

Study of the Traits Heritability in Some Varieties of Potato (*Solanum tuberosum*) under the Climatic Conditions of Romania

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ABSTRACT

Currently, the potato (*Solanum tuberosum* L.) is one of the basic crops, representing a guarantee of food security and food safety, for a large part of the world's population. So, in the current context of climate change, it is important to identify those genotypes with stable traits in unstable weather conditions.

The study aims to present the morphological traits of five potato genotypes (Dragomirna, Alina, Rapsodia, Lord and Temerar), to emphasize the role of the genotype in obtaining stable productions, regardless of the climatic conditions.

The morphological traits determined at the 5 cultivars were: bush height (cm), number of stems/bush, number of eyes/tuber, number of tubers/nest, average weight/tuber (gr) and average yield/ha (t/ha). Average yield/ha at all cultivars was compared with the production obtained by the Alina Variety, used as a control. In both experimented years the Temerar variety obtained the highest average production per hectare (35.4 t/ha - 2020; 41.7 t/ha - 2021) compared to the control variety.

The correlations coefficient emphasize the highly significant positive correlations between the average yield/ha and average yield/tuber at all cultivars. The existence of significant positive correlations between the average yield and the number of tubers/nest, respectively yield/tuber, in the Dragomirna ($r=,552^{***}$; $,682^{***}$) and Temerar varieties ($r=,758^{***}$; $r=,665^{***}$) is also were established. In the Alina variety, there is a significant negative correlation between the average weight/tuber and the number of tubers/nest ($r=-,755^{000}$). The same negative correlation but distinctly significant were also recorded in Lord ($r=-,476^{00}$) and Rapsodia ($r=-,436^{00}$) cultivars.

The studies carried out in two consecutive years (2020, 2021) on 5 advanced cultivars emphasize a small to medium variability. The cultivar Temerar occurred the first place, if we refer at the yield level obtained in both years of experimentation.

Keywords: potato, variability, morphological traits, varieties.

INTRODUCTION

At a time when the whole world is facing wars, pandemics, extreme climatic conditions, lack of fossil fuels and food, the potato still remains one of the basic crops, as a guarantee of food security and food safety, which will ensure the world's nutrition for decades to come (Chiru et al., 2013; Hermeziu et al., 2023; Hermeziu and Negrușeri, 2024).

The potato is cultivated especially in Europe but also on the other continents. European countries own 50% of the area occurred by the potato crop worldwide (FAO, 2017). This species is cultivated in more than 130 countries, the tubers being consumed

daily by approximately one billion people. Residents of poor countries largely depend on this crop, the daily livelihood of hundreds of millions of people depends on the production of tubers obtained each year (Muntean et al., 2008; Tsuda et al., 2010).

In less developed countries, the land occurred with this crop grows from year to year, because it is a species that has a fairly short vegetation period, is easy to cultivate, and thanks to the valuable nutritional elements it possesses, ensures safety and food security (Lutaladio et al., 2009; Mohammady et al., 2011).

In food, the potato is used almost daily, it is cooked in different ways, and in some countries it replaces bread. Farmers with

small areas of land and with limited financial resources and equipment, cultivate this plant because it has an accessible cultivation technology and can reduce the risks due to extreme climatic conditions (Cromme et al., 2010).

In Romania, many areas of arable land in mountain and sub-mountain areas have been abandoned. Due to the extreme climatic conditions, few species of cultivated plants can adapt to these pedoclimatic stress factors, that is why potato cultivation in geographical areas in mountainous areas represents a solution for the food security of the inhabitants of isolated mountain villages, by: ensuring the daily food needs for the whole family, animal feeding, organic fertilization of the land, the use of ash as a natural fertilizer, but also as an amendment for acid soils and at the same time a sustainable source of income for the inhabitants of these areas (Bodea, 2002, 2007; Bodea and Gontaru, 2005).

The use of productive varieties and appropriate cultivation technologies are essential for obtaining high and quality productions but also for the conservation and protection of natural habitats in each cultivation area. Therefore, the main objective of potato growers is to increase the economic efficiency of this crop, which can only be achieved with modern genotypes, adapted to each crop area and with the most efficient crop management (Chiru and Olteanu, 2010; Hermeziu, 2021).

