Natural Sources of Plant Disease Resistance and their Importance in the Breeding

J. POLÁK[1*] and P. BARTOŠ[2]

[1]Division of Plant Medicine and [2]Division of Genetics and Plant Breeding – Research Institute of Crop Production, 161 06 Prague-Ruzyně, Czech Republic
[*]e-mail: polak@vurv.cz

Abstract: In the contribution examples on the application of wild species as sources of disease resistance are presented. Information on sources of resistance to plum pox on apricot and peach trees and to wheat rusts, powdery mildew and aphids, tested and kept in the Research Institute of Crop Production, Prague-Ruzyně, is included. Natural sources of resistance represent an important part of the collections of genetic resources kept in the Czech Republic.

Keywords: interspecific crosses; intergeneric crosses; resistance breeding; plum pox; stone fruit trees; rusts; powdery mildew; aphids; wheat

Availability of suitable sources of resistance is a basic prerequisite for successful resistance breeding. In the beginnings of resistance breeding sources of resistance were selected among cultivated crops. Later on, attention was paid also to interspecific, as well intergeneric crosses including wild species related to crops. At present alien species represent an important part of genetic sources of disease resistance. E.g. of 47 resistance genes to wheat leaf rust (*Puccinia recondita* Rob. ex Desm.) listed by MCINTOSH *et al*. (1995) 22 originate from other sources than *T. aestivum* including all 10 last registered genes.

The transfer of resistance from a wild alien species to a commercial cultivar often has several steps, the first step being the choice of the most suitable source. Resistance has to be thorougly tested and also other traits considered. By the next step barrieres of crossability and sterility of hybrids have to be often overcome if the source of resistance and the crop are not related closely enough. This is a part of the pre-breeding that should lead to resistant and stable lines though still lacking the necessary agronomic characters. Finally, the agronomic value is achieved mostly by conventional breeding methods when pre-bred resistant lines are crossed with commercial cultivars.

In wheat crosses Jumillo (*Triticum durum*) × Marquis (*T. aestivum*) from which cv. Marquillo has been developed, and Yaroslav Emmer (*Triticum dicoccum*) × Marquis (*T. aestivum*) from which cvs Hope and H44-24 have been derived, were of historical, as well as of practical importance. The above mentioned cultivars were broadly used in further breeding in North America and were utilised as sources of stem rust resistance also in Europe. In Europe, the work carried out with crosses between wheat and rye in Germany in Salzmünde and Weihenstephan are of particular importance. The substitution 1B.1R and the translocation T1BL.1RS, developed there, possessed resistance genes to all three rusts attacking wheat, and to powdery mildew (BARTOŠ & BAREŠ 1972). It was often used in the world wheat breeding. Other translocations important for European wheat breeding were those from *Triticum ventricosum* (*Aegilops ventricosa*). E.g., the line VPM1 (from a cross of *Aegilops ventricosa, Triticum persicum* and cv. Marne) contains the gene *Pch2* conditioning eye spot resistance. Resistance to rusts (linked genes *Yr17*, *Lr37* and *Sr38*) originates from the same source. Several important genes for powdery mildew resistance were transferred also from alien species, e.g., *Pm2* from *Aegilops squarrosa* and *Pm6* from *Triticum timopheevi*.

Supported by the Grant Agency of the Czech Republic (Grant No. 522/99/0108) and by the Ministry of Agriculture of the Czech Republic (Grants No. MZe-M0l-01-03 and EP 1311).

Growing concern about narrowing the genetic basis of modern wheat cultivars including the basis of disease resistance is reflected in the growing attention paid to the gene banks. In total, nearly 800 000 wheat germplasm accessions are held globally (FAO 1996). Although wheat wild relatives constitute a relatively small part (3%) of the gene bank accessions, they are of high importance as sources of disease resistance.

In the Gene Bank of the Research Institute of Crop Production, Prague-Ruzyně the collection of wild *Triticeae* counts over 1 300 entries of annual and perennial species. Most entries, particularly of *Aegilops*, were tested for resistance to wheat rusts, powdery mildew and aphids (VALKOUN *et al*. 1985a; HOLUBEC *et al*. 1992, 1993; HANUŠOVÁ & HOLUBEC 1993; HAVLÍČKOVÁ & HOLUBEC 1995). Collection of *Aegilops speltoides* contained most resistant accessions (HOLUBEC *et al*. 1992). Of other genera some accessions of *Elymus caninus*, *E. dahuricus, Leptopyrum elongatum, Leymus racemosus, Psathyrostachys juncea, Thinopyrum junceum, Dasyspyrum villosum, Agropyron cristatum, Hordeum brevisubulatum, H. secalinum, Elymus fedtschenkoi, E. mutabilis, E. yezoensis, Leymus angustus* and *L. villosissimus* were also resistant (HOLUBEC *et al.* 1998).

