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Evaluation of potato cultivars for resistance to diseases and pests under the high-altitude conditions of the Gornyi Altai testing site

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Abstract. The relevance of this study lies in the need to identify potato cultivars with the highest resistance to diseases and pests under the unique high-altitude conditions of the Gornyi Altai, contributing to improved crop yield stability. This study aimed to assess the resistance of early maturing potato cultivars – Belukha, Gorets, Suvenir Gornogo Altaya, and Snegir – to diseases and pests under the conditions of the high-altitude testing site in the Gornyi Altai. The research was conducted in 2023 in the village of Aktash, Ulagansky District, Altai Republic, Russia. The main findings and conclusions concerned the following aspect: the level of resistance to diseases and pests in each cultivar was influenced by various factors, including climatic conditions, soil composition, and the presence of pathogens and pests at the testing site. The study employed field trials, phytopathological analysis, and statistical data processing methods to assess the resistance of various potato cultivars. The presence and severity of plant infection by phytopathogens such as late blight and common scab, as well as damage caused by the Colorado potato beetle and other pests, were analysed. It was established that all cultivars exhibited complete resistance to late blight, common scab, and dry rot, indicating a high level of adaptation to the regional conditions. However, the cultivar Suvenir Gornogo Altaya showed minor infection by soft rot, with a damage level of 0.2%. The productivity of the studied cultivars ranged from 1,120 g per plant (Snegir) to 1,870 g per plant (Belukha). The findings support the recommendation of these cultivars for cultivation in the high-altitude conditions of the Altai Republic, with the aim of minimising crop losses. The practical value of the study lies in the potential use of its results to recommend well-adapted potato cultivars to farmers working in similar climatic conditions, thereby reducing crop losses and plant protection costs

Keywords: genotype; Gorets; Belukha; Suvenir Gornogo Altaya; late blight; common scab

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Introduction

The topic of potato cultivar resistance to diseases and pests in high-altitude testing sites, such as Gornyi Altai, is of significant importance. The climatic conditions of mountainous regions differ considerably from lowland areas, creating unique ecological niches and, consequently, specific agricultural challenges. In this context, selecting suitable potato cultivars that exhibit resistance to local pathogens and pests becomes a priority for agronomists and farmers working in these highaltitude conditions. This research emphasises the need for potato cultivars adapted to the specific environmental conditions of the Altai Republic's high-altitude testing sites. It highlights the importance of timely cultivar replacement and renewal, along with a structured plan for providing the region's population with healthy seed material (Okasheva *et al.*, 2023a; 2023b). Therefore, evaluating the disease and pest resistance of potato cultivars Belukha, Gorets, Suvenir Gornogo Altaya, and Snegir in the highaltitude Gornyi Altai region (Aktash Village, Ulagansky District) is a crucial aspect for agricultural producers and researchers. Special attention was also given to the harmful insects that affect potatoes, as they can cause substantial crop damage.

Long-term research by S. Krasnikov *et al.* (2023) identified common potato diseases found in the Altai Republic: late blight, common scab, and dry and soft rots. These diseases were mainly observed in lowland areas, where potato infection rates ranged from 0.7%-3% of total plantings. Air temperatures in these lowlands remained more stable throughout the summer compared to the highlands, where daytime temperatures reached +30°C and nighttime frosts dipped to −4°C. This extreme temperature fluctuation likely explains the absence of potato pests in the highland regions.

Late blight is a widespread and serious potato disease caused by microorganisms from the *Phytophthora* genus. These organisms can induce root and leaf necrosis, as well as stem and flower bud rot (Chizhik *et al.*, 2024). As noted by N. Zoteyeva *et al.* (2024), late blight can lead to significant yield losses if its progression is not prevented or controlled. Common scab is caused by the *Leptosphaeria maculans* fungus, which attacks the plant's leaves and stems. Initial symptoms include dark spots on the leaves, which expand and cause extensive leaf damage. The disease can then spread to the stems and roots, hindering plant development and reducing potato yields (Bethke & Jansky, 2021).

Dry and soft rots are diseases caused by various types of fungi, including *Alternaria*, *Fusarium*, and *Rhizoctonia*. Dry rots affect dry parts of the plant, such as stems, leaves, and roots, forming grey-brown or brown spots and lesions (Bomok & Pikovskyi, 2019). Soft rots, on the other hand, typically affect plants in wet weather conditions, forming grey-green or grey-brown lesions on leaves and stems. A significant amount of research focuses on studying the resistance of various potato cultivars to these pathogens. For example, the research of M. Anoumaa *et al.* (2022) emphasises the importance of using cultivars that exhibit resistance to late blight, one of the most destructive potato diseases. Their research results showed that some cultivars, when adapted to high mountain conditions, do not lose their protective properties, making them promising for use in such regions.

