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Article

Identifying Fire Blight-Resistant *Malus sieversii* Rootstocks Grafted with Cultivar 'Aport' Using Monitoring Data

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Abstract: In the present study, the most valuable cultivar 'Aport krovavo-krasnyy' was grafted onto *M. sieversii* genotypes harvested from 11 populations in Dzungarian Alatau and Ile Alatau to identify ones resistant to *Erwinia amylovora*. The wild apple populations included in the present research have not been previously explored. Seedling population 10, developed using rootstocks from a *M. sieversii* population growing in Turgen, demonstrated the highest resistance to *Erwinia amylovora*, showing no fire blight symptoms and no positive PCR results for *E. amylovora* during the eight years of monitoring in the Talgar field (Kazakhstan) from 2015 to 2022. The population from Steep Tract (seedling population 1) was also valuable for breeding and reduced the pathogen distribution to below 30%. Genotypes from a genetic reserve (seedling population 5) were the most susceptible among the researched populations, with a disease distribution level of 24–95%. In seedling population 5, trees affected at least twice by the pathogen exhibited wilting, shepherd's crook formation, leaf necrosis, and occasional exudate droplets, while trees in other combinations primarily showed shoot wilting and leaf death. Fire blight disease also developed more rapidly within the plant in seedling population 5; by 2020, one tree nearly died after only two infections.

Keywords: Aport; *Malus sieversii*; fire blight; *Erwinia amylovora*; resistance

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1. Introduction

The *Malus domestica* 'Aport' is a famous national apple cultivar in Kazakhstan. Although the origin of the 'Aport' cultivar is still unclear, recent research has indicated that it may be related to 'Landsberg Reinette' [1,2]. The average weight of 'Aport' fruit falls within the range of 200–260 g; however, in some cases, larger fruits can reach 600–700 g [2]. Breeding of this cultivar has focused on improving its size, organoleptic quality, taste, and fruit appearance. 'Aport' apples are famous for their unique rich flavor profile, which is a harmonious blend of sweetness and tartness. The fruit also has a distinctive pleasant aroma that makes it highly desirable among consumers. One of the notable traits of the 'Aport' cultivar is its excellent storage capability. The apples can be stored for several months without a significant quality loss, retaining their flavor and texture over time. Currently, more than 115 forms of the cultivar have been described in Kazakhstan [2]. 'Aport' is extensively employed in country breeding programs to improve the agronomic traits of local cultivars and to maintain the germplasm for research and preservation purposes. Grafting of 'Aport' onto *M. sieversii* is the only efficient method for fruit production. For more than 50 years, 'Aport' was cultivated on *M. sieversii* genotypes growing in the mountain zones of Tien Shan. A significant issue with the 'Aport' cultivar is its high susceptibility to fire blight disease, which necessitates stringent measures to control the spread of the pathogen. Fire blight disease is caused by bacteria *E. amylovora*, which is widely distributed throughout the country and causes devastating yield losses [3–6]. One potential solution for cultivating not only 'Aport', but also other valuable apple varieties that are highly susceptible to fire blight is the identification of resistant rootstocks derived from wild apple species. *Malus sieversii*, the wild ancestor of the domesticated apple, holds significant ecological and genetic importance within Kazakhstan's biodiversity. Kazakhstan is considered the center of origin for *Malus sieversii*, which includes extensive populations spread across varied and remote regions [7–9]. *Malus sieversii* has a high level of genetic diversity and many unique alleles that are not found in cultivated apple varieties, making it a valuable source of novel traits that can be used to improve apple quality and disease resistance [10]. The different fire blight resistance levels of *M. sieversii* accessions from Kazakhstan have been reported in previous studies [11–14]. About 13 strain-specific and environment-dependent minor quantitative trait loci (QTLs) in a segregated *Malus sieversii* × *Malus* × *domestica* population have been identified, which may be useful in further breeding programs [15]. To date, over 30 major and minor fire blight resistance loci that provide both strain-specific and broad-spectrum resistance have been identified in wild and cultivated apples; however, some of these loci may be identical [15–17]. The most effective QTLs are derived from wild species, which are actively utilized in both rootstock and scion cultivar breeding programs [18–22]. However, research efforts have primarily targeted specific characterized populations of *M. sieversii*, leaving numerous other populations unexplored [8]. The mountains of Ile Alatau and Dzungarian Alatau, as well as Tarbagatai and Karatau, are the growth centers of wild apple species in Kazakhstan [23,24]. Most populations are located in Ile Alatau, Dzungarian Alatau, and Tarbagatai. The 15 most explored seed nurseries in Dzungarian Alatau and Ile Alatau were established by Aimak Dzhangaliev in the 1960s with the aim of renewing wild apple populations and breeding new cultivars. However, many trees have died, disrupting the populations. Identifying new genotypes and establishing nursery fields from these genotypes will enhance the identification of fire blight resistance sources for breeding and deepen our understanding of the underlying disease mechanisms.

