Wheat Breeding for Disease Resistance by Interspecific and Intergeneric Hybridization

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In various countries, efforts were made from olden days to introduce disease-resistant genes from close relatives of different genera into cultivating wheat varieties and in recent years excellent results of breeding have been obtained especially by chromosome engineering.

In wheat breeding in Japan, leaf-rust resistance is an important breeding object and a plan of wheat breeding by interspecific and intergeneric hybridization has been under way at the Tôhoku National Agricultural Experiment Station since 1951 to cope with various races of wheat leaf-rust (*Puccinia recondita* Rob. ex Desm.).

The progress of this work is outlined in the following:

Pathogenicity of leaf-rust races distributed in Japan

At the beginning of this breeding work, Yamada et al.[10] carried out a systematic investigation on the geographical distribution of leaf-rust races in Japan over a period from 1952 to 1958 and identified 11 race groups (1, 21, 6, 37, 9, 5, 45, 17, 2, 73 and 109).

Among these groups, race group 1 was judged as weak in pathogenicity, while race groups 9 and 37 were medium and race groups 5, 6 and 21 were strong in pathogenicity.

As to their geographical distribution, it was found that race groups of strong pathogenicity were prevalent in the northern part of Japan and race group 1 of weak pathogenicity prevailed in the southern part, especially in Kyûshû.

They also carried out inoculation tests of seedlings with many urediosporial samples of each race group in many wheat varieties including major cultivating varieties in Japan and classified the wheat varieties into seven groups according to the seedling reaction.

Using typical varieties (Nôrin–16, Nôrin–55, Nôrin–31, Aoba-komugi, Nôrin–62, Akasabi-shirazu-1 and Eclipse) of them as supplemental varieties to Chester's standard differential varieties, they divided race group 1 into five biotypes (A–E) and the other race groups into two biotypes (A–B) respectively and adopted race 21B as an objective race because it was the highest in pathogenicity.

For the breeding of wheat varieties resistant to such a virulent race of leaf-rust, *T. timopheevi* was taken up as the first parental species to cross with common wheat. *Agropyron* and rye were also used after that. The breeding experiment is being carried on by introducing new leaf-rust resistant strains (Transfer and Agrus, etc.) derived from interspecific and intergeneric hybrids from foreign countries into use as materials.

Yamada et al.[10] used the brushing method as an inoculating techinque for their resistance tests, but we now perform efficiently and facilitate work in our seedling inoculation tests by storing urediospores in liquid nitrogen[1] and spraying seedlings with a spore suspension in mobilsol 100.[6]

Breeding by interspecific hybridization

At the beginning of the breeding work, many cultivating wheat varieties were crossed with *T. timopheevi* and the F_1-plants were backcrossed to the wheat parent to subject the progeny to seedling inoculation tests with urediospores of race group 21.

Though the tests showed that most of the individuals were susceptible to the disease, two stable lines, which were resistant to race 21B and had a chromosome configuration of 21″, respectively, were finally selected from among the progeny derived from combinations with Fultz No. 1 and Kanred.[7),8)]

