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Identification of scab resistance genes in apple trees by molecular markers

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Apple scab is a widespread and one of the most harmful fungal diseases of apple trees in Belarus. Molecular markers were used for detection of resistance genes in 130 apple accessions including old, modern and introduced cultivars. The presence of genes *Vm, Vr1* and *Vh2* were detected using the molecular markers OPB12STS, AD13 and OPL19 respectively. Gene *Vf* was identified with the markers VfC, AL07 and AM19.

The gene *Vr1* was detected in modern cultivars as well as in old ones grown in Belarus from 19th century, such as 'Papirovka', 'Bely naliv', 'Korobovka krupnoplodnaya', etc. The marker OPL19 presents in genome of 81 accessions. Gene *Vm* was revealed in 7 accessions related to the parental cultivars McIntosh and SR0523. Gene *Vf,* which was transferred from *M. Xfloribunda* 821 and introduced into cultivated cultivars, was identified in 41 cultivars of different breeding (France, USA, Poland, Russia, Belarus, etc.). The presence of this gene provides a high scab resistance in apple cultivars. This was verified by field trials carried out during 2004–2007. The cultivars containing gene *Vf* and some cultivars with polygenic resistance shown a high scab resistance both in leaves and fruits.

Key words: apple scab, *Malus* accession, resistance genes.

Introduction. Apple scab is a widespread and one of the most harmful fungal disease of apple trees in Belarus. This disease is caused by an ascomycetes fungus *Venturia inaequalis.* In the years of intensive expansion that happens once per 3 years or even more often, scab causes premature leaf loss of trees and 100 % fruit lesion in susceptible cultivars if chemical protection is not used. Its control in co mMercial orchards can require up to 15 fungicide treatments per year. Such a large amount of chemical treatments raise numerous ecological problems and consumer health concerns, in addition to the economic cost (Lespinasse et al., 2002). An alternative approach is the use of resistant cultivars, which can be grown with much less pesticide treatment. Apple breeding is aimed for developing cultivars with durable scab resistance genes. There are many progra mMes for creating new cultivars with durable resistance of apple to scab (Crosby et al., 1992; Janick, 2002; Lespinasse et al., 2002).

Scab resistance is a complicated biological character determined genetically and depending on environmental conditions during morphogenesis. Various sources of apple scab resistance have been found (Williams, Kuc, 1969). Several major scab resistance

genes originated from small fruited asiatic *Malus* spp. The genes *Vbj* from *Malus baccata jackii*, *Vb* from *M. baccata*, *Vm* from *M. Xmicromalus* and *M. Xatrosanguinea* 804, *Vr* from *M. pumila* (Russian Seedling) R12740-7A, *Vf* from *M. Xfloribunda* 812 have been introgressed into breeding lines and selections to make them available for breeding purposes (Liebhard et al., 2003). Until now, mostly the *Vf* resistance has been incorporated into co mMercially available cultivars. The sources of scab resistance are 'Golden Delicious' (*Vg*), GMAL 2473 (*Vr2*), 'Durello di Forli' (*Vd*), differential host 2 (*Vh2*) and host 4 (*Vh4*) (derived from *M. pumila* R12740-7A), *M. sylvestris* W193b (*Vh8*) too (Durel et al., 2000; Patocchi et al., 2004; Tartarini et al., 2004; Bus et al., 2004; Bus et al., 2005a, 2005b).

Most known major resistance genes are "recognition genes" (Bergelson et al., 2001; Jones, 2001). The resistance genes differ in their level of resistant. Durable scab resistant cultivars were created combining major resistance genes and polygenic resistance. It is important to identify genes resistance to scab in apple cultivars and determine its significance for breeding.

Cultivars with multiple resistance genes can be easily selected with molecular markers associated with the resistance genes. The molecular markers have been developed for identification of gene resistance to scab in apple genome (Gessler et al., 2006). They are an excellent instrument for identification of durable genes and creation resistance cultivars using marker assisted selection.

The aim of this study was to identify durable genes leading to high level resistance to scab in the collection of apple accessions grown in Belarus and to determine valuable cultivars for breeding process. The molecular markers were used for determining scab resistance genes.

Object, methods and conditions. Plant material and estimation. The collection of apple accessions from the orchard of the Institute of Fruit Growing of Belarus, which include 130 accessions including old, modern and introduced cultivars, was studied in this investigation. The assessment of apple scab lesion was made according to the Program and methods of fruit, small fruit and nut cultivar assessment (Sedov, Ogoltsova, 1999).

