry matter content and total tubers yields of fifteen promising potato clones and five commercial varieties under at three different locations in the Middle Black Sea Region in Turkey in 2017-2018 for genotype environmental interactions and stability analyses.

Materials and methods

This investigation was conducted in Erbaa (276 m – 294 m), Kazova (571 m) and Artova (1191 m), Middle Black Sea Region in Turkey, during growing seasons of 2017-2018 years. The multi locational trials were carried out at three locations and two years that differed with respect to soil type, vegetation, annual precipitation and temperatures and elevations (*Table 1*). Accordingly, the trial in the geographical field position in the first year Tokat-Erbaa; there are 40.58° north latitude and 36.89° eastern longitude. The altitude is 276 m. In the second year, 40.53° north latitude and 36.93° eastern longitude, altitude is 291 m. The field trial area in Tokat-Kazova is between 40.33° north latitude and 36.36° eastern longitude geographically location, altitude is 571 m. The Tokat-Artova between 40.13° and 36.33° east longitude and north latitude and altitude is 1191 m.

Table 1. *Description of the experimental locations. (Source: Turkish State Meteorological Service)*

Location	Altitude (m)		Soil type		Average precipitation (mm)			Min. temperature/mean annual max. (°C)		
	2017	2018	2017	2018	2017	2018	Long term (1964-2017)	2017	2018	Long term (1964-2017)
Tokat-Erbaa	276	294	Silty clay loam	Silty clay loam	408.5	406.6	488.4	2.7 °C /25.9 °C	6.2 °C /25.3 °C	4.0 °C /23.9 °C
Tokat-Kazova	571	571	Clay loam	Clay loam	391.9	329.9	433.4	0.4 °C /24.5 °C	4.4 °C /23.8 °C	1.7 °C /22.2 °C
Tokat-Artova	1191	1191	Sandy clay loam	Sandy clay loam	372.4	464.1	464.1	-3.9 °C /20.6 °C	0.7 °C /19.5 °C	-3.2 °C /18.0 °C

Weather conditions such as soil, temperature and rainfall data were recorded during the experimental years and long-term period are presented in *Table 1*. In all locations, average temperatures were higher than the long-term averages in both years. On the other hand, total precipitations were lower compared to the long-term values in both years. The total precipitation was 408.5 mm in Erbaa location in 2017. In 2018, total precipitation was 406.6 mm in Erbaa location. In Tokat-Erbaa temperature range was 2.7 °C and 25.9 °C in 2017, and 6.2 °C and 25.3 °C in 2018. Tokat Kazova had average annual rainfall of 329.9 mm in 2017 and 433.4 mm in 2018. Also, in Tokat

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Kazova in the first year of experiment minimum and maximum temperature 0.4 °C and 24.5 °C, respectively. As for the second year of experiment minimum and maximum temperature in Tokat Kazova location was 4.4 °C and 23.8 °C respectively. Total annual precipitation in Tokat-Artova location was 464.1 mm in the first year and 464.1 mm in the second year. The minimum and maximum temperature values in Tokat Artova were -3.9 °C and 20.6 °C in 2017, and 0.7 °C and 19.5 °C in 2018, respectively.

Plant material used in experiment

In the experiment, 15 different promising potato breeding lines and 5 different commercially available cultivars were used as plant material (*Table 2*).

Table 2. *Plant material used in the experiment*

Number	Genotype name	Pedigree	Maturity	Breeding institution	Tuber flesh color
1	PAI-8-1-6	Provento × Marfona	Early to intermediate	PAI	Light yellow
2	PAI-8-3-15	Agria × Van Gogh	Intermediate to late	PAI	Yellow
3	PAI-8-5-34	Atlantic × Hermes	Early	PAI	Yellow
4	PAI-8-6-35	Agria × Granola	Very early to early	PAI	Yellow
5	PAI-8-7-49	Atlantic × R. Russet	Early to intermediate	PAI	Cream
6	PAI-8-8-57	Provento × Granola	Early to intermediate	PAI	Yellow
7	PAI-8-9-63	L. Rosetta × Granola	Very early to early	PAI	Light yellow
8	PAI-8-11-79	Atlantic × Laura	Early to intermediate	PAI	Light yellow
9	PAI-8-12-86	Atlantic × Granola	Early to intermediate	PAI	Cream
10	PAI-8-15-138	Atlantic × Konsul	Early	PAI	Light yellow
11	GOÜ-3/110	Serrana × TS-9	Late	GOU	Yellow
12	GOÜ-4/4	Granola × TS-2	Intermediate to late	GOU	Light yellow
13	GOÜ-6/28	Serrana × LT-7	Intermediate to late	GOU	Light yellow
14	GOÜ-7/12	Serrana × TS-4	Intermediate to late	GOU	Cream
15	GOÜ-10/15	MF-1 × LT-7	Intermediate to late	GOU	Cream
16	Agata	BM5272 × Sirco	Very early to early	Agrico	Light yellow
17	Alegria	Flava × _@	Very early		Yellow
18	Agria	Quarta × Semlo	Intermediate to late	Agrico	Yellow
19	Lady Claire	Agria × KW 78-34-470	Early	Meijer Seed Potatoes Ltd	Light yellow
20	Lady Olympia	Agria × KW 78-34-470	Early	Meijer Seed Potatoes Ltd	Yellow