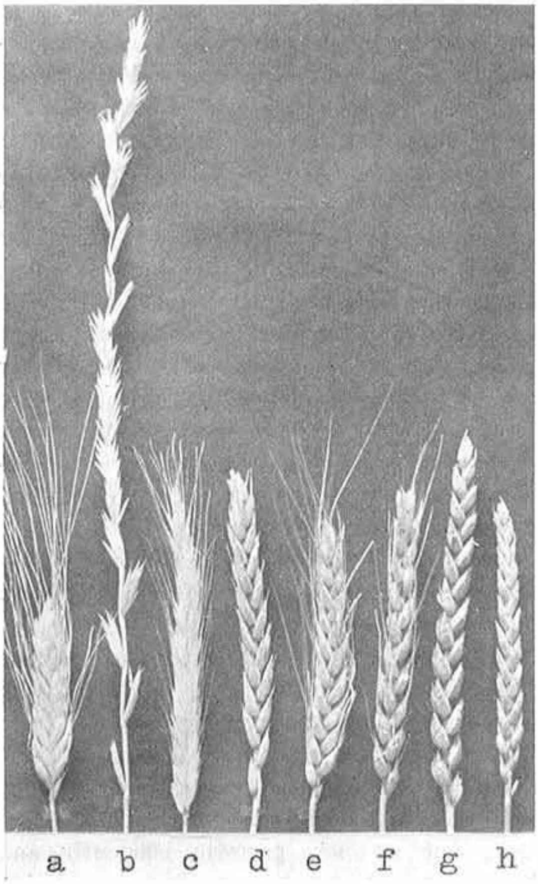

Fig. 1. Spikes: Alien species; (a) *T. timopheevi* (b) *Agropyron glaucum* (c) *Secale cereale*, leaf-rust resistant strains; (d) FTF (e) KTK (f) LR-9 (g) WA-3 (h) ST-1

These lines were named FTF and KTK, respectively, but they were of no economic use because of their long culms or late maturity. Therefore, they were crossed with cultivating wheat varieties again to improve their characters.

Especially as to the FTF line, cytogenetical studies have revealed that it is a so-called alien chromosome substitution line with a pair of *timopheevi* chromosomes (named T-chromosome) which have no relation to leaf-rust resistance and interfere with the fixation of the progeny of the hybrid. On the basis of these findings, measures how to cope with the breeding of this line have been considered.[2),3)]

After such progresses, many lines which are comparable to cultivating wheat varieties in culm length and earliness of maturity have been secondarily brought up, and 16 lines selected from among them are now being subjected to characteristic and preliminary yield tests under serial numbers of LR[4)].

Breeding by intergeneric hybridization

For the breeding by intergeneric hybridization, *Agropyron* and 8X-*Triticale* have been in use as parental genera since 1956 and 1962, respectively.

In case of hybridization with *Agropyron glaucum*, fixed lines were selected in and after the B_2F_8 generation and serial numbers of WA (WA 1–8) were given to the primary lines, which showed long culms and late maturity as the progeny of the above-mentioned interspecific hybrids did. They were crossed with cultivating wheat varieties, and the secondary lines are now being bred.

In case 8X-*Triticale* was used as a parent chromosome engineering was particularly adopted into the breeding.

In this case, for introducing the leaf-rust resistance of rye into common wheat, we focused attention at the selection of leaf-rust resistant wheat-rye addition lines as the first step and the induction by X-ray irradiation

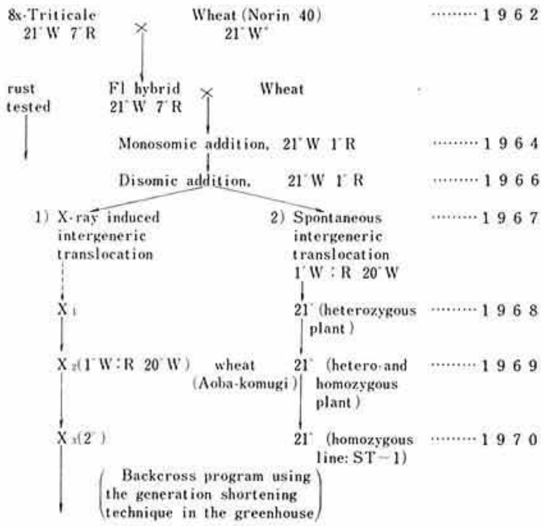

Fig. 2. Breeding processes for the transfer of leaf-rust resistance from rye to wheat by intergeneric addition and translocation
(W=wheat and R=rye chromosomes, ‴= trivalent, ″=bivalents and ′=univalents at meiosis.)

of intergeneric translocation between the chromosomes of both genera as the second step (Fig. 2).