Research highlights that potato resistance to late blight is a key area of study. For example, L. Weng *et al.* (2024) explored the genetic mechanisms of resistance to this disease, identifying markers that facilitate the breeding of resistant cultivars. T. Adekanmbi *et al.* (2023) examined the impact of changing climatic conditions across various ecological sites on potato quality and yield, which is crucial in today's world. The authors emphasise that in mountainous environments, where agroclimatic factors can change rapidly, cultivars with multi-component resistance are needed. Another study by D. Griffin *et al.* (2022) investigates potato cultivars for their ability to withstand complex infections, i.e., combinations of multiple diseases. A. García-Serquén *et al.* (2024) demonstrate that in the high-altitude regions of the Peruvian Andes, different soil management techniques are commonly used, especially for growing potatoes on mountain slopes. These methods help mitigate the effects of nighttime frosts, which are more pronounced than in lowland areas.

This study aimed to assess the level of resistance to major diseases (late blight, common scab, dry and soft rots) and pests in selected potato cultivars under high-altitude conditions in the Gornyi Altai testing site. The research objectives were as follows: to examine three early-maturing potato cultivars (with four replications) in the village of Aktash, Ulagansky District of the Altai Republic, using the locally adapted cultivar Snegir as a control; and to compare the resistance of the cultivars Belukha, Gorets and Suvenir Gornogo Altaya to common diseases prevalent in the region.

Materials and Methods

The study materials consisted of early-maturing potato cultivars developed by the Gorno-Altaisk State University: Belukha, Gorets, and Suvenir Gornogo Altaya (cultivar authors: T. Streltsova, S. Krasnikov), with the adapted cultivar Snegir used as a control. The planting of the experimental cultivars took place on 8 June 2023 at the high-altitude site in Aktash, Ulagansky District, Altai Republic, on a plot belonging to B. Kozhamiarov. The planting date was selected due to the high amount of precipitation and the location's distance from Gorno-Altaysk (365 kilometres). The planting was done according to the following scheme: 90×30 cm spacing, with a planting depth of 10 cm, in two rows of

60 plants, and four replications. The arrangement was randomised, with cultivar-specific weeding, phytosanitary care, timely harvesting and other research stages performed. The results are presented both before and after storage. The tests were conducted following the Guidelines for Ecological Testing of Potato Varieties (Karmanov *et al.*, 1982), Research Methods for Protecting Potatoes from Diseases, Pests, Weeds, and Immunity (Volovik *et al.*, 1995), and the Field Experiment Methodology by B. Dospekhov (1985). All procedures were carried out in compliance with the Convention on Biological Diversity (1992).

The research methodology encompassed physiological and genetic selection, alongside direct observation of plant interactions with various pathogens and pests. Agronomic analysis methods were used to evaluate the results. Yield was assessed in kilograms per hectare, and the size and quality of tubers and disease resistance were analysed. Statistical methods were also employed to determine the significance of differences between cultivars. The studied cultivars (Fig. 1) are known for their productivity and ability to withstand diverse weather conditions and diseases, making them popular among the local population.

Figure 1. Studied potato cultivars
Note: the photo shows the potato cultivars Belukha, Gorets, and Suvenir Gornogo Altaya
Source: authors' photo

The soil in the Aktash area is known for its fertility and loamy composition, providing good aeration and moisture retention. During the study, no organic fertilisers or mineral complexes were applied to the soil. The trials were conducted on a natural soil background. Standard agricultural equipment, including a tractor for ploughing, was used, with all other tasks performed manually. The climatic conditions in Aktash during the experiment featured a moderately warm summer with temperatures ranging from 15°C to 25°C, which is favourable for potato growth. Precipitation was moderate (Table 1), with periods of increased humidity, supporting consistent plant growth.

Table 1. Precipitation and average air temperature in 2023 in the village of Aktash

Aktash testing site (month)	Average air temperature, °C	Precipitation, mm
May	11.3	31.2
June	28.6	11.9
July	17.9	74.7
August	18.9	58.3
September	17.3	42.4

Source: developed by the authors based on research

After harvesting, the potatoes were stored in a purpose-built storage facility with controlled temperatures between 2°C and 4°C and air humidity of approximately 85%-90%. The storage was equipped with a ventilation system to prevent condensation and maintain optimal storage conditions. However, during early spring, a roof leak occurred in the storage facility. Two sacks of the Suvenir Gornogo Altaya cultivar were directly exposed to water, leading to rapid tuber decay. When the potatoes became wet, they became more susceptible to diseases such as soft and dry rot. The excessive moisture and constant dampness created ideal conditions for the growth of mould fungi. Even if the external appearance of the potatoes did not change immediately, their internal structure was compromised by the excess moisture, deteriorating the product's quality. This ultimately reduced the nutritional value and flavour of the cultivar.

