PROTECTION OF GENETIC RESOURCES OF POMOLOGICAL PLANTS AND SELECTION OF GENITORS WITH TRAITS VALUABLE FOR SUSTAINABLE FRUIT PRODUCTION

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GENETIC RESOURCES AS BASIS FOR NEW RESISTANT APPLE CULTIVARS

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ABSTRACT

Fruit breeding is heavily dependent on the use of genetic resources: old and new varieties as well as different wild species. This needs especially for disease, pest and environmental stress resistance or tolerance. Besides collecting and preservation in collections the evaluation for subsequent use in breeding is of great importance. Priority in respect of collecting and preserving should be given to varieties and species which show significant properties and express them under different ecological conditions. For breeding purposes there is a distinct advantage that, with exception of polyploids and apomicts, *Malus, Pyrus* and some *Prunus* species can be crossed unlimitedly with cultivated forms. Therefore the genetic information originating from wild species can be transferred to cultivated forms.

Integrated and biological cultivation methods are becoming increasingly important. The situation concerning the acceptance of pesticides is becoming more critical as increased attention is given to environment. An alternative solution is the cultivation of resistant cultivars, which can be grown with much less pesticides. It was the aim of the Pillnitz apple breeding to combine improvements in fruit quality, yield and resistance to different pathogens in new cultivars. Early-, mid-, and late-season apple cultivars were selected in two series, Pi- and Re-cultivars®. The Re-cultivars® guarantee a high degree of resistance. Triple and multiple resistant cultivars are selected with resistance to scab (*Venturia inaequalis*), mildew (*Podosphaera leucotricha*) and fire blight (*Erwinia amylovora*): ‘Remo’, ‘Regia’ ‘Rewena’, and ‘Rebella’. ‘Rebella’ was found to have resistance also to bacterial canker (*Pseudomonas spec*.), red spider mites (*Tetranychus urticae, Panonychus ulmi*), green apple aphid (*Aphis pomi*), and abiotic damages.

Various degrees of scab infection on *Vf*-resistant cultivars have been observed since 1984 in Middle-Europe. No infection was found in cultivars with other genetic background such as ‘Reglindis’ (*VA*), ‘Reka’ (*Vr*) or ‘Regia’ (*Vr*). New sources for resistance breeding (scab, mildew) especially for pyramiding of resistance genes were found in the Fruit Gene Bank in some *Malus* species and in < 2% of old apple cultivars. However, if the *Vf*-gene is overcome new resistance sources and new bred cultivars with two or more different sources of resistance to stabilize healthiness in the field will be required in the future. Resistant cultivars are the cultivars for the future.

Key words: Gene bank, genetic resources, genetic erosion, apple breeding, multiple-resistant cultivars, stability of resistance

1. The German national gene bank systems

The ongoing loss of genetic resources requires systematic activities for their conservation. In addition to *in situ* and *on farm* procedures, the *ex situ* conservation forms the basis of a modern management of plant genetic resources. Notwithstanding the mode of conservation, a two dimensional approach is needed to cover the biodiversity of cultivated plants. On one hand, the preservation of interspecific variability requires a large number of plant species to be maintained, while on the other hand the conservation of the intraspecific variability within a given species necessitates the preservation of a sufficiently large number of individual genotypes. Both variables are reflected in the structure of the collection held at the Gatersleben Gene Bank of the Institute of Plant Genetics and Crop Plant Research (IPK), which, at present, comprises more than 105.000 accessions belonging to about 2.150 species (Graner, 2003).

The scope of the collection ranges from major crop species and their wild progenitors to endangered and neglected species. About 20% of the accessions originate from more than 130 collection trips that have been performed since the 1920ies. While the long term storage of seed material is efficiently managed at low temperatures, clonally propagated plants require labour intense efforts ranging from field cultivation to *in vitro* culture and cryo-preservation. The availability of molecular marker techniques has initiated the development of new strategies regarding the characterisation of genetic resources ranging from molecular fingerprinting to gene mapping. Together with an appropriate documentation of genetic and phenotypic data this is expected to form the basis for a more efficient deployment of genetic resources in plant breeding (Börner et al., 2000).

