

Phytosanitary diagnostics of apple powdery mildew, *Podosphaera leucotricha* and apple scab, *Venturia inaequalis*

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ABSTRACT

The article presents the results of phytosanitary monitoring of apple orchards in the Almaty region, Kazakhstan conducted in 2023. The aim of the study was to determine the distribution and development level of major fungal diseases of apple trees – scab, *Venturia inaequalis* and powdery mildew, *Podosphaera leucotricha* – under the conditions of Southern and Southeastern Kazakhstan. Surveys were carried out in the orchards of “Koram” farm (Koram village, Enbekshikazakh district), where nine apple cultivars (Gala, Fuji, Golden Delicious, Quinti, Red Delicious, Shaphida, Korean, and Stark Earliest) were grown on an area of 110 ha. For the phytosanitary assessment, 95–100 trees of each cultivar were examined, and 2500–3000 leaves per cultivar were analyzed. The results revealed cultivar-specific susceptibility to fungal pathogens. Scab infection was recorded in Gala, Golden Delicious, and Stark Earliest (15.0–22.0% prevalence with a low development level of 0.4–1.3%). Symptoms of powdery mildew were observed in Gala, Fuji, Golden Delicious, and Red Delicious, where the prevalence reached 30.0–33.3%, while the disease development remained weak (0.3–1.5%). No symptoms of either disease were detected in the Quinti, Shaphida, and Korean cultivars. Thus, Gala, Golden Delicious, and Red Delicious were identified as the most susceptible cultivars, whereas Quinti, Shaphida, and Korean demonstrated relative resistance to scab and powdery mildew. The findings confirm the necessity of systematic phytosanitary monitoring of orchards and may serve as a scientific basis for breeding programs and for the introduction of resistant apple cultivars in the southern regions of Kazakhstan.

Keywords: Apple (*Malus domestica*), Scab (*Venturia inaequalis*), Powdery mildew (*Podosphaera leucotricha*), Phytosanitary monitoring, Cultivar resistance

Article type: Research Article.

INTRODUCTION

In many countries around the world, especially in Kazakhstan, the most important fruit crop is the apple, *Malus domestica* Borkh., which is the leader in increasing fruit production. In our country, orchards cultivating pome and stone fruit crops cover an area of 47.18 thousand hectares, of which 75% are used for apple orchards (Gross *et al.* 2014). Apples also possess excellent storability and year-round availability in markets at affordable prices (Vallée Marcotte *et al.* 2022). As of 2023, the State Register of Breeding Achievements approved for use in the Republic of Kazakhstan includes 73 different apple varieties, of which 29% are local varieties obtained from the Kazakh Research Institute of Fruit and Vegetable Growing, and 38% are unregistered original varieties. Currently, Kazakhstan offers a sufficiently wide assortment of fruit crops. The most important condition for improving the economic efficiency of horticulture is the continuous improvement of varieties. New varieties must possess

