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Virus Diseases of *Sorbus* L.: Role in Biodiversity

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ABSTRACT

Twenty years of experimental data under Main Botanical Garden conditions have been compiled to assess the spectrum of viral species, their combination character, nature of spread and resistance. For the first time in Russia monitoring of the distribution of viruses in the *Sorbus* genus complex in collections, dendrological and industrial types of plantations were carried out. In all virus diseases registered in 8 species and 17 varieties 3 *Ilar*-, 9 *Nepo*- and 16 non-specific viruses from 8 genera were revealed. For the first time on mountain ashes Raspberry ringspot virus, Prune dwarf virus, Grapevine fanleaf virus, Bean yellow mosaic, Soybean mosaic virus and Alfalfa mosaic virus were identified. Infection with a complex of viruses on mountain ash fruit crops, in particular industrial varieties, reaches 84-100%, and monoinfection is only registered in a small percentage of crops. A complex infection of more then 2 pathogens was registered on 75% of varieties. The evaluation of resistance to *Ilar*- and *Nepo*- viruses we conducted among 40 *Sorbus* species, and also 19 varieties and hybrids, has allowed us to select valuable genotypes of mountain ash *S. matsumurana* and *S. aucaparia* with complex resistance. We also established that all tested varieties appear susceptible, except for 5 with tolerance. There was a greater degree of infection in *S. aucaparia* including different forms of the species in creation.

Keywords: evolution of resistance, identification, monitoring, mountain ash
Abbreviations: ASTIHA, All Russian Selection Technical Institute of Horticulture and Arboretum; **ELISA**, enzyme-linked immunosorbent assay; **MBG of RAS**, Main Botanical Garden of the Russian Academy of Sciences; **MSU**, Moscow State University; **PCR**, polymerrase chain reaction; **TBIA**, tissue blot immunoassay; **TPIB**, tissue print immunobloting

CONTENTS

INTRODUCTION

Mountain ash is an important, perspective and exceptionnally interesting plant in the tree crop industry. The genus *Sorbus* comprises of over 100 species growing preferably in temperate regions of the Northern hemisphere (Gabrielian 1978). In Russia 28 species grow in the wild (Sokolov and Svyazeva 1965). Eighty-two appellations were introduced to the Main Botanical Garden of the Russian Academy of Sciences in the dendrological plantations which include 56 species, 5 varieties, 16 cultivars and 5 intergenus hybrids (Petrova 1986).

Mountain ash is also a medicinal, melliferous and fruit tree. It attracts interest in selection, possesses valuable wood and is marked for high decorative qualities. It is a relatively new and perspective tree crop for industrial gardening. Virus diseases are among the limiting factors in obtaining stable yield of mountain ash and reduce its decorative qualities. Virus diseases were not studied to any depth on this tree, and in Russia, until recent times, they were not registered. The first report appeared in 1985 (Keldish and Pomaskov 1985; Verderevskaya *et al*. 1985), then in 1992 (Chervyakova 1992). These authors described different pathological changes on mountain ash leaves caused by viruses, identified widely spread viruses among wood plants such as *Apple clorotic leaf spot virus* (ACLSV), *Prunus necrotic ring spot virus* (PNRSV), *Arabis mosaic virus* (ArMV), *Strawberry latent ring spot virus* (SLRSV), *Tomato ring spot virus* (ToRSV), *Cherry leaf roll virus* (CLRV), *Tomato black ring virus* (TBRV), *Tobacco mosaic virus* (TMV), and *Apple mosaic virus* (ApMV). It was observed that on varieties and species of mountain ash, different virus combinations and differentiation of external symptoms occur during viral infections. According to Upadishev (1994) and Prikhodko (1998) viral diseases on mountain ash trees were found in the collections of government trial fields, on farms in Moscow, Brynsk and Volgograd regions as well as in Kuban and Nechernozem where *Ilar*-, *Nepo*- and *Poty*-groups of viruses were registered. The most widespread were chlorotic and necrotic ring spots: from 23% to 51%; ACLSV, 46%; TBRV, ArMV, ASGV (*Apple stem grooving virus*) – from 20% to 29% and small infection of PPV (*Plum pox virus*) 10% to 17%. The varieties most infected by viral diseases were 'Nevejinskaya Red', 'Nevejinskaya Yellow', 'Businka', 'Rosina', 'Likernaya' (Upadishev 1998).