If in 1985, in Romania, potatoes were cultivated on 321 thousand ha, in the period 1993-2000, the cultivated area decreased to 224 thousand ha, and in 2020 only 180 thousand ha were cultivated. The average production in 2020 was 15-16 t/ha, with a total production of 2600 thousand tons (Berindei, 2007).

For the researches accomplishing, the experiments were located in the potato breeding field within Agricultural Research and Development Station of Suceava. The five modern varieties created by the Suceava Station, were used in this study: Alina, Dragomirna, Rapsodia, Lord and Temerar.

The aims of this research is to present the morphological and physiological characteristics of the potato genotypes created at Suceava, in order to deepen some theoretical and practical aspects, able to lead to the increase of surfaces cultivated with this crop in farms from northern of Romania and beyond.

MATERIAL AND METHODS

The studies were carried out at the Agricultural Research and Development Station (ARDS) of Suceava, Romania, an institution located in the Suceava Plateau, respectively the Liteni Depression, with the following geographical coordinates: 47°39" north latitude; 26°15" east longitude.

The experiments were carried out in two consecutive years (2020-2021) on the land occupied by the potato breeding laboratory, which is part of the category of soft soils, called faenziom cambic. The horizons of this soil are of type Am-AB-Bv-C or Cca.

In the years 2020-2021, no pronounced negative temperatures were recorded during vegetation period, with the exception of March when a minimum temperature of -6.3°C was recorded on 4 March 2021. During the rest of the growing period, temperatures were fairly constant, except for June and July, 2021 when the average temperature was 19°C and 22.5°C, respectively (Table 1).

Regarding the precipitation regime, there were very large variations. In April, 2020 there were 7.8 mm, and in July 2021, 11 mm, this fact negatively affecting potato productivity (Table 1).

In the experiment, 5 varieties characterized by a good production capacity but different in terms of precocity were studied. The advanced cultivars (Dragomirna, Alina, Rapsodia, Lord and Temerar) were created, during 2000-2010, by the team breeders from ARDS of Suceava, Romania.

The placement of the experiment in the field was done according to the method of randomized blocks in 3 replications. Each block consists of 5 plots of 18 m², having a length of 6 m and a width of 3 m of 4 rows with 20 tubers per row.

The morphological traits studied at the 5 cultivars were: bush height (cm), number of stems/bush, number of eyes/tuber, number of tubers/nest, average weight/tuber (gr) and average yield/ha (t/ha).

The valorization of the experimental data

obtained from the biometric analyzes was done by the following calculation statistical methods: variance (s^2), variation amplitude ($\bar{x} \pm s_x$), coefficient of variation (CV%), standard deviation (s) and the Pearson correlation (r).

Table 1. Air temperature and amount of rainfall during the experiment

	The months of the year (vegetation period)					Average
	April	May	June	July	August	
Year	Temperature of the air (°C)					
2020	9.9	12.7	19.2	19.7	21.1	16.52
2021	7.1	14.1	19.0	22.5	19.9	16.52
Multiannual average	8	13.7	16.9	18.4	18.3	15.06
Year	Rainfall (mm)					Amount
2020	7.8	73.4	118	57.4	36.8	58.68
2021	23.6	44.3	35.2	11.0	35.0	29.82
Multiannual amount	48.2	80.2	93.6	88.6	62.8	74.68

RESULTS AND DISCUSSION

Variability of bush height (BH) is conditioned polygenic but also by environmental and crop conditions. However, the bush height in the studied material shows a medium to small variability. This trait shows different values depending on the variety, thus the Temerar variety has the highest bush average (79.60 cm respectively 99.80 cm) in both years of study

and the lowest average height belongs to the Dragomirna variety in 2020 and the Alina variety in 2021 (Table 2). The values of variability coefficient (s%) show that the varieties Lord and Temerar recorded a small variability (3.04-5.84%), a fact also demonstrated by the uniformity present in the experimental field, but the varieties Alina, Rapsodia and Dragomirna have recorded a medium variability of this trait (12.11-14.69%).

