II. Recombination: Novel Gene and Genome Combinations for Resistance Breeding by Interspecific Hybridization and Genetic Transformation

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1. Introduction

Many wild relatives of cultivated crops possess resistance genes against a broad variety of diseases and can serve as sources for resistance. It seems to be most advisable to exploit this opportunity in breeding programs. Depending on the phylogenetic relationships amongst the taxa, species can be crossed to each other to some extent. Nevertheless, in most of the cases, there are incompatibility systems that prevent the production of viable hybrids. This incompatibility between two related species can be overcome by using embryo rescue techniques, i.e., embryo (Kräuter et al. 1991) or ovule culture (Piccirilli and Arcioni 1992; Diederichsen and Sacristan 1994), and somatic hybridization (Melchers et al. 1978).

Difficulties in the production of interspecific hybrids lie in the detection of hybrids and the determination of gene introgression into the recipient species. Gene introgression from alien donor species to cultivated recipients and genome composition of hybrids can be monitored cytologically or by using molecular or phenotypic markers.

Transformation of plants with foreign genes provides a direct approach for introducing disease resistance into commercially acceptable cultivars or breeding lines. Besides host-derived protection also pathogen-derived strategies can be applied. Most transgenic plants are produced by the use of Agrobacterium tumefaciens but a variety of free DNA delivery methods, including microinjection, electroporation, and particle gun have also been developed.

This review gives an overview on the progress obtained in breeding for disease resistance by interspecific hybridization and genetic transformation.

2. Introgression of Foreign Genes for Disease and Pest Resistance by Interspecific Hybridization

a) Sexual Hybridization and Embryo Rescue

Different genes conferring resistance to fungal diseases were transferred from alien species into wheat (Triticum aestivum). Wild relatives as well as rye
(Secale cereale) cultivars can serve as sources for resistance in wheat breeding. Cox et al. (1994) transferred leaf rust resistance from the diploid goatgrass [Triticum tauschii (Coss). Schmal.] to hexaploid wheat lines. Localization of the new genes was examined by crosses to the Wichita D-Genome monosomic stocks. Mena et al. (1992) verified the introgression of resistance to eyespot disease (Pseudocercospora herpotrichoides Fron) from Aegilops ventricosa into wheat using isozyme markers and DNA probes. New sources of powdery mildew resistance present in wheat-rye chromosome addition and substitution lines were reported by Heun and Friebe (1990). One of them, preliminarily designated MIPL6, was located on 6RL and showed resistance to all tested powdery mildew isolates. Since wheat-rye chromosome addition lines are cytologically unstable, MIPL6 was transferred from a monosomic 6RL (6D) chromosome substitution line by homologous recombination to a cytologically stable T6BS.6RL wheat-rye chromosome translocation (Friebe et al. 1994). The resistance gene was designated Pm20. C-banding analysis showed that Pm20 is located in the distal third of the recombinant translocation chromosome T6BS.6RLrec.

Furthermore, Friebe et al. (1994) presented a strategy for transferring interesting genes to wheat from alien donor species with nonhomologous genomes: first a complete set of addition lines of the alien chromosomes to wheat as well as genetically compensating whole arm translocations involving all arms of the alien chromosome complement and all appropriate arms of wheat are required. The addition lines can then be crossed with additional accessions of the donor species containing useful genes. In the case of poor transmission frequencies, chromosomal location of the gene can be determined by analyzing linkage of the target gene with molecular markers in segregating populations of the donor species itself. Once the chromosomal location of the gene of interest is known, the progeny from the critical cross with the addition lines can be crossed with the appropriate whole-arm translocation line to transfer the gene by homologous recombination. If whole-arm translocations are agronomically undesirable, the alien segment can be shortened by either radiation treatment or induced homoeologous recombination.

In addition, a transfer by homoeologous recombination may be generally possible but will often not provide the required genotype (Devo et al. 1993). Although the homoeologous relationship between rye and wheat chromosomes is well known and meiotic exchange seems to be predictable, the authors suppose that still some complications will remain. Homoeologous recombination must be induced between a recipient chromosome with homoeology to the chromosome segment carrying the target gene. In the case of a gene located on an interstitial segment, either a double cross-over event or a further round of homoeologous recombination will be required to return to a balanced genomic state. These transfers need some knowledge of the chromosomal and map location of the target gene. Rye-wheat pairing data presented by Naranjo and Fernandez-Rueda (1991) indicate, at least for rye and wheat, that chromosome pairing is reduced if the distal chromosome regions are not homoeologous.

Bread wheat (Triticum aestivum) itself can serve as a bridge between alien donor species and tetraploid durum wheat (T. turgidum) to introgress