advantages such as productivity, resistance to abiotic and biotic stress factors, fruit quality, and novelty. Disease resistance of fruit crop varieties is one of the most important indicators determining their market value. Despite numerous studies conducted in various countries, many issues related to the resistance of fruit crop varieties to scab and powdery mildew remain insufficiently studied. The creation of new perennial crop varieties involves several cycles of hybridization and, depending on the crop, may take on average 20–25 years. In the last decade, there have been clear prerequisites for shifting from traditional breeding methods based on phenotypic traits to approaches that aim to use genomic characteristics, such as identifying “trait–locus” associations. Apple orchards affected by fungal diseases such as scab, *Venturia inaequalis* (Cooke Winter) and powdery mildew, *Podosphaera leucotricha* (Ellis & Everh. Salmon) require intensive care. In integrated fruit production, up to 20 fungicide treatments may be applied to prevent scab and powdery mildew infections (Soriano *et al.* 2009). Organic management practices, which ensure high ecosystem service productivity, are reported to result in 48% lower yields compared to conventional fruit production (Nasonov & Suprun 2015). Planting resistant varieties is a promising strategy. Some apple varieties with sufficiently high fruit quality carry the Rvi6 gene for scab resistance, derived from *Malus floribunda* Siebold ex. Van Houtte 821. Unfortunately, the Rvi6 gene has proven ineffective in several European fruit-growing regions (Yakuba 2013), as well as in other parts of the world (Bus *et al.* 2006). Powdery mildew is a fungal disease caused by the obligate biotrophic pathogen *Podosphaera leucotricha* of the order Erysiphales, typical of apple-growing regions worldwide. The life cycle of this fungus is closely linked to the phenology of its perennial host, the apple tree (*Malus × domestica* Borkh.), and has been the subject of many academic studies. Powdery mildew, *P. leucotricha* infects not only apple but also almond, pear, quince, African cherry, peach, and ornamental evergreen shrubs (Pessina *et al.* 2016). The annual economic losses caused by apple powdery mildew may significantly increase in the coming decades, as climate change creates favorable environmental conditions for disease development. Indeed, climate change is expected to affect many powdery mildew pathogens worldwide (Weber & May 1989). Economically valuable crops such as grapevine (*Erysiphe necator*), cucumber (*Podosphaera xanthii*), oak (*Erysiphe alphitoides*), and wheat (*Blumeria graminis* f. sp. *tritici*) are also affected by powdery mildew pathogens. Recent studies have shown that rising temperatures and increased carbon dioxide levels create favorable conditions for powdery mildew development and its spread beyond established areas (Hokanson *et al.* 1998; Di Gaspero *et al.* 2000). As suggested in previous literature on grapevine powdery mildew, climate change has altered the dynamics between host plants and pathogens. In apple-growing regions such as the Northeastern United States or Canada, regional climate change may lead to prolonged survival of *P. leucotricha* infections, as earlier spring onset allows the pathogen to persist longer and spread more widely (Cipriani *et al.* 1999). Research over the last two centuries has primarily focused on understanding the epidemiology of powdery mildew and controlling the pathogen through chemical measures. The continuous development of new tools and technologies has also opened up new approaches to disease prevention, such as transgenic apple lines carrying resistant (R) and pseudogenized susceptible (S) genes (Gessler *et al.* 2006; Xu & Crouch 2008; Savelyev *et al.* 2009). In the future, to ensure that apple fruits are environmentally friendly, durable, and sustainable, long-term resistance and high agronomic value of varieties are urgently needed. In the last decades of the 20th century, breeding goals were primarily aimed at maintaining aesthetic standards, while fruit quality and disease resistance became a priority (Khajuria *et al.* 2018). Many breeding programs worldwide are focused on improving resistance to apple scab and powdery mildew, often combined with reducing susceptibility to other diseases (e.g., phytophthora, black rot), pests (e.g., insects), and abiotic stress factors (frost, heat, drought, ultraviolet radiation). However, enhancing resistance to scab and powdery mildew remains the main goal (Evans & James 2003).

MATERIALS AND METHODS

Objects of the Study

Phytopathological assessment of resistance to apple scab and powdery mildew

The varieties were evaluated for disease resistance under natural field infection conditions in July 2022. The susceptible varieties “Golden Delicious” and “Idared” were used as controls. Apple scab severity was assessed using the scale proposed by Chevalier *et al.* (1991) cited in Gessler *et al.* (2006).

According to this scale:

- 0 – no symptoms;
- 1 – hypersensitivity;
- 2 – chlorosis without sporulation;

3a – chlorosis and necrosis with weak sporulation;

3b – chlorosis and necrosis with abundant sporulation.

Apple scab assessment on leaves was performed using a quantitative scale:

0 – no visible lesions;

1 – isolated small spots, less than 1.0% of the leaf surface infected;

2 – 1.0–10.0% of the leaf surface infected;

3 – 11.0–25.0% of the leaf surface infected;

4 – 26.0–50.0% of the leaf surface infected, enlarged lesions with darker sporulation;

5 – lesions covering more than 50.0% of the leaf surface, large, merging, with dark sporulation (Zhdanov 1991).