Table 2. The morphological traits analysed at the 5 advanced potato cultivars

Bush Height (BH)					
Cultivars	Years	Variation amplitude ($\bar{x} \pm s_x$)	Variance (s^2)	Standard deviation (s)	Coefficient of variation (CV%)
Dragomirna	2020	50.40±3.31	54.80	7.40	14.69
	2021	56.40±3.54	62.80	7.92	14.05
Rapsodia	2020	56.00±3.03	46.00	6.78	12.11
	2021	66.00±2.61	34.00	5.83	8.83
Alina	2020	52.40±2.99	44.80	6.69	12.77
	2021	51.60±2.32	26.80	5.18	10.03
Lord	2020	62.20±1.62	13.20	3.63	5.84
	2021	71.40±2.44	29.80	5.46	7.65
Temerar	2020	79.60±2.58	33.30	5.77	7.25
	2021	99.80±1.36	9.20	3.03	3.04

Number of Stems/Bush (NSB)					
Cultivars	Years	$\bar{x} \pm s_x$	s^2	s	CV%
Dragomirna	2020	6.27±0.17	1.17	1.08	17.22
	2021	6.9±0.38	5.87	2.42	35.07
Rapsodia	2020	6.55±0.23	2.30	1.51	23.05
	2021	6.66±0.20	1.95	1.39	20.87
Alina	2020	5.12±0.20	1.59	1.26	24.60
	2021	5±0.24	2.44	1.56	31.2
Lord	2020	10.5±0.4	6.35	2.52	24.0
	2021	7.7±0.32	4.25	2.05	26.62
Temerar	2020	5.42±0.23	2.25	1.50	27.67
	2021	6.33±0.29	3.61	1.84	29.06
Number of Eyes/Tuber (NET)					
Cultivars	Years	$\bar{x} \pm s_x$	s^2	s	CV%
Dragomirna	2020	8.82±0.22	2.19	1.43	12.81
	2021	7.9±0.27	0.76	0.87	11.01
Rapsodia	2020	8.9±0.16	1.11	1.05	11.79
	2021	8.5±0.19	0.55	0.74	8.70
Alina	2020	8.27±0.18	1.43	1.19	14.38
	2021	7.4±0.26	0.71	0.84	11.35
Lord	2020	9.02±0.22	1.92	1.38	15.29
	2021	9.6±0.12	1.38	1.17	12.18
Temerar	2020	8.3±0.2	2.26	1.50	18.07
	2021	8.55±0.31	1.88	1.34	15.67
Number of Tubers/Nest (NTN)					
Cultivars	Years	$\bar{x} \pm s_x$	s^2	s	CV%
Dragomirna	2020	18.57±0.67	17.94	4.23	22.77
	2021	19.7±0.75	22.6	4.76	24.16
Rapsodia	2020	19.97±1.11	49.15	7.01	35.10
	2021	20.6±1.64	27.66	5.26	25.53
Alina	2020	15.15±0.87	30.18	5.49	36.23
	2021	15.4±1.2	57.15	7.56	49.0
Lord	2020	18.6±0.6	14.81	3.84	20.64
	2021	15.70±0.70	20.01	4.47	28.47
Temerar	2020	15.92±0.66	17.40	4.17	26.19
	2021	19.33±1.2	58.47	7.64	39.51
Average Weight/Tuber (WT)					
Cultivars	Years	$\bar{x} \pm s_x$	s^2	s	CV%
Dragomirna	2020	59.17±2.06	168.81	12.99	21.95
	2021	59.07 ±1.69	113.91	10.67	18.06
Rapsodia	2020	85.3±3.69	547.34	23.3	27.31
	2021	84.38±4.68	871.08	29.51	34.97
Alina	2020	115.37 ±5.56	1227.36	35.03	30.36
	2021	103.38±4.82	923.92	30.39	29.39
Lord	2020	77.87±3.57	509.80	22.5	28.89
	2021	75.76±2.95	347.02	18.62	24.57
Temerar	2020	63.92±3.30	432.94	20.80	32.54
	2021	69±3.32	439.41	20.96	30.37

The second trait studied was represented by the *number of stems per plant (NSB)*. From the data presented in the above table (Table 2), it is observed the existence of high and very high values of the coefficient of variability, being between 17.22% for the Dragomirna variety, in 2020 and 35.07% also for the Dragomirna variety, but in the year 2021.

