Annals of Agrarian Science

Journal homepage: http://journals.org.ge/index.php

Hazelnut diseases and their causing pathogens in the hazelnut-growing regions of Georgia

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Received: 07 November 2020; accepted: 28 November 2020

A B S T R A C T

Hazelnut (Corylus avellana L.) is an important agricultural crop for Georgia and one of the main agro-export products. Significant reductions in hazelnut production in recent years and a deterioration in its quality have necessitated certain research measures. Based on the three-year study conducted in 24 sample plots of hazelnuts in Samegrelo, Guria and Kakheti Regions, a wide range of hazelnut diseases is revealed. In particular, 18 pathogenic microorganisms were isolated and identified on hazelnut stems and fruits. Fifteen of them are fungal, one - bacterial, and two - viral pathogens. The incidence of each pathogen and the three-year average disease prevalence rates are determined.

Keywords: Hazelnut (Corylus avellana L.), Hazelnut diseases, Phytopathogenic microorganisms, Symptoms, Isolation, Identification.

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Introduction

Hazelnut *(Corylus avellana L.)* is an important agricultural crop for Georgia and one of the main agro-export products, which allows the country to be among the top five hazelnut producing countries in the world. However, over the past three to four years, the quality of hazelnuts has decreased, and its export earnings have dropped significantly [1], which was facilitated by widespread of fungal diseases and the appearance of various pests in western Georgia [2,3].

According to experts, in 2017-2018 there was a strong spread of pathogenic fungi of hazelnuts, outbreaks of diseases, or epiphytotics [4]. The rot of the hazelnut fruit increased sharply. There are known various scientific studies of pathogenic microorganisms found in the culture of hazelnuts. [5-8]. It is also noteworthy that there are different types of hazelnut defects, such as: hollow fruit, rotten fruit with black tip, crushed heart with brown spots, various spots on the fruit, etc. Some of them are considered to be a physiological problem of the plant, while others are associated with fungal diseases and pests [9-14].

The results of systematic-ecological research of fungi spread on hazelnut plants are of great importance for the viability and high productivity of the hazelnut plant [15]. The influence of various factors on the spread of diseases has been studied [16]. According to literary sources, more than 100 pests and more than 20 different diseases have been registered on hazelnut crops by scientific researchers [17,18]. The current problems in the hazelnut growing areas have made it necessary to identify their causes and search for the ways to solve them, it has become important also to identify and clarify the causes of diseases and develop appropriate control measures.

In 2018-2020, we conducted surveys in both eastern and western Georgia in order to identify hazelnut diseases and their causes. In eastern Georgia,

observations were carried out in Kakheti (Kvareli municipality), while in western Georgia, the Samegrelo (Zugdidi, Chkhorotsku, Abasha municipalities) and Guria (Ozurgeti municipality) region were determined for this purposes.

Research objects and methods

The research took place in hazelnut growing plots from late April to October. These hazelnut orchards were studied in 12 villages of Samegrelo, 10 villages of Guria and 2 villages of Kakheti. The GPS coordinates of the recording locations are given in **Table 1.**

The data has been obtained according to the method adopted in the field of plant protection, on equal-by-size areas allocated in several different places on the diagonal of the plot, on all four sides of the selected plants. For the monitoring, we used the visual observation method and a magnifying glass. Diagnostics of the diseases was made both on the basis of visual observations and in the laborato-