RESULTS AND DISCUSSION

Phytosanitary monitoring was carried out based on route surveys of the orchard area, taking into account at least five plants of each variety. Phytosanitary assessment of fungal diseases was conducted at each observation point. Between 95 and 100 apple trees of each variety were examined. We carefully studied the trunk, leaves, and fruits of the fruit trees for signs of infection. Phytosanitary monitoring was conducted from June 10 to July 30 in 2022–2024 to determine the distribution and level of development of apple scab and powdery mildew diseases. The route surveys were carried out in apple orchards of Almaty, Zhambyl, and Turkestan regions – the main fruit-growing regions of our country (Madenova *et al.* 2024; Galymbek *et al.* 2024; Galymbek *et al.* 2025). The main apple varieties grown in these regions are Starkrimson, Golden Delicious, Idared, Samured, Gala, Fuji, and Golden Delicious. Rootstocks used were varieties M9 and MM106. During the route surveys in each district, samples of diseased leaves and fruits were collected, and a herbarium was prepared in the apple orchards of the “Akkazy” and “Ermeke” farms of the Enbekshikazakh district, with a planting area of 14 hectares. These orchards are located at the foothills of the Zailiyskiy Alatau Mountains. The spread of apple scab was at a moderate level, ranging between 23.0–31.0% in the varieties Starkrimson, Golden Delicious, and Idared, while the disease development remained at a low level of 1.0–2.84%. In the varieties Starkrimson and Idared the disease did not develop. No signs of distribution or development of powdery mildew were detected (Table 1). In 2023, phytosanitary monitoring of fungal diseases was continued. In the Almaty region, phytopathological assessment of apple scab and powdery mildew was conducted in the orchards of the “Koram” farm in the village of Koram, Enbekshikazakh district. According to the chief agronomist of “Koram” farm, the orchard area is 110 hectares, with an annual yield of 50 tons per hectare and a total production volume of 5,500 tons. The age of the fruit trees is 2–5 years. Pesticides are used to control pests, diseases, and weeds. The orchard cultivated the following varieties: Gala, Fuji, Golden Delicious, Quinti, Red Delicious, Shafida, Korean, and Stark Earliest (Table 1).

Table 1. Results of phytosanitary surveys on fungal diseases of apple trees in the orchards of Koram farm, Koram village, Almaty region, Enbekshikazakh district (2023)

Variety	Total trees at the control point	Scab – infected trees (pcs)	Rate of infected trees (%)	Avg. disease development in leaves (score)	Powdery mildew – Infected trees (pcs)	Rate of infected trees (%)	Avg. disease development in leaves (score)
Gala	1600	320	20.0	1	480	30.0	1
Fuji	1500	0	0	0	316	21.10	1
Golden Delicious	700	156	22.29	1	201	28.71	1
Quinti	2100	0	0	0	0	0	0
Red Delicious	650	0	0	0	217	33.33	1
Golden Delicious	1800	0	0	0	0	0	0
Shaphida	700	0	0	0	0	0	0
Korean	1600	0	0	0	0	0	0
Stark Earliest	1700	256	15.06	1	0	0	0
Total	12,350	732	0.57	3	1214	11.31	4

Out of the 9 apple varieties under observation, three were affected by scab and four by powdery mildew. On an area of 1.5 hectares, 1,600 trees of the Gala variety were planted, of which 320 trees, or 20.0%, were affected by scab (Fig. 1). A total of 156 Golden Delicious trees were affected, which means 22.29% of the total number of trees were infected with scab. Of the 1,700 trees of the Stark Earliest variety, 15.06% were infected. Powdery mildew infection was identified in the orchards of the Koram farm in the village of Koram. Powdery mildew was found in 480 Gala trees, which indicates that 30.0% of the trees were affected by the disease. Infection with powdery mildew was detected in 28.71% of Fuji trees and 33.33% of Red Delicious ones. No powdery mildew pathogen was found on the other apple varieties.



Fig. 1. Infection of leaves and fruits with the apple scab pathogen (infection rate 70%).