Results and Discussion

The study of the Gorets, Belukha, and Suvenir Gornogo Altaya potato cultivars, with Snegir as a control, revealed that regardless of the precipitation and air temperatures experienced in the high-altitude testing site of Aktash, Ulagansky District, Altai Republic, in 2023, the tested cultivars exhibited resistance to diseases and pests. No pests were observed, likely due to the low nighttime air temperatures in the highlands. Only the Suvenir Gornogo Altaya cultivar showed a 0.2% infection rate with soft rot, attributed to storage conditions (Table 2). Considering the site's distance from Gorno-Altaisk, mechanical damage to the tubers of the tested cultivars was expected, but none was found. As the harvest occurred during dry weather in the sandy soil of the highlands, all tubers were clean, large and yielded more than the control cultivar.

Table 2. Disease resistance of studied genotypes

No.	Cultivars	Potato diseases, %			
		Late blight	Common scab	Dry rot	Soft rot
1	Belukha	0	0	0	0
2	Gorets	0	0	0	0
3	Suvenir Gornogo Altaya	0	0	0	0.2
4	Snegir	0	0	0	0

Source: developed by the authors based on research

The study found a lack of Colorado potato beetles and other potato pests in the high-altitude Gornyi Altai region. This absence can be attributed to several factors related to the unique climatic and ecological conditions of the area. The high-altitude climate is characterised by cold temperatures and a short growing season. Colorado potato beetles and many other insect pests actively reproduce and develop in warm climates. The cold temperatures in the mountains may limit their life cycle and survival capabilities. Additionally, at high altitudes (above sea level), atmospheric pressure decreases, affecting insect respiration and potentially hindering their existence. The reduced oxygen levels and lower temperatures further contribute to their inability to thrive.

The productivity levels in the highlands were 1,120 g/plant (Snegir cultivar), 1,340 g/plant (Suvenir Gornogo Altaya), 1,570 g/plant (Gorets), and 1,870 g/plant (Belukha). These results indicate that the studied potato cultivars demonstrate higher resistance and productivity in highaltitude conditions, enabling stable yields even in challenging climates. A comprehensive approach, including breeding, improved agricultural practices, and effective resource management, is crucial for successful potato cultivation in mountainous regions.

Indian researchers V. Bhardwaj *et al.* (2022) identified 1,253 locations across India for testing potato cultivars with a cumulative positive temperature sum of 70 days. They conducted similar studies on potato cultivars at these test sites, considering meteorological conditions. While the Aktash site experiences significant negative nighttime temperatures (−4°C), India, conversely, has high nighttime temperatures. This difference is crucial to consider when studying potatoes in the context of changing climates.

Research conducted in the Himalayas by A. Choudhary *et al.* (2021) examined the combination of genetically resistant cultivars with integrated crop management methods. The results demonstrated that using organic protection methods and selecting resistant cultivars can significantly reduce crop losses from diseases without substantially increasing costs. Consistent with these findings, the current study identified resistant potato cultivars – Gorets, Belukha, and Suvenir Gornogo Altaya – that are ideally suited for cultivation in the high-altitude environment of Gornyi Altai.

The studies of W. Pérez *et al.* (2022) and C. Patarroyo *et al.* (2024) examined the resistance characteristics of various potato cultivars to late blight, one of the most destructive diseases, in the mountainous regions of Peru and Colombia. Similarly, T. Dey *et al.* (2018) conducted research in India. M. Gastelo *et al.* (2024) carried out field trials that demonstrated that local cultivars, bred using traditional knowledge, exhibited higher resistance compared to commercial cultivars. The studied potato cultivars in the Gornyi Altai region proved to be highly productive and diseaseresistant.

W. Fry (2020) emphasises that *Phytophthora infestans* populations, the causative agent of late blight, in different regions of the world, are primarily represented by several clonal lines, whose dominance can be temporary and variable. The migration of exotic strains with new phenotypic characteristics poses a significant threat, as they may be resistant to traditional disease control methods and cause substantial damage. J. Arcos-Pineda *et al.* (2024) studied the adaptive properties of various potato cultivars in the high-altitude conditions of the Andes. Similar to the Gornyi Altai conditions, researchers found that cultivars with shorter growing seasons are better adapted to mountain environments, where growing seasons are shorter. P. Bagchi *et al.* (2024) highlight the importance of selecting cultivars resistant to the low nighttime temperatures and high UV radiation characteristic of mountainous regions.