Table 1. *Location of the research object and its coordinates*

Regions	Sampling villages	GPS coordinates	Height above sea level (m)
Samegrelo	Ingiri	42°30’17’’ N 41°49’08’’ E	82
	Kakhati	42°29’51’’ N 41°45’41’’ E	48
	Mikava community	42°37’18’’ N 42°06’13’’ E	266
	Narazeni	42°24’54’’ N 41°56’52’’ E	103
	Darcheli	42°26’21’’ N 41°41’19’’ E	12
	Natsuluku	42°33’37’’ N 41°52’46’’ E	141
	Pakhulani	42°39’12’’ N 41°57’45’’ E	190
	Akhalsopeli	41°54’17’’ N 45°59’11’’ E	439
	Ganmukhuri	42°25’43’’ N 41°37’40’’ E	5
	Chitatskari	42°28’38’’ N 41°51’58’’ E	60
	Tqviri	42°10’11’’ N 42°14’43’’ E	21
	Shamgona	42°31’09’’ N 41°46’10’’ E	60
Guria	Makvaneti	41°54’30’’ N 42°00’55’’ E	93
	Chochkhati	42°01’51’’ N 41°54’39’’ E	92
	Shua Amaghleba	42°02’30’’ N 42°12’31’’ E	18
	Melekeduri	41°57’03’’ N 42°01’35’32’E	99
	Anaseuli	41°54’05’’ N 41°59’11’’E	123
	Likhauri	41°52’36’’ N 42°00’20’’ E	132
	Dvabzu	41°56’06’’ N 42°03’024’’E	131
	Shemokmedi	41°54’38’’ N 42°04’04’’ E	163
	Gvara	41°49’58’’ N 41°50’23’’ E	31
	Naruja	41°54’26’’ N 41°57’28’’ E	137
Kakheti	Kvareli	41°56’45’’ N 45°48’20’’ E	401
	Shilda	41°59’35’’ N 45°43’09’’ E	482

ry with a moist chamber, culturing infected specimens on artificial media and microscopic analysis.

We considered the spread of diseases in separate areas of the gardens with the formula:

$P = n \times 100 / N$

Where: P is the percentage of disease spread, n is the number of diseased plants, N is the total number of registered plants.

The average percentage of diseases spread as a result of the conducted monitoring in different areas was calculated by the formula:

$Pav = \Sigma SP / S$

Where: Pav is the average prevalence of the disease, Σ SP is the sum of the multiplication of the percentage of the disease spread over this area of the individual area indicator, while S is the total area.

It was kept records of the symptoms such as: various necroses or white powdery spots on leaves, twigs and fruits, knotted wounds on the stem, deformity on twigs and rot on fruits.Diseased samples were placed in special packages and taken to the laboratory for analysis, where a detailed analysis of diseased samples of hazelnut stems and fruits was carried out.

Isolation and identification of the pathogens

Tissues of the diseased organs of the nut with these symptoms were cleaned with an alcohol and 1% NaOCl solution for 1-2 minutes, and then placed in petri dishes in a moist chamber or transferred into the tubes with Malt Extract agar (MEA) and Sabouraud dextrose agar (SDA). Both petri dishes and test tubes were placed in a thermostat at a temperature of 23-25 ℃. To identify the fungal pathogens, 7-10 days old cultures of the pathogens were studied under the Phase Contrast Microscope at 400X magnification [19-23].

Research results

Studies carried out in 2018-2020 have shown that the number of nut diseases and symptoms on different organs is quite large. It was revealed following symptoms on hazelnut leaves: light and dark brown spots ; thin reddish-brown spots; thin brown spots; whitish-gray powdery spots; black powdery spots ; yellow spots and rings between veins **(Table 2, Figure 1).**

As can be seen from the table, gray powdery spots on hazelnut leaves were detected in almost all the gardens we surveyed in all regions; Light brown spots were mostly registered in 6 villages of Samegrelo (Ingiri, Kakhati, Mikava community, Darcheli, Ganmukhuri, and Chitatskari), while in Guria they were registered only in 2 villages (Naruja, Makvaneti); Small red spots were observed in 5 villages of Samegrelo and 1 in Guria; Brown spots were found in 5 villages of Samegrelo, 2 of Guria and 1 of Kakheti; Small brown spots were observed only in Samegrelo (Ingiri, Kakhati, Narazeni); Yellow spots and rings were detected only in two villages - Darcheli (Samegrelo) and Likhauri (Guria).

