Using Scab Resistant Donors in Apple Breeding

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Abstract

Apple cultivars were crossed according to the half-diallel and topcross mating design. Apple scab resistance of seedlings was estimated by using a 0–5 scale: 0 – no infection on leaves, 5 – more than 75% of leaf area infected. Percentage of scab resistant seedlings in crosses involving cultivars Prima varied from 35.8% to 67.6%, involving cultivars Florina and Arbat – 51.9–59.5% and 53.5–72.5%, respectively. Significant differences for resistance to scab were found among the crosses. Both general combining ability (GCA) and specific combining ability (SCA) were highly significant. The significance of GCA for scab resistance shows that genetic variability exists for this trait and selection should result in genetic progress, because the mean square for GCA was larger than that calculated for SCA. Therefore, selection of parents on its phenotype should be effective for development of resistant apple cultivars. The significant SCA estimates indicate that a large number of resistant seedlings from particular crosses should be selected.

Keywords: *Venturia inaequalis*; apple cultivars; general and specific combining ability; inheritance

INTRODUCTION

Malus floribunda 821 and its derivatives are the most widely used donors of scab (*Venturia inaequalis* (Cke) Wint) resistance in apple breeding programs around the world (SANSAVINI & VENTURA 1994; ALLAN *et al*. 1999; FISCHER 2000). HOUGH (1944) was the first identify a source from *M. floribunda* as monogenic dominant and designated V_f. Later it was revealed, that the proportion of resistant seedlings depended not only on inherited dominant gene but on presence of modifying genes with additive effect as well (LAMB & HAMILTON 1969; GESSLER 1992). Susceptible parents could contribute significantly to resistance in a progeny. It was reported (PARISI *et al*. 1993), that some apple cultivars carrying V_f gene can be infected by scab. Nowadays, when resistance determined by V_f gene is overcome, it is very important to use scab resistance from polygenic sources, which increase stability of resistance. Another way is to receive new cultivars with more resistance genes V_f, V_r, V_A and others.

MATERIALS AND METHODS

Eight apple cultivars were crossed according to the half diallel mating design (GRIFFING 1956): Orlik, Noris, Auksis, Kaunis, Katja, Tellissaare, Prima, Idared. Seedlings of 28 crosses were planted in the orchard in 1991. A randomised complete-block design with 5 blocks was used. Every cross was represented by 10 plants per block. The combining ability was calculated according to Griffings method 4. Another group of apple cultivars was crossed according to the topcross mating design (CHOTILIOVA 1965), when 8 cultivars (Tellissaare, Sylvia, Shtaris, Auksis, Aktiubinskoye, Discovery, Lodi and Quinte) were used as a female and 3 as a male (Arbat, Florina and Prima). Seedlings of 24 crosses were placed in orchard according to the randomised complete-block design with 4 blocks. Scab resistance of apple seedlings in orchard was estimated by using a 0–5 scale: 0 – no infection on leaves, 5 – more than 75% of leaf area infected.

RESULTS

Results presented in Figure 1, show that the highest percentage of resistant seedlings was ascertained in the cross Noris × Prima (67.6%) and only 35.8% of resistant seedlings was selected in progeny Kaunis × Prima. The amount of resistant plants in the cross Orlik × Prima was 37.3%. The number of resistant seedling was very close in crosses Katja × Prima

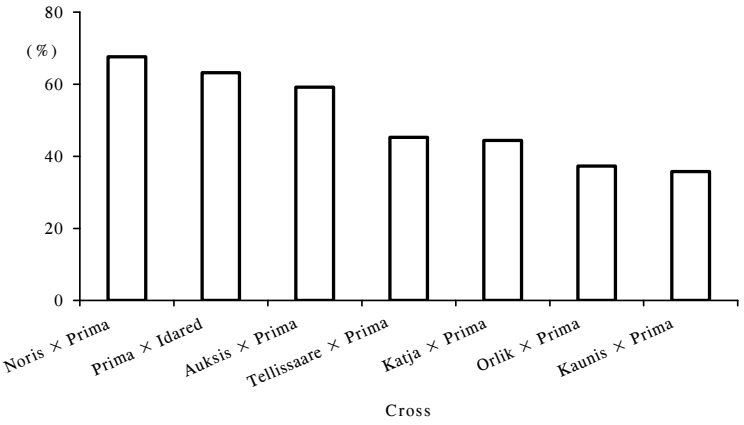

Figure 1. Susceptible parents effect on the scab resistance of the progeny

(44.4%) and Tellissaare × Prima (45.3%). More than 50% of resistant seedlings were selected in crosses Auksis × Prima and Prima × Idared (59.2% and 63.2%, respectively). Percentage of scab resistant apple seedlings in crosses involving cultivars Arbat, Florina and Prima caring V_f gene is presented in Figure 2. The amount of resistant individuals in crosses with Arbat varied from 53.5% to 72.5%, Florina – 51.9–59.5% and Prima – 51.9–63.4%. Progenies of Arbat had about 7% more resistant seedlings (62.4%) than progenies of Florina (55.8%) and Prima (55.2%). The crosses Aktiubinskoye × Arbat, Aktiubinskoye × Florina and Quinte × Prima had the highest percentage of resistant plants, 72.5%, 59.5% and 63.4%, respectively.