In this review, we have compiled the data for viral disease spread in representatives of the genus *Sorbus* and evaluations of resistance to some viruses.

METHODOLOGIES USED

The experimental work was carried during the past 20 years out in the Department of Plant Protection, MBG, RAS. This is situated in the northern part of Moscow City, having pod-

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zolic soils. During the study period, comparative research was also carried out on the dynamics of virus spread that infect representatives of the *Sorbus* genus in mountain ash plantations of ASTIHA, MBG RAS, MSU and in the industrial mountain ash plantations of the collective farm "Starodubsky" in the Bryansk region.

The main research objects were representatives of the *Sorbus* genus, *Rosaceae* family. In order to reveal the *Sorbus* virus diseases, systematic observations were carried out in ecosystems of MBG RAS, on the collections and dendrological natural types of mono- and polyplantations.

In our investigation were used different methods ELISA (Clark and Adams 1977; Bobkova 1983; Gnutova 1985), PCR (Zavriev *et al*. 2005), TBIA, TPIB (Lin *et al*. 1990; Dicenta *et al*. 1995), and electron microscopy (Robinson *et al*. 1987).

In order to reveal and identify the viruses, were used a standard set of indicator plants (Fulton 1970; Murrat 1970; Fulton 1972; Pomaskov 1978; Keldish and Pomaskov 1980). During virus identification, back (repeated) transfer was carried out on the tested species and varieties. The study of the virus diseases infections through grafting was carried out using the Kiray *et al*. (1974) method (Pomaskov and Keldish 1979).

All experimental work for identification and plant testing was carried out in the glasshouse or acclimatizer, under conditions that exclude the possibility of secondary and cross infections as well as on the infection plot of plant protection department. Artificial infection on different varieties and species were carried out in order to evaluate resistance to *Ilar*- and *Nepo*- viruses on the infection plot of the plant protection department. Thus, artificial transmission of viruses was carried out on 40 species and 6 varieties of *Sorbus*. Evaluation of resistance to infection was carried out during the period of their maximum appearance. The species and varieties which were not infected underwent thorough checking for latent infection using ELISA. Where latent infections were not registered, grafting was carried out as a means for artificial infections. Disease registering on *Sorbus* varieties in the industrial type of plantations was carried out by counting the aggregate number of plants and the number of infected plants according to the varieties selected on the field.

MONITORING OF DISTRIBUTION OF VIRUSES IN THE GENUS COMPLEX OF *SORBUS*

As a result of the inspection of *Sorbus* plantations during the last 20 years, we found that the external appearance of viral diseases varied considerably. Plants from the genus *Sorbus* grew on land at MBG, RAS in 3 types of plantations: collections, dendrological and natural, which include 19 varieties and hybrids as well as 56 species. In the natural plantations there is basically 1 species, *S. aucuparia* and its different forms. In all the plantations, plants with viral disease symptoms were recorded (**Fig. 1**). In the collection-type of plantations, vars. 'Krasavitsa', 'Nevejinskiye' ('Red', 'Kubovaya'), 'Likernaya' (ecotype 2), 'Khosta' and 1 species, *S. turkestanica* were found to be infected. Apart from that, at the beginning of the vegetative period of 1988, external symptoms were observed for the first time on var. 'Titan', which was previously considered to be healthy. Two out of four growing specimens were infected. On the leaves of the plants clear, bright-yellow and light-green spots, ring spots and fusing mottle, and crinkling of leaf surfaces appeared. It is worth noting that var. 'Titan' grows within the immediate vicinity of other mountain ash varieties. In addition, in the same location in 1990, the infection of another variety, 'Otbornaya forma 1-5', was registered. Visible viral diseases symptoms were not previously observed on this variety. The symptoms were found to be analogous to the ones on var. 'Titan' and others.