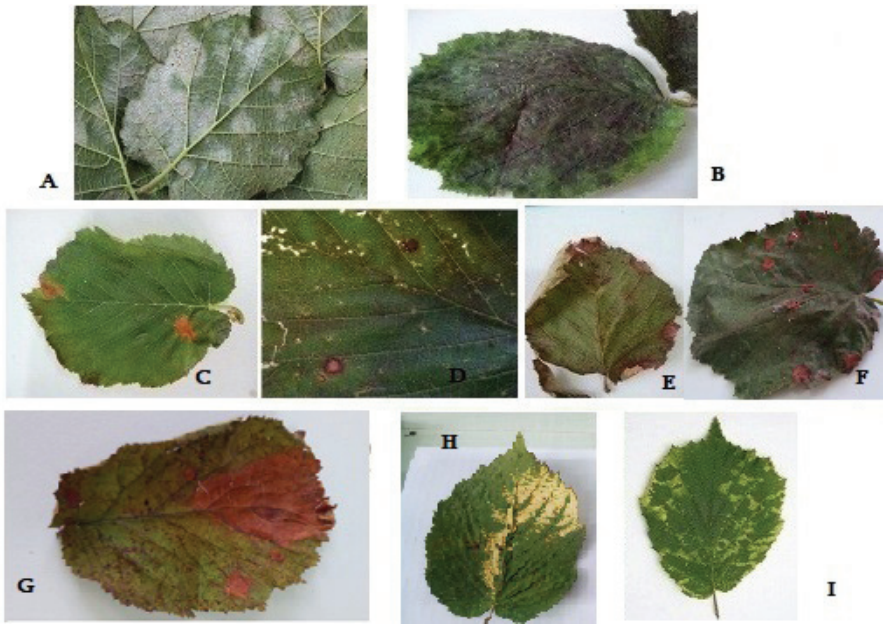

Fig.1. *Symptoms detected on hazelnut leaves*

A- gray powdery spots; B - black powdery spots; C - G - various spots; H, I - yellow spots and rings

Table 2. *Symptoms of diseases detected on hazelnut leaves by locations*

Sampling villages	Light brown spots	Thin reddish-brown spots	Dark brown spots	Thin brown spots	Whitish-gray powdery spots	Black powdery spots	Yellow spots between the veins
Ingiri	+	+		+	+		
Anaseuli	+	+	+		+		
Kakhati	+		+	+	+	+	
Mikava community	+				+		
Narazeni		+		+	+		
Likhauri					+		+
Darcheli	+		+		+	+	+
Natsuluku					+	+	
Akhalsopeli		+	+		+	+	
Ganmukhuri	+				+	+	
Dvabzu					+		
Chitatskari	+	+			+		
Shemokmedi					+		
Tqviri					+		
Gvara		+			+		
Naruja	+				+		
Kvareli			+		+		
Makvaneti	+		+		+		
Shilda					+		
Chochkhati					+		
Shua Amaghleba			+		+		
Shamgona			+		+		
Melekeduri					+		

The symptoms we observed by monitoring the hazelnut stems are few, to compare with the leaves. Wounds, brown spots and black powdery spots were noted on the stems. The data are shown in **Table 3 and Figure 2.**

Table 3. *Symptoms of diseases detected on hazelnut stems*

Sampling villages	Wounds	Brown spots	Black powdery spots
Akhalsopeli	+	+	+
Ingiri	+	+	
Kakhati	+	+	+
Ganmukhuri	+		+
Natsuluku		+	
Dvabzu	+		
Mikava community		+	
Chochkhati	+		
Darcheli			+

As can be seen from the table, the symptoms of the disease on hazelnut stems were observed in a smaller number of orchards compared to the leaves.

Fig. 2. *Wound (cancer symptom) on the hazelnut stem*

Table 4. *Symptoms of diseases found in hazelnut kernel and leafy involucre*

Sampling villages	Dark brown rot	Black spots	Thin, brown, sunken spots	Gray powdery spots	Black powdery spots	Green powdery spots	Whitish-pink powdery spots	Undeveloped dried fruits
Ingiri	+	+	+	+			+	
Anaseuli	+	+	+	+			+	
Kakhati	+	+	+	+	+		+	
Mikava community	+	+		+				
Narazeni	+	+	+	+				
Likhauri	+	+		+				
Darcheli	+	+	+	+	+		+	
Natsuluku	+	+			+			
Pakhulani				+	+	+		
Akhalsopeli	+	+	+	+	+		+	
Ganmukhuri	+	+	+	+	+		+	
Dvabzu	+	+		+				
Chitatskari			+	+				
Shemokmedi				+				
Tqviri				+				
Gvara			+	+				
Naruja	+		+	+			+	+
Kvareli		+		+				
Makvaneti	+	+	+	+	+		+	+
Shilda				+				
Chochkhati				+				
Shua Amaghleba		+		+				
Shamgona		+		+				
Melekeduri				+			+	