The number of eyes/tuber (NET) is the traits that influences the vigor of the future plant. Given the fact that it is an important descriptor in breeding works, we note that there are not very big differences between the 5 studied varieties, the average number of eyes varying between 7.4 (2020) for the Alina variety and 9.6 (2021) for the Lord variety (Table 2). Analyzing the coefficient of variability, we notice that it presents values between 8.70% (Rapsodia variety - 2021) and 18.07% (Temerar variety - 2020), which tells us that, the coefficient of variability is small to medium for most tested varieties.

The number of tubers/nest (NTN) is a character that is pursued in breeding work to create varieties with more than 15 tubers per nest. From the table above (Table 2), it can be seen that all the varieties, in both years of experimentation, exceed the mentioned limit, so that in the Alina variety 15.15 tubers/nest were harvested in 2020, and at the Rapsodia variety, 20.6 tubers/nest, in 2021. In most varieties, the number of tubers was higher in 2021, compared to 2020. If we refer to the coefficient of variability, we observe a great variability in all tested varieties, the values of

this coefficient varying between 20.64% at the Lord variety in 2020 and 49% at the Alina variety, in 2021, which gives us the confidence that this character can be improved in the next period, due to genetic instability.

The average weight/tuber (WT) is another important agronomic characteristic of potato varieties. In the varieties tested, we also observe high variability for this descriptor in all varieties (Table 2), the coefficient of variability varying from 18.06%, for the variety Dragomirna (2021), to 32.54% for the variety Temerar (2020). In the 5 varieties tested, a minimum weight of 59.07 g is observed for the Dragomirna variety (2021) and a maximum weight of 115.37 g for the Alina variety (2020).

Average yield/ha (AY). In both experimented years (2020-2021) it determined the yield of tubers/ha for each variety studied. The yield levels were compared with the yields obtained by the Alina Variety, being used as a control. In 2020, it is observed that the Temerar variety obtained the highest average yield per hectare (35.4 t/ha) compared to the control variety and the other analyzed varieties (Table 3). Also, in 2020, there were significant differences compared with the yields level of control, for the Temerar (+7.6 t/ha) and Lord (+7.0 t/ha) varieties (Table 3). In 2021, the Temerar variety also maintained supremacy over the other varieties, registering a yield surplus of 10.5 t/ha compared with the control, being a distinctly significant difference (Table 3).

Table 3. Average yield/ha of the experimented potato cultivars at the ARDS of Suceava (2020-2021)

Cultivars	Average yield (t/ha)		Relative yield (%)		Differences (t/ha)		Signification	
	2020	2021	2020	2021	2020	2021	2020	2021
Alina - control	27.8	31.2	100	100	-	-	-	-
Dragomirna	31.6	37.7	113.7	120.8	+3.8	+6.5	-	-
Rapsodia	34.2	35.5	123.0	113.7	+6.4	+4.3	-	-
Lord	34.8	36.3	125.1	116.3	+7.0	+5.1	*	-
Temerar	35.4	41.7	127.3	133.65	+7.6	+10.5	*	**

LD 5% = 7 t/ha; LD 1% = 9.6 t/ha; LD 0.1% = 12.9 t/ha

The studies carried out by Mohammady et al. (2011) on 10 potato varieties “Finna, Kondor, Dilta, Romana, Bright, Picaso, Santa, Marfona, Bolesta and Cosmos” highlighted the great differences between the different traits, it was highlighted two varieties “Finna and Kondor” that showed superior values of plant height, the number of tubers per nest and average weight/tuber.

Analysis of correlations between quantitative characters. By using the Pearson correlation

system, it was determined the correlation coefficients of the 6 descriptors: bush height, the number of stems/bush, the number of eyes/tuber, the number of tubers/nest, the average weight/tuber and the average yield/ha at the five varieties studied. At the varieties Dragomirna (Table 4), it observe two very significant positive correlations between the AYxNTN (0.682***), respectively, the AYxWT (0.552***).