The primary aim of this study is to identify fire blight-resistant *M. sieversii* genotypes suitable for use as rootstocks to enhance the overall resistance of highly susceptible apple cultivar 'Aport krovavo-krasnyy'. This study specifically focuses on accessions from nine populations in the Dzungarian Alatau and two populations in the Ile Alatau regions, which have not been previously explored for their fire blight resistance potential.

Over the course of eight years, the established apple orchard was monitored to analyze the incidence, distribution, and severity of fire blight infection. Field observations were conducted systematically, focusing on the development of disease symptoms in both the rootstocks and grafted scions. The data collected provide insights into the potential of *M. sieversii* genotypes to mitigate fire blight damage and offer a valuable basis for selecting robust rootstocks for future breeding programs.

2. Materials and Methods

2.1. Collecting Wild Apple Seeds and Grafting

Apples were collected from 11 *M. sieversii* populations in the Alatau mountains in the autumn of 2010, Table 1.

The sampling altitude varied from 1121 to 1470 m above sea level (masl). Each population included at least 20 trees. The ages of the populations varied between 30 and 40 years. The apples were collected from the ground beneath 5–10 randomly chosen trees. Approximately 40–50 seeds from each population were planted in the soil after they were removed from the apples in October of 2010 in nursery fields to produce seedlings. The seeds were covered with 7 cm of sawdust, followed by 2.5 cm of soil. Of the seeds, 80–82% germinated in the spring of 2011. The seedlings were watered five times during the vegetation period. All surviving seedlings from every population were used for grafting the 'Aport krovavo-krasnyy' cultivar [25] (Figure 1).

Table 1. Geographical characteristics of wild apple populations.

№	Location and Altitude of the Population	Seedling Population
	Dzungarian Alatau	
1	Steep Tract (Genetic reserve), 1457 masl	C1
2	Chernova River (Genetic reserve), 1329 masl	C2
3	Chernova River (Genetic reserve), 1470 masl	C3
4	Chernova River (Genetic reserve), 1350 masl	C4
5	Chernova River (Genetic reserve), 1190 masl	C5
6	Bulenka River, 1237 masl	C6
7	Bulenka River, 1121 masl	C7
8	Population of *Malus niedzwetzkyana*, 1370 masl	C8
9	Form 28 of wild apple; the altitude is not available	C18
	Ile Alatau	
10	Talgar, 1340 masl	C9
11	Turgen, 1250 masl	C10

masl—meters above sea level.