Disease symptoms revealed on hazelnut kernel and leafy involucre of the nuts are quite numerous **(Table 4, Fig. 3,4)**

It is clear from the Table 4 that gray powdery spots were observed in most places on the fruit of the nut, as well as on the leaves (in almost all villages); Various spots were detected in up to 14 villages. Undeveloped fruits were observed by us in 2 gardens; We recorded 7 black powdery spots, 8 white-pink powdery spots, and 1 green powdery spots in 1 village;

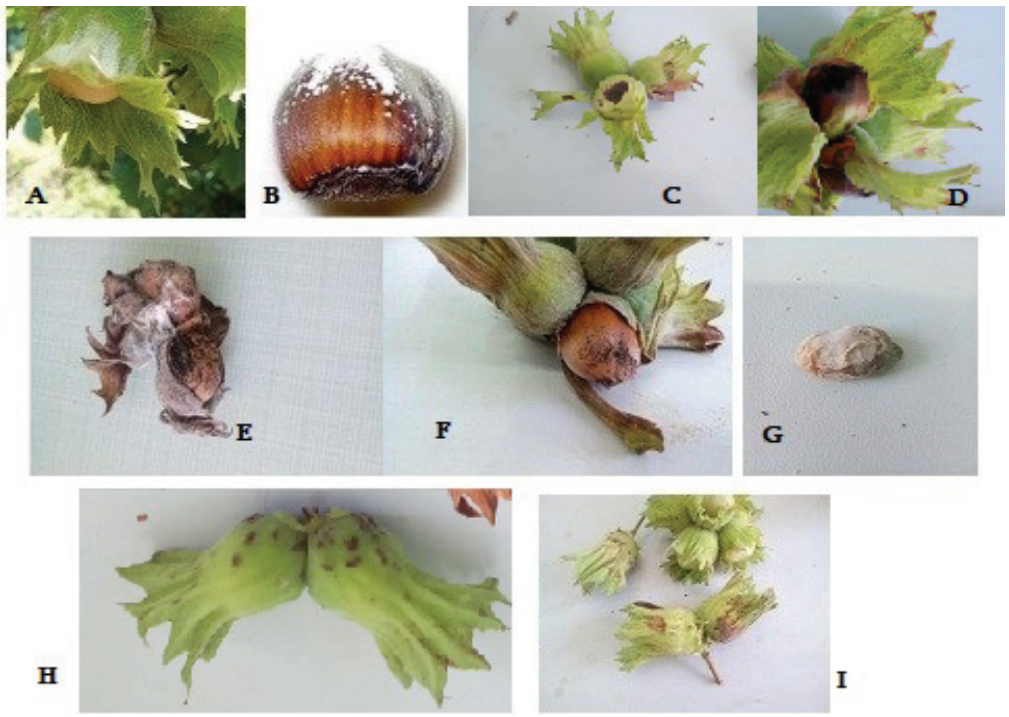

Fig. 3. *Symptoms of diseases on the kernel of the nut*

A - gray powdery spots on leafy involucre ; B - white powdery spots on a hazelnut seed coat; C - black powdery spots on leafy involucre; D - greyish brown rot on seed coat and leafy involucre; E - F - powdery spots and black dots on the seed coat; G - whitish-pink powdery spots on the kernel; H - I - thin, brown, sunken spots on the leafy involucre

