

# Adaptability and stability of potato samples in the forest-steppe conditions of the Northern Caucasus

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**Abstract.** This work aimed to study the response of 10 potato varieties to changes in environmental conditions during the 2018-2020 growing season in the forest-steppe zone of the Republic of North Ossetia-Alania. Ecological adaptability, stability, and genetic flexibility were evaluated for 8 varieties and 2 hybrids of the North Caucasian Research Institute of Mountain and Piedmont Agriculture (SKNIIGPSKh) breeding. Analysis of variance revealed that the proportion of the influence of genotype (factor-variety) on the yield of the studied samples for three years of observation was 40%. The effect of weather conditions on the variability of potato productivity during the years of research was 42% and the effect of other factors was 18%. Complex evaluation of flexibility, stability, genetic flexibility was carried out according to the methods of S.A. Eberhart and W.A. Russell, A.A. Rosielle and J. Hamblin, V.V. Khangildin and N.A. Litvinenko. The calculated indices of flexibility, stability, homeostability, and genetic flexibility allowed us to identify a group of intensive varieties responding with increased yield under optimal conditions: Udacha, El Mundo, Hybrid 04.560/4. The second group included extensive varieties: Sambo, Primabel, hybrid 04.573/1. The hybrid 04.573/1 selected by SKNIIGPSKh is adapted to forest-steppe conditions, resistant to stress  $(Y_{min}-Y_{max})=8$ , and shows genetic flexibility  $(Y_{max}+Y_{min})/2=31.2$ . In the hot year of 2020, it gave the yield higher than all the studied samples (27.7t/ha). Hybrids 04.560/4 and 04.573/1 are being prepared for state variety testing.

## 1 Introduction

Potatoes are the main food of the population of Russia, including the North Caucasus. The demand for potatoes for the population and the processing industry can be met with high yield of quality tubers. Under the conditions of climate change and the spread of quarantine pests, new high-yielding varieties are required. Amid the application of modern agrotechnical and technological methods, variety as a biological system remains a decisive factor in increasing the crop yield [1, p. 21]. However, often new varieties, including

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potatoes, can not realize the potential yield, since the phenotypic manifestation of this feature is influenced by agroclimatic, biotic and anthropogenic factors [2, p. 75]. The size and quality of the potato harvest by years is by 60-80% dependent on weather and anthropogenic factors [3, p. 185]. Variety gives the maximum yield in the optimal conditions. So, breeding programs should be regional and focused on the creation of varieties that maximize the impact of favorable factors on yield formation, and resistant to environmental stresses in the considered soil and climatic zone [4, p.4]. Thus, the newly created variety must have a wide range of ontogenetic adaptability, adapted to the soil and climatic conditions of the region [5]. Adaptability of genotype in interaction with the environment is determined by flexibility, stability, resistance. One of the methods to increase the adaptability of potatoes is the creation of new ecologically flexible varieties [6, p.7]. The creation of adaptive varieties is one of the main tasks in potato breeding. Adaptive variety is an ecologically flexible variety, adapted not only to optimal conditions but also to the minimum and maximum changes in external environmental factors [7]. Therefore, varieties with high resistance to the most common diseases and pests that cause significant damage to the crop and its quality are of particular importance for agricultural production. Equally important is the use of varieties with high adaptability to adverse environmental influences (weather and soil conditions, heat, drought or overwatering) [6, 8]. The environment is a factor for the selection of newly created varieties adaptive to a particular ecological niche of the region, district [9, p. 18]. Each variety of crops, including potatoes, has its genetic level of resistance, which is manifested in stressful conditions [10]. The basic principle of creating a new variety is a close interaction between the genotype and environment [11, p. 26]. The newly created varieties must have a positive response to changes in climatic and agrotechnological conditions, and to the predecessor [12, p.58]. Selection of modern potato varieties is determined by the requirements of producers, the consumer market and the natural conditions of the region. A modern potato variety must combine more than 50 different genetically controlled traits; yield and its components (number of tubers with attractive shape and small eyes in the nest, with a high level of dry matter content, suitability for long-term storage) [8, 13, p. 45], as well as the maturation period, resistance to common diseases and pests, adaptability to stress, to the applied agrotechnics and mechanized harvesting [14, 10]. Resistance to pests, stresses and diseases is controlled by certain gene systems. So, to involve certain potato genotypes in the breeding program, it is necessary to carefully study them [15, p. 242].