As a result of phytopathological assessment, conidia of scab spores were clearly observed on the underside of apple leaves. It was evident that 5.0–30.0% were infected with the pathogen. From each apple variety, 2,500–3,000 leaves were sampled. A phytopathological assessment was performed on 3,000 Gala leaves. It was found that 35 of these leaves were affected by scab. The average disease development in the leaves was 6.86%, or scored as 1, which indicates weak development. The average level of infection in the leaves of Golden Delicious was 7.65%. The number of infected leaves was 17, or an average of 0.58%. From the Stark Earliest variety, 2,800 leaves were collected, of which 37 leaves, or 1.32%, were affected by scab. The average disease development in the leaves was 8.82%, scored as 1, indicating low-level development. No scab infection was detected on the leaves of the other apple varieties. It was determined that 3.1% of Gala leaves were infected with powdery mildew. The disease development in the leaves was 7.42%, or scored as 1, indicating weak development. A phytopathological assessment was performed on 2,800 Fuji leaves, and no signs of scab were found. However, symptoms of powdery mildew were detected in 34 leaves, which accounts for 1.22% of infection. The average powdery mildew development in the leaves was 8.29%, scored as 1, indicating weak development. The average number of infected leaves in the Golden Delicious variety was 2.5%. The average disease development in the leaves was 10.75%, scored as 2, indicating moderate development. A phytopathological assessment was carried out on 2,500 Red Delicious leaves. Powdery mildew was detected in 19 leaves, with an average of 0.76% infected leaves. The average development of the disease in the leaves was 6.84%, scored as 1, indicating weak development (Table 2). In the village of Koram, the “Koram” farm used M9 and M106 rootstocks for planting apple varieties. The apple orchard is located at the foothills of the Zailiyskiy Alatau Mountains at an altitude of 609 meters above sea level. The research area covers 29 hectares. Based on the phytosanitary studies conducted at the “Koram” farm, village of Koram, the prevalence and level of development of apple scab and powdery mildew diseases in this region were determined. According to the results of Table 3, in 2023, in the orchards of the “Koram” farm of Almaty region, village of Koram, the prevalence of apple scab ranged from 16–20%, while the level of infection development varied from 0.43–1.27%. It is evident that the prevalence of powdery mildew ranged from 1.9–30%, while its development remained at a low level: 0.32–1.5% (Table 3). In the orchard where the Gala variety was grown, the prevalence of apple scab was 16.7%, while the development of the disease was at a lower level – 0.8%. In the Golden Delicious variety, the prevalence of infection reached up to 20.0%, whereas disease development was at a lower level: 0.4%. Signs of scab were detected in the field where the Stark Earliest variety was cultivated. In this area, the prevalence of the pathogen was 16.7%, and the disease development was 1.23%. No symptoms

of scab infection were observed on the leaves of the other varieties, i.e., Fuji, Quinti, Red Delicious, Shaphida, and Korey.

Table 2. Results of determining the development of fungal diseases on apple leaves in the orchards of Koram farm, Koram village, Almaty region, Enbekshikazakh district (2023).

Variety	Total leaves sampled	Scab – Infected leaves (pcs)	Rate of infected leaves (%)	Avg. disease development on leaves (%)	Score	Powdery mildew – Infected leaves (pcs)	Rate of infected leaves (%)	Avg. disease development on leaves (%)	Score
Gala	3000	35	1.17	6.86	1	93	3.1	7.42	1
Fuji	2800	0	0	0	0	34	1.22	8.29	1
Golden Delicious	3000	17	0.58	7.65	1	75	2.5	10.75	2
Quinti	3000	0	0	0	0	0	0	0	0
Red Delicious	2500	0	0	0	0	19	0.76	6.84	1
Golden Delicious	3000	0	0	0	0	0	0	0	0
Shaphida	3000	0	0	0	0	0	0	0	0
Korean	3000	0	0	0	0	0	0	0	0
Stark Earliest	2800	37	1.32	8.82	1	0	0	0	0
Total	26,100	89	0.03	0.23	3	221	0.08	0.33	5

The Gala, Fuji, Golden Delicious, and Red Delicious varieties were affected by powdery mildew. In the plots where Gala and Golden Delicious were cultivated, the prevalence of infection was 26.0–30.0%, while the development of the disease was weak: 1.3–1.5%. In the Fuji variety, powdery mildew spread within 20%, and disease development remained at a lower level: 0.58% (Table 3). It is evident that in the Red Delicious variety, powdery mildew spread and developed at a low level, with a prevalence of 1.9% and development of 0.3%. No powdery mildew was observed on the leaves of the other varieties, i.e., Quinti, Shaphida, Korey, and Stark Earliest.