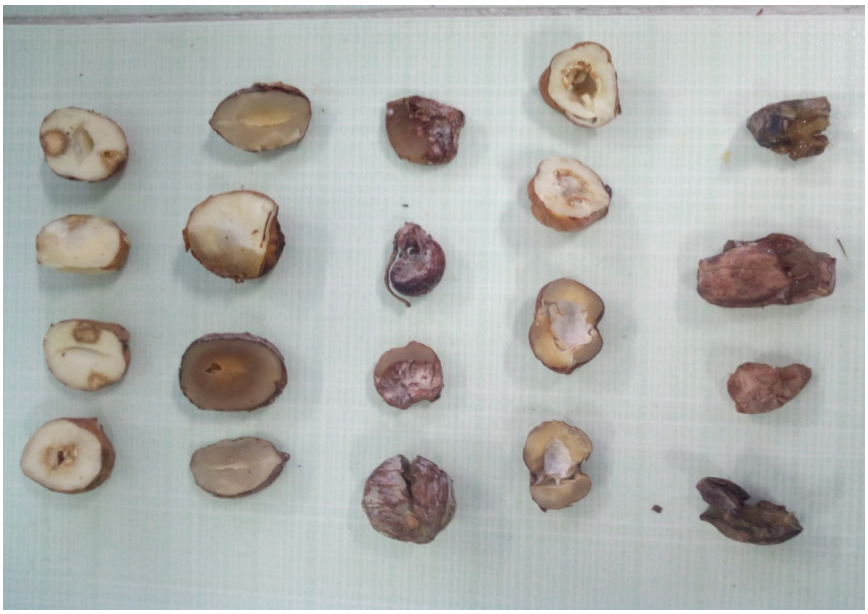

Fig. 4 *Rotten kernel samples*

Whitish-gray powdery spots characteristic of the powdery mildew was dominated in percentages among the symptoms on the leaves . The presence of yellowish spots and rings between the veins were relatively rare. The percentages of symptom prevalence and the pathogens corresponding to these symptoms that we have identified are given **in Table 5.**

Table 5. *Average Percentage of Diseases Detected on Nut Leaves by Symptoms (2018-2020)*

Symptoms / Pathogen	Light brown spots	Thin reddish-brown spots	Dark brown or brown spots	Thin brown spots	Gray powdery spots	Black powdery spots	Yellow spots or rings between the veins
	Prevalence %						
	6	4	3	2	15	10	2
Erysiphe corylacearum U. Braun& S. Takam					+		
Phyllactinia guttata Kar.					+		
Gloeosporium coryli (Desm.) Sacc.	+	+					
Colletotrichum acutatum J.H.	+	+					
Alternaria coryli Israf.			+				
Pestalotiopsis sp.			+				
Phyllosticta sp.				+			
Cercospora sp.	+			+			
Phomopsis sp.			+				
Xanthomonas arboricola Vaut. pv. *Corylina*		+					
Apple chlorotic leaf spot virus (ApMV);							+
Prunus necrotic ringspot virus (PNRSV)							+

The percentages of the prevalence of the symptoms detected on the stem and the corresponding pathogens of these symptoms identified by us are given in Table 6, while the same rates in the case of the kernels and leafy involucres are shown in Table 7.

Table 6. *Percentage of disease prevalence on hazelnut stem by symptoms (2018-2020)*

Symptoms / Pathogen	Wounds	Brown spots	Black powdery spots
	Prevalence %		
	2	3	5
Nectria ditissima Tul.	+		
Capnodium sp.			+
Pestalotiopsis sp.		+	
Xanthomonas arboricola Vaut. pv. *Corylina*		+	
Colletotrichum acutatum J.H.		+	
Gloeosporium coryli (Desm.) Sacc.		+	

Table 7. *Average Percentage of Diseases Detected in Nut kernels and leafy involucres by Symptoms (2018-2020)*

Symptoms / Pathogen	Dark brown rot	Black spots	Thin, brown, sunken spots	Gray snowflake	Black powdery spots	Green powdery spots	Whitish-pink powdery spots	Undeveloped dried fruits
	Prevalence %							
	10	5	5	7	2	0.5	3	4
Colletotrichum acutatum J.H.	+		+					+
Pestalotiopsis sp.	+	+						
Trichotecium roseum Fr.							+	
Erysiphe corylacearum U. Braun& S. Takam				+			+	+
Phyllactinia guttata Kar.				+			+	+
Alternaria coryli Israf.		+						
Fusarium sp.							+	
Xanthomonas arboricola Vaut. pv. *Corylina*			+					
Capnodium sp.					+			
Gloeosporium coryli (Desm.) Sacc.	+		+					+
Phomopsis sp.	+	+						
Aspergillus sp.					+			
Penicillium sp.						+		

Tables 5-7 show that gray powdery spots are common in hazelnuts and reach 15% on leaves and 7% on green fruits. Black powdery spots (10% on leaves, 7% on stems and 2% on fruits) also have high rates of spread among the symptoms. According to the prevalence, different spots may be observed, the percentages of which vary from 2% to 10% by organs. The prevalence of other symptoms of nut diseases do not exceed 0.5% - 4%.