PAI: Potato Research Institute, Nigde-Turkey; GOU: Gaziosmanpasa University Faculty of Agriculture

Methods

At all locations, the study was arranged in a completely randomized block design. The trial consisted of three replications. Potato genotypes of tubers were planted in Erbaa in early March, in Kazova in the second decade of April, and in Artova in May in the first decade of May in both years. For both years and both sites, the plot size for each genotype consists of 4 rows of 6 m. length. Planting of potato tubers was performed at spacing of 70 cm between rows and 30 cm between plants. At each site and year, plots were fertilized with 120 kg nitrogen, phosphorus, potassium ha^{-1} in the form of 15:15:15. The entire rate of phosphorus and potassium were applied at the time of planting. Nitrogen fertilizer was applied at 80 kg/ha at the beginning of tuber formation. (Tugay et al., 1995). The potato varieties and promising clones were watered to maintain adequate moisture levels with drip irrigation. According to FAO, for high yields, the crop water requirements for a 120 to 150 day crop are 500 to 700 mm,

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depending on climate. The water needs of potato plants are generally lower during the first stages of the plant development and they gradually increase towards maturation and the later stages of tuber growth (FAO, 2020). In both years, irrigation was started in Erbaa in mid-May, in Kazova in early June, and in Artova in mid-June. Irrigation intervals were approximately 10 days in all environments. The amount of water applied varied between 50 and 100 mm per event to bring the soil moisture level to field capacity. Cultural and chemical practices such as weeding and pest-control were used in all locations and years. The fields were harvested when the plants reached harvest maturity. Tubers were harvested in early September in Erbaa, at end of September in Kazova and in the mid of October in Artova in both years. After harvest, the tubers were stored for 8 weeks. Dry matter content was measured as weight in water, which can be turned into specific gravity by the formula: Specific Gravity (gcm^{-3}) = Weight in air / (Weight in air –Under water weight). 5 kg tubers were randomly taken from each location with water then weighed first in air and then in water. (Meijers and Van Veldhuisen, 1972). Total tuber yield per hectare was calculated using tuber weight of center rows.

Evaluation of the data

Statistical analyses

The experimental design used was a randomized complete block design with three replications at each location and year. An analysis of variance (ANOVA) was done for each potato genotype and cultivar separately as randomized complete block design. Combined ANOVA result of each location and years showed significant ($P < 0.01$) genotypic differences for dry matter content and total tuber yield. Potato genotypes and cultivars were compared using Duncan statistical test with SPSS software (Duzgunes et al., 1987).

Stability analysis or parametric approach

Genotype × environment interaction variances should be statistically significant before performing stability analysis. Because of this, combining multiple experiments and repeated experiments in a year, the genotype × location, genotype × year and genotype × location × year interaction in the variance analysis chart should be identified by checking the F test by means of the F test (Arshad, 1990). Yield stability and adaptation terms are often used in different senses (Lin et al., 1986; Becker and Leon, 1988). The process to be performed after the interactions are important is to create a bilateral genotype × environment interaction chart by using the mean values of the genotypes in the environment (İkiz, 1972;1976; Yıldırım et al., 1979 and Arshad, 1990). From this chart, the stability criteria such as the regression coefficients on the environmental mean of the genotypes and the squared deviations of this regression can be calculated (Finlay and Wilkinson 1963). From this table, stability criteria such as regression coefficients of genotypes (Y) on environment (X) can be calculated later (Arshad, 1990), where: X_{ij} = The mean of i^{th} genotype at the j^{th} environment; $\overline{X}$.. = Genotypes general average in all environment; g_i = Effect of i^{th} genotype; e_j = Effect of j^{th} environment; (ge)ij = i. genotype j. interacts with the environment and is estimated by (ij- i.- .j + ..).

The main parameters of genotype × environment analyses are summarized in *Table 3* (Lin et al., 1986).