In Germany the national plant germplasm system includes Federal, State and private organisations (NGOs) and research units. The system is coordinated at present by the Central German Gene Bank at the IPK Gatersleben (*ex situ*), and by the Federal Ministry of Agriculture, Bonn (*in situ, on farm*). Fruit species are preserved in Dresden-Pillnitz at the Institute or Fruit Breeding (under administration of the Federal Ministry of

Agriculture). Support and funding comes from State appropriations. All fruit accessions of Germany are specified in a National Fruit Varieties List. It contains 17.200 documentary records on varieties from 45 fruit species, among them 2703 varieties of apples (1053 of there grow in the former Fruit Gene Bank Dresden-Pillnitz – (Fig. 1), 837 of pears, 560 of strawberries, 409 of plums, 438 of sweet cherries, 59 of sea buckthorn accessions and others (Hohlfeld and Fischer, 2000).

Figure 1. Genetic diversity in apples (photo: M. Fischer)

The German Fruit Gene Bank Dresden-Pillnitz comprises one of the most important collections of *Malus* and *Fragaria* wild species in Europe. 440 of wild relatives and 240 accessions of varieties are unique in the Fruit Gene Bank in Germany. Apart from cultural tasks in conservation of old German varieties and indigenous wild fruit species the collections of the gene bank serve as a stock and a source of basic material for fruit breeding. At present, the identification and preservation of donors for resistance is particularly important (Fischer et al., 2003).

Table 1 documents the stock of the Fruit Gene Bank on the 31.11.02. All accessions were evaluated as plants in the field. Additionally to the passport data numerous results of evaluation are recorded on pollen fertility, morphology, phenology, apomixis, cropping behaviour, fruit quality, as well as resistance to diseases and pests (viruses, fire blight, *Pseudomonas*, *Cytospora*, mildew, scab, aphids) and frost hardiness of shoots and flowers. The main task for evaluating the collections was the permanent supply of these evaluation data, because in woody plants several years are necessary for a reliable judgement of these characters. The evaluation data of apple and stone fruit are available in ”EVA“ – Database (http://www.dainet.de/genres/eva/).

Table 1. Accessions of the Fruit Gene Bank Dresden-Pillnitz (2002)

Varieties	
Apple (*Malus domestica*)	985 varieties and breeding clones
Apple (*Malus x domestica*)	34 rootstocks
Sweet cherry (*Prunus avium*)	240 varieties and breeding clones
Sour cherry (*Prunus cerasus*)	107 varieties and breeding clones
Plum (*Prunus domestica*)	189 varieties and breeding clones
Peach (*Prunus persica*)	20 varieties
Apricot (*Prunus armeniaca*)	29 varieties
Nectarin (*Prunus nucipersica)*	11 varieties
Pear (*Pyrus communis*)	164 varieties and breeding clones
Pear *(Pyrus x communis)*	12 rootstocks
Asian Pear (*Pyrus pyrifolia*)	15 varieties
Strawberry (*Fragaria x ananassa)*	320 varieties
Sea buckthorn (*Hippophae rhamnoides*)	25 varieties and breeding clones
Others	67 varieties
Varieties	**2218 accessions**
Species, hybrids of species	
Malus	379 species, hybrids
Pyrus	58 species, hybrids
Prunus	88 species, hybrids
Fragaria	179 species
Others	46 species, hybrids
Species	**750 accessions**
Entire Stock on 30.11.2002	**2968 accessions**
***Malus sieversii* and other offsprings of wild species for evaluation**	
180 populations with 2650 plants	

The former working group of the Fruit Gene Bank Dresden-Pillnitz was integrated into the Institute for Fruit Breeding Dresden-Pillnitz at the end of 2002. The new curator is Dr. Monika Höfer (m.hoefer@bafz.de).