By laboratory analysis of the symptomatic samples taken in the field conditions of the hazelnut growing areas, we have identified under the microscopic examination various diseases and their pathogenic microorganisms on the basis of morphological signs . The results are shown in Table 8 and Figure 5.

Based on our research, it is established that among the detected pathogens in the hazelnut plots of Samegrelo, Guria and Kakheti regions, the pathogenic microorganism Erysiphe corylacearum U. Braun & S. Takam is characterized with the highest prevalence (in all 24 locations), which occurs on the leaves, twigs, and fruits of the plant. The second position by this indicator take Gloeosporium coryli (Desm.) Sacc. and Colletotrichum acutatum J.H. (9 locations) See. **Fig. 5.**

Thus, based on 3-year study of 24 locations in the hazelnut growing areas in different regions of Georgia, we can conclude that the range of hazelnut diseases is quite diverse. We have isolated and identified 18 pathogenic microorganisms on hazelnut stems and fruits. Of these, 15 are fungal, 1 bacterial and 2 viral pathogens. These pathogens cause great damage to the hazelnut crop and significantly reduce the yield and its quality.

Table 8. *Pathogens detected in hazelnut orchards in the regions of Georgia (2018-2020)*

Name of the disease	Causing pathogen	Diseased organ	Villages of detection of the disease
Powdery mildew	*Erysiphe corylacearum* U. Braun& S. Takam	Shoot, leaves, fruit	Ingiri, Anaseuli, Naruja, Kakhati, Chitatskari, Akhalsopeli, Makvaneti, Mikavacommunity, Darcheli, Kvareli, Shilda, Narazeni, Likhauri, Natsuluku, Ganmukhuri, Dvabzu, Shemokmedi, Tqviri, Chochkhati, Shuaamaghleba, Shamgona, Melekeduri, Pakhulani
	Phyllactinia guttata Kar.	Shoot, leaves, fruit	Kvareli, Shilda
Anthracnose disease	*Gloeosporium coryli* (Desm.) Sacc.	Shoot, leaves, fruit	Chitatskari, Darcheli, Ganmukhuri, Naruja, Mikavacommunity, Kvareli, Shilda, Akhalsopeli, Natsuluku
	Colletotrichum acutatum J.H.	Shoot, leaves, fruit	Anaseuli, Naruja, Kakhati, Makvaneti, Ingiri, Narazeni, Mikavacommunity, Likhauri, Dvabzu
Common stem cancer	*Nectria ditissima* Tul.	Stem-branches	Ingiri, Akhalsopeli, Chochkhati, Kakhati, Dvabzu
Alternaria disease	*Alternaria coryli* Israf.	Leaves, fruit	Kvareli, Darcheli, Kakhati, Akhalsopeli, Makvaneti, Shuaamaghleba, Anaseuli
Fumagina (Sooty mould)	*Capnodium* sp.	Stem-branches leaves, fruit	Kakhati, Ganmukhuri, Akhalsopeli, Darcheli
Grey necrosis	*Pestalotiopsis* sp.	Shoot, leaves, fruit, bud	Kakhati, Darcheli, Anaseuli, Akhalsopeli, Shuaamaghleba, Shamgona, Makvaneti, Ingiri
Leaf spot	*Phyllosticta* sp.	Leaves	Ingiri, Narazeni
Cercosporiose	*Cercospora* sp.	Leaves	Darcheli, Kakhati
Fusarium kernel rot	*Fusarium* sp.	Fruit, bud	Kakhati, Anaseuli, Makvaneti, Melekeduri, Akhalsopeli, Darcheli
Phomopsis disease	*Phomopsis* sp.	Shoot, leaves, fruit	Naruja, Darcheli, Akhalsopeli, Anaseuli, Makvaneti
Pink rot	*Trichotecium roseum* Fr.	Fruit	Ganmukhuri, Akhalsopeli, Naruja, Darcheli, Ingiri
Black mold	*Aspergillus* sp.	Fruit	Makvaneti, Natsuluku, Pakhulani, Akhalsopeli
Green mold	*Penicillium* sp.	Fruit	Pakhulani
Bacterial blight	*Xanthomonas arboricola* Vaut. pv. *Corylina*	Shoot, leaves, fruit	Anaseuli, Gvara, Chitatskari, Akhalsopeli
Hazelnut ring spot	Apple chlorotic leaf spot virus (ApMV); Prunus necrotic ringspot virus (PNRSV)	Leaves	Darcheli, Likhauri
Hazelnut mosaic	Prunus necrotic ringspot virus (PNRSV)	Leaves	Darcheli