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Table 3. *Detailed bilateral chart for genotype environment interaction*

Genotypes	E_1	E_j	$E_ç$	Genotype average	Effect of genotype (g_{ii})
G_1	x_{11}	X_{1j}	x_{1e}	$\bar{X}_{1.}$	$\bar{X}_{1.} - \bar{X}_{..}$
G_i	x_{i1}	x_{ij}	x_{ie}	$\bar{X}_{i.}$	$\bar{X}_{i.} - \bar{X}_{..}$
G_g	x_{g1}	x_{gj}	x_{ge}	$\bar{X}_{g.}$	$\bar{X}_{g.} - \bar{X}_{..}$
Environment average	$\bar{X}_{.1}$	$\bar{X}_{.j}$	$\bar{X}_{.ç}$	$\bar{X}_{..}$ general average	
Effect of environment (E_J)	$\bar{X}_{.1} - \bar{X}_{..}$	$\bar{X}_{.j} - \bar{X}_{..}$	$\bar{X}_{e} - \bar{X}_{..}$		

According to Finlay and Wilkinson (1963), the regression of the genotype values that each genotype received in different environments was calculated on environmental averages.

$$\beta i = \sum_{j}^{q} = 1(XiJ - \bar{X}i.)\,(\bar{X}.j - \bar{X}..) / \sum_{j}^{q} (\bar{X}.j - \bar{X}..)2 \qquad \text{(Eq.1)}$$

where: i = genotypes; j = environments; $X_{iJ} - \bar{X}_{i.}$ = It is the difference between the phenotype value of the I; genotype and the mean of the genotype on all environmental; $\bar{X}_{.j} - \bar{X}_{..}$ = effect of j^{th} environment; βi: regression coefficient for the response of the i^{th} genotype to varying environments; q: number of environments.

The regression coefficient (βi) were used as measures of stability, with respect to Finlay and Wilkinson (1963). Regression coefficients approaching 1.0 show mean stability, but to determine adaptability, the genotype should always be associated and interpreted with the average total tuber yield and dry matter content.

Genotypes with regression coefficients close to 1.0 and high total tuber yields and dry matter contents are adapted to all environments. Genotypes with low average total tuber yields and dry matter content with regression coefficients close to 1.0 are poorly adapted to all environments regression coefficients over 1.0 means that genotypes have higher sensitivity to environmental variation with below average stability and great specific adaptability to high yielding environments.

Regression coefficients below 1.0 represents a measure of stability against environmental change and more specific adaptation to low efficiency environments. Confidence limits are calculated by multiplying the standard error of the mean with the appropriate t-value. The t-value is determined by the probability and the degrees of freedom (n−1). *Figure 1* illustrates genotypic patterns when regression is plotted against genotypic performance.

Results and discussion

Total tuber yield (ton/ha)

The results in *Table 4* showed that total tuber yield per hectare. Since each year and location were regarded as an environment in respect of stability, the study was conducted with 15 advanced generation clones and 5 commercial varieties in six environments. Total tuber yields were notably influenced by genotypes and different environments (*Table 4*). Accordingly, the overall mean of the test in regards of tuber

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yield 32.44 ton/ha., average of standard commercial cultivars 35.13 ton/ha., average of advanced clones was 31.54 ton/ha.

$\beta_i \geq 1$ $X_i < X$ poorly adapted to favourable environments	$\beta_i > 1$ $X_i = X$ medium adapted to favourable environments	$\beta_i > 1$ $X_i > X$ well adapted to favourable environments
$\beta_i = 1$ $X_i < X$ poorly adapted to all environments	$\beta_i = 1$ $X_i = X$ medium adapted to all environments	$\beta_i = 1$ $X_i > X$ well adapted to all environments
$\beta_i \leq 1$ $X_i < X$ bad adapted to unfavourable environments	$\beta_i < 1$ $X_i = X$ medium adapted to unfavourable environments	$\beta_i < 1$ $X_i > X$ well adapted to unfavourable environments

Figure 1. *Mathematical and verbal correction of genotypic adaptation*

In 2017, the tuber yield of genotypes ranged from 5.46 ton/ha (PAI-8-9-63) to 42.67 ton/ha (Agria) in Erbaa, from 9.30 ton/ha (GOU 4/4) to 39.28 ton/ha (Agata) in Kazova, and from 7.44 ton/ha (PAI-8-9-63) to 49.31 ton/ha (PAI-8-1-6) in Artova. In 2018, the total tuber yield of genotypes ranged from 18.00 ton/ha (PAI-8-9-63) to 48.56 ton/ha (GOU 7/12) in Erbaa, from 17.44 ton/ha (PAI-8-9-63) to 46.96 ton/ha (PAI-8-8-57) in Kazova, and from 13.81 ton/ha (PAI-8-9-63) to 50.98 ton/ha (PAI-8-8-57) in Artova. PAI-8-8-57 and GOU 6/28 clones had high yields in all locations and years (*Table 4*).