Significant differences were found among crosses (half diallel and topcross mating design) for scab resistance ($P < 0.01$). General combining ability (GCA) was highly significant ($P < 0.01$) and specific combining ability (SCA) as well ($P < 0.01$). The mean square for GCA was more than 12 times larger than mean square for SCA (half diallel). It means that scab resistance in this group of apple cultivars is controlled predominantly by additive gene action. Mean square for SCA was higher (1.2–1.6 times) than that calculated for GCA in another group of cultivars crossed according to topcross mating design and it shows that dominance and epistasis are important for inheritance of scab resistance.

GCA constants (half diallel) varied from –0.79 for Prima to 0.40 for Idared (Table 1). The value of Prima GCA constant was the highest and the main reason is that it carries V_f gene. An other apple cultivars that had high GCA constant value was Katja and it means that Katja transmitted heritable factors to its progenies. Noris, Kaunis and Idared had high positive values of GCA constants. Shtaris and Lodi GCA constants differed significantly from other cultivars involved in topcross mating design as female parents (Table 1). GCA constants of these cultivars were the highest (–1.0 and –1.07, respectively). Tellissaare, Aktiubinskoye and Quinte had high positive values

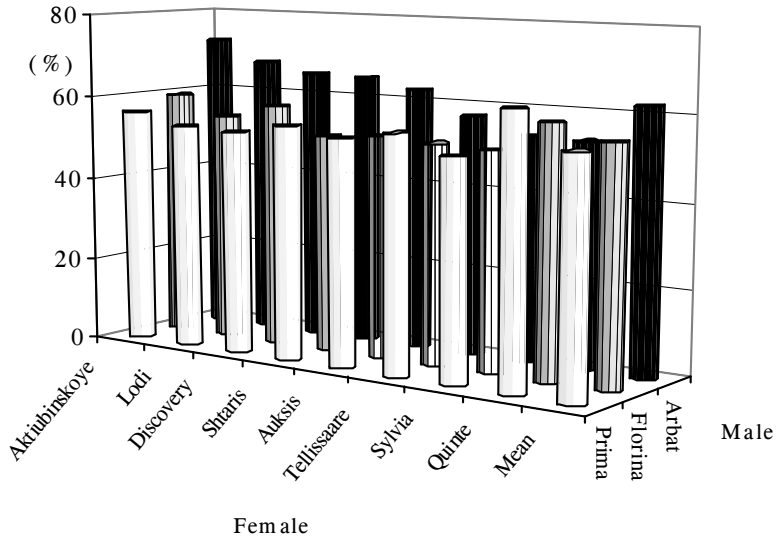

Figure 2. Scab resistance in progenies involving susceptible apple cultivars

Table 1. Combining ability constants and error for scab resistance

Cultivar	Number of crosses	$\hat{g}_i$	Error
Half diallel			
Orlik	7	0.03	
Noris	7	0.34	
Auksis	7	–0.06	
Katja	7	–0.18	0.11**
Kaunis	7	0.27	
Tellissaare	7	0.00	
Prima	7	–0.79	
Idared	7	0.40	
Topcross			
Female			
Tellissaare	3	0.84	
Sylvia	3	–0.32	
Shtaris	3	–1.00	
Auksis	3	–0.74	0.83*
Aktiubinskoye	3	1.43	
Discovery	3	–0.66	
Lodi	3	–1.07	
Quinte	3	1.51	
Male			
Arbat	8	–0.32	
Florina	8	–0.32	0.44*
Prima	8	0.64	

of GCA constants (0.84, 1.43 and 1.51). It means that contribution to its progenies resistance is not so significant as of previous two cultivars. Arbat and Florina had the highest negative values of GCA constants (–0.32) within male parents.

DISCUSSION

Apple cultivars Prima, Florina and Arbat carry V_f gene from *M. floribunda* 821. Shtaris is highly field scab resistant. It has *M. prunifolia* in pedigree and probably resistance to scab was received form this species. Orlik, Noris, Idared and Quinte were the most sensitive cultivars to scab involved in crosses. Since all resistant cultivars had V_fv_f genotype it could be expected 50% of seedlings would be resistant. In our case proportion of resistant seedlings varied in different crosses. Cultivars, which are little susceptible to scab, such as Auksis (Figure 1), Aktiubinskoye and Discovery (Figure 2), gave a higher proportion of resistant seedlings than very susceptible ones such as Orlik, Sylvia and others. But on the other hand, susceptible cultivars gave a high proportion of resistant individuals in some crosses: Noris × Prima (67.6%), Prima × Idared (63.2%) (Figure 1), Aktiubinskoye × Arbat (72.5%), Quinte × Prima (63.4%) (Figure 2). It is evident that a susceptible cultivar can significantly contribute to the resistance of the progeny. Our results correspond with results of other researchers (ROUSSELLE *et al.* 1974; KELLERHALS *et al.* 1993; TOTH *et al.* 1999) that susceptible cultivars transmit scab resistance to their progenies. It is important to combine parents carrying polygenically determined resistance to scab with parents carrying dominant genes to strengthen resistance and avoid its erosion through backcrosses.

The results indicate that significant amount of additive genetic variance exists for scab resistance in both groups of investigated apple cultivars. Non-additive genetic factors contribute significantly to the total variance of scab resistance. Thereby selection of parents on their phenotype or their general combining ability effects should be effective to increase scab resistance progenies. The significant SCA estimates indicate that a large number of resistant seedlings from particular crosses should be selected.

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