DNA isolation. DNA was extracted from frozen leaves in all evaluated genotypes. DNA was isolated by Genomic DNA Purification Kit (Fermentas) according to manufacturer's instructions.

PCR markers. The molecular markers OPB12STS, AD13 and OPL19 linked to genes *Vm, Vh2* and *Vr1* (Cheng et al., 1998; Bus et al., 2005a; Boudichevskaia et al., 2006) were used respectively. The gene *Vf* was identified with the markers VfC, AL07 and AM19 (Afunian et al., 2004; Tartarini et al., 1999) (Table 1).

Table 1. Markers for detection of scab resistance genes
1 lentelė. Žymenys rauplėms atsparių genų nustatymui

Detected gene Nustatyti genai	Resistance source Atsparumo šaltinis	Marker Žymuo	LG	Expected size Laukiamas dydis (bp)	T°an	Reference Šaltinis
Vf	*M. Xfloribunda* 821	VfC	1	R 286 S 484, 646	58	Afunian et al., 2004
Vf	*M. Xfloribunda* 821	AL07 AM19	1	Vf – 466, 526 vf – 724	60	Tartarini et al., 1999
Vm	*M. Xatrosanguinea* 804; *M. Xmicromalus* 245-38	OPB12 STS	17	687	58	Cheng et al., 1998
Vh2 /Vr-A	R12740-7A	OPL19	2	433	55	Bus et al., 2005 a
Vr1/Vh4/Vx	R12740-7A	AD13	2	950	58	Boudichevskaia et al., 2006

A m p l i f i c a t i o n. Amplification was performed in 20 мl final volume containing: 40 ng of genomic DNA as template, 67 mM Tris-HCl pH 8.8, 16 mM $(NH_4)_2SO_4$, 1.5 mM $MgCl_2$, 0.2 mM of each dNTP, 0.25 мM of each primers, and 1U Taq DNA Polymerase. The program of amplification was: 3 min at 94 °C; followed by 40 cycles of 94 °C for 40 s, Tєan for 1 min, 72 °C for 1 min; and a final extension of 72 °C for 10 min.

Amplified DNA fragments were analyzed by horizontal electrophoresis on a standard 1.0 % agarose gel in Tris-acetate-EDTA buffer (Sambrook et al., 1989). DNA was visualized by ethidium bromide. Gels were photographed with BioRad camera under UV light. GeneRuler^{tm} 100 bp DNA Ladder Plus (Fermentas) was used as a molecular weight marker.

Results. The gene *Vr1/Vh4/Vx* was identified in the *Malus* scab resistance source R1740-7A (Russian seedling) (Bus et al., 2005b). This gene was mapped on linkage group 2. The codominant, multiallelic molecular marker AD13-SCAR have been developed by Boudichevskaia et al. (2006). Marker AD13-SCAR was used for identification of gene *Vr1* in 130 accessions of apple trees and presence of gene *Vr1* was detected in 34 accessions. AD13-SCAR was detected in both modern cultivars and old cultivars grown in Belarus from 19th century, such as 'Papirovka', 'Bely naliv', 'Korobovka krupnoplodnaya', etc. (Table 2). Presence of the locus from 'Papirovka' was detected in modern cultivars 'Mechta' and 'Narodnoe'. This marker also was found in old cultivar 'McIntosh' and in its progenies 'Wijcik', 'Auksis', 'Melba'.

The SCAR marker OPL19 developed by Bus et al. (2005b), was applied for testing locus *Vr2/Vr-A*. This locus of linkage group 2 contains linked genes *Vr2/Vr-A* and *Vh8* (Bus et al., 2005a). The marker OPL19 dispose at a distance of 1.3 cM from *Vh8*. SCAR maker OPL19 was identified in 81 accessions. Possibly this marker do not let to test the gene in collection, but it is very important for testing breeding forms. Information about this locus can be used in breeding process for testing new accessions, if their parents contained this locus.

The sources of the gene *Vm* in breeding are *M. Xatrosanguinea* 804 and *M. Xmicromalus* 245-38 (Dayton, Williams, 1970). The marker OPB12 STS have been developed for *Vm* by Cheng et al. (1998). The OPB12 STS being placed at about 6 cM

from *Vm* is an excellent indicator for the presence of *Vm* in germplasm collection. This marker is mapped on apple linkage group 17 (Patocchi et al., 2005). The gene *Vm* was revealed by OPB12 STS marker in 7 accession including 'McIntosh' and its progeny 'Wijcik'. This marker also detected presence of the gene *Vm* in 'SR0523' and its progenies 'Orlovim', 'Pervinka', '84–39/58', '84–50/9'.

