

Assessment of ecological plasticity and stability of promising potato hybrids of the Komi Republic (Russia)

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Abstract. In the Republic of Komi (Russia), one of the main agricultural vegetable crops cultivated by agro-enterprises, peasant farms and the population in the private sector is potatoes. The food security of Russia in the Arctic zone and obtaining competitive varieties for the regions of the Far North of our country is the main task solved by agricultural science in the field of breeding. New, promising varieties of potatoes must meet modern requirements for high yields obtained in various natural, soil and climatic conditions of their cultivation. In addition, varieties should have high stability in terms of commercial and economic characteristics and give an equivalent yield in constantly changing environmental conditions, both for the better (favorable) and for the worse (unfavorable). The use of modern methods of mathematical, statistical analysis, calculation of the assessment of environmental stability, plasticity, adaptability, as well as an objective and complete assessment of the potential of potato genomes, rigorous selection of promising lines and hybrids and screening for various negative traits, especially at the first stages of breeding, variety samples that do not correspond and do not satisfy these parameters, allow you to quickly obtain new varieties adapted to the Arctic zone of the Russian Federation. In order to strengthen breeding work aimed at breeding promising varieties of potatoes, in 2020-2022, a research program was carried out in breeding nurseries of the dynamic competitive first, second and third years of testing (hybrids of the sixth, seventh and eighth tuber generation) on the basis of the Institute of Agricultural Biotechnology of the Federal Research Center Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences (Russia, Syktyvkar). New promising potato hybrids (varieties) were selected as the object of study: 2341-265 (Amur x Gala), 2339-8 (Oksania x Gala), 2339-9 (Oksania x Gala), 1992-14 (Udacha x Elmundo), 2000-60 (Colette x FZ 1867); the standards were zoned and recommended for this region varieties of two groups of ripeness: Udacha - early, early ripening, Nevsky - medium early. As a result of research work in the course of a comprehensive assessment of ecological plasticity and stability, a promising potato hybrid 2000-60 was identified. This hybrid is characterized by stability to growing conditions,

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responsiveness to improved cultivation conditions, high average yield (33.7 t/ha).

1 Introduction

The creation and selection of crop varieties for cultivation in the Northern regions of the Russian Federation and its Arctic zone is an important scientific problem. The most relevant for the Komi Republic is such a crop as potatoes for food purposes. Potato (*Solanum tuberosum* L.) is the most common tilled crop cultivated in the republic [1]. To select the most promising hybrids and create new varieties, it is necessary to comprehensively assess them in terms of yield, stability of its production under adverse weather conditions. Preference in further breeding to create promising varieties for the Arctic zone of Russia should be given to potato genotypes that have a high average yield over the entire period of the breeding process, high responsiveness to improved growing conditions, and stable yields [2].

2 Materials and methods

For a comprehensive assessment of five potato hybrids of the competitive testing dynamic nursery presented in table 1, scientific studies were carried out, which included an assessment of the ecological plasticity and stability of the studied samples based on the results of field trials in 2020–2022.

Table 1. Scheme of the experience of the nursery of the competitive testing of potatoes.

Breeding number / variety	Parent forms
2341-265	Amur x Gala
2339-8	Oksania x Gala
2339-9	Oksania x Gala
1992-14	Udacha x Elmundo
2000-60	Colette x FZ 1867
Nevsky, st	Candidate x Veselovskaya
Udacha, st	Anoka x Vilnia

Potato variety samples were tested on the experimental fields of the Institute of agrobiotechnology of the Federal Research Center of the Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences (cadastral number - 11:05:0104001:115; coordinates - 61.661897, 50.762800; the accounting area of the experimental plot is 1400 m², the area of the accounting plot is 50 m², in four repetitions according to the predecessor, annual grasses (vetch, oats) in a six-field cultural crop rotation.

The soil of the experimental plot is soddy-podzolic with an average content of organic matter of 7.81%, pH_{sol} – 6.23, Hr – 1.46 mmol/100 g, P₂O₅ – 670.8 mg/kg, K₂O – 249.6 mg/kg of soil, exchangeable calcium – 13.75 mmol/100 g, exchangeable magnesium – 3.50 mmol/100 g of soil.