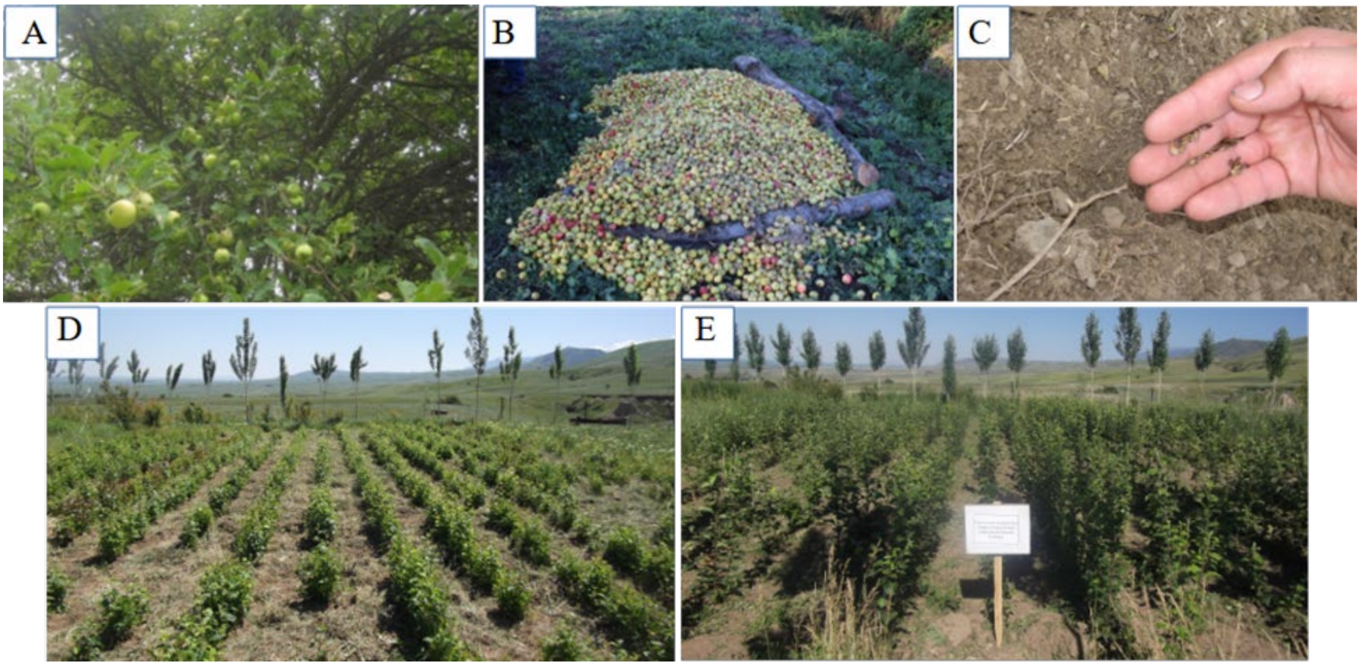

Figure 1. Wild apple trees (**A**) and fruit (**B**) harvested in the Dzungarian Alatau population in 2010. Seeds (**C**) were planted in 2010. The nursery of *M. sieversii* seedlings in 2011 (**D**) and before grafting in 2012 (**E**).

In August 2012, Aport scions were grafted onto *M. sieversii* seedlings and grown in a nursery field for 2 years before being replanted in the Aport field in 2015. For grafting, a single bud and a shield-shaped piece of stem was cut from the scion and inserted beneath the bark of the rootstock through a T-shaped incision during periods of active growth [26].

2.2. Planting of Grafted Trees and Disease Monitoring

Two-year-old plants were used to establish the ‘Aport’ field apple garden in Turgen. The altitude of the garden ranged from 950 to 1100 masl. Before the apple trees were planted, soil steaming was performed for 4 years. Each seedling population included an average of 25 trees in 3 rows. The distance between trees in each row was 6 m, with 8 m between each row (Figure 2, Video S1). Aport is a vigorous apple variety that demands a significant amount of space to grow, particularly when self-rooted or grafted onto standard rootstocks. No more than 208 trees were planted per ha. From 1950 to the early 1960s, the Aport cultivar planting scheme broadly accepted in the USSR used 8 or 9 m spacing between trees.

Figure 2. The Aport field in April of 2022. Seedling populations 10 (**A**), 3 (**B**), and 5 (**C**).

The ‘Aport’ field was watered seven times during the vegetation period and was cultivated in grass sod humus soil formed by alfalfa (*Medicago sativa*) [27] since 2020. The alfalfa planted in 2020 was mowed three times after planting. The use of alfalfa is an important agricultural technique that improves fruit quality and is broadly applied in Kazakhstan. The ‘Aport’ cultivar requires soft protection against pests and diseases. Therefore, chemicals were not applied, and the apple field is considered to be growing under natural conditions. Pruning and other conventional agrotechnical methods [28,29] were regularly used to prevent disease from spreading.

Monitoring of the spread of fire blight started in 2015 and lasted 8 years. The inspections were conducted every month except during wintertime, and each tree from the 11 seedling populations was observed. From 2015 to 2019, only visual observation was conducted, and the results were not included in the disease assessment since the symptoms of fire blight were not observed before active flowering. The first year of active flowering was 2019. The assessment of fire blight distribution in the ‘Aport’ field was conducted every late spring and summer from 2019 to 2022. Visual monitoring and PCR testing were conducted.