The highest total tuber yield occurred in Erbaa in Agria variety in both years. The highest tuber yield produced in Kazova from GOU 6/28 (39.28 ton/ha) in 2017. Second year of this study, the results showed that the highest total tuber yield were belonged to the PAI-8-8-57 (46.96 ton/ha). However, PAI-8-857 and GOU 6/28 (46.62 ton/ha) were statistically in the same group. In Artova, first year of study, the tuber yields were highest with PAI-8-1-6, PAI-8-8-57, GOU 6/28, PAI -8-5-34, Alegria, Lady Olympia, PAI-8-7-49, PAI-8-12-86 and GOU 10/15. Also, these genotypes were statistically in the same group. The highest tuber yield produced in Artova from PAI-8-8-57 (50.98 ton/ha) in 2018. In terms of locations, the highest average tuber yields in decreasing order were in Artova, Kazova and Erbaa locations in both years (*Table 4*).

In parallel with this study, yields of 13 potato clones were investigated by Hajianfar et al. (2017). These potato clones had yield levels in the range of 35.19-41.22 t/ha. These clones were significantly superior to the check cultivar, Agria whose yield was 28.58 ton/ha, and other potato clones.

In a potato breeding program, three promising clones with good quality and quantity features were defined among 18 superior potato genotypes in Iran (Hassanpanah and Hassanabadi, 2012). In another study, stability of 13 promising potato clones for high total tuber yield in different environmental condition was studied. Among the potato clones, three with high stability performance and good characteristics compared to the check cultivars were selected (Hassanpanah and Hassanabadi, 2014).

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When all environments were considered separately, PAI-8-8-57 and GOU 6/28 clones produced highest tuber yields compare to other clones. In all environments, genotypic differences were statistically significant (P < 0.01) for tuber yields.

According to Finlay and Wilkinson (1963) a regression coefficient closest at βi = 1 shows average sensitiveness. When this is correlated with high average total tuber yield the genotype has general adaptively and when correlated with low average total tuber yield, the genotype has poor adaptability. High and stable yield levels in potato tubers are always desirable. It is also reported that tuber yield is one of the most important components for the person trying to define an ideal variety (Hoopes and Plaisted, 1987).

When the findings of total tuber yield were investigated in regards of stability and GEI, and the regression coefficients varied from βi = 0.10 to 3.39. Accordingly, PAI-8-857, PAI-8-3-15, PAI-8-6-35 and PAI-8-5-34 were closest to βi = 1 in the all environmental in respect to the general average and regression coefficient. PAI-8-8-57 and GOU 6/28 were better suited to grow than other clones in all environmental (*Table 4* and *Fig. 2*).

Table 4. *Total tuber yield (ton/ha) and regression coefficients (βi) of clones and cultivars in all environments*