Agrochemical analyzes of the soil were carried out according to the methods generally accepted in the system of the agrochemical service in the analytical laboratories of the institute and the Federal State Budgetary Institution “Station of the Agrochemical Service “Syktyvkarskaya” (Russia, Republic of Komi, Syktyvkar): soil sampling of the site - GOST 17.4.4.02-2017, organic matter and humus - GOST 26213-91, pH in salt extract - GOST

26483-85, hydrolytic acidity - GOST 26212-91, mobile phosphorus and potassium - GOST 54650-2011, exchangeable calcium and magnesium - GOST 26487-85.

Potatoes were planted according to the technology generally accepted for agricultural enterprises of the Komi Republic [3]: planting depth 8–10 cm, density 47600 bushes per ha, planting pattern 70x30 cm. The technology includes: spring plowing, tillage with disc harrows to a depth of 15–20 cm, application of mineral fertilizers, calculated according to the removal, based on the planned yield of 25 t/ha ($N_{150}P_{50}K_{200}$), pre-planting formation of ridges, followed by planting potatoes in them using a four-row planter SN-4B. Protective measures against weeds included double inter-row cultivation with a cultivator. Treatment with chemicals from diseases and pests was not carried out.

Potatoes were planted in the first ten days of June, when the optimum soil temperature was set at 10 °C, the tubers were completely harvested on the 90th day after planting, taking into account the total yield.

The zoned variety included in the State Register of Breeding Achievements in the Komi Republic - Nevsky (medium early) was chosen as standards, having a responsiveness parameter to environmental conditions close to linear and the recommended variety - Udacha (early, early ripening) - weakly responsive (not plastic) [4–7].

The assessment of ecological plasticity and stability of potato hybrids is based on the methods of S. A. Eberhart, W. A. Russell [8] and V. A. Zykina, V. V. Meshkov, V. A. Sa-pegga [9]. Testing of hybrids, varieties, accounting for their yields were carried out according to methodological guidelines [10–13]. Statistical and mathematical processing of the data was carried out by analysis of variance [14] and data analysis package Microsoft Office Excel 2010 on a personal computer.

3 Results and discussion

To assess the prospects of their cultivation in the conditions of the Komi Republic and the Arctic zone of Russia, an analysis of the ecological plasticity and stability of these hybrids was carried out, which determines the dependence of the yield on the weather and climatic factors of the growing environment [9].

For this analysis, yield results for the last three years (2020–2022) shown in table 2 were used.

Table 2. Assessment of ecological plasticity and stability of promising hybrids and varieties of standards in 2020–2022.

Hybrid/variety	Potato yield, t/ha				b_i	σ_d^2
	2020	2021	2022	Average (\bar{X}_{av})		
1992-14	30.0	60.8	40.8	43.9	1.51	77.1
2000-60	22.3	43.2	35.5	33.7	1.11	1.7
2341-265	30.2	51.5	38.3	40.0	1.06	31.0
2339-8	29.3	41.3	45.0	38.5	0.75	32.5
2339-9	28.7	45.7	47.5	40.6	1.02	28.5
Nevsky, st	26.4	39.0	37.4	34.3	0.71	2.7
Udacha, st	21.4	35.7	35.3	30.8	0.83	8.9
I_j (environment factor)	-10.5	7.9	2.6			

The calculation of the analysis of variance of the results of testing potato hybrids is presented in table 3 [9].

Table 3. Analysis of variance of the results of testing hybrids in 2020–2022.

Source of variation	Degree of release	Sum of squares	Medium square
General	20	1902.63	-
Varieties	6	382.90	63.82
Conditions and interaction "varieties x conditions"	14	1519.73	-
Conditions (linear)	1	1256.49	-
"sort x terms" interaction (linear)	6	80.92	13.49
Generalized Deviations	7	182.32	26.05
1992-14	1	77.07	-
2000-60	1	1.69	-
2341-265	1	31.03	-
2339-8	1	32.48	-
2339-9	1	28.54	-
Nevsky, st	1	2.66	-
Udacha., st	1	8.85	-

The calculation of ecological plasticity and stability is based on the assessment of the yield response of varieties and hybrids to growing conditions [8-9].

Since soil conditions, planting dates and agricultural practices in all years of the study practically did not differ from each other, the main parameters affecting the yield are weather and climatic factors, namely the temperature of the growing season and the amount of precipitation during this time.