Disease spread and severity were evaluated by observing the ‘Aport’ field along the entire field X trajectory. The calculation formulas were previously described by Maltseva et al. [30].

The distribution of the disease as a percentage was calculated using the following formula:

$$P = \frac{H * 100}{N}$$

where P is the disease prevalence, %; H is the number of infected trees; and N is the number of studied trees.

The disease severity score was evaluated on a 6-point scale: 0—healthy trees; 1—the initial stage of disease manifestation (single wilting and blackening of the flowers, twisting, and browning of shoots and leaves are noticeable); 2—more than 10% of flowers, shoots, and leaves are affected; 3—damage to the bark of branches, trunks, fruits (bacterial exudate is released on the affected areas); 4—more than 75% of the crown is burnt; and 5—trees dead from disease, Figure S1. The degree of disease development was calculated using the following formula:

$$\boldsymbol{S} = \frac{\sum (\boldsymbol{a} * \boldsymbol{b}) * \mathbf{100}}{\boldsymbol{N} * \boldsymbol{K}}$$

where S is the disease severity index, %; Σ is the sum of the products of a and b values; a is the number of trees with the same lesion score; b is the lesion score; N is the total number of trees; and K is the highest score of the lesion scale.

2.3. qPCR Detection of Pathogen

DNA isolation from leaf and shoot samples of each observed tree for pathogen testing was performed using Plant/Fungi DNA Isolation Kits (Norgen Biotek Corp., Thorold, Canada). *Erwinia amylovora* was detected using the qPCR method described by Gottsberger [31] using Luna Universal Probe qPCR Master Mix (New England Biolabs, Ipswich, MA, USA).

2.4. Statistical Analysis

A two-way analysis of variance (ANOVA) was conducted to assess the main effects of the seedling population and year factors, as well as their interaction on fire blight distribution and severity. The two-way ANOVA analysis was performed using GraphPad Prism version 10.3.1 for Windows (GraphPad Software, Boston, MA, USA). The significance level was set at 0.05 for all statistical tests. Sum of squares (Type III) was used to partition the variance attributed to each factor and their interactions. F-values were calculated for each factor, and corresponding p-values were used to determine statistical significance. All statistical analyses were interpreted according to standard conventions, with p-values less than 0.05 considered statistically significant.

3. Results

'Aport krovavo-krasnyy' scions were grafted onto *M. sieversii* seedlings from 11 populations, and the percentage of successfully grafted plants was 80%. First flowering was observed in 2019, and in the years that followed, flowering activity became increasingly enhanced. The onset of flowering slightly varied among the different genotypes and seedling populations, with some showing early bloom and others exhibiting a later flowering period from 2020 to 2022. The number of flowering trees varied significantly only in 2019. The flowering began approximately in the second week of April, with full bloom reaching its peak in late April. The flowers were characterized by a medium-pink hue with a consistent number of petals per blossom.

In the first two years, the flowering time resulted in fruit production on only 30–50% of the trees for each seedling population. Some trees produced fewer than ten fruits. This relatively low fruit production is expected, as the trees are still in their developing stages, focusing on growth rather than on producing a high fruit yield. In 2022, the largest apple harvest was obtained (Figure 3). At least 97% of apple trees produced fruits.

Figure 3. Apple fruit from tree seedling population 10 in 2022 (**A**,**B**).

Fire Blight Monitoring and Pathogen Identification

Due to the lack of flowering during the initial four years of monitoring, up to 2019, fire blight was not detected through visual inspection or qPCR. Symptoms such as wilting and shepherd's crook on the affected stem, leaf necrosis, and trichome development were observed for the first time in the summer of 2019 (Figure 4). As mentioned previously, 2019 was the first year of flowering, where the open flowers served as the primary site of colonization by *Erwinia amylovora* [32]. The symptoms were observed only on the scion; the rootstock was free of infection. The disease prevalence was highest (95.0%) in 2020, with the most susceptible seedling population being C5, followed by C7 and C6 (Figure 4). The distribution index for these seedling populations was above 75%. The disease prevalence ranged from 25 to 70% for the remaining seedling populations, except C10, which displayed no symptoms.