On the dendrological type of plantation, *S. aucuparia* (ecotypes 1, 2), *S. decora*, *S. takhtadzhiani* and 'Likernaya' (ecotype 1) were infected (**Table 1**). We established, identified and recorded that symptoms on var. 'Likernaya' in the dendrological and collection plantations (ecotype 2) (**Table 1**). Annual symptom transformations were also observed (**Table 1**): in two years on var. 'Likernaya' and in 1 year on 'Nevejensky' mountain ash. In a common mountain ash population (*S. aucuparia*), variations of symptoms were also recorded (**Table 1**). Only on plants of var. 'Krasavitsa' were

Fig. 1 Symptoms of virus diseases of *Sorbus* plants. 1, 'Nevejinskiye'; 2, 'Krasavitsa'; 3, *Sorbus turkestanica*; 4, 'Likernaya'; 5, 'Desertnaya'; 6, 'Rubinovaya'; 7, 'Khosta'; 8, 9, *S. aucuparia*.

Table 1 Analyses the symptoms for variety and species *Sorbus* different type of plantation.

Variety, species	Symptoms		
	1st year	2nd year	3rd year
Collectional type			
'Likernaya' (ecotype 2)	RSp, Sp, M	RSp, Sp, M	RSp, Sp, M, Mo, D (Wr, Cr), LP
'Krasavitsa'	Wr, Cr	Wr, Cr	Wr, Cr
'Khosta'	RSp, Sp	RSp, Sp	RSp, Sp
'Nevejinskiye' ('Red', 'Kubovaya')	RSp, LP	RSp, LP, Mo	RSp, LP, Mo
S. turkestanica	D, LeL, LH, F	D, LeL, LH, F, Mo, E	D, LeL, LH, F, Mo, E
Dendrological type			
S. aucuparia (ecotype 2)	MoM	MoM	RSp, Mo
S. aucuparia (ecotype 1)	RSp, Sp, ILP	RSp, Sp, ILP, LP, V, Cr, Wr	RSp, Sp, ILP, LP, V, Cr, Wr
S. takhtadzhiani	Mo, Sp	Mo, Sp	Mo, Sp
'Likernaya' (ecotype 1)	RSp, Sp, M	RSp, Sp, M	RSp, Sp, M, Mo, D (Wr, Cr), LP

Cr, crinkle of leaf; D, leaf distortion; E, enation; F, filamenting (filamentous); ILP, imitation of line pattern; LH, leaf hardness; LeL, leathery leaf; LP, line pattern; M, mosaic; Mo, mottle; MoM, mottle mosaic; RSp, ring spotting; Sp, spotting; V, variegation; Wr, wrinkling of leaf surface

Table 2 Origin mountain ash variety*.

Variety	Origin
'Likernaya'	*S. aucuparia* × *Aronia melanocarpa*
'Krasavitsa'	*S. aucuparia* × mix of pollen of *Pyrus* variety
'Nevejinskiye' ('Yellow', 'Red', 'Kubovaya')	*S. aucuparia* of folk-selection
'Titan'	*S. aucuparia* × (*Pyrus* × *Malus*)
'Desertnaya'	'Likernaya' × *Mespilus germanica*
'Rubinovaya'	*S. aucuparia* × mix of pollen of *Pyrus* variety
'Granatnaya'	*S. aucuparia* × *Crataegus sanguinea*
'Burka'	*Sorbaronia alpina* (*S. aria* × *Aronia arbutifolia*) × *S. aucuparia*
Variety N10 ('Alaya krupnoplodnaya')	*S. aucuparia* × mix of pollen of *Pyrus* variety × *S. aucuparia* var. *moravica*

* Cicin *et al*. (1978)

Table 3 Virus infected *Sorbus* plantation Starodubsky collective farm (Brianskaya rigion).

Variety	Symptoms	Number of plants tested	Infected plants	
			Specimen	%
'Nevejinskiye'	RSp, Sp, Mo, F, M, NL	382	331	87
'Granatnaya'	RSp, Sp, Mo, Wr, M	215	7	3
'Rosina'	Mo, M	14	12	86
'Rubinovaya'	F, Mo, CuL	172	6	3
'Titan'	RSp, Sp, Mo, M	90	24	27
'Desertnaya'	RSp, Sp, Mo, M, F, Wr, CuL	14	6	43

CuL, curling upwards of leaves; F, filamenting (filamentous); M, mosaic; Mo, mottle; NL, leaf narrowing; RSp, ring spotting; Sp, spotting; Wr, wrinkling of leaf surface

Table 4 Evaluation the resistance of different varieties *Sorbus* to some isolates.