Genotype	Erbaa				Kazova				Artova				Genotype average	Effect of genotype (g_{ii})	βi
	2017		2018		2017		2018		2017		2018				
Agata	25.73	d-h**	27.65	bcd**	39.28	a**	39.62	abc**	25.16	bc**	29.71	de**	31.19	-1.24	0.50
Alegria	33.61	a-e	38.60	ab	37.72	ab	39.81	abc	44.35	a	40.38	a-d	39.08	6.64	0.57
Agria	42.67	a	47.85	a	26.20	cd	42.25	ab	36.55	ab	44.72	abc	40.04	7.61	0.64
Lady Claire	30.21	b-g	35.85	abc	25.80	c	30.85	bcd	21.91	cd	35.95	b-e	30.09	-2.34	0.55
Lady Olympia	21.21	f-h	28.50	bcd	36.60	ab	38.51	abc	43.16	a	43.51	a-d	35.25	2.81	1.75
Cultivar average	**30.68**		**35.69**		**33.12**		**38.20**		**34.23**		**38.85**		**35.13**		
GOÜ 3/110	20.75	f-h	26.50	bcd	29.57	cde	27.27	cde	17.27	cde	22.23	ef	23.93	-8.51	0.10
GOÜ 4/4	22.89	e-h	37.42	ab	9.30	f	19.49	de	9.49	de	24.14	ef	20.45	-11.98	0.31
GOÜ 6/28	33.61	a-e	38.50	ab	39.28	a	46.62	a	46.62	a	49.65	ab	42.38	9.94	1.88
GOÜ 7/12	40.40	ab	48.56	a	27.18	c	35.82	abc	10.83	de	39.95	a-d	33.79	1.35	0.20
GOÜ 10/15	9.24	ij	18.50	d	17.77	d	40.71	ab	40.71	a	42.52	a-d	28.24	-4.19	3.39
PAI-8-1-6	19.11	g-i	22.01	cd	33.37	abc	30.80	bcd	49.31	a	43.93	a-d	33.09	0.65	1.69
PAI -8-3-15	30.28	b-g	35.88	abc	31.26	abc	38.55	abc	26.31	bc	39.28	a-d	33.59	1.16	0.96
PAI -8-5-34	30.95	b-f	37.42	ab	34.08	abc	30.52	bcd	44.32	a	46.45	abc	37.29	4.85	0.85
PAI-8-6-35	33.90	a-e	31.09	bcd	30.61	abc	37.34	abc	37.34	ab	43.90	a-d	35.70	3.26	0.96
PAI-8-7-49	15.51	h-j	24.83	bcd	33.83	abc	42.45	ab	42.45	a	40.79	a-d	33.31	0.87	2.31
PAI-8-8-57	38.50	abc	35.01	abc	37.49	ab	46.96	a	46.96	a	50.98	a	42.65	10.21	1.29
PAI-8-9-63	5.46	j	18.00	d	13.07	ef	17.44	e	7.44	e	13.81	f	12.54	-19.90	0.82
PAI-8-11-79	27.92	c-g	32.49	bc	36.49	ab	37.70	abc	37.70	ab	34.04	cde	34.39	1.96	0.56
PAI-8-12-86	34.50	a-d	25.00	bcd	27.52	c	41.15	ab	41.15	a	34.39	cde	33.95	1.52	0.59
PAI-8-15-138	23.16	d-h	30.05	bcd	34.55	abc	36.18	abc	16.18	cde	26.43	ef	27.76	-4.68	0.46
Clone average	**25.75**		**30.75**		**29.02**		**35.27**		**31.60**		**36.83**		**31.54**		
Environmental average	26.98		31.99		30.05		36.00		32.26		37.34		**32.44**		**1.00**
													Confidence interval		
Effect of environment	-5.46		-0.45		-2.39		3.57		-0.18		4.90		± 4.67		**± 0.52**

**Significant at 1% level of probability

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In environments with different characteristics such as altitude, temperature, precipitation and soil types, the findings of the advanced generation clones and varieties with different properties have been examined. According to this GOU 6/28 clone showed well adapted in the favorable environmental. PAI-8-1-6, PAI-8-7-49, GOU 10/15 clones and Lady Olympia cultivar showed medium adapted in the favorable environments. PAI-8-8-57, PAI-8-5-34 clones and Alegria and Agria cultivars showed well adapted in the all environments. PAI-8-6-35, PAI8-12-86, PAI-8-3-15, PAI-8-11-79 and Agata, Lady Claire cultivars showed medium adapted in the all environments. PAI-8-9-63 clone cultivar showed poorly adapted in the all environments.