2. The current situation in fruit production

Integrated and biological cultivation methods are becoming increasingly important. The situation concerning the acceptance of pesticides is becoming more critical as increased attention is given to environment. The control of certain pests or diseases with chemicals is already being questioned to some degree. An alternative solution is the cultivation of resistant cultivars which can be grown with much less pesticides. Unfortunately, however there is still a very low level of acceptance of resistant cultivars in the commercial cultivation of apples. Why?

Essential conditions must be met before a new cultivar can be introduced on the market:

1. with respect to the **cultivars:**

- two colours with attractive shiny red shades as an over colour,
- sweet, aromatic taste,
- firm, crisp fruit flesh with a long shelf life;

2. with respect to the **trade:**
- the will to introduce a new cultivar,
- substitute for an established cultivar,
- considerable advertising expenditure.

After all the grower must and will produce what the trade wants, not the other way round, whereby it doesn't matter to the trade at present how the cultivars are produced as long as they conform to the required quality standards. There will however be certain changes with the introduction of trademarks such as "Eco Label" or "Certified Organic" labels. The demand for "organic" products will increase even if the price is higher.

Producing fruit, especially apples, organically – and to the best quality in the long term – is not very simple and requires excellent specialists. In addition pest control is still necessary in "organic" cultivation, the more sensitive the cultivars grown, the more protection is needed.

All these factors are of little interest to the **consumer**, who wants
- high-quality fruit, free of pesticide residues (the consumer who is not well informed in this area feels this is more probable in "organic" cultivation, which explains partly the increased demand for this),
- continuous, consistently good supply,
- diversity in varieties (whereby the demand here keeps within limits),
- good (low !) price.

The **resistance of one cultivar** to specific diseases or pests resulting from the decrease in the use of plant protection agents in cultivation **is still not a sales argument**. This requires more intensive explanation and corresponding advertising (Stehr, 2000).

Nevertheless, fruit breeding still aspires towards cultivating new cultivars, which will have stable resistance and comply with the demands of the wholesale trade and of consumers. None of the resistant cultivars which have become known internationally meet these stringent requirements sufficiently yet and this is why there are still reservations about their large-scale cultivation. However, resistant cultivars have already been accepted for a long time in the self-supply and small garden sector.

3. Previous Pillnitz apple breeding work as an example for using genetic resources

Apple breeding work in Germany started in 1928. The first aim was to breed for both good fruit quality and high yield. All clones with high susceptibility to scab and mildew were eliminated in field evaluations. The program developed the "Pi-series" of apple cultivars ("Pi"- = Pillnitz), which are 'Pinova' (Fig. 2), 'Pilot' and other Pi-cultivars.

Figure 2. ‘Pinova’ - one of the most promising new apple cultivars from Dresden-Pillnitz (photo: M. Fischer)

In scab resistance breeding the cultivar 'Antonovka kamienna' was used at first as a polygenic scab resistance source (VA) (Schmidt, 1938). Later *Malus floribunda* and other wild species carrying different resistance sources (Vf, Vm, Vr) were also involved. The resistance breeding program was extended in Pillnitz for mildew, fire blight, bacterial canker, red spider mite and abiotic damage, such as winter frost and spring frosts. The results are the cultivars of the "Re-series" ("Re"- = **Re**sistance) ‘Remo’, Rebella’, ‘Reglindis’, ‘Regia’ and others. These cultivars have good fruit quality, early and high cropping and show resistance to scab and to some extent to other fungal and bacterial diseases (Fischer and Fischer, 1996).

3.1 Breeding methods

In long-term combination breeding programs (diallels, topcross, backcross and others) different sources of resistance were combined with donors for good fruit quality, high cropping capacity, storability etc. In these programs the following species and cultivars were used as sources for resistance:

- for scab resistance: in the first step ‘Antonovka kamienna’ (VA), in the next steps *Malus* x *floribunda* (Vf), *M.* x *micromalus* (Vm), *M.* x *atrosanguinea* (Vf ?), *M. pumila* (Vr) and the cultivars ‘James Grieve’, ‘Cox Orange’, ‘Duchess of Oldenburg’ and others.
- for mildew resistance: *M.* x *zumi* ‘Calocarpa’, *M.* x *robusta* ‘Persicifolia’, *M.* x *floribunda*, *M.* x *micromalus* and the cultivars ‘Dülmener Rosenapfel’, ‘James Grieve’, ‘Helios’, ‘Alkmene’, ‘Lord Lambourne’, ‘Worcester Permain’ and others,

- for fire blight resistance: *M.* x *robusta* 'Persicifolia', *M.* x *sublobata, M.* x *floribunda, M. prunifolia* and later the cultivars 'Remo', 'Rewena', 'Rebella' and 'Reanda'.

It is still the aim of the apple breeding to bring together in new cultivars improvements in fruit quality, yield and resistance to different pathogens. Another new challenge is establishing a lasting resistance in field cultivation, now that observations from different parts of Europe on the breakdown in the monogenic scab resistance sources from the *Malus floribunda* (Fischer et al., 1998, 2000; Weibel et al., 1997) have come to attention.

3.2 Breeding and evaluation results up to now

Early-, mid-, late-season apple cultivars were selected in both series, Pi- and Re-cultivars. The Re-cultivars® guarantee a high degree of resistance. Initially the cultivars were only scab resistant but they carry different resistance sources. Later two and more scab resistance sources were combined for pyramiding resistance. New clones are currently in field evaluation. Some scab resistant cultivars especially with the Vf gene, proved also to be mildew resistant. Fire blight resistance is very important because there are no efficient bactericides registered for use in orchards.

Figure 3. 'Rewena' - the most stabile multi-resistant apple cultivar from Dresden-Pillnitz in spite of the Vf-resistance basis (photo: M. Fischer)

One of the most important results of the Pillnitz apple resistance breeding program is the selection of a number of cultivars with resistance to economically important diseases by conventional combination breeding methods. The advanced Pillnitz resistant cultivars have been tested under a wide range of environmental conditions. They demonstrated their ability to maintain their resistance and provide fruit suitable either for fresh market and/or processing. With their resistance properties they are suitable for organic and integrated fruit production. Triple and multiple resistant cultivars are selected with resistance to scab, mildew and fire blight within the Re-cultivars® 'Remo', 'Rewena' (Fig. 3), 'Regia' and 'Rebella'. 'Rebella' was found with resistance not only to fungi and fire blight but also to bacterial canker, red spider mite and abiotic damage. All other cultivars have a different level of multiple resistance (Tab. 2). This multiple resistance can be transmitted to the offsprings by classical combination breeding and needs no genetic engineering.

Table 2. Multiple resistant Pillnitz apple Re-cultivars® (Fischer, 2000, completed 2002)

Re-cultivar®	Source of resist.	Scab	Mildew	Fire-blight	Bact. canker	Red spider mite	Spring frost	Winter freeze
Reanda	$\boldsymbol{V_f}$	R[1]	LR	R	LS	S	R	LS
Rebella	$\boldsymbol{V_f}$	LR	R	LR	R	R	R	R
Regine	$\boldsymbol{V_f}$	LR	LR	LR	LR	R	R	R
Releika	$\boldsymbol{V_f}$	LR	LS	LR	R	R	LR	S
Relinda	$\boldsymbol{V_f}$	R	LR	LS	R	S	LR	R
Remo	$\boldsymbol{V_f}$	LR	R	LR	LS	LS	LS	R
Rene	$\boldsymbol{V_f}$	LR	S	R	LR	S	R	LS
Renora	$\boldsymbol{V_f}$	R	LR	LS	LS	LS	LR	LR
Resi	$\boldsymbol{V_f}$	LR	LS	LS	R	S	R	S
Retina	$\boldsymbol{V_f}$	LR	LR	LS	LS	LR	R	S
Rewena	$\boldsymbol{V_f}$	R	R	R	R	LS	R	LS
Realka	$\boldsymbol{V_r}$	R	S	R	LS	LS	S	LS
Regia	$\boldsymbol{V_r}$	R	R	LR	LR	LS	LS	R
Reka	$\boldsymbol{V_r}$	R	LR	LS	R	S	S	LR
Releta	$\boldsymbol{V_r}$	R	S	LS	R	LS	LS	LS
Remura	$\boldsymbol{V_r}$	R	LR	LS	LS	S	LS	R
Reglindis	$\boldsymbol{V_A}$	R	LR	LR	LS	R	R	R