To facilitate the use of resistance of wild relatives in conventional breeding, pre-breeding was oriented at the introgression of genes for resistance to lines with acceptable agronomic traits. Leaf rust resistance genes *Lr9*, *Lr19* and *Lr24* were transferred from CIMMYT spring lines into commercial winter wheats (STUCHLÍKOVÁ 1993). Of this pre-bred material the advanced line Lutea, possessing *Lr19* was selected in Slovakia and tested in the official trials. Leaf rust resistance was introgressed into crosses with commercial bread wheats from the line W49 (Lr38 from *Thinopyrum intermedium*) as well as from the cv. Amigo, possessing the translocation T1AL.1RS and resistance genes *Lr24*, *Sr24*, *SrAmigo* and *Pm17* (BARTOŠ *et al.* 1998). Another source of leaf rust and powdery mildew resistance was *Triticum durum* cv. Soldur from which resistance was transfered to crosses with commercial bread wheat cultivars (HANUŠOVÁ *et al*. 1997). A resistant accession of *Triticum monococcum* was crossed with *T. durum*, F1 crossed with *T. aestivum* and after two or three back-crosses hexaploid lines resistant to stem rust, leaf rust and powdery mildew were selected (VALKOUN *et al.* 1985a,b, 1986a,b). In selected lines two genes for stem rust were determined (one to be the earlier described gene *Sr35*); gene for powdery mildew resistance has been identified as a new allele (b) of *Pm1* (ZELLER & HSAM 1998); gene for leaf rust resistance was not determined. A line of the above mentioned cross, possessing powdery mildew resistance, is in the pedigree of the commercial cultivar Vlasta (ŠÍP *et al.* 1999). Cv. Vlasta is highly resistant to powdery mildew though the presence of *Pm1b* has not been confirmed (BARTOŠ *et al*. 2002).

Another important topic of the research in the Research Institute of Crop Production (RICP) in Prague-Ruzyně is sharka (plum pox) of stone fruit species. Research on resistance to sharka on plums was initiated more than 50 years ago in Bulgaria (CHRISTOFF 1947). Over 300 original papers on resistance of stone fruit to PPV (*Plum pox virus*) have been published (KEGLER *et al*. 1998). In the Czech Republic the first paper on plum resistance to PPV appeared in 1980 (SEIDL & DROBKOVÁ 1980). Resistance breeding of apricots to PPV in the Czech Republic started in 1983 (POLÁK 1994). Complex research program on apricot and peach resistance to PPV has been performed in the RICP in Prague-Ruzyně in cooperation with the Faculty of Horticulture, Lednice since 1991 (POLÁK *et al.* 1995). First, sources of resistance were searched for and resistance of selected donors was tested. Over 50 apricot cultivars/genotypes, however only less than 20 peach cultivars/genotypes resistant or tolerant have been described (KEGLER *et al*. 1998). We used 16 different apricot genotypes, varieties described as resistant to PPV. These cultivars were grafted on young trees infected with highly pathogenic PPV strain with heavy disease symptoms on leaves and fruits and with a high relative virus concentration in the leaves. After four years of evaluation of symptoms on leaves and fruits, determination of the relative concentration of PPV protein in leaves by ELISA and determination of the presence of RMK PPV in leaves by IC-PCR we were able to characterise resistance of the tested apricot cultivars to PPV.

Cv. Harlayne was classified as immune to PPV.

Cvs. Harval, Leronda, Marri de Cenad and Stark Early Orange were classified as resistant to PPV.

Cvs. Harcot and Sundrop were classified as medium resistant.

Cvs. Mai Chua Sin and Goldrich were classified as medium susceptible to PPV.

Cvs. Chuang Zhi Hong, Dacia, Pentagonala, San Castrese, Vegama, Velkopavlovická (susceptible control) and Vestar were classified as susceptible to PPV and cv. Krymskij Amur as highly susceptible to PPV.