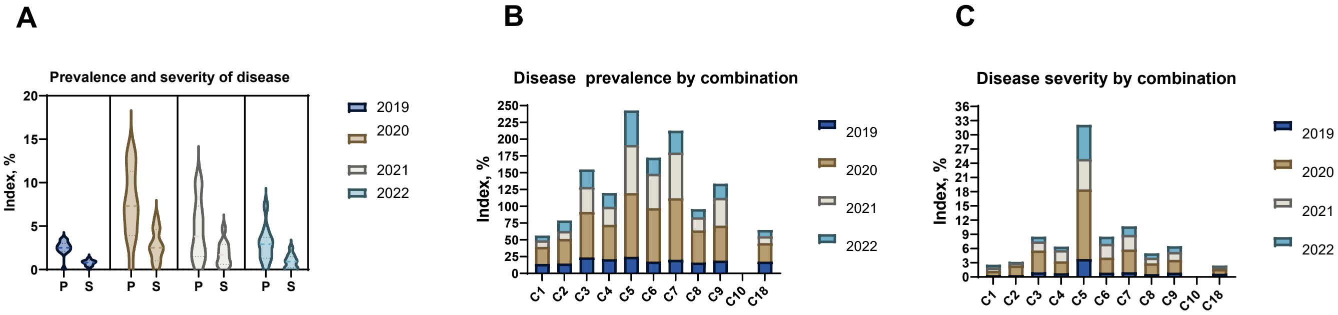

Figure 4. Distribution and severity of fire blight disease in the 'Aport' field (**A**). P—prevalence; S—severity. Disease prevalence (**B**) and severity (**C**) by seedling population from 2019 to 2022. C—seedling population. Seedling population factor accounted for 50.75% of the total variation for prevalence with F-value of 9351 (10, 30) and a *p*-value < 0.0001. The total variation for severity considering seedling population factor was 66.30% with F-value of 10.44 (df = 10, 30) and a *p*-value < 0.0001.

In 2020 and 2021, there was a noticeable increase in the distribution of infection, possibly due to the occurrence of favorable weather conditions for disease development [33–35]. According to weather data, humidity increased significantly in 2020 and 2021 compared with 2019 (https://www.kazhydromet.kz/en/meteo_db, (in Russian), (accessed on 15 May

2023)). The disease occurrence stayed below 24% in 2019 and 33% in 2022 for all seedling populations, except for C5, which displayed a rate of 25 and 52% respectively, Table 2.

Table 2. Prevalence and severity of fire blight disease across seedling populations from 2019 to 2022.

		Prevalence by Years				Severity by Years			
Seedling Population	Number of Trees	2019	2020	2021	2022	2019	2020	2021	2022
C1	25	14.1	25.3	9.9	7.0	0.4	0.9	0.7	0.6
C2	25	14.8	36.6	12.0	15.5	0.4	2.0	0.6	0.2
C3	25	23.9	67.6	37.3	26.0	1.0	4.6	1.9	1.0
C4	30	21.1	51.4	26.7	20.4	0.8	2.5	2.4	0.7
C5	30	24.6	95.0	71.8	51.4	3.8	14.7	6.4	7.2
C6	25	17.6	79.5	51.4	23.9	0.9	3.2	2.9	1.5
C7	25	20.4	91.5	68.3	32.4	1.0	4.8	3.1	1.8
C8	25	16.2	47.9	19.7	12.0	0.6	2.3	1.2	0.9
C9	28	19.0	52.1	41.5	21.1	0.9	2.7	1.7	1.2
C10	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C18	25	17.6	27.4	10.6	9.2	0.7	1.0	0.5	0.2

The disease severity index depended on the year and reached a maximum of 14.7% (Figure 4). When considering different years, the variability in the severity index was the same for all seedling populations except C5. In 2020, the index reached its maximum value of 14.7% for C5. C7 and C3 demonstrated index values of 4.8 and 4.6%, respectively. In other seedling populations, the severity index was below 3.2%. In 2021, the index remained high compared to 2019 and 2022. The severity index was barely 2% in 2019 and 2022 for all seedling populations except C5, which displayed severity index values of 3.8 and 13.3%, respectively. C10 remained unaffected by the pathogen throughout the entire 8-year monitoring period.