Table 2. The list of observed cultivars
2 lentelė. Tirtų veislių sąrašas

Cultivar title Veislių pavadinimai	Origin Kilmė	Grade of resistance Atsparumas	VfC	AL07 AM19	AD13	OPB12 STS	OPL19
1	*2*	*3*	*4*	*5*	*5*	*6*	*7*
'Afrodita'	Russia / Rusija	Re	+	+	+		
'Alamata	USA / JAV	Re					
'Alesya'	Belarus / Baltarusija	LS					
'Alkmene'	Germany / Vokietija	LS					+
'Amulet'	Ukraine / Ukraina	LS	+	+			+
'Antei'	Belarus / Baltarusija	MS					
'Antonovka obyknovennaya'	Russia / Rusija	LS					+
'Antonovka mogilevskaya'	Belarus / Baltarusija	LS					+
'Auksis'	Lithuania / Lietuva	MS			+		+
'Babushkino'	Russia / Rusija	LS					
'Bananovoe'	Belarus / Baltarusija	MS					
'Belorusskiy sinap'	Belarus / Baltarusija	FRe					+
'Belorusskoe letnee'	Belarus / Baltarusija	FRe					+
'Belorusskoe malinovoe'	Belarus / Baltarusija	MS					
'Belorusskoe sladkoe'	Belarus / Baltarusija	Re	+	+			+
'Bely naliv'	Russia / Rusija	LS			+		+
'BM41497'	Sweden / Švedija	FRe	+	+			+
'Bolotovskoe'	Russia / Rusija	Re	+	+			+
'Borovinka'	Belarus / Baltarusija	MS					+
'Charavnitsa'	Belarus / Baltarusija	LS					+
'Chornoe derevo'	Russia / Rusija	LS					
'Chulanovka'	Russia / Rusija	FRe					
'Creb GK-1'	Belarus / Baltarusija	MS			+		+
'Darunak'	Belarus / Baltarusija	Re	+	+			+
'Discovery'	Great Britain / Didžioji Britanija	LS					
'Dolgo'	Russia / Rusija	MS			+		+
'Edera'	Ukraine / Ukraina	Re	+	+			+
'Elena'	Belarus / Baltarusija	MS			+		+
'Elstar'	Netherlands / Olandija	LS					+
'Empire'	USA / JAV	MS					+
'Fiesta'	UK / Jungtinė Karalystė	LS					
'Florina'	France / Prancūzija	Re	+	+	+		
'Freedom'	USA / JAV	Re	+	+			+
'Golden Delicious'	USA / JAV	MS					
'Gravenstein'	Germany / Vokietija	MS					
'Hibernal'	USA / JAV	FRe					+
'Hislop'	USA / JAV	FRe					
'Idared'	USA / JAV	MS					+