At the same time 148 original Czech apricot hybrids from previous crosses were evaluated by a similar procedure. One was classified as immune to PPV, 12 as resistant, 3 as medium susceptible and others as susceptible to PPV (POLÁK *et al*. 1997). For further research on inheritance of apricot resistance to PPV and for identification of molecular markers of apricot resistance to PPV cv. Harlayne, immune to PPV and cv. Stark Early Orange, resistant to PPV were used. By crossing with apricot cultivars susceptible to PPV progenies were obtained that were evaluated for inheritance of resistance. By evaluation of five apricot crosses inoculated with PPV by means of aphids and reinoculated by grafting infected grafts of the apricot cv. Vegama, in one cross (Lejuna × Harlayne) the ratio 7 resistant to 1 susceptible was obtained, which fits the hypothesis of three dominant independent resistance genes. In other cases the ratio 3:1 and 5:3 was obtained, which may indicate 2 genes (POLÁK *et al*. 2002).

For the identification of molecular markers of resistance of apricots to PPV the bulk segregation analysis combined with AFLP technique was applied. In this case back-cross of the susceptible hybrid clone LE-3218 to the resistant cv. Stark Early Orange was used. In the bulk of the resistant parent four AFLP markers were determined that were not present in the bulk of the susceptible parent. Four AFLP markers were also identified in the majority of resistant individuals of BC1, whereas none was determined in any tested susceptible progeny (SALAVA *et al*. 2002).

Besides apricots also research on sources of resistance of peaches to PPV is being performed. Using a similar procedure as in apricots 80 peach cultivars and 4 nectarine cultivars were studied for resistance to PPV after natural infection or inoculation by grafting. Till now, no peach cultivar resistant to PPV has been determined; though several cultivars were classified as medium resistant, e.g., Envoy, Favorita Morettini 3, Harcrest, Maycrest, Maygrand and others (POLÁK 1998, 1999). For this reason we began to search for sources of resistance to PPV among related species and genera. At present we are testing *Prunus davidiana, P. amygdalus* and *P. amygdalo-persica* as natural sources of resistance to PPV with the aim to use them as resistance donors in crosses with peach.

Results of the research on apricot resistance to PPV (OUKROPEC *et al*. 1996) that led in cooperation with American geneticists and biologists to identification of molecular markers of resistance, have proved the importance of application of safely determined and verified natural sources of resistance.

References

BARTOŠ P., HANUŠOVÁ R., BLAŽKOVÁ V., ŠKORPÍK M. (1998): Odrůda pšenice Amigo a linie W49 jako zdroje rezistence. Czech J. Genet. Plant Breed., **34**: 49–54.

BARTOŠ P., BAREŠ I. (1971): Leaf and stem rust resistance of hexapoloid wheat cultivars Salzmünder Bartweizen and Weique. Euphytica, **20**: 435–440.

BARTOŠ P., ŠÍP V., CHRPOVÁ J., VACKE J., STUCHLÍKOVÁ E., BLAŽKOVÁ V., ŠÁROVÁ J., HANZALOVÁ A. (2002): Achievements and prospects of wheat breeding for disease resistance. Czech J. Genet. Plant Breed., **38**: 16–28.

CHRISTOFF A. (1947): Plum pox disease. Bul. Chambre de Culture Nationale, Ser.: Biol., Agric. et Silvicult., **1**: 261–296 (in Bulgarian).

FAO (1996): The state of the world's plant genetic resources for food and agriculture. FAO, Rome.

HANUŠOVÁ R., HOLUBEC V. (1993): Rust and powdery mildew resistance of *Aegilops* collection. Poľnohospodárstvo, **39**: 533–539.

HANUŠOVÁ R., STUCHLÍKOVÁ E., BARTOŠ P., ŠKORPÍK M. (1997): Přenos genů rezistence ke rzi pšeničné a padlí travnímu z *Triticum durum* do *Triticum aestivum*. Genet. a Šlecht., **33**: 13–20.

HAVLÍČKOVÁ H., HOLUBEC V. (1995): Wild grasses of the genus *Aegilops* L. as hosts for cereal aphids. J. Pl. Dis. Prot., **102**: 627–632.

HOLUBEC V., HANUŠOVÁ R., KOSTKANOVÁ E. (1992): The *Aegilops* collection in the Praha-Ruzyně (Czechoslovakia) Gene Bank: Collecting, evaluation and documentation. Hereditas, **116**: 271–276.

HOLUBEC V., HAVLÍČKOVÁ H., HANUŠOVÁ R., BOCKOVÁ R. (1998): Wild *Triticeae* as genetic resources of aphid, rust and powdery mildew resistance. In: JARADAT A.A. (ed.): *Triticeae* III. Sci. Publ. Inc., USA: 341–350.