This study aimed to give a comparative assessment of breeding samples in terms of the level of yield, phenotypic flexibility, stability and environmental sustainability in the forest-steppe zone of the Republic of North Ossetia, and to select genotypes adapted to changing environmental conditions. The ecological flexibility and stability of two promising hybrids of the North Caucasian Research Institute of Mountain and Piedmont Agriculture (SKNIIGPSKh) selection were assessed.

## **2 Materials and Methods**

The adaptability of 8 varieties and two hybrids of SKNIIGPSKh breeding was studied in 2018-2020. The degree of influence of weather conditions during the growing season on tuber yield formation differed significantly by year. 2018 was considered the most favorable year for potato plant development. 2019 differed in the degree of moisture availability in some periods. 2020 was characterized by high temperatures and lack of moisture in the soil.

Precipitation during the first 10 days of April 2020 was 164% of the norm, while the second and third 10 days accounted 68-82% of the norm. May was characterized by warm weather with rain, and sometimes hail. In June, the first and third ten-day periods were

characterized by high air temperatures, lack of moisture in the soil, which affected flowering and crop formation. Hydrothermal index was 1.1. July was characterized by hot and dry weather, hydrothermal index was 0.56. Maximum air temperature was 35-36 °C. The temperature was 50-56 °C at the soil surface in the potato plantings, 30 °C at a depth of 15 cm under the sprawling bushes, 28 °C at a depth of 25 cm. Soil moisture was 7.3% at a depth of 15 cm under the sprawling bushes, 9.9% at a depth of 15 cm, 10% under upright and multi-stem bushes at 15 cm depth, and 11.0% at 25 cm depth. In the third ten-day period, precipitation was 113% of the norm, which contributed to an increase in tuber weight.

Assessment of adaptability and stability was performed according to the method of Eberhart S. A., Russell W. A. [16, p.36] as presented by Pakudin V.Z. and Lopatina L.M. [17, p.109]. Homeostaticity was assessed according to the method of Khangildin V.V. and Litvinenko N.A. [18, p.1], ecological flexibility was assessed according to Rosielle A. A., Hamblin I [19, p.943] as described by A.A. Goncharenko [20, p.49]. Analysis of variance was performed according to Dospekhov B.A. [21].

### 3 Results

Analyzed was data of 3-year (2018-2020) testing of eight varieties and two hybrids. Table 1 shows the parameters of adaptability, stability and environmental sustainability in terms of yield on the example of 10 samples (Table 1).

**Table 1.** Parameters of phenotypic flexibility, stability and environmental stability of potato varieties.

Variety	Yield by year, t/ha				$\frac{Y_{min}-Y_{max}}{Y_{max}}$	$(Y_{max}+Y_{min})/2$	Hom	bi	$S_i^2$
	2018	2019	2020	Medium					
Udacha	32.1	27.2	11.9	23.7	-20.2	14.69	69	1.80	788
Vega	19.0	15.2	15.4	16.3	-3.8	17.1	89	0.35	29.4
Sambo	21.9	11.9	13.0	15.6	-10.0	16.9	45	0.87	328
Primabel	20.7	15.9	13.9	16.8	-6.8	17.3	180	0.64	93.3
Babushka	29.9	21.9	11.3	21.0	-15.7	20.6	47.5	1.71	351
Oceania	26.9	14.2	20.2	20.4	-12.7	20.5	68.6	0.70	90.3
Gala	21.9	22.6	14.5	19.6	-8.1	18.2	85.5	0.64	156
El Mundo	27.1	24.8	12.7	21.5	-14.4	19.9	64.3	1.29	377
04.573/1	35.2	27.2	27.7	30.0	-8.0	31.2	250	0.73	139
04.560/4	32.0	26.4	19.2	25.8	-16	27.2	73.9	1.18	322
Average Yi	26.67	20.73	15.9	21.0					
$\sum Yi$	266.68	207.3	159.0	210					
Indices $l_i$	5.6	-0.5	-5.1						

The table shows indices of environmental conditions  $l_i$ , describing the conditions in the years of research. The indices of conditions in 2018 have a positive sign ( $l_i = 5.6$ ), climatic conditions in 2019-2020 are less favorable ( $l_i = -0.5, -5.6$ ).