Authors J. González-Jiménez *et al.* (2023) developed an effective model simulating potato crop losses due to late blight. This model accounts for the dynamic interaction between disease development and crop growth,

utilising available meteorological data. Despite the complexity of these interactions, the authors successfully created a relatively simple model that closely correlates with real-world crop loss data. Furthermore, the model can predict the impact of climate change (temperature increases) on both potato development and late blight, suggesting that this increase may be more detrimental to the pathogen than to the crop.

Therefore, the authors of this study recommend the following key measures to prevent and control potato diseases in the Altai Republic:

- use resistant potato cultivars such as Gorets, Belukha, and Suvenir Gornogo Altaya, which have genetic resistance to major diseases;
- apply preventive treatments with fungicides to prevent fungal development and maintain plant health in the lower-altitude regions of the Gornyi Altai, where infected tubers were previously found;
- employ appropriate sanitation and field-cleaning methods to avoid the spread of diseases from previous crops;
- proper fertilisation and plant nutrition will strengthen their immune system and reduce susceptibility to diseases.

It is important to note that potato diseases can be caused by microorganisms other than fungi, such as viruses and bacteria. Therefore, for accurate diagnosis and effective disease treatment, laboratory analysis is necessary to determine the specific cause of the disease.

Conclusions

The results of evaluating the disease and pest resistance of potato cultivars in the high-altitude testing site of Gornyi Altai (Aktash Village, Ulagansky District, Altai Republic) can assist producers and experts in making informed decisions about selecting optimal potato cultivars for cultivation in the Gornyi Altai conditions. The Belukha cultivar exhibits high resistance to the major diseases and pests encountered at the testing site. This may be attributed to its genetic potential and ability to adapt to adverse conditions. The Gorets cultivar also demonstrates high resistance to the studied diseases and pests. The Suvenir Gornogo Altaya cultivar displays mixed results regarding disease and pest resistance. Some aspects of resistance were high, while others raised concerns related to the optimal storage of the cultivar. The findings of this research can be used to develop strategies for improving disease and pest resistance in cultivated potato cultivars within the Gornyi Altai region.

The studied cultivars demonstrated resistance to late blight regardless of meteorological conditions and the testing site. The evaluation of the Belukha, Gorets, and Suvenir Gornogo Altaya potato cultivars at the Gornyi Altai testing site (Aktash Village, Ulagansky District) indicates that the high-altitude environment influences the level of disease and pest resistance in different potato cultivars. Factors determining resistance levels include climatic conditions, soil composition, and the absence of pathogens and pests at the testing site. To protect potatoes from pests and preserve yields, a comprehensive approach is necessary. This approach should encompass preventative measures such as selecting healthy seeds, implementing proper soil preparation and cultivation techniques, and utilising biological control methods.

Studies in this field demonstrate a variety of approaches to evaluating potato cultivar resistance. They highlight the interconnectedness of biodiversity, regional climatic features, and agronomic practices. This data forms the basis for further research and the development of recommendations for selecting potato cultivars best suited for cultivation in high-altitude conditions. The experiment showed that all cultivars exhibited high yields and resistance to local conditions, confirming their suitability for cultivation in the temperate continental climate of the Ulagansky district. Evaluating the disease and pest resistance of potato cultivars such as Belukha, Gorets, Suvenir Gornogo Altaya, and Snegir in the high-altitude testing site of Gornyi Altai is an important area of research. High-altitude regions have specific climatic conditions that can affect the development of both cultivated plants and pathogens. Prospects for further research include developing biological control methods and studying the impact of specific high-altitude climatic conditions on potato development and resistance. These studies will contribute to increasing the yield and resilience of potato cultivars in Gornyi Altai and promoting the development of the agricultural sector in this unique climatic zone.

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Conflict of Interest

None.