Table 4. Pearson correlations between the quantitative traits analyzed in the five potato variety, ARDS of Suceava (2020-2021)

Dragomirna cultivar						
Morphological traits	BH	NSB	NET	NTN	WT	AY
BH						
SNB	0.117					
NET	-0.111	-0.065				
NTN	0.025	-0.086	-0.084			
WT	0.113	0.045	-0.095	-0.216		
AY	0.110	-0.060	-0.144	0.552***	0.682***	
Rapsodia cultivar						
Morphological traits	BH	NSB	NET	NTN	WT	AY
BH						
SNB	0.174					
NET	0.037	0.163				
NTN	-0.189	0.120	-0.049			
WT	-0.144	0.041	-0.013	-0.436⁰⁰		
AY	-0.230	0.199	-0.053	0.115	0.796***	
Alina cultivar						
Morphological traits	BH	NSB	NET	NTN	WT	AY
BH						
SNB	0.292					
NET	-0.139					
NTN	0.129	-0.345⁰	0.181			
WT	-0.254	-0.177	-0.109	-0.755⁰⁰⁰		
AY	-0.219	0.091	0.098	-0.086	0.641***	
Lord cultivar						
Morphological traits	BH	NSB	NET	NTN	WT	AY
BH						
SNB	-0.099					
NET	0.044	-0.084				
NTN	-0.114	0.064	0.100			
WT	0.281	0.267	0.187	-0.476⁰⁰		
AY	0.167	0.346*	0.299	0.190	0.748***	
Temerar cultivar						
Morphological traits	BH	NSB	NET	NTN	WT	AY
BH						
SNB	0.013					
NET	-0.064	0.078				
NTN	0.214	0.026	0.200			
WT	-0.159	0.228	-0.006	0.037		
AY	0.035	0.121	0.139	0.758***	0.665***	

In the case of the Rapsodia variety, the existence of two correlations it is observed, one of which is very significant positive (AYxWT; 0.796***) and one is distinctly significant negative (WTxNTN=-0.436**) (Table 4).

Regarding the Alina variety, it is noted the presence of three correlations, one of which is very significant positive (AYxWT=0.641***) and two negative: very significant (WTxNTN=-0.755⁰⁰⁰), and significant (NTNxNSB=-0.345⁰) (Table 4).

The variety Lord reacted somewhat similar to the varieties Rapsodia and Alina, so that in Table 4, it is observed the existence of three significant correlation coefficients: a very significant positive (AYxWT=0.748***), a significant negative one (WTxNTN=-0.476⁰⁰), and a significant positive (AYxNSB=0.346*) correlation.

The Temerar variety behaved the same as the Dragomirna variety, with two highly significant positive correlations: AYxNTN=0.758*** and AYxWT=0.665*** (Table 4).

Zamora et al. (2009) conducted various studies on different descriptors such as plant height, stem diameter, number of stems and number of tubers/nest in cultivars native to Venezuela (Kennebec and Atlantic). Following the obtained results, it was observed that the Kennebec variety presented higher values of the mentioned descriptors than the values obtained in the case of the Atlantic variety.

From the correlations coefficient presented, it is observed that in all varieties there are highly significant positive correlations between the average weight/tuber and average yield/ha. The existence of significant positive correlations between the average yield/tuber and the number of tubers/nest, in the Dragomirna and Temerar varieties, is also observed. In the Alina variety, there is a significant negative correlation between the average weight/tuber and the number of tubers/nest. The same negative but distinctly significant were also recorded in Lord and Rapsodia cultivars.

The classification of the six traits analyzed in the potato varieties taken in the study was carried out by using the SPSS 2.0 program. Dendrogram using Average Linkage (Between Groups) constructed on the basis of hierarchical grouping of the analyzed morphological traits, illustrated the presence of 2 clusters:

Cluster 1: average weight/tuber, average yield/ha, bush height and number of eyes/tuber.

Cluster 2: number of stems/bush and number of tubers/nest.

This grouping it shows how the analyzed characters correlate with each other. So, it is observed that the number of stems/bush correlates with average weight /tuber and bush height. Also the number of eyes/tuber correlate with bush height and the number of tuber/nest correlate with number of stems/bush.