HOLUBEC V., HAVLÍČKOVÁ H., HANUŠOVÁ R., KOSTKANOVÁ E. (1993): Evaluation of *Aegilops* for aphid infestation, rust and powdery mildew resistance and seeed quality. In: DAMANIA A.B.: Biodiversity and Wheat Improvement. ICARDA, J. Wiley and Sons, Chichester: 375–384.

KEGLER H., FUCHS E., GRUNTZIG M., SCHWARZ S. (1998): Some results of 50 years of research on the resistance to plum pox virus. Acta Virol., **42**: 200–215.

MCINTOSH R.A., WELLINGS C.R., PARK R.F. (1995): Wheat Rusts. An Atlas of Resistance Genes. CSIRO, Australia.

OUKROPEC I., KRŠKA B., POLÁK J. (1996): Výzkum zdrojů rezistence využitelných ve šlechtění broskvoní na odolnost k viru šarky švestky. Zahradnictví – Hort. Sci. (Prague), **23**: 81–83.

POLÁK J. (1994): Sampling and detection of plum pox virus in the Czech Republic. In: Conf. on Plum pox. EPPO, Bordeaux 1993, Bull. EPPO: 30–31.

POLÁK J. (1998): Relative concentration of plum pox virus in leaves and flowers of some *Prunus* species and cultivars. Acta Virol., **42**: 264–267.

POLÁK J. (1999): Further serological evaluation of peach and nectarine cultivars for resistance to Plum pox virus. Protectia Plantelor, **36**: 15–20.

POLÁK J., KRŠKA B., KOMÍNEK P., SASKOVÁ H., SALAVA J. (2002): Preliminary studies on the inheritance of resistance to *Plum pox virus* (PPV) in apricots. Plant's Health (Special Ed.), July 2002: 28–30.

POLÁK J., OUKROPEC I., CHOD J., KRŠKA B., JANSTA Z., PÍVALOVÁ J. (1995): Virological programme in breeding of apricots for resistance to plum pox virus in the Czech Republic. Acta Hortic., **384**: 581–585.

POLÁK J., OUKROPEC I., KOMÍNEK P., KRŠKA B., BITTÓOVÁ M. (1997): Detection and evaluation of resistance of apricots and peaches to plum pox virus. J. Pl. Dis. Prot., **104**: 466–473.

SALAVA J., WANG Y., KRŠKA B., POLÁK J., KOMÍNEK P., MILLER W., DOWLER W., REIGHARD G.L., ABBOTT A.G.

(2002): Identification of molecular markers linked to resistance of apricot (*Prunus armenica* L.) to *Plum pox virus*. J. Plant Dis. Protect., **109**: 64–67.

SEIDL V., DROBKOVÁ R. (1980): Detekce šarky švestky na indikátoru *Prunus tomentosa*. Ochr. Rostl., **16**: 7–12.

STUCHLÍKOVÁ E. (1993): Přenos genů rezistence ke rzi pšeničné *Lr9*, *Lr19* and *Lr24* do produktivních ozimých odrůd pšenice. Genet. a Šlecht., **29**: 105–110.

ŠÍP V., ŠKORPÍK M., KUČERA L., BOBKOVÁ L., AMLER P. (1999): Winter wheat Vlasta. Czech J. Genet. Plant Breed., **35**: 92.

VALKOUN J., HAMMER R., KUČEROVÁ D., BARTOŠ P. (1985a): Disease resistance in the genus *Aegilops* L. – stem rust, leaf rust, stripe rust, and powdery mildew. Kulturpflanze, **33**: 133–153.

VALKOUN J., KUČEROVÁ D., BARTOŠ P. (1985b): The third independent transfer of the *Sr35* gene from *Triticum monococcum* to *T. aestivum*. Cereal Rusts Bull., **13**: 37–39.

VALKOUN J., KUČEROVÁ D., BARTOŠ P. (1986a): Přenos odolnosti ke rzi travní z *Triticum monococcum L.* do *T. aestivum* L. Genet. a Šlecht., **22**: 9–16.

VALKOUN J., KUČEROVÁ D., BARTOŠ P. (1986b): Transfer of leaf rust resistance from *Triticum monococcum* L. to hexaploid wheat. Z. Pfl.-Zücht., **96**: 271–278.

ZELLER F.J., HSAM S.L.K. (1998): Progress in breeding for resistance to powdery mildew in common wheat (*Triticum aestivum* L.). In: SLINKARD A.E. (ed.): Proc. 9th Int. Wheat Genetic Symp., Univ. Saskatchewan, Saskatoon, 2–7 August 1998, **1**: 178–180.