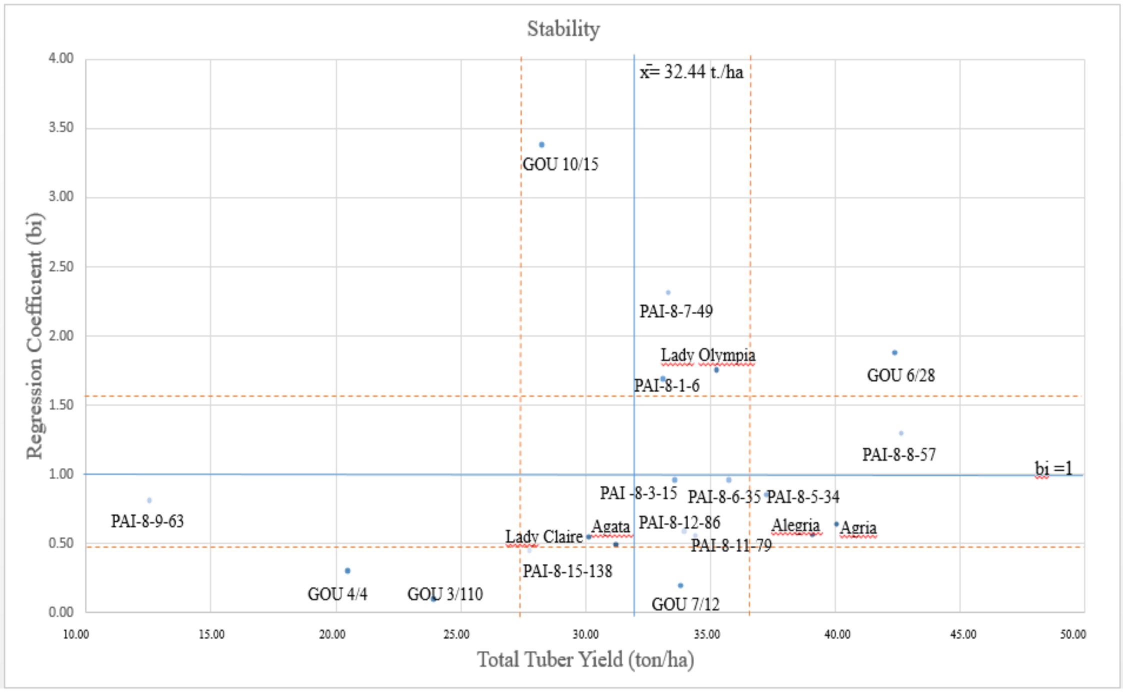

***Figure 2.** Adaptation classes of clone and varieties of total tuber yield (ton/ha)*

While GOU 7/12 and PAI-8-15-138 clones showed medium adapted in the unfavorable environment, GOU 4/4 and GOU 3/110 clones showed poorly adapted in the unfavorable environment (*Fig. 2*).

Dry matter content (%)

In this research, the dry matter percent of the potato clones and cultivars were given in *Table 5*. Accordingly, first year of this study the overall average of the promising clones and cultivars in regards of the dry matter ratio 20.70% in Erbaa, 19.07% in Kazova, 18.21% in Artova. In the second year of this study, the overall mean of the tubers in regards of the dry matter ratio was 19.92% in Erbaa, 19.73% in Kazova, 20.22% in Artova. The overall mean of the study in regards of dry matter was 19.64%, average of standard commercial varieties 19.47%, mean of promising clones was 19.70%. Dry matter ratios of the 15 promising clones and 5 commercial varieties were different. In this research, the dry matter ratio of the genotypes varied from 17.35 to 21.96%.

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According to *Table 5,* the maximum dry matter ratio was observed from PAI-8-7-49 clone (% 21.96) in all genotypes, in all locations and years. Similarly, the highest dry matter was obtained from Lady Olympia (% 20.62) in all commercial cultivars.

In 2017, the dry matter content of genotypes ranged between 16.93% (Agata) and 23.37% (PAI-8-8-57) in Erbaa, between 15.57% (PAI-8-1-6) and 22.87% (PAI-8-7-49) in Kazova, and between 17.50% (PAI-8-12-86) and 21.07% (PAI-8-7-49) in Artova. In 2018, the dry matter content of genotypes ranged between 17.20% (Agata) and 22.87% (PAI-8-7-49) in Erbaa, between 16.40% (PAI -8-5-34) and 21.90% (PAI-8-7-49) in Kazova, and between 17.50% (PAI-8-12-86) and 22.40% (PAI-8-7-49) in Artova (*Table 5*).

Table 5. *Total dry matter (%) and regression coefficients (βi) of clones and cultivars in all environments*