The breeding processes were as follows: In the beginning 8X-*Triticale* (Nôrin-40 × Petkus) was backcrossed with the wheat parent to subject the progeny to seedling inoculation tests with leaf-rust race 21B and chromosomal selection. The wheat-rye monosomic addition line (21″ W1′ R) involving rye chromosome bearing the gene for leaf-rust was selected in 1964.

Subsequently, disomic (21″ W1″ R) and ditelosomic addition lines were also obtained and they were used as materials for further breeding, respectively.

To attain the second purpose, a portable X-ray apparatus (Hida Elec. Co., Yamato-SS-54, 75 kVp, 2.5 mA, 249 R/min) was used for irradiation and the first experiment was carried out by irradiating pollen grains of the disomic addition line in 1967.

In 1968, X-rays were applied to pollen grains of the disomic addition line (600–900 R) and young plants of the monosomic addition line at the VII–VIII stages of spike differentiation (1000 R). Aoba-komugi was used as the parental common wheat to pollinate with the pollen thus treated for the purpose of obtaining translocation between a wheat chromosome and the rye addition chromosome.

In the course of the selection of addition lines, 179 monosomic addition individuals, in total, were examined, but no meiotic pairing was observed between the rye addition chromosome and wheat chromosomes because of the nonhomologous genomes of different genera.

In 1969, an individual among the progeny was unexpectedly found to show a chromosome configuration of 1‴ + 20″, and, from its resistance to race 21B in seedling inoculation tests, the 1‴ (trivalent) chromosome was presumed to represent spontaneous translocation between wheat and rye chromosomes.

The leaf-rust reaction and the chromosomal constitution examined in the next generation of this individual demonstrated clearly that the individual resulted from translocation between wheat and rye chromosomes. In this way, three individuals among 57 plants examined appeared to have desired leaf-rust resistant rye gene incorporated into a wheat chromosome.

The progeny test of the three individuals (heterozygous) by seedling inoculation with race 6A proved that resistant and susceptible individuals were segregated in the next generation as expected, that is, in the monofactorial ratio. The chromosome configuration was stabilized in 21″, and in 1970 a homozygous line was selected by seedling inoculation with race 21B. This line was named ST-1.

The rye gene introduced into the ST-1 line, however, proved to show the X-reaction to race 37B. Therefore, we are now carrying on the breeding of this line by successive backcrossing with Aoba-komugi, a cultivating wheat variety resistant to the race, and making use of the generation-shortening technique.

The wheat breeding work by intergeneric hybridization has been carried on in a very small scale since its inception in 1962 but