As a result of the analysis of variance, the criterion  $F_{act} = 4.71$ ,  $F_{05} = 4.26$  was calculated. There were significant differences between the variants in the experiment, and the null hypothesis was rejected. Analysis of variance revealed that the resultant trait (productivity) was influenced by the genotypes of the studied breeding forms, their share was 40%. The dependence of crop yield fluctuations on the climatic conditions and stresses in the growing season reached 42%, the dependence on other factors was 18%.

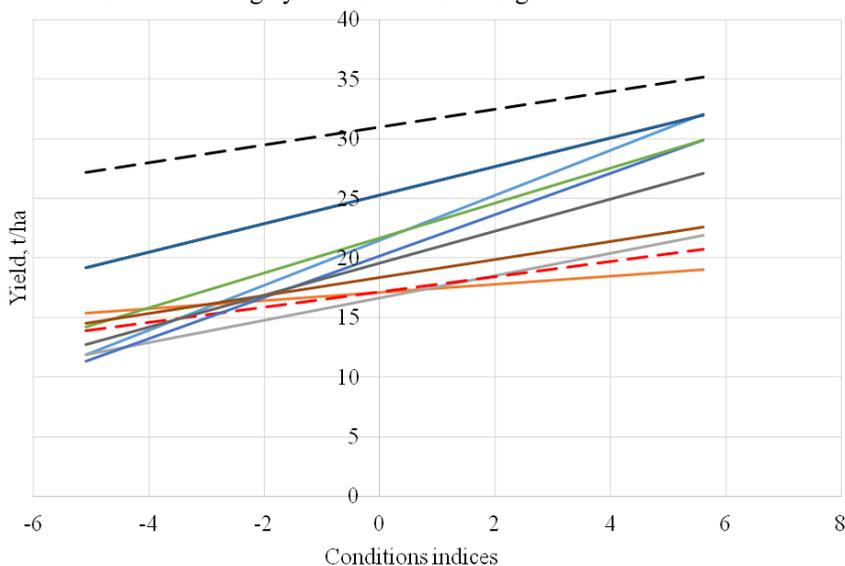
Flexibility and stability parameters were calculated according to the method of S. A. Eberhart, W. A. Russell [16, p.36]. Linear regression coefficients  $b_i$  were 1.8, 1.71, 1.29, 1.18 for the Udacha, Babushka, El Mundo varieties, and the 04.560/4 hybrid, respectively. Judging by regression coefficients, these forms are of intensive type. The response of the genotype of intensive-type varieties to improved conditions is an increase in phenotypic indicators, in this case productivity. Under better conditions in 2018, yields were high.

Under worsening conditions in 2021, yields decreased sharply (Table 1). For example, the Udacha variety had yields ranging from 11.9 t/ha to 32.1 t/ha (Table 1). Consequently, the optimal conditions should be created for these samples to realize the potentially high yields.

For the Sambo, Primabel, Gala, Oceania, 04.573/1 varieties  $b_i$  were equal to 0.87, 0.64, 0.70, 0.73, respectively (Table 1). These varieties are suitable for cultivation under unfavorable conditions, but they are also responsive to optimal conditions. The homeostaticity index (Hom) characterizes the degree of genotype resistance to heat, moisture deficit, and poor precursors. The hybrid 04.573/1 and Primabel variety are homeostatic.