Variety tested	Isolate N1 (PNRSV, RpRSV, ArMV)		Isolate N2 (RpRSV, ArMV, SLRSV)	
	Incubative period (months)	Type of symptoms	Incubative period (months)	Type of symptoms
'Rubinovaya'	11	RSp, Sp, Mo, Cr, Nlt, SpB, NSp	11	RSp, Sp, Mo, Cr, V
'Granatnaya'	24	RSp, Sp, Mo, Cr	--	--
'Titan'	11	RSp, Sp, Mo, M, ECh	11	RSp, Sp, Mo
'Burka'	11	RSp, Sp, Mo, ECh	11	RSp, Sp, Mo, Cr, Ch, V, LH
'Variety N10'	0	0	11	RSp, Mo, Wr, LH,NL,Nlt
'Likernaya'	--	--	9-10	RSp, Ne

Ch, chlorosis; Cr, crinkle of leaf; CuL, curling upwards of leaves; ECh, leaf edge chlorosis; LH, leaf hardness; M, mosaic; Mo, mottle; NL, leaf narrowing; Nlt, no leaf teeth; NSp, necrotic spotting; RSp, ring spotting; Sp, spotting; SpB, spot browning; V, variegation; Wr, wrinkling of leaf surface; 0, no symptoms; --, not tested

variations in symptoms not registered in recent years. In both types of plantations, 100% plant infection was observed on var. 'Likernaya' where disease spread was registered through grafting. On leaves of *S. takhtazhiani* and *S. aucuparia* viruses produced chlorotic ring spots, developed mottles, vein banding and yellowing. The different symptoms of virus diseases can appear during the growing season in *S. decora*.

Observations for mountain ash development with viral diseases for the period from 1984 to 2005 revealed that the infections gradually progressed with a subsequent deterioration of plants' conditions: exacerbation symptoms and infection of new specimens.

The studies show that viruses greatly affected *S. aucuparia* plants and their derivative varieties (**Table 2**).

In the ASTIHA collections about 28 varieties of mountain ash were collected: 'Rosina', 'Bucinka', 'Sorbinca', 'Concentra', 'Alaya krupnoplodnaya' ('Variety N10'), etc. Results of of our studies indicate that on 'Krasnaya sladkaya' and 'Krasnaya urojainaya', the symptoms resemble the ones observed in MBG, RAS (bright ringspot, light green and bright yellow mottling). Some infections in the form of a bright ring and small mottle spots, light green in colour, bright mottling and yellow colors of line pattern – bow-like but enclosed patterns along the midribs of 'Bucinka', 'Sorbinka', 'Concentra', 'Variety N10' and 'Nevejinskaya Yellow'. Some spots merge together to give the leaves variegation, bright netting with bright yellow secondary veins and form bright yellow to white primary veins; some leaves (portions of leaves) turned completely yellow or white with dark green mottling, as noted on var. 'Rosina'.

In the "Starodubsky" farm collection 7 varieties were collected from an area of 12.4 hectares. From them 6 varieties and 1 species (*S. aucuparia*) were infected by viral diseases. Bright merging mottling and from light yellow to white scales mosaic were recorded on var. 'Rosina' (**Table 3**). The symptoms' colour intensity resembled those of plants recorded in ASTIHA. The signs of disease that ap-

peared on 'Titan', 'Nevejinskiye' and *S. aucuparia* were exactly the same as those recorded in MBG on the same varieties. However, on some specimens of var. 'Nevejinskaya', narrow leaves and blue-green filamenting was recorded. These symptoms were not previously registered (**Table 3**). On var. 'Granatnaya', leathery leaves, wrinkling of the leaf surface, bright spotting, ring spots, mottling, light green and yellow mosaic were registered. On var. 'Rubinovaya', leathery texture, filaments (outgrowths of leaves), crinkling and wrinkling with leaf ends curling upwards were observed. On var. 'Desertnaya' some old branches were observed to have curved. According to our observations, the most infected were mountain ash 'Nevejinskiye' (87%), 'Rosina' (86%) and 'Desertnaya' (43%), relatively-speaking. A minimum of the affected plants were found in var. 'Granatnaya' (3%) and 'Rubinavaya' (3%) (**Table 3**). Viral infection on var. 'Konsentra' was not registered.

In the MSU Botanical Garden, 2 types of viral diseases were registered: one in the form of a strong crinkle of leaf surfaces and small, ring and big mottle spots, light green and yellow-green in colour.