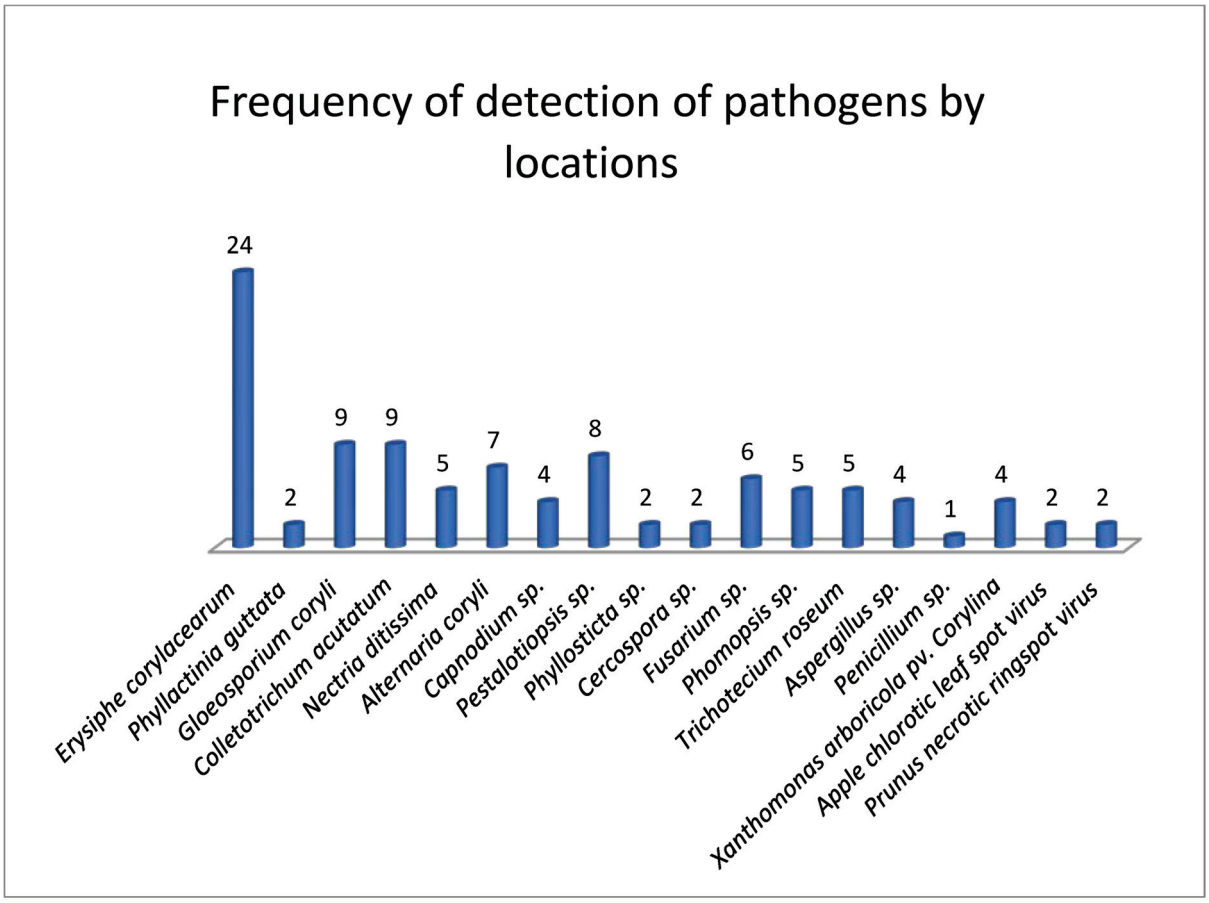

Fig. 5. *Frequency of detection of pathogens on hazelnut leaves, stems and fruits, 2018-2020*

Acknowledgements

This work was supported by the Shota Rustaveli National Science Foundation of Georgia (SRNSFG) grant number # FR17_581

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