The results from ANOVA analyses indicate that both the seedling population and year have significant effects on prevalence and severity. In prevalence, both factors were significant; the year had a more pronounced effect relative to the seedling population. In severity, the seedling population had a more substantial impact compared to the year, Table 3. The residuals in both data show some variability that is not accounted for by the factors in the model, but the relatively low mean squares suggest that the factors included do explain a considerable portion of the variation in the dependent variable.

Table 3. Two-Way ANOVA summary for prevalence and severity of fire blight disease.

Dependent Variable	Factor	SS (Type III)	DF	MS	F (DFn, DFd)	*p* Value
Prevalence	Seedling population	12893	10	1289	F (10, 30) = 9.351	<0.0001
	Year	8374	3	2791	F (3, 30) = 20.25	<0.0001
	Residual	4136	30	137.9		
Severity	Seedling population	187.4	10	18.74	F (10, 30) = 10.44	<0.0001
	Year	41.39	3	13.80	F (3, 30) = 7.686	0.0006
	Residual	53.85	30	1.795		

C5 exhibited symptoms such as wilting, shepherd's crook formation on the affected shoots, leaf necrosis, and occasional exudate droplets, while the primary symptoms in other seedling populations involved shoot wilting followed by leaf death. Nevertheless, no trees died after infection, except in the case of C5, where a significant portion of one tree died in 2020 (Figure 5). All pathogen-positive trees were confirmed for the presence of *E. amylovora* using qPCR.