Genotype	Erbaa				Kazova				Artova				Genotype average	Effect of genotype (g_{ii})	βi
	2017		2018		2017		2018		2017		2018				
Agata	16.93	f**	17.20	d**	19.03	cde**	17.90	cde**	14.87	f**	18.30	bc**	17.37	-2.27	0.69
Alegria	18.35	ef	18.30	bcd	20.10	bcd	20.50	abc	18.63	bc	20.50	abc	19.83	0.19	0.19
Agria	19.80	a-f	19.20	a-d	19.00	cde	20.00	abc	17.43	cde	19.70	abc	19.19	-0.45	0.93
Lady Claire	20.67	a-e	19.20	a-d	21.47	ab	20.70	abc	18.97	abc	20.90	abc	20.32	0.68	0.43
Lady Olympia	20.93	a-e	21.10	ab	19.53	b-e	21.50	a	18.97	abc	21.70	ab	20.62	0.98	1.06
Cultivar average	**19.34**		**19.00**		**19.83**		**20.12**		**17.77**		**20.22**		**19.47**		
GOU 3/110	20.13	a-f	19.00	a-d	17.43	efg	18.00	b-e	17.93	cd	18.30	bc	18.47	-1.18	0.80
GOU 4/4	21.53	a-e	20.70	abc	18.37	def	19.00	a-e	19.50	abc	21.70	ab	20.13	0.49	1.11
GOU 6/28	22.30	a-d	20.50	abc	18.20	def	20.70	abc	17.47	cde	20.10	abc	19.88	0.24	1.74
GOU 7/12	22.50	abc	19.80	a-d	19.13	cde	20.40	abc	15.23	ef	21.70	ab	19.79	0.15	2.79
GOU 10/15	19.47	b-f	20.70	abc	16.53	fg	21.10	abc	19.40	abc	19.70	abc	19.48	-0.16	0.61
PAI-8-1-6	19.13	c-f	19.50	a-d	15.57	g	15.80	e	16.10	def	18.00	bc	17.35	-2.29	1.41
PAI -8-3-15	22.97	ab	20.70	abc	18.03	def	19.70	a-d	19.40	abc	20.40	abc	20.20	0.56	1.41
PAI -8-5-34	19.90	a-f	19.90	a-d	16.63	fg	16.40	e	17.83	cd	18.80	abc	18.24	-1.40	0.99
PAI-8-6-35	22.40	a-d	18.00	cd	20.73	bc	21.40	ab	19.10	abc	20.90	abc	20.42	0.78	0.90
PAI-8-7-49	22.43	a-d	21.10	ab	22.87	a	21.90	a	21.07	a	22.40	a	21.96	2.32	0.32
PAI-8-8-57	23.37	a	21.10	ab	19.03	cde	20.20	abc	18.33	bcd	21.00	abc	20.51	0.86	1.89
PAI-8-9-63	20.60	a-e	20.70	abc	20.73	bc	19.80	a-d	20.47	ab	20.90	abc	20.53	0.89	0.06
PAI-8-11-79	18.80	def	19.40	a-d	20.53	bc	19.90	abc	19.00	abc	20.00	abc	20.06	0.41	0.22
PAI-8-12-86	20.50	a-e	21.30	a	17.83	ef	16.60	de	15.33	ef	17.50	c	18.18	-1.46	1.80
PAI-8-15-138	21.30	a-e	20.50	abc	20.57	bc	21.00	abc	19.17	abc	19.10	abc	20.27	0.63	0.50
Clone average	**21.16**		**20.19**		**18.81**		**19.46**		**18.36**		**20.03**		**19.70**		
Environmental average	**20.70**		**19.92**		**19.07**		**19.73**		**18.21**		**20.22**		**19.64**		**1.00**
													Confidence Interval		
Effect of environment	1.06		0.27		-0.57		0.09		-1.43		0.58		**±0.75**		**±0.44**

**Significant at 1% level of probability

Dry matter contents of the 15 promising potato breeding lines and commercial cultivars varied from each other. When all the environments were analyzed separately,

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it was identified that some of the advanced clones could have a dry matter ratio of over 20%. These clones have the capacity to be utilized as clones with supreme dry matter content. These are PAI-8-7-49 (% 21.96), PAI-8-9-63(% 20.53), PAI-8-8-57 (% 21.51), PAI-8-6-35 (%20.42), PAI-8-15-138 (% 20.27), PAI -8-3-15 (% 20.20), GOU4/4 (% 20.13), PAI-8-11-79 (% 20.06). Results of dry matter content indicated that differences among different cultivars and promising clones were significant statistically ($P < 0.01$) in all locations and years. It has been reported that late maturing cultivars accumulate higher dry matter content in cool climatic conditions and high-altitude locations. In addition, differences in quality of seed tubers affect the content of dry matter (Yılmaz and Karan, 2011).

When the research findings are examined in regards of GEI interaction and stability of the dry matter contents, the regression coefficients varied from $\beta i = 0.06$ to 2.76. When the suitability in regards of dry matter ratio was examined, PAI-8-8-57 had maximum dry matter content in the suitable condition. GOU 6/28 and GOU 7/12 indicated medium adaptation in the suitable condition, PAI8-12-86 was bad adapted to favorable environments. Lady Olympia and PAI-8-6-35 had high dry matter content in the all environments. Agria, GOU 4/4 and PAI-8-3-15 were medium adapted in the all environments. GOU 6/28, PAI-8-5-34, PAI-8-1-6 and Agata produced lowest dry matter content in the all environments. PAI-8-7-49 and PAI-8-9-63 clones were superior in that they had high dry matter contents even in unfavorable conditions.

GOU4/4, PAI 8-6-35 and PAI-8-3-15 clones were superior to other clones in regards of dry matter ratio. The mean dry matter ratio of these clones in all locations and years was upward the overall mean and the regression coefficient was closest to $\beta i = 1$ (*Table 5* and *Fig. 3*). Dry matter content of genotypes was affected by environment. When stability of a genotype for dry matter is high, efficient selection for specific dry matter percentages is possible (Wang et al., 2017).