From 2020 to 2022, the conditions for the cultivation of potato varieties and hybrids were heterogeneous. The worst year for potato cultivation was 2020 - environmental factor $I_j = -10.5$, which negatively affected the yield in all variants, the best year was 2021, environmental factor $I_j = 7.9$. This year, the maximum yield of potatoes in the hybrid 1992-14 was noted - 60.8 t/ha. This figure was almost twice as high as in the worst year of 2020. At the same time, the yield increase for standard varieties was only 50% on average.

Based on the calculation of the parameters of the linear regression coefficient (b_i), showing the response of the genotype to a change in growing conditions for the better and dispersion (σ_d^2), characterizing the stability of the sample, hybrid or variety in various environmental conditions, as well as the value of the parameter under consideration, for example, as in our studies - the average yield, the model proposed by S.A. Eberhart and W.A. Russell to determine the group to which the variety can be attributed according to its response to changing growing conditions [8]. If the coefficient b_i is greater or significantly greater than one, then the hybrid or variety can be characterized as responsive, and in order to obtain maximum parameters, as in our case in terms of yield, it is necessary to provide it with a high level of agricultural technology. When the value of the coefficient is less than one, the variety is less responsive to changes in external environmental factors and it is recommended to grow it on an extensive background to obtain maximum yield at minimum cost. If b_i is close or equal to one, then the variety changes its yield value in direct proportion to the improvement or deterioration of the external conditions for its cultivation. Taking into account the conjugate system of indicators b_i and σ_d^2 , as well as the condition under which genotypes with a coefficient $b_i > 1$ are classified as highly plastic, and with $b_i \leq 1$ they are relatively low plastic, the studied genotypes can be characterized and assigned to the following conditional six groups or ranks:

- Unstable type, the yield indicator tends to a maximum in unfavorable environmental conditions – $b_i < 1$ and $\sigma_d^2 > 0$,
- Unstable type, the yield index is directly proportional to the improvement of external environmental conditions – $b_i = 1$ and $\sigma_d^2 > 0$,
- Unstable type, the yield indicator will be maximum under favorable external environmental conditions – $b_i > 1$ and $\sigma_d^2 > 0$,
- Stable type, the yield will be maximum under adverse environmental conditions – $b_i < 1$ and $\sigma_d^2 = 0$,
- Stable type, the yield index responds well to the improvement of external environmental conditions – $b_i = 1$ and $\sigma_d^2 = 0$,
- Stable type, the yield indicator will have the best result under favorable environmental conditions – $b_i > 1$ and $\sigma_d^2 = 0$.

In the period from 2020 to 2022, in the breeding nurseries of the dynamic competitive first, second and third years of testing (hybrids of the sixth, seventh and eighth tuber generation), the total and average yields of potato hybrid tubers were recorded.

Based on these indicators, the coefficient of ecological plasticity (b_i) and stability (σ_d^2) of new potato hybrids was calculated. The hybrid 1992-14 showed the highest coefficient $b_i = 1.51$ and $\sigma_d^2 = 77.1$. This variety is able to significantly increase yields with improved growing conditions, however, under adverse weather and climatic conditions during the growing season, the yield will also noticeably decrease. However, since the yield of this hybrid, even in the worst year, is higher than in standard varieties, it can be recommended for cultivation in the conditions of the Komi Republic [15-16]. Hybrids 2000-60, 2341-265, 2339-9 have an ecological plasticity coefficient close to unity ($b_i = 1.02-1.11$). This indicator indicates that the yield of these hybrids is linearly dependent on the weather and climatic conditions of the environment, as a result, if they worsen or improve, the yield will change in the predicted corridor of values. The hybrid 2339-8 has the coefficient $b_i = 0.75$ (< 1), $\sigma_d^2 = 32.5$ (> 0), which is at the level of Udacha and Nevsky standards. These indicators indicate the instability of the type of this variety and the ability to produce high yields even under adverse conditions. At the same time, the yield of this variety is higher than the standards, which makes it the most promising for cultivation in the conditions of the Komi Republic and the Arctic zone of Russia.

Based on the model proposed by S. A. Eberhart and W. A. Russell ($X_{av} \rightarrow \max$, $b_i \rightarrow 1$, $\sigma_d^2 \rightarrow 0$), the closest hybrid corresponding to this formula is 2000-60, which can be characterized as a stable variety type that responds well to improved conditions [8-9;17-19].