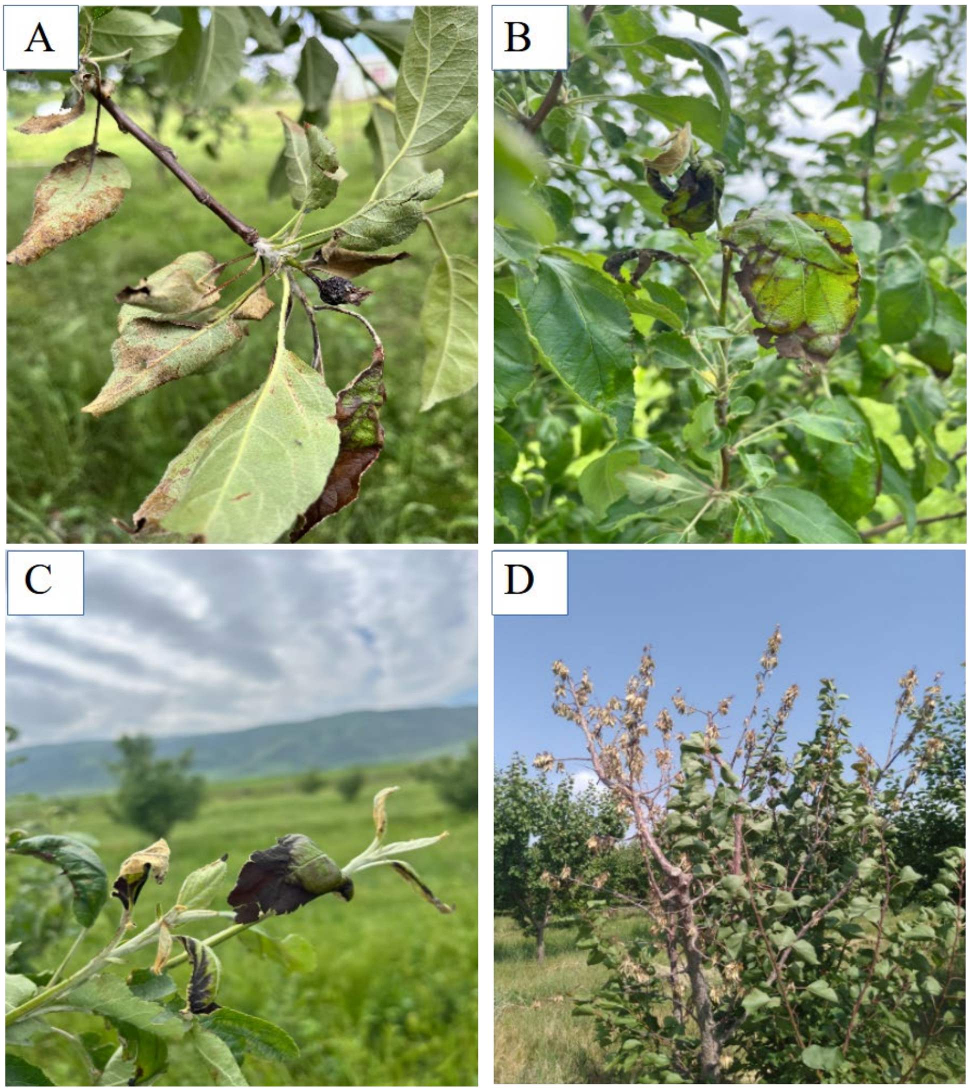

Figure 5. Fire blight symptoms in the Aport field. Symptoms such as leaf necrosis (**A**,**C**), rotted young fruits (**A**), and Shepherd's crook formation in young shoots (**B**) have been observed since 2019. The tree in seedling population 5 nearly died from a severe disease in 2020 (**D**).

4. Discussion

'Aport' cultivars and lines are extensively employed in national breeding programs to improve the agronomic traits of local cultivars and maintain the germplasm for research and preservation purposes. The renewal of 'Aport' propagation is crucial due to the aging of most orchards, which are approximately 50–60 years old. Additionally, in most fields, severe symptoms of infection have been identified. These symptoms include shoot wilting, mosaic, cankers, scaly spots, and scab lesions. The degradation of orchards continues to this day. The ongoing expansion of Almaty city towards the mountainous regions has led to a notable reduction in the available land area suitable for cultivation, disrupting extensive 'Aport' orchards. The optimal growth zone for 'Aport' ranges from 950 to 1100 masl, encompassing both foothills and mountainous areas.

The grafting of 'Aport' onto *M. sieversii* is the only efficient method for fruit production. The precise genotype of *M. sieversii* for 'Aport' grafting has not yet been determined. All orchards were established by grafting the cultivar onto genetically diverse seedlings obtained from apples collected in mountainous regions. As a result, variations in yield, resistance to abiotic and biotic factors, and viability were confirmed (unpublished testing in a pomological garden). Grafting the cultivar onto M9 or Arm18 rootstocks negatively impacted fruit quality, particularly in terms of size, taste, and aroma (unpublished testing in a pomological garden). The 'Aport' cultivars still depend on the identification of reliable *M. sieversii* genotypes for successful cultivation. In addition to preserving its high yield capacity, it is crucial to consider the rootstock's resistance to pathogens, particularly *E. amylovora*, which is widely distributed throughout the country and causes devastating yield losses [3–6,30]. Previous plantings of susceptible scion cultivars on susceptible rootstocks have substantially heightened the potential for unprecedented levels of fire blight epidemics in apple orchards [36]. The high susceptibility of the 'Aport' cultivars to fire blight disease has been confirmed through field observations conducted as part of a farmer survey since 2010 [37]. Enhancing the cultivar's resistance to fire blight by identifying reliable resistant rootstock genotypes of *M. sieversii* leads to long-term orchard establishment since host plant resistance is one of the most effective and sustainable options for managing fire blight [38]. Moreover, genotypes of *M. sieversii* that are known to be resistant to pathogens are valuable sources for further breeding of both apple rootstocks and cultivars. In the current study, the phenotypic resistance of 'Aport' scions to fire blight disease, when grafted onto *M. sieversii* rootstocks, was confirmed. However, only three out of the 11 *M. sieversii* seedling populations were identified as resistant to the pathogen, confirming the resistance observed in the grafted scions. Previously, QTLs conferring the highest level of resistance to *E. amylovora* have been already identified in wild species of *Malus* [14,21,22,39,40]. Additionally, many *M. sieversii* seedling accessions have previously demonstrated high resistance to *E. amylovora* in natural and controlled conditions [13]. *Malus sieversii* collected from 11 populations from Dzungarian Alatau and Ile Alatau in the present work showed a strong connection between resistance to fire blight and their place of origin, indicating their diverse genetic background. In the most favorable year for disease development, the variability in fire blight prevalence in the field conditions among the 11 seedling populations ranged from 0 to 95.0%. The significant variability in pathogen resistance of *M. sieversii* accessions was also previously confirmed [13]. The highest pathogen resistance in the present work was revealed in C10, for which the rootstocks were obtained from a population of *M. sieversii* growing in Turgen (1250 masl). We assumed that the Turgen population embraces apple trees that bear reliable and durable QTLs providing pathogen resistance. The rootstocks from *M. sieversii* populations in the Steep Tract and the Unknown area suppressed the pathogen distribution to below 30%. These populations are also considered promising for germplasm collection and breeding. *Malus sieversii* genotypes from the genetic reserve (Dzungarian Alatau), collected at 1190 masl, were the most susceptible among the researched populations, with a disease distribution level of 95.0%. Nevertheless, genotypes analyzed from the same genetic reserve but collected at 1470, 1350, and 1329 masl showed fire blight distribution levels of 67.56, 51.37, and 36.59%, respectively. This reserve is considered a pool for maintaining, conserving, and renewing wild apple populations. More attention should be given to the resistance potential of trees at the reserve to harmful pathogens and pests, as its seedlings are often used in breeding programs.