As a result, the dynamic viral analysis carried out over 20 years testified that varieties 'Krasavitsa', 'Red', 'Kubovaya', 'Likernaya', 'Titan', 'Otbornaya forma 1-5' and 'Khosta' were more susceptible to viral attack. Among the most infected species were *S. aucuparia*, *S. decora*, *S. turkestanica*, and *S. takhtadzhiani*.

Within the *Sorbus* genus complex, 10 different types of infections were registered on 8 species and hybrids and on 17 varieties of *Sorbus* in the collection, dendrological and industrial types of plantations. The most dominant among them was different types of spots in combination with wrinkling and mottling with up to a 100% infection level. The resistance tendency of their spread and widening of their area were elucidated.

In all, virus diseases were registered on 8 species and 17 varieties, including: *S. aucaparia*, *S. discolor*, *S. itehen-*

Table 5 Comparative evaluation susceptibility of different species *Sorbus* infected by two isolates.

Species	PNRSV	RpRSV, ArMV	RpRSV	ArMV, SLRSV
	Incubative period (months)	Symptoms	Incubative period (months)	Symptoms
Aronia melanocarpa	11	Sp, Mo, Cr	11	Sp, WhV
S. amurensis	12	D (Wr, LeL, NL), Ch, Mo	9	RSp, Sp, Mo
S. aucuparia	12	RSp, Sp, Mo, Wr	12	RSp, Sp, Mo
S. decora	12	ChSp	12	RSp, LP, ILP
S. discolor	12	Sp	12	RSp, Mo, Wr,Ne
S. gracilis	0	0	12	RSp, Mo, V, ILP
S. kochneana	11	Mo	12	RSp, Sp, Mo, Wr, Ch
S. matsumurana	0	0	0	0
S. microphylla	11	Sp, Mo, Cr	12	Mo, Wr, V
S. pohuashanensis	0	0	12	RSp, M
S. serotina	12	Mo, Cr, CuL	10	Sp, Mo
S. sitchensis	11	Sp, Mo, Wr	12	RSp, Sp, Wr, V, WhV
S. alnifolia	23	RSp	--	--
S. americana	23	RSp, Sp, Mo, Cr	--	--
S. aria f. magestica	12	RSp, Mo, Wr	--	--
S. colchica	12	RSp	--	--
S. intermedia	0	0	--	--
S. latifolia	0	0	--	--
S. luristanica	0	0	--	--
S. mougeottii	23	Mo, Ch	--	--
S. torminalis	0	0	--	--
S. thuringiaca	0	0	--	--
S. umbellata f. orbiculata	12	Sp, Wr	--	--
S. arnoldiana	--	--	12	Mo, Wr, M, Ch
S. caucasica	--	--	10	Cr, ILP, Y
S. commixta	--	--	0	0
S. hupechensis	--	--	9	RSp, Sp, Mo
S. persica	--	--	23	Mo, Cr, SpB
S. reflexipetata	--	--	0	0
S. sambucifolia	--	--	12	Wr, ECh, NSp
S. scopulina	--	--	12	Sp, Mo, Wr, V, Ch, WhV

Ch, chlorosis; ChSp, chlorotic spotting; Cr, crinkle of leaf; CuL, curling upwards of leaves; D, leaf distortion; ECh, leaf edge chlorosis; ILP, imitation of line pattern; LeL, leathery leaf; LP, line pattern; M, mosaic; Mo, mottle; Ne, netting; NL, leaf narrowing; NSp, necrotic spotting; RSp, ring spotting; Sp, spotting; SpB, spot browning; V, variegation; WhV, white veins; Wr, wrinkling of leaf surface; Y, yellow; 0, no symptoms; --, not tested

Table 6 Evaluation of resistance *Sorbus aucuparia* to different isolates.