[1]R = resistant, LR = low resistance, LS = low susceptibility, S = susceptible

Büttner found a high potential of resistance to scab and mildew in the Fruit Gene Bank collection of wild *Malus* species (Büttner et al., 2000). Crossing experiments with widely related species have shown a wide range of crossability. The transmission of resistance traits to the offsprings has been proved. New sources for resistance breeding, especially for pyramiding resistance genes, were found in some *Malus* species and old apple cultivars. However, if the V_f-gene is to overcome new resistance sources and cultivars with two or more different sources of resistance will be required in the future to stabilize healthiness in the field.

The evaluation of the *Malus* wild species in the Pillnitz Fruit Gene Bank showed that 4% of all accessions had no symptoms of scab <u>and</u> mildew. Only a few of these are used as donors in breeding up to now, like some *Malus domestica* (scab, mildew), *M. baccata* (scab, mildew, winter frost), *M.* x *robusta* (scab, mildew, fire blight), *M. micromalus* (scab), *M.* x *zumi* (mildew) and *M. floribunda* (scab, fire blight). But the potential of wild species is much higher, especially by using modern breeding methods. Furthermore the following species are carriers of resistance genes: *M. coronaria* (scab, mildew), *M. florentina* (scab), *M. fusca* (immune to fire blight), *M. hupehensis* (mildew, scab), *M. sargentii* (mildew, scab), *M. sylvestris* (mildew), *M. trilobata* (mildew, scab), *M.* x *halliana* (scab), *M. sieversii* (scab, mildew, fire blight in offsprings) (Büttner et al., 2000).

Figure 4. 'Bittenfelder Seedling' – one of the most (polygene ?) scab and mildew resistant old cultivar in the field without fungicide spraying (photo: M. Fischer)

To find donors of polygenic resistance to both apple scab and mildew, the assortment of apple cultivars in the Fruit Genebank remained untreated with fungicides for two years. It was found that only 2% of 850 cultivars were not infected with scab or mildew. This result is important for breeding of resistant apple cultivars with polygenic sources of resistance after the first results were noted of overcoming the monogenic scab resistance in apple cultivars. The most susceptible cultivars were found to be the cultivars cultivated all round the world, such as 'Delicious', 'Golden Delicious', 'Granny Smith', 'Gala', 'Rubinette', and others. The group that showed **both scab and mildew resistance** includes: 'Bittenfelder Sämling (Fig. 4)', 'Börtlinger Weinapfel', 'Engelsberger Weinapfel', 'Gewürzluiken', 'Hibernal', 'Jacob Fischer', 'Kardinal Bea', 'Kirschweinling', 'Merton Prolific', 'Peasgoods Nonsuch', 'Prinzenapfel', 'Rote Sternrenette' and 'Spätblühender Taffetapfel'. These cultivars can be regarded as carriers of polygenic scab and mildew resistance but crossing experiments are required to confirm these assumptions. A marker analysis gave no indication of the existence of the well-known genes for monogenic resistance to scab or mildew.

These old and new cultivars are suitable for use in landscape improvement, for small orchards and home gardens, and as parents for transferring polygenic resistance in fruit breeding. Of the scab resistant cultivars with V_f-resistance only 'Cidor', 'Juliane' and 'Rebella' were found to be without mildew infection (Fischer and Dunemann, 2000). The former Fruit Gene Bank evaluation data are available in the following databases: http://www.dainet.de/genres/eva/ or http://www.dainet.de/genres/bosr/.

3.3 Concept for durable scab resistance under field conditions

This will be very important for breeding work in the future because the *M. floribunda* scab resistance is not stable under all ecological conditions (Fischer et al., 2000).