Wilting, shepherd's crook formation on the affected shoots, leaf necrosis, and occasional exudate droplets were observed in trees affected by the pathogen at least twice in C5, while the primary symptoms in trees affected twice in other seedling populations involved only shoot wilting followed by leaf death. The spread of disease within the trees in C5 also occurred much faster; in 2020, one tree almost died after being infected only twice. The high severity and low frequency of infection for C5 are consistent with the results observed previously in several *M. sieversii* accessions [14]. The distribution and severity of fire blight are significantly influenced by environmental factors, as has been shown in previous studies [41]. Therefore, it is crucial to assess resistance through extended monitoring, particularly under natural conditions. This approach allows for a reliable distinction between the effects of the host's genetic resistance and environmental factors, considering genotype × environment interactions.

The prevalence of fire blight disease among the most studied seedling populations in the present research is still low compared with the distribution under natural conditions in an *M. sieversii* orchard in Geneva, NY, USA [42]. In Geneva, the incidence of light infection was evaluated at 30–70%, while heavy and very heavy infections comprised above 20%. However, the monitoring period was longer, lasting 9–11 years, with the evaluation based on cumulative data [42]. The overall low incidence of infection in the present work can be explained by the shorter monitoring period, varying environmental conditions, and present pathogen strains. Greenhouse testing can reveal truly resistant forms of *M. sieversii*, as previously shown [15,42]. However, discrepancies also occur when comparing the resistance of trees under natural and controlled conditions [15].

Resistant apple rootstocks have previously been used to enhance the disease tolerance of grafted scion cultivars [38,43–46]. Resistance occurs by influencing the expression of disease-associated genes through long-distance signaling between roots and shoots [38]. Superior resistance to *E. amylovora* has also been shown for susceptible scion cultivars grafted onto resistant ‘B.9’, ‘Geneva® 935’, ‘Geneva® 41’, and ‘Geneva® 11’ apple rootstocks [45,46]. To achieve sustainable disease management in commercial apple orchards and to preserve valuable cultivars such as ‘Aport’, which are susceptible to fire blight, grafting onto resistant *M. sieversii* genotypes identified in this study could be considered a viable strategy.

5. Conclusions

In the present study, we identify new *M. sieversii* genotypes resistant to *E. amylovora* by scoring fire blight incidents under natural conditions. The disease prevalence varied from 0 to 95% in an orchard established by grafting the ‘Aport krovavo-krasnyy’ cultivar onto *M. sieversii* genotypes collected from 11 populations. The most resistant forms of *M. sieversii* were identified in the population obtained from Turgen. The results of this study will aid in renewing Kazakhstan‘s orchards and enhancing the breeding of apple rootstocks and cultivars resistant to *E. amylovora*.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/horticulturae10101052/s1, Figure S1: Disease severity scoring; Video S1: Apple trees developed from various seedling populations of ‘Aport’ scion and *Malus sieversii* rootstocks.

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Data Availability Statement: The original contributions presented in the study are included in the article/Supplementary Materials, further inquiries can be directed to the corresponding author.

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