Graft		Rootstock (*S. aucuparia*)				
Isolate	Origin (variety, species)	Incubative period (months)	Variants	Number infected	ELISA	Symptoms
PNRSV, ArMV, RpRSV, TBRV	'Khosta'	22	5	5	+	RSp, Sp, Mo
PNRSV, ArMV, RpRSV, ToRSV	'Likernaya' (ecotype 1)	12	6	6	+	RSp, Sp, Mo, Wr, LP
PNRSV, ArMV, RpRSV, ToRSV	'Likernaya' (ecotype 2)	12	5	5	+	RSp, Mo
RpRSV, PDV, ToRSV	'Kubovaya'	24	6	6	+	RSp, Mo, ILP
ApMV, RpRSV, ACLSV, ArMV	'Red'	--	4	--	--	--
ArMV, RpRSV, SLRSV, ToRSV	'Titan'	--	4	--	--	--
ToRSV, CLRV	'Krasavitsa'	0	4	0	0	0
PNRSV, ArMV	*S. turkestanica*	0	4	0	0	0
ArMV, SLRSV	*S.aucuparia* (ecotype 1)	0	4	0	0	0
PNRSV, ApMV, RpRSV, ToRSV	*S.aucuparia* (ecotype 2)	48	3	3	+	RSp, Mo

ILP, imitation of line pattern; LP, line pattern; Mo, mottle; RSp, ring spotting; Sp, spotting; Wr, wrinkling of leaf surface; 0, no symptoms; --, not tested

sis, *S. palescens*, *S. amurensis*, *S. commixta*, *S. decora*, *S. matsumurana*, 'Likernaya', Khosta', 'Krasavitsa', 'Burka', 'Titan', 'Businka', 'Sorbinka', 'Nevejinskaya' ('Red', 'Kubovaya', 'Yellow', 'Yellow krupnoplodnaya'), 'Granatnaya', 'Rosina', 'Rubinovaya', 'Desertnaya', 'Otbornaya forma 1-5', and var. 'N10'.

Having monitored the distribution of viruses by complex methods we detected 3 *Ilar*-, 9 *Nepo*- and also 16 non-specific viruses from 8 genera on mountain ash. The dominant ones were PNRSV, ApMV, ArMV, ToRSV, SLRSV, RpRSV, TBRV, CLRV, and ACLSV. For the first time on mountain ashes we identified RpRSV, Prune dwarf virus (PDV), Grapevine fanleaf virus (GFLV), Bean yellow mosaic (BYMV), Soybean mosaic virus (SoMV) and Alfalfa mosaic virus (AMV). Infection with a complex of *Sorbus* viruses on industrial varieties reached 84-100%, and mono-infection was registered only in a minor percentage of cases. It was found, that complex infection of more then 2 pathogens was registered on 75% of varieties revealed several variances of infections in different combinations.

EVOLUTION OF RESISTANCE OF *SORBUS* VARIETIES TO SOME VIRUSES

The results of resistance estimation for different *Sorbus* varieties to PNRSV, RpRSV, ArMV isolates by mechanical transmission through grafting are summarized in **Table 4**.

According to our results, all the tested varieties were practically found to be susceptible. Disease symptoms appeared on most varieties a year after grafting – an indication of relatively high susceptibility even during brief isolate control with a healthy plant. Transmission was not registered on var. 'Likernaya'.

Var. 'N10' was resistant to PNRSV, RpRSV, ArMV. It should be noted that the incubation period was 11 months for vars. 'Titan', 'Rubinovaya', and 'Burka'; for var. 'Likernaya' it was 9-10 months and for 'Granatnaya' it was two years. All the tested varieties were susceptible to RpRSV, ArMV, and SLRSV, excepting for var. 'Granatnaya'.

The results of resistance estimation for different *Sorbus* species to viruses by mechanical transmission through grafting are summarized in **Table 5**.

Experiments of resistance estimation were carried out for 40 species for each isolate. Resistance to PNRSV, RpRSV, ArMV was shown for 8 species: *S. gracilis*, *S. intermedia*, *S. latifolia*, *S. luristanica*, *S. matsumurana*, *S. pohuashanensis*, *S. thuringiaca*, and *S. torminalis*. Symptoms identical to initial isolates were noted in the remaining species, but had some special features (**Table 5; Fig. 2**). Resistance to RpRSV, ArMV, SLRSV was most evident in 3 species: *S. commixta*, *S. matsumurana* and *S. reflexipetata* (**Table 5**). *S. matsumurana* had group resistance to all 4 viruses.