4 Conclusion

Based on the results of research and a comprehensive assessment of ecological plasticity and stability, a promising potato hybrid 2000-60 was identified. This hybrid is characterized by stability to growing conditions, responsiveness to improved growing conditions, high average yield (33.7 t/ha).

References

1. Shmorgunov G T, Tulinov A G, Konkin P I, Kokovkina S V, Yudin A A and Oblizov A V 2016 *The Development of Agricultural Technologies to Increase the Productivity of Potato Growing In the North: a Monograph* (Syktyvkar: FGBNU NIISKh Respubliki Komi/GOU VO KRAGSiU) 127

2. Kotova Z P, Evdokimova Z Z, Kalashnik M V, Golovina L N and Chelnokova V V 2019 Selection of promising potato hybrids according to their adaptability parameters for the conditions of the European North. *Agrarian Bulletin of the Urals* **7(186)** 26–32
3. Korshunov A V 2003 *Russian potatoes. Volume III* (Moscow: LLC "Redaktsiya zhurnala "Dostizheniya nauki i tekhniki APK") 332
4. *State register of breeding achievements approved for use. "Plant varieties" (official edition)* Retrieved from: <https://gossortrf.ru/gosreestr/>
5. Glaz N V, Vasil'ev A A, Dergileva T T and Mushinskii A A 2019 Evaluation of the ecological plasticity of mid-early and mid-ripening potato varieties. *Far Eastern Agrarian Bulletin* **1(49)** 10–19
6. Popova L A, Golovina L N, Shamanin A A and Maslova V M 2017 Evaluation of the productivity and adaptability of potato varieties of different ripeness groups in the conditions of the Arkhangelsk region. *Agrarian science of the Euro-North-East* **3(58)** 26–31
7. Tulinov A G 2015 Results of testing promising varieties of potatoes in the conditions of the Komi Republic. *Agrarian science of the Euro-North-East* **4(47)** 21–28
8. Eberhart S A and Russell W A 1966 Stability parameters for comparing varieties. *Crop Science* **6(1)** 36–40
9. Zykin V A, Meshkov V V and Sapega V A 1984 *Parameters of ecological plasticity of agricultural plants, their calculation and analysis: methodological recommendations* (Novosibirsk: Sibirskoe otdelenie VASKhNIL) 25
10. Pisarev B A, Yashina I M, Makarov P P and Loginov I Ya 1994 *Methodological instructions according to potato breeding technology* (Moscow: Rossel'khozakademiya) 22
11. Simakov E A, Sklyarova N P and Yashina I M 2006 *Methodical instructions on the technology of selection process of potato* (Moscow: OOO "Redaktsiya zhurnala "Dostizheniya nauki i tekhniki APK") 70
12. Kiru S D, Kostina L I, Truskinov E V, Zoteeva N M, Rogozina E V, Koroleva L V, Fomina V E, Palekha S V, Kosareva O S and Kirilov D A 2010 *Methodological instructions for the maintenance and study of the world collection of potatoes* (Saint Petersburg: GNU GNTs VIR RF) 29
13. Korshunov A V 2002 *Multivariate experiments on potatoes (planning, conducting, analysis)* (Moscow: VNIKKh) 100
14. Dospikhov B A 1985 *Methods of Field Experience (with the basics of statistical processing of research results)* (Moscow: Agropromizdat) 351
15. Tulinov A G and Lobanov A Yu 2021 Assessment of environmental plasticity of new potato varieties of the Komi Republic, Russia. *Research on Crops* **22** 118–121
16. Tulinov A G and Lobanov A Yu 2020 The study of a new potato variety Vychevodsky according to a complex of economically valuable traits. *Agricultural science of the Euro-North-East* **21(3)** 283–292
17. Tai G C 1971 Genotypic stability analysis and its application to potato regional trials. *Crop Science* **11(2)** 184–190
18. Pakudin V Z and Lopatina L M 1984 Assessment of ecological plasticity and stability of crop varieties. *Agricultural biology* **4** 109–112
19. Pakudin V Z 1976 *Parameters for assessing the ecological plasticity of varieties and hybrids. Selection theory in plant populations* (Novosibirsk: Nauka) 189