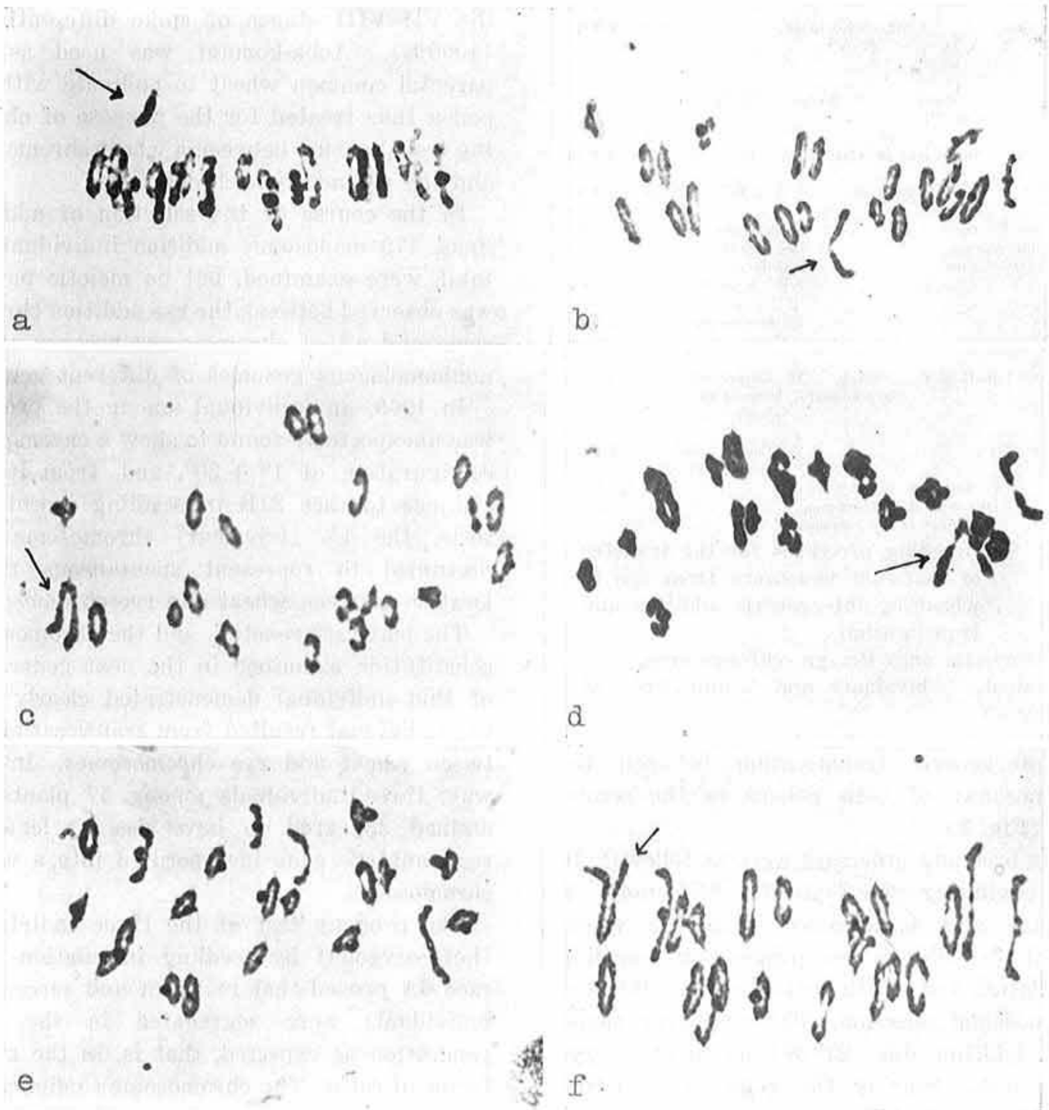

Fig. 3. First metaphase of meiosis:

(a) Monosomic addition, 21″W 1′R. Arrow indicates the rye chromosome carrying leaf-rust resistance.

(b) Disomic addition, 21″W 1″R.

(c) Spontaneous wheat-rye chromosome translocation (arrowed) 1‴W:R 20″W.

(d) X-ray wheat-rye chromosome translocation (arrowed), 1‴W:R 20″W.

(e) ST-1 (homozygous translocation line).

(f) 1 (ST-1 × ditelosomic addition line), 1‴W:R 20″W.

we expect to obtain a leaf-rust resistant line, which carries rye gene and is resistant to main leaf-rust races in Japan, of Aoba-komugi (a leading variety in the northern part of Japan) in the near future.

Direction of breeding to obtain leaf-rust resistant wheat

To introduce efficiently leaf-rust resistant genes from closely related species or genera into common wheat, we must more actively apply basic cytogenetical knowledge, as chromosome engineering and gene transfer, to practical breeding in the future.

Since it takes many years to obtain practically good results in wheat breeding by interspecific or intergeneric hybridization, we need to consider how to reduce the years necessary for the work.

Furthermore, in the breeding of disease-resistant varieties, it is necessary to pay ceaseless attention to the differentiation of the races of pathogenic fungi to prevent resistant varieties, which were brought up by many years of hard work, from becoming susceptible to them. One of our basic subjects of breeding is on this point.

As a measure to meet these situations, in our laboratory we are making efforts to breed leaf-rust resistant lines by combining and accumulating various resistant genes of *timopheevi*, *Agropyron*, *Aegilops* and rye as well as adopting actively generation-shortening techniques into the breeding works by interspecific and intergeneric hybridization.

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