Table 2 continued
2 lentelės tęsinys

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
‘Imant’	Belarus / Baltarusija	Re	+	+			+
‘Imrus’	Russia / Rusija	Re	+	+			+
‘Jay Darling’	USA / JAV	FRe					
‘Jeneva’	USA / JAV	MS			+		+
‘Jonafree’	USA / JAV	Re	+	+	+		
‘Jonagold de Costa’	Belgium / Belgija	MS					
‘Jubilyar’	Russia / Rusija	Re	+	+			+
‘Jupiter’	UK / Jungtinė Karalystė	LS			+		+
‘Kandil orlovsky’	Russia / Rusija	FRe	+	+	+		+
‘KBM F_2’	Russia / Rusija	LS					
‘Kent’	UK / Jungtinė Karalystė	LS					
‘Korobovka krupnoplodnaya’	Local / Vietinė	LS			+		+
‘Koshtelya’	Poland / Lenkija	LS					+
‘Kovalenkovskoe’	Belarus / Baltarusija	MS					
‘Lawfam’	Canada / Kanada	MS					
‘Lawfam seedling’	Belarus / Baltarusija	LS					+
‘Loshitskoe’	Belarus / Baltarusija	MS					
‘Luchezarnoe’	Belarus / Baltarusija	LS					
‘McIntosh’	Canada / Kanada	HS			+	+	+
‘Mechta’	Russia / Rusija	LS			+		+
‘Medunitsa’	Russia / Rusija	LS					+
‘Melba’	Canada / Kanada	HS			+		+
‘Minkar’	Ukraine / Ukraina	FRe					
‘Minskoe’	Belarus / Baltarusija	LS					+
‘Nadzeiny’	Belarus / Baltarusija	Re	+	+			
‘Narodnoe’	Russia / Rusija	LS			+		+
‘Nesravnennoe’	Belarus / Baltarusija	LS					
‘Nora’	USA / JAV	FRe					
‘Novinka oseni’	Belarus / Baltarusija	Ls					
‘Novoe sladkoe’	Belarus / Baltarusija	FRe			+		+
‘Orlovim’	Russia / Rusija	LS				+	+
‘Orlovskoe polesye’	Russia / Rusija	Re	+	+	+		+
‘Osennee polosatoe’	Germany / Vokietija	LS					+
‘Otava’	Czech / Čekija	Re	+	+			
‘Pamyat Isaeva’	Russia / Rusija	FRe					+
‘Pamyat Kovalenko’	Belarus / Baltarusija	Re	+	+			+
‘Pamyat Pashkevicha’	Belarus / Baltarusija	LS					+
‘Pamyat Sikory’	Belarus / Baltarusija	MS					
‘Pamyat Syubarovoi’	Belarus / Baltarusija	FRe					+
‘Pamyat Vavilova’	Belarus / Baltarusija	FRe					
‘Papirovka’	Russia / Rusija	LS			+		+
‘Pepin litovsky’	Belarus / Baltarusija	MS					+
‘Pepin litovsky uluchshenny’	Belarus / Baltarusija	LS					+
‘Pepinka zolotistaya’	Ukraine / Ukraina	LS					+
‘Perlyna Kieva’	Ukraine / Ukraina	Re	+	+			+
‘Pervinka’	Russia / Rusija	LS				+	+
‘Pinova’	Germany / Vokietija	FRe					+
‘Pospeh’	Belarus / Baltarusija	Re	+	+			+
‘Reanda’	Germany / Vokietija	Re	+	+			+
‘Rebristoe’	Belarus / Baltarusija	LS					

Table 2 continued
2 lentelės tęsinys

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
'Red Boskoop'	Holland / Olandija	MS			+		
'Redfree'	USA / JAV	Re	+	+	+		+
'Reka'	Germany / Vokietija	LS					+
'Relinda'	Germany / Vokietija	Re	+	+			
'Retina'	Germany / Vokietija	Re	+				
'Revena'	Germany / Vokietija	Re	+	+			
'Sawa'	Poland / Lenkija	Re	+	+	+		
'Seruel'	Belarus / Baltarusija	MS					+
'Shchedroe'	Belarus / Baltarusija	LS					+
'Sinap orlovsky'	Russia / Rusija	LS					+
'Skala'	Russia / Rusija	Re	+	+			+
'Slava pobeditelyam'	Ukraine / Ukraina	MS					+
'Solnyshko'	Russia / Rusija	FRe	+	+	+		+
'SR0523'	USA / JAV	HS			+	+	+
'Start'	Russia / Rusija	Re	+	+	+		+
'Stoikoe'	Belarus / Baltarusija	LS					
'Stroevskoe'	Russia / Rusija	Re	+	+			
'Svezhest'	Russia / Rusija	Re	+	+			+
'Syabryna'	Belarus / Baltarusija	Re	+	+			
'Tellisaare'	Estonia / Estija	LS					+
'Topaz'	Czech / Čekija	Re	+	+			
'Tsyganochka'	Ukraine / Ukraina	Re	+	+	+		+
'Utro'	Ukraine / Ukraina	LS			+		+
'Venyaminovskoe'	Russia / Rusija	Re	+	+	+		+
'Verbnoe'	Belarus / Baltarusija	FRe					
'Vesyalina'	Belarus / Baltarusija	LS					+
'Veteran'	Russia / Rusija	MS					
'Wealthy'	USA / JAV	MS					+
'Wijcik'	Canada / Kanada	LS			+	+	+
'Witos'	Poland / Lenkija	Re	+	+	+		+
'X1924'	France / Prancūzija	Re	+	+			
'Yellow transparent'	Russia / Rusija	LS			+		+
'Zarya Alatau'	Kazahstan / Kazakstanas	MS					
'Zaslavskoe'	Belarus / Baltarusija	LS					
'M. floribunda K2362'	Russia / Rusija	Re					+
'K:1343'	Sweden / Švedija	Re	+	+			+
'K:1430'	Sweden / Švedija	Re	+	+			+
'COOP-10'	USA / JAV	Re	+	+			
'78-14/245'	Belarus / Baltarusija	Re			+		+
'84-39/58'	Belarus / Baltarusija	Re			+	+	+
'84-50/9'	Belarus / Baltarusija	Re			+	+	+
'78-15/108 (F_1OR 38T17)'	Belarus / Baltarusija	FRe	+	+			