The slope angle of the regression lines of the samples was determined on the graph showing the average yields, conditions indices, regression coefficients  $b_i$  (Fig. 1). The slope angle of the lines clearly shows the response of genotypes to changes in growing conditions. Breeding forms with regression lines in the right part (conditions indices are positive) raised high and in the left part (conditions indices are negative) lowered slightly, have a genotype that adapts to adverse conditions. These are hybrid 04.573/1, Primabel, Oceania, Sambo varieties. Stability variant Si2 estimates the variation in actual yield near the regression lines. The most unstable by yield varieties Udacha, Sambo, Babushka, 04.560/4 were characterized by a significant scatter of the yield indicator near the regression lines (Table 1).

Varieties with increased environmental tolerance can realize the yield potential under extreme conditions. The Rossielle and Hamblin equations were used to determine environmental tolerance and average yield under contrasting conditions.



**Fig. 1.** Regression lines for the condition indices of the studied potato varieties

The difference  $Y_{min}-Y_{max}$  has a negative sign and reflects the level of resistance of genotypes to stressful conditions. The smaller is the gap between the maximum and minimum yields, the higher the stress tolerance of the variety is. In our case, the hybrid 04.573/1 showed high stress tolerance ( $Y_{min}-Y_{max}$ )=-8.0 in comparison with other varieties of high yielding samples.

The index  $(Y_{max}+Y_{min})/2$  shows the average yield of the variety under contrasting conditions and characterizes its genetic flexibility. The higher is this index, the greater the compliance of the genotype with climatic and biotic factors of the environment is. Hybrids 04.573/1, 04.560/4, as well as Babushka and El Mundo varieties have a higher index of

genetic flexibility (31.2, 27.2, 20.6, 19.9). Hybrid 04.573/1 has the highest index of genetic flexibility and forms a higher yield under stress conditions compared with other varieties.

## 4 Discussion

It was found that the studied varieties could be divided into several groups according to adaptability, homeostability, resistance to stress and genetic flexibility. The first group included varieties Udacha ( $b_i = 1.8$ ,  $Hom = 69.0$ ,  $S_i^2 = 788$ ), Babushka ( $b_i = 1.71$ ,  $Hom = 47.5$ ,  $S_i^2 = 351$ ), Elmundo ( $b_i = 1.29$ ,  $Hom = 64.3$ ,  $S_i^2 = 377.9$ ), 04.560/4 ( $b_i = 1.18$ ,  $Hom = 73.9$ ,  $S_i^2 = 322$ ). Indices of flexibility coefficient  $b_i$  in these samples are higher than unity and are typical for potato varieties of intensive type. Judging by the coefficients  $(Y_{min} - Y_{max})$ ,  $(Y_{max} + Y_{min})/2$ , and  $Hom$ , these genotypes under the influence of environmental stresses reduce the yield (Table 1). Analysis of the data obtained showed that in these high-yielding intensive type varieties, the proportion of genotype influence on yield variability under stress conditions decreases.

Genotypes Sambo ( $b_i = 0.87$ ,  $Hom = 328$ ,  $S_i^2 = 45$ ), Primabel ( $b_i = 0.67$ ,  $Hom = 93.3$ ,  $S_i^2 = 189$ ), and 04.573/1 ( $b_i = 0.73$ ,  $Hom = 250$ ,  $S_i^2 = 139$ ) are able to produce stable yield, both under improved and deteriorated conditions. Of this group, hybrid 04.573/1 is stable ( $S^2 = 139$ ), homeostatic ( $Hom = 250$ ) and resistant to stress  $(Y_{min} - Y_{max}) = 8.0$  and shows genetic flexibility under changing conditions  $(Y_{max} + Y_{min})/2 = 31.2$ , able to produce high yields. Yields in this hybrid ranged from 27.2 to 30.2.

## 5 Conclusion

The 3-years studies of varieties and hybrids allowed us to identify a group of flexible specimens of intensive type with a positive response to improving the environmental conditions. In this group, the best is 04.560/1 hybrid with a high level of productivity. Hybrid 04.573/1 has a high stability, genetic flexibility, and a higher level of yield in worst conditions (27.7 t/ha). Under optimal conditions, it gives a high yield of tubers (35.1 t/ha). The obtained hybrids will be used for further breeding work and will be sent to the state test.

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