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Аннотация. Иштин актуалдуулугу Алтай тоолорунун уникалдуу шарттарында илдеттерге жана зыянкечтерге эң туруктуу картошка сортторун аныктоо зарылдыгында турат, бул түшүмдүн туруктуулугун жогорулатууга өбөлгө түзөт. Иштин максаты Тоолуу Алтай полигонунун шарттарында Белуха, Горец, Тоолуу Алтай сувенири жана Снегирдин алгачкы сортторунун илдеттерине жана зыянкечтерине туруштук берүү деңгээлин аныктоо болгон. Изилдөө 2023 – жылы Россиянын Алтай Республикасы Улаган районундагы Акташ айылында жүргүзүлгөн. Изилдөөнүн негизги табылгалары жана тыянактары төмөнкү аспектиге байланыштуу: картошканын ар бир сортундагы ооруларга жана зыянкечтерге туруштук берүү деңгээли климаттык шарттар, топурактын курамы жана полигондо патогендер менен зыянкечтердин болушу сыяктуу ар кандай факторлор менен аныкталат. Изилдөө картошканын ар кандай сортторунун туруктуулугун баалоо үчүн талаа сыноосунун, фитопатологиялык анализдин жана статистикалык маалыматтарды иштеп чыгуунун ыкмаларын колдонгон. Фитопатогендер, мисалы, фитофтора жана кадимки котур сыяктуу өсүмдүктөрдүн катышуусу жана даражасы, ошондой эле Колорадо коңузу жана башка зыянкечтер келтирген зыяндуулар талданды. Бардык сорттор кеч күйүүгө, кадимки котурга жана кургак чирикке толук туруштук берери аныкталган, бул сорттордун аймактын шарттарына жогорку ыңгайлашуусун көрсөтүп турат. Бирок, Алтай тоосундагы Сувенир сорту 0,2 % бузулуу деңгээли менен нымдуу чириктер менен бир аз бузулганын көрсөттү, ал эми изилденген сорттордун өнүмдүүлүк көрсөткүчү 1120 г бадал (Снегирь сорту) 1870 г бадал (Белуха сорту) сортун түздү. Алынган маалыматтар түшүмдүн коромжулугун азайтуу үчүн ушул сортторду Алтай Республикасынын бийик тоолуу шарттарында өстүрүүгө сунуш кылууга мүмкүндүк берет. Иштин практикалык мааниси окшош климаттык шарттарда иштеген фермерлерге ылайыкташтырылган картошка сортторун сунуштоо үчүн изилдөөлөрдүн натыйжаларын колдонуу мүмкүнчүлүгү болуп саналат, бул өсүмдүктөрдү коргоо үчүн продукциянын жоготууларын жана чыгымдарын азайтууга мүмкүндүк берет

Негизги сөздөр: генотип; Тоо; Белуха; Алтай тоосундагы Сувенир; кеч Жара; кадимки котур

Оценка сортов картофеля на устойчивость к болезням и вредителям в условиях высокогорного полигона Горного Алтая

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Аннотация. Актуальность работы заключается в необходимости выявления сортов картофеля, наиболее устойчивых к болезням и вредителям в уникальных условиях высокогорья Горного Алтая, что способствует повышению стабильности урожая. Цель работы состояла в том, чтобы определить уровень устойчивости к болезням и вредителям ранних сортов картофеля Белуха, Горец, Сувенир Горного Алтая и Снегирь в условиях высокогорного полигона Горного Алтая. Исследование проходило в 2023 году в с. Акташ Улаганского района Республики Алтай, Россия. Основные находки и выводы исследования касаются следующего аспекта: уровень устойчивости к болезням и вредителям у каждого сорта картофеля определяется различными факторами, такими как климатические условия, почвенный состав и наличие патогенов и вредителей на полигоне. В ходе исследования применялись методы полевых испытаний, фитопатологического анализа и статистической обработки данных для оценки устойчивости различных сортов картофеля. Было проанализировано наличие и степень поражения растений фитопатогенами, такими как фитофтора и парша обыкновенная, а также повреждения, наносимые колорадским жуком и другими вредителями. Установлено, что все сорта проявляют полную устойчивость к фитофторозу, парше обыкновенной и сухим гнилям, что говорит о высокой адаптированности этих сортов к условиям региона. Однако, сорт Сувенир Горного Алтая показал незначительное поражение мокрыми гнилями с уровнем поражения 0,2 %, а показатели продуктивности изучаемых сортов составил от 1120 г/куст (сорт Снегирь) до 1870 г/куст (сорт Белуха). Полученные данные позволяют рекомендовать к выращиванию в высокогорных условиях Республики Алтай данные сорта для минимизации потерь урожая. Практическая ценность работы состоит в возможности использовать результаты исследований для рекомендации адаптированных сортов картофеля фермерам, работающим в аналогичных климатических условиях, что позволит снизить потери продукции и затраты на защиту растений

Ключевые слова: генотип; Горец; Белуха; Сувенир Горного Алтая; фитофтороз; парша обыкновенная