* Grade of resistance: Re – resistant, FRe – field resistant, LS – low susceptive, MS – moderate susceptive, HS – high susceptive. Symbols + – indicate presence of markers.
* Atsparumas: Re – atsparus, FRe – lauke atsparus, LS – mažai jautrus, MS – vidutiniškai jautrus, HS – labai jautrus. Simboliai + – parodo žymenų buvimą.

Gene *Vf* originates from the wild apple accession *M. Xfloribunda* 821. Vinatzer et al. (1998) have cloned a cluster of resistance genes *HcrVf* from the *Vf* locus of the chromosome 1. The cluster consisted of four homologous genes encoding receptor-

like protein. It is possible that one of them is related to resistant (Belfanti et al., 2004). Marker VfC have been designed based on conserved regions in the *Vf* candidate genes from *HcrVf* members (Afunian et al., 2004). Three fragments of 646, 484 and 286 bp in length were revealed in the result of PCR with VfC marker. The presence of the gene is determined by the presence of the fragment of 286 bp in length.

Tartarini et al. (1999) suggested using two primers pair AL07 and AM19 for identification of the gene *Vf*. This marker allows *Vf* homozygous resistant, *Vf* heterozygous resistant and susceptible genotypes to be reveled. Amplification fragments of 466 and 526 bp-long indicate gene *Vf*. Amplification fragment of 724 bp-long indicate gene *vf*.

Markers VfC, AL07 and AM19 were detected in genomes of 41 accessions of diverse breeding – France, USA, Poland, Russia, Belarus, etc. (Table 2). Cultivars 'Relinda', 'Freedom' and 'Jonafree' contain the genotype *VfVf*. The other resistant cultivars contain genotype *Vfvf*.

Comparison of the obtained results with apple pedigree made it possible to determine that the line BM41497 was the source of the gene *Vf* in cultivars of Belarus breeding: 'Belorusskoe sladkoe', 'Darunak', 'Nadzeiny', 'Pamyat Kovalenko', 'Pospeh'. The line BM41497 inherited this gene from *M. Xfloribunda* 821. Cultivar 'Imant' inherited the gene from 'Liberty'. Line 814 was a source of gene *Vf* in cultivars of Russian breeding 'Afrodita', 'Jubilyar', 'Orlovskoe polesye', 'Solnyshko', 'Start', 'Stroevskoe', 'Venyaminovskoe'.

Levels of resistance detected for tested accessions in Belarus are presented in Table 2. 41 cultivars demonstrated resistant to apple scab, 18 – field resistant, 43 – low susceptive, 25 – moderate susceptive, 3 – high susceptive of the 130 tested cultivars.

Discussion. Great scab lesion was found in the cultivars 'McIntosh', 'SR0523', 'Melba'. Presence of gene *Vm* in genome of 'McIntosh' and 'SR0523' did not protect them from scab lesion. Gene *Vm* has been overcome by *V. inaequalis* race 5, an event first discovered in England (Williams and Brown, 1968). Scab affection for these cultivars was the same as for the cultivar 'Melba', which has been originated from the cultivar 'McIntosh' but do not contained gene *Vm*.

Old cultivars 'Antonovka obyknovennaya', 'Babushkino', 'Bely naliv', 'Borovinka', 'Gravenstein', 'Korobovka krupnoplodnaya', 'Koshtelya', 'Papirovka', 'Pepin litovsky' had low or moderate susceptibility to scab. Some of them do not contain the markers tested; the markers OPL19 and (or) AD13-SCAR were detected in others (Table 2). Inversely the source of resistance of different genotypes of 'Antonovka' reported to be monogenic and polygenic (Williams and Kuc, 1969; MacHardy, 1996; Quamme et al., 2003).

The accessions, in which the markers OPL19 and AD13-SCAR were detected, shown different levels of scab resistance: from low level in 'SR0523' up to high level in '78-14/245'. It is possible that impact of these loci on scab resistance is not determinative.