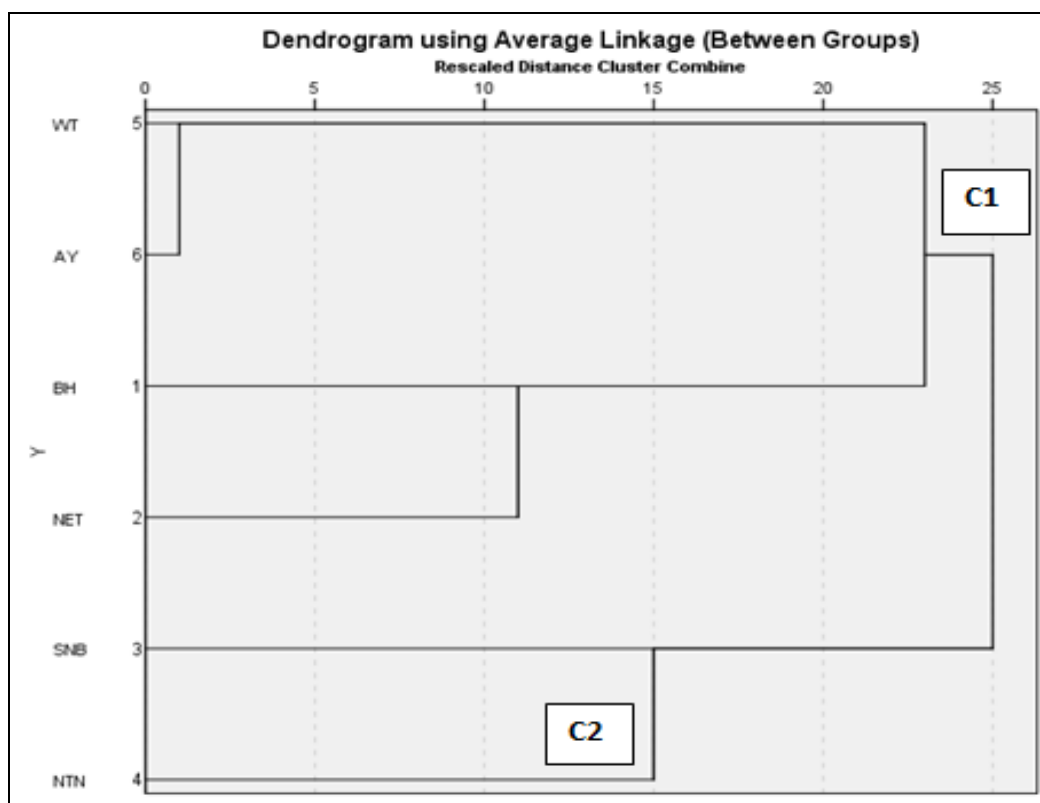


Figure 1. Hierarchical grouping of the six quantitative traits in the analyzed potato varieties, based on Pearson correlations

CONCLUSIONS

Our results emphasized the diversity of hereditary characters in the studied potato varieties. Concerning variability in bush height, the Temerar variety recorded the highest bush height while Dragomirna and Alina had the lowest. Number of stems per bush exhibited high variability, for cultivar Dragomirna in both experimented years. Number of eyes per tuber is very important for plant vigor, ranged from small (Lord) to medium (Alina) variability coefficients among the studied varieties. Number of tubers per nest registered significant genetic variability and also a high variability was observed for average weight per tuber. The variety Temerar recorded the highest yields in both years, in comparison with control variety (Alina).

Highly significant positive correlations between the yield and the weight/tuber of potato tested varieties were observed. Also, there were highly significant positive correlations between weight/tuber and no of tubers/nest in Temerar and Dragomirna cultivars. In the Alina and Rapsodia varieties, very significant and distinctly significant

negative correlations were obtained between the average weight/tuber and the number of tubers/nest.

The number of stems/bush was correlated with average weight/ tuber and bush height. As well as the number of tuber/nest was correlated with number of stems/bush.

The studies carried out in two consecutive years (2020, 2021) on 5 varieties created at ARDS of Suceava (Dragomirna, Rapsodia, Alina, Lord and Temerar) demonstrate that they are all promising, with the Temerar variety in first place, if we refer at the level of the yields obtained in both experimented years.

The high genetic variability in some traits (e.g., number of tubers per nest, average weight per tuber, yield) suggests that selective breeding could further enhance desirable characteristics. Increasing tuber numbers may reduce tuber weight, so balancing these traits is critical for efficient maximizing yield. The variety Temerar stands out as a high-yielding variety with stable traits, while Alina and Dragomirna show higher variability, indicating possibility to improvement in breeding programs.

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