It should be noted that a long incubation period was practically the same for all the species within a year. However in *S. americana*, *S. alnifolia*, *S. mougeottii* (PNRSV, RpRSV, ArMV), and *S. persica* (RpRSV, ArMV, SLRSV), symptoms appeared two years after inoculation, that may support the notion that it hss relatively little susceptibility compared with the other *Sorbus* species. It is necessary to emphasis that the characteristic symptoms for *S. amurensis* in isolate 1 (PNRSV, RpRSV, ArMV) appeared 12 months after inoculation, but after 9 months in isolate 2 (RpRSV, ArMV, SLRSV).

We also conducted a test on the wild species, *S. aucuparia*, which is more widespread and predominant on the European territory of Russian and appears to be resistant to more harmful virus diseases (**Table 6; Fig. 3**).

In transferring isolates from *S. turkestanica* and 'Krasavitsa' to *S. aucuparia* no symptoms were displayed during the 3-4 yearly periods of observation. Apart from that, the differential infecting capacity of viruses may be due to different degrees of interaction of the agents under conditions of mixed infection. Longer incubation periods vary depending on the virus. The minimum incubation period of 12

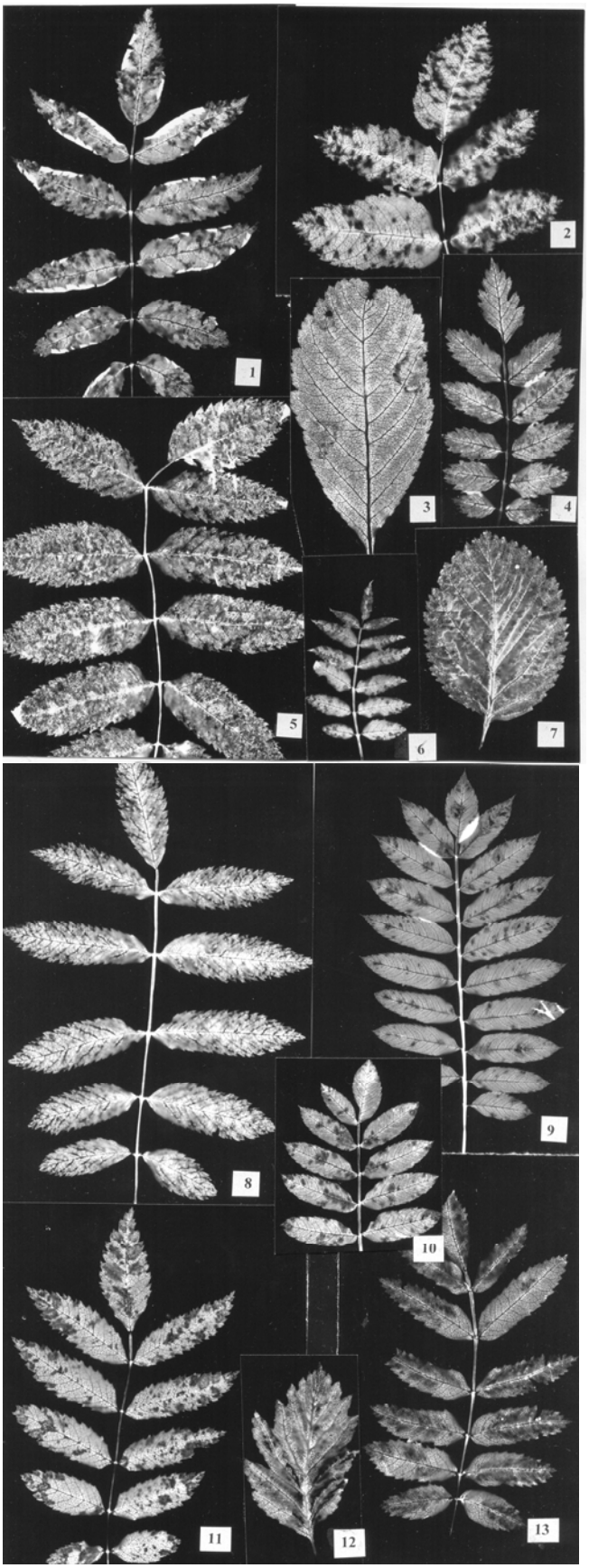

Fig. 2 Symptoms of different species *Sorbus* after grafting isolates N1 (PNRSV, RpRSV, ArMV) and N2 (RpRSV, ArMV, SLRSV). 1, PNRSV, RpRSV, ArMV x *S. serotina*; 2, PNRSV, RpRSV, ArMV x *S. sitchensis*; 3, PNRSV, RpRSV, ArMV x *S. colchica*; 4, PNRSV, RpRSV, ArMV x *S. kochneana*; 5, RpRSV, ArMV, SLRSV x *S. scopulina*; 6, RpRSV, ArMV, SLRSV x *S. kochneana*; 7, PNRSV, RpRSV, ArMV x *S. aria* f. *magestica*; 8, RpRSV, ArMV, SLRSV x *S. latifolia*; 9, RpRSV, ArMV, SLRSV x *S. hupechensis*; 10, RpRSV, ArMV, SLRSV x *S. decora*; 11, RpRSV, ArMV, SLRSV x *S. gracilis*; 12, RpRSV, ArMV, SLRSV x *S. caucasica*; 13, RpRSV, ArMV, SLRSV x *S. arnoldiana*.