The field resistance to scab demonstrated 17 cultivars, such as 'Hislop', 'Jay Darling', 'Minkar', 'Nora', 'Pamyat Vavilova', 'Kovalenkovskoe', 'Verbnoe' and others, in which the markers studied were not detected. Sasnauskas et al. (2006) have

characterized cultivars of Belarus breeding 'Verbnoe', 'Kovalenkovskoe' and 'Pamyat Syubarovoi' (carrying the markers OPL19) as having a stable resistance to scab in Lithuania in 2003–2005. Therefore, scab resistance in these cultivars is determined by other genes or can by polygenic.

All cultivars with gene *Vf* were detected to be resistance to scab during the period of study in Belarus except cultivar 'Amulet', which had low scab susceptibility. It has been proposed that the variation in resistance reactions of *Vf*-carrying plants may be due to the presence and action of modifier genes (Belfanti et al., 2004). Resistance to scab was found in the cultivars of Russian breeding 'Bolotovskoye', 'Yubilyar', 'Svezhest' in Lithuania (Sasnauskas et al., 2006). Cultivar 'Freedom' demonstrated resistance in other region of growing (Sestras, 2003). An unspecified 'Antonovka' clone is included in the pedigree of 'Freedom'. The large proportion of resistant seedlings observed in progenies derived from 'Freedom', suggested that this cultivar is containing two resistance genes (Lamb et al., 1985). Later Zini (2005) mapped the scab-resistance gene from 'Antonovka' at 20–25 cM from *Vf* .

Vf gene has been used most extensively in apple breeding programs around the world. *Vf* locus confers resistance to five races *V. inaequalis*. However, it have been investigated that *Vf* resistance has been overcome by *V. inaequalis* races 6 and 7 (Parisi et al., 1993; Benaouf and Parisi, 2000). All major resistances in apple are ephemeral. It is only a question of time until the pathogen with the matching virulence appears and overcomes such a resistance (MacHardy et al., 2001). The durability of resistance depends on the pathogen's evolutionary potential (McDonald and Linde, 2002). Actually, it is necessary to create new cultivars with two or more resistance sources. New sources of resistance should be discovered and tools to exploit these resistances in breeding programs (Liebhard et al., 2003). The combination of different resistances in the same genotype was proposed as a possible way to obtain a durable scab resistance for a long time (Lespinasse et al., 1999). This strategy was named 'pyramiding' and the role of molecular markers in its implementation is very important as they allow to detected necessary genes in different stages of ontogenesis.

Conclusion. Molecular methods of resistance gene detection can be successfully used in breeding programs. The use of them can significantly reduce time for genotype estimation and improve reliability of necessary gene detection.

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Rauplėms atsparių genų nustatymas obelyse naudojant molekulinius žymenis

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Santrauka

Obelų rauplės yra viena labiausiai paplitusių ir viena žalingiausių grybinių ligų Baltarusijoje. Molekuliniai žymenys buvo naudojami atsparumo genų nustatymui 130-tyje obelų pavyzdžių, įskaitant senas, naujas ir introdukuotas veisles. Genų *Vf, Vm, Vr1* ir *Vh2* buvo nustatytas naudojant molekulinius žymenis OPB12STS, AD13 ir OPL19, kurie atitinkamai susiję su genais *Vm, Vr1* ir *Vh2*. Genas *Vf* buvo identifikuotas žymenimis VfC, AL07 ir AM19.

Genas *Vr1* buvo nustatytas ir naujose, ir senose veislėse, kurios auginamos Baltarusijoje nuo 19 a., tokios kaip 'Papirovka', 'Bely naliv', 'Korobovka krupnoplodnaya' ir kt. Žymuo OPL19 buvo 81 pavyzdžio genome. Genas *Vm* buvo nustatytas 7 pavyzdžiuose susijusiuose su tėvinėmis veislėmis 'Mcintosh' ir SR0523. Genas *Vf,* kuris buvo perkeltas iš *M. Xfloribunda* 821 ir įvestas į auginamas veisles, buvo identifikuotas 41 skirtingos selekcijos (Prancūzijos, JAV, Lenkijos, Rusijos, Baltarusijos ir kt.) veislėje. Šio geno buvimas duoda didelį obelų veislių atsparumą rauplėms. Tai buvo patikrinta lauko bandymuose 2004–2007 m. Veislės, turinčios geną *Vf*, ir kai kurios veislės su poligeniškų atsparumu parodė didelį atsparumą rauplėms ir ant lapų, ir ant vaisių.

Reikšminiai žodžiai: atsparumo genai, *Malus* pavyzdžiai, obelų rauplės.