Figure 5. 'Otava' (Vf) with scab infection in N-Germany (June 1999) (photo: M. Fischer)

Scab on Vf-resistant cultivars has been observed at Ahrensburg, N-Germany since 1984 (Krüger, 1999). At different degrees of intensity some Re-cultivars (Vf) showed weak infections, sometimes with defensive reactions. At another location in N-Germany the infection occurred as a primary infection at an early stage before the opening of the blossoms and caused severe symptoms on peduncles, calyx, and, somewhat later, on petals. Foliar infection spread from 'Gerlinde' (Vf) to the neighbouring 'Ecolette' (Vf), 'Topaz' (Vf), and 'Rebella' (Vf). **Scab developed and resulted in consecutive infections during the summer,** because **no fungicides were applied**. At other location near the Baltic Sea scab was observed in 2000 only on 'Prima' and 'Ecolette' and in 2001 on all tested resistant cultivars (fig. 5) (Höhne, 2001). In fact: the situation is very variable but not hopeless because of different results in each year according to the actual environmental situation (Dierend, 2003).

Apparently the entire genetic background of the resistant cultivars is the cause of differences in stability of resistance. The results indicate that a number of resistant cultivars remained healthy in the respective locations, which allows a rather stable resistance to be assumed. This group includes ‘Reglindis’ (VA), ‘Reka’ (Vr), ‘Regia’ (Vr), ‘Renora’ (Vf), ‘Relinda’ (Vf), ‘Reanda’ (Vf), and ‘Rewena’ (Vf) (Fig. 3). However, the future **needs new cultivars with two or three different sources of resistance** to stabilise healthiness in the field, if the Vf-gene overcomes and does not work any longer.

Two or three fungicide spray applications are, however, required to control spring infection. Fungicides can be reduced by at least 80% for these cultivars. In years of high disease pressure sprays can be reduced to three or four treatments (conventional cultivars need to 15 treatments !). With their resistance properties the Re-cultivars® are suitable for organic and integrated fruit production at present. With the Re-cultivars® we offer a **concept for a new growing management in the orchards**. Different resistance sources can be combined with different maturing periods of cultivars. In this way a complete cross-pollination and fruit set of the resistant cultivars is guaranteed.

For the **durability of scab resistance** in the field we recommend

- no “monoculture” with Vf-cultivars,
- tolerance of a slight leaf infection on polygenic/oligogenic resistant cultivars to preserve the stability of the host-pathogen system (using VA- or Vr-cultivars like ‘Reglindis’ or ‘Regia’),
- promoting the breeding of cultivars with two or more resistance sources by pyramiding different resistance genes and using more cultivars with polygenic scab resistance in combination breeding programs (Lespinasse et al., 2001).

4. Outlook

One of the most important results of the Pillnitz breeding programs is the selection of a number of cultivars with resistance to economically important diseases by conventional recombinant breeding methods. The advanced Pillnitz resistant apple cultivars have been tested under a wide range of environmental conditions. They demonstrated their ability to maintain their resistance and provide fruit suitable either for fresh market and/or processing. With their resistance properties they are suitable for organic and integrated fruit production methods.

There are many possibilities for resistance breeding in the future. It requires widespread international co-operation. **All resistance breeding work is a race against time and nature.** The ever increasing interest of consumers in “healthy food” demands new growing methods such as an integrated and organic production of fruit with a minimization of the use of pesticides. This demands a very high commitment to better quality resistant cultivars.

To achieve this, we need more information for the public about the value of resistant cultivars and we need the large food chains and supermarkets as partners. We believe **that the future lies in resistant cultivars**. And we need a sustained evaluation and goal-directed use and international exchange of genetic resources as basis for the breeding success in the future.