Table 3. Distribution and development of apple scab and powdery mildew in apple orchards of Almaty region (2023).

Village / Farm	Variety	Rootstock	Planting area (ha)	Scab – Prevalence (%)	Scab – Development (%)	Powdery mildew – Prevalence (%)	Powdery mildew – Development (%)	Altitude (m)	Coordinates
Koram village, “Koram” farm	Gala	M9, MM106	1.5	16.7	0.8	30	1.5	609	N 43°31'.431" E 78°11'.480
Koram village, “Koram” farm	Fuji	M9	1.5	0	0	20	0.6	609	N 43°31'.414" E 78°11'.493
Koram village, “Koram” farm	Golden Delicious	M9	0.5	20	0.4	26.7	1.3	609	N 43°31'.423" E 78°11'.506
Koram village, “Koram” farm	Quinti	M9	2.0	0	0	0	0	609	N 43°31'.499" E 78°11'.478
Koram village, “Koram” farm	Red Delicious	M9	0.5	0	0	1.9	0.3	609	N 43°31'.499" E 78°11'.478
Koram village, “Koram” farm	Shaphida	M9	0.5	0	0	0	0	612	N 43°31'.386" E 78°11'.570
Koram village, “Koram” farm	Korean	M9	1.5	0	0	0	0	612	N 43°31'.387" E 78°11'.596
Koram village, “Koram” farm	Stark Earliest	MM106	1.5	16.7	1.3	0	0	609	N 43°31'.431" E 78°11'.480

CONCLUSION

Phytopathological surveys of apple orchards conducted in 2023 in the farms of Koram village, Enbekshikazakh district of Almaty region, made it possible to determine the prevalence and development level of fungal diseases – apple scab, *Venturia inaequalis* and powdery mildew, *Podosphaera leucotricha*. The monitoring results showed that among the nine apple varieties under observation, symptoms of scab infection were detected in Gala, Golden Delicious, and Stark Earliest. The prevalence of the disease ranged from 15.0 to 22.0%, with a low level of development (0.4–1.3%). In Fuji, Quinti, Red Delicious, Shaphida, and Korean varieties, no scab symptoms were observed. Powdery mildew was diagnosed in Gala, Fuji, Golden Delicious, and Red Delicious varieties. The prevalence of the disease varied from 1.9 to 33.3%, while the development was assessed as weak to moderate (0.3–1.5%). No powdery mildew pathogen was found in the other varieties. Phytopathological analysis of leaves confirmed the presence of scab conidia on the underside of the leaf blades, with the average infection rate ranging from 0.5 to 1.3% of infected leaves and the disease development level from 6.8 to 8.8%. Leaf infection by powdery mildew ranged from 0.8 to 3.1%, with disease development varying from 7.4 to 10.7%, corresponding to weak or moderate levels. Thus, the conducted studies revealed variety-specific susceptibility to fungal pathogens. The most vulnerable were Gala, Golden Delicious, and Red Delicious, while Quinti, Shaphida, and Korean varieties demonstrated relative resistance to these diseases. The obtained results confirm the necessity of systematic phytopathological monitoring of orchards and a differentiated approach to plant protection. They may serve as a scientific basis for breeding programs and for recommendations on the introduction of resistant apple varieties under the conditions of Southern and Southeastern Kazakhstan.

FUNDING STATEMENT

This article is published within the framework of financial support of the integrational scientific project, implemented jointly with research institutes of RK under the university grant according to the order №05-04/250 from 3 April 2025, Abai Kazakh National Pedagogical University ("Identification of sources of genes which are resistant to fungal diseases in Sivers apple using DNA-marking technology and their cultivation at the agrobiostation of Abai Kazakh National Pedagogical University").

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Bibliographic information of this paper for citing:

Galymbek, K, Madenova, A, Bakirov, S, Tastanov, Y, Ualiyeva, R, Zhangazin, S, Arystanova, S, Seilkhan, A 2025, Phytosanitary diagnostics of apple powdery mildew, *Podosphaera leucotricha* and apple scab, *Venturia inaequalis*. *Caspian Journal of Environmental Sciences*, 23: 885-891.