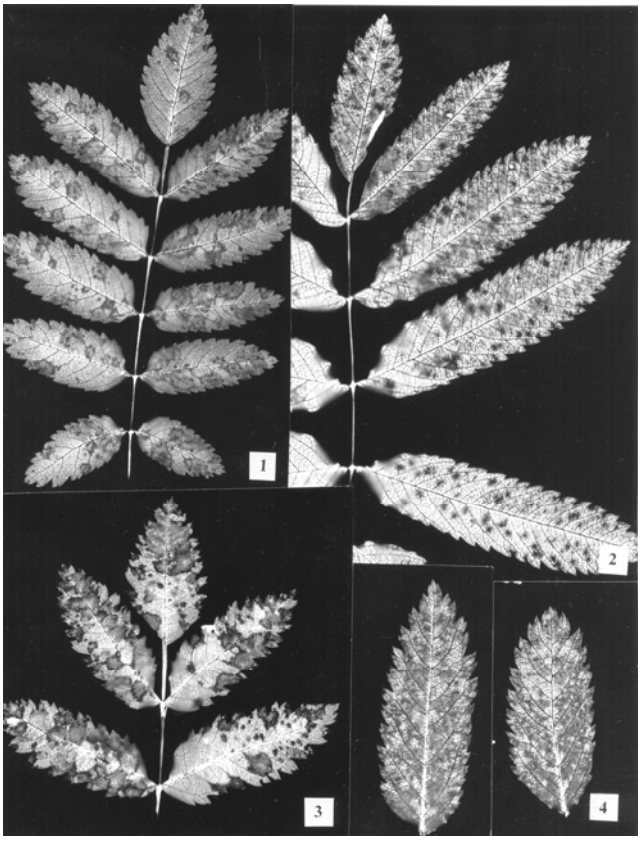

Fig. 3 Symptoms of *S.aucuparia* after grafting of different isolates. 1, *S. aucuparia* x 'Likernaya' (ekotype 2); 2, *S. aucuparia* x 'Kubovaya'; 3, *S. aucuparia* x 'Likernaya' (ekotype 1); 4, *S. aucuparia* x 'Khosta'

months was required for isolates PNRSV, ArMV, RpRSV, and ToRSV; 22 months for PNRSV, ArMV, RpRSV, and TBRV; 24 months for ToRSV, RpRSV, and PDV. A maximum incubation period of 48 months was applied to PNRSV, ApMV, RpRSV, and ToRSV.

We also conducted studies relating to the reaction within *Sorbus* genus stocks of *Ilar*- and *Nepo*-viruses, which showed that the species were resistant to field conditions. A greater degree a resistant was shown to viruses by 'Likernaya' (to 5 viruses), 'Titan' (to 6 viruses) and *S. aucuparia* (ecotype 1), also to 6.

We showed that there was a greater degree of infection in *S. aucuparia*, including different forms of the species in creation. In our work, the varieties were damaged (destroyed) by virus infection that may otherwise explain the origin of *S. aucuparia* (**Table 2**).

We evaluated the result of 17 varieties and 40 species of *Sorbus* and noted that viruses were discovered in 5 varieties and 1 species which had a tolerant reaction. Ten species and 12 varieties were not infected while 28 species were susceptible.

With the constant expansion of different types of species and varieties in botanical gardens, it is necessary to systematically carry on work to evaluation their infection by complex viruses. In this way we limit the spread of viruses and preserve biodiversity of the *Sorbus* genus.

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