The International Undertaking of the FAO on plant genetic resources, adopted in 1983 but legally not constraining stated that genetic resources are a heritage of mankind and consequently should be available without restriction. It also aimed to preservation, evaluation and documentation of genetic resources. Nevertheless, during the eighties, new concepts on ‘farmer’s rights’ and ‘sovereignty of the states over their plant genetic resources’ were developed and adopted by the International Conference on Biodiversity in Rio in 1992. This convention, legally constraining, makes provision for sharing in a fair and equitable way the benefits arising from the utilisation of genetic resources. Its implementation provoked the opening of big discussions, it is still unfinished (Börner et al., 2000). It needs international agreements from the beginning of an international co-operation and exchange of material. It can be helpful for the future to develop new varieties, new technologies for growing and harvesting, new products and new processing possibilities.

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ZASOBY GENOWE JAKO ŹRÓDŁO DLA HODOWLI NOWYCH ODPORNYCH ODMIAN JABŁONI

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STRESZCZENIE

Hodowla roślin sadowniczych w dużym stopniu zależy od wykorzystania zasobów genowych: starych i nowych odmian, jak również różnych dzikich gatunków. Od nowych odmian wymaga się odporności lub tolerancyjności na choroby, szkodniki i warunki środowiskowe. Oprócz gromadzenia i utrzymywania kolekcji, bardzo ważna jest ocena drzew pod kątem ich użyteczności dla hodowli. Pierwszeństwo pod względem zbierania i zachowywania powinno być dane odmianom i gatunkom, które pokazują znaczące właściwości i powtarzalność pod

wpływem różnych warunków naturalnych. Dla celów hodowlanych niewątpliwą korzyścią jest to, że z wyjątkiem poliploidów i apomiksji, gatunki z rodzajów *Malus, Pyrus* i *Prunus* mogą być krzyżowane nieograniczenie z formami uprawnymi.

Integrowane i biologiczne metody uprawy zyskują na znaczeniu. Wzrasta krytyka stosowania pestycydów i jednocześnie troska o środowisko naturalne. Alternatywnym rozwiązaniem jest uprawa odmian odpornych, które mogą być uprawiane z użyciem mniejszych ilości pestycydów. Dlatego też celem hodowli nowych odmian jabłoni w Pillnitz było połączenie poprawy jakości owoców i plonowania z odpornością na różne patogeny. Odmiany jabłoni wcześnie, średnio i późno dojrzewające zostały wyselekcjonowane w dwóch seriach: nazwy pierwszej z nich zaczynają się od liter Pi- drugiej od Re-®. Odmiany serii Re® gwarantują wysoki stopień odporności. Odmianami z potrójną i wielokrotną odpornością na parcha jabłoni (*Venturia inaequalis*), mącznika jabłoni (*Podosphaera leucotricha*) i zarazę ogniową (*Erwinia amylovora*) są: ‘Remo’, ‘Regia’, ‘Rewena’ i ‘Rebella’. Odmiana ‘Rebella’ okazała się także odporną na raka bakterynjego (*Pseudomonas* spec.), przędziorki (*Teranychus urticae, Panonychus ulmi*), mszycę jabłoniową (*Aphi pomi*) i dobrze przystosowaną do różnych warunków środowiska.

Od roku 1984 w Europie środkowej zaobserwowano różne stopnie porażenia parchem odmian posiadających gen odporności Vf. Odmiany posiadające inne geny odporności, na parcha jak ‘Reglindis’ (VA), ‘Reka’ (Vr), czy odmiana ‘Regia’ (Vr) nie uległy infekcji tym patogenem. Nowe źródła dla hodowli odpornościowej (parch, mączniak jabłoni), zwłaszcza posiadające kompleks genów odporności zostały znalezione w Kolekcji Roślin Sadowniczych u kilku gatunków z rodzaju *Malus* i w < 2% u starych odmian jabłoni. Jednakże, jeśli odporność na gen Vf będzie przełamana, to w przyszłości będą wymagane nowe źródła odporności i nowo wyhodowane odmiany posiadające dwa lub więcej różnych źródeł odporności. Odmiany takie są odmianami przyszłości.

Słowa kluczowe: Bank Genów, zasoby genowe, hodowla jabłoni, wielokierunkowa odporność odmian, odporność ustabilizowana