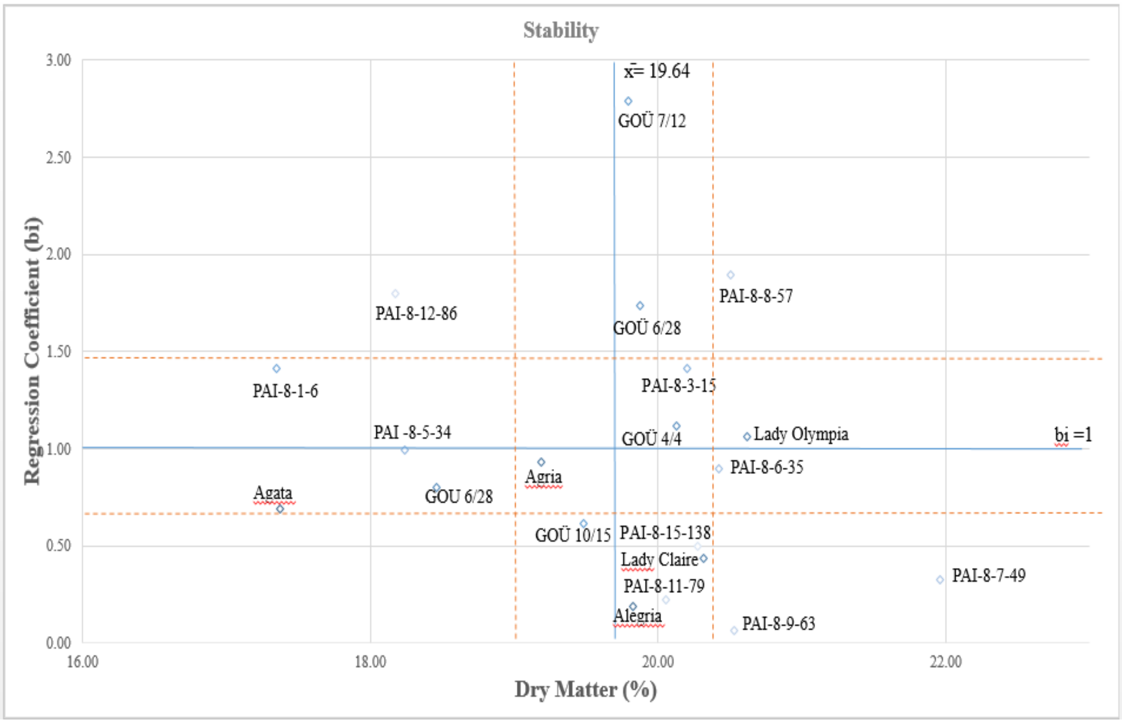

Figure 3. *Adaptation classes of clone and varieties of dry matter ratio (%)*

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Conclusion

Stability of some potato cultivars was investigated by Jankowska et al. (2015). However, contrary to Jankowska et al. (2015), the genotypes in the present study were evaluated in six locations, not just in one. Generally, stability evaluation is based on the data from multi-environment experiments. To acquire reliable stability assessments, an adequate number of environments is required (Lenartowicz et al., 2020).

GEI for yield and quality is a common reality that has been showed in multiple environment experiments with a large number of species of crop plants including potato (Mallory and Porter, 2007; Mulema et al., 2008).

Field trials in this experimental were carried out in various locations in terms of different climate, weather and soil types. Based on the GEI analysis, genotypes from different programs was found to be stable for dry matter and tuber yield.

The research confirmed the presence of remarkable variation among the genotypes as dry matter ratio and for tuber yield. The genotypes were observed to have different reactions to dry matter ratio and tuber yield in the various environments. The observed significant GEI for dry matter ratio and total tuber yield indicated that potato breeders should take into account the GEI while advancing stable genotypes defined by maximum total tuber yield and dry mater content. The observed significant genotype × environment interactions for dry matter ratio and total tuber yield are of major importance to plant breeders.

In all years and locations, the tuber yield average of standard varieties was 35.13 t/ha. PAI-8-8-57 (42.65 t/ha), GOU 6/28 (42.38 t/ha), PAI-8-5-34 (37.29 t/ha) and PAI-8-6-35 (35.70 t/ha) clones yielded more than the average of commercially registered varieties.

As the average of all years and locations, average dry matter of standard varieties was 19.47%. The clones which were found to be superior for total tuber yield (PAI-8-8-57, GOU 6/28, PAI-8-5-34 and PAI-8-6-35) generally had higher dry matter contents. In addition to these clones, GOU 4/4, GOU7/12, GOU10/15, PAI-8-3-15, PAI-8-7-49, PAI-8-9-63 and PAI-8-11-79 clones had higher dry matter contents than the standard varieties.

The locations investigated were highly different from each other. While the highest total tuber yield was obtained from Artova location, the lowest total tuber yield was obtained from Erbaa location.

As a result of this research, GOU 6/28 clone have been applied to The Republic of Turkey Ministry of Agriculture and Forestry Variety Registration and Seed Certification Center for National variety of registration by Tokat Gaziosmanpasa University Faculty of Agriculture.

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