Indian J. Pl. Genet. Resources 9(1): 53-61, 1996

# GENETIC RESOURCES FOR DISEASE RESISTANCE IN WILD DIPLOID *TRITICUM* AND *AEGILOPS* SPECIES

**S.M. Tomar and M. Kochumadhavan**

Division of Genetics,
Indian Agricultural Research Institute,
New Delhi 110 012

One hundred and twenty accessions of wild diploid species of *Triticum* and *Aegilops* were screened for resistance to stem rust (*Puccinia graminis tritici*), leaf rust (*Puccinia recondita*), stripe rust (*P. striiformis*) and powdery mildew (*Erysiphe graminis tritici*) under natural and artificial epiphytotic conditions in adult plant stage at Wellington and New Delhi. Twelve accessions belonging to *T. monococcum* and *Ae. squarrosa* were tested for resistance to karnal bunt (*Neovossia indica*). Einkon wheats, *T. boeoticum*, *T. monococcum* and *T. sinskajae* exhibited spectacular resistance to leaf rust and powdery mildew. Many accessions of *Ae. speltoides* showed resistance to stem rust also. Resistance to all the rusts and powdery mildew was observed among species such as *Ae. comosa*, *Ae. markgrafii*, *Ae. uniaristata*, *Ae. mutica* and *Ae. umbellulata*. Twelve diverse wheat stocks carrying specific genes derived from diploid wild species were also evaluated for rusts. The study revealed that the genes, Lr9, Lr28, Lr32 and Lr36 conferred a high level of resistance to leaf rust while Sr32 conditioned adult plant resistance to stem rust.

**Key Words :** *Triticum*, *Aegilops*, wild species, adult plant, stem, leaf & stripe rusts, specific genes.

The improvement of any crop lies in exploring and exploiting the rich gene pools available in plant's wild relatives. In India, wheat is attacked by several diseases, but rusts (*Puccinia* spp.), powdery mildew and karnal bunt are some of the important diseases of concern. Since the resistance in cultivars breaks down in a short span due to the evolution of new races in the pathogen, the need for additional sources of resistance against diseases arises to counter them. In the search of additional variation the progenitors of hexaploid wheat and other diploid *Triticum and Aegilops* species are becoming increasingly important. In the present study, evaluation of wild wheats was carried out to identify new and diverse genetic resources against rusts, powdery mildew and karnal bunt. A number of specific genes for rust resistance that have been transferred from diploid wheats are available in common wheat background. These genes conferring resistance to different rusts were also evaluated for rust resistance against Indian rust races flora and powdery mildew collected from the Nilgiris.

## MATERIALS AND METHODS

The collection of wild diploid wheats available at the Indian Agricultural Research Institute, New Delhi was partly received from USDA and IPSR Cambridge, UK. The diploid wheats included the immediate progenitors of common wheat (*Triticum aestivum* L., 2n = 6x = 42, genome AABBDD), the species belonging to sitopsis group and other genomes such as U, M, C, T and Un. These species were evaluated for rusts and powdery mildew in adult plant stage at Wellington (South India), a'hot spot' for foliar diseases of wheat under natural epiphytotic conditions over a period of six seasons. The material was also screened under artificial epiphytotic conditions at Delhi for three seasons. All the accessions grown in pots were artificially inoculated with most virulent races, 40-1, 117-1 of stem rust (*Puccinia graminis* Pers f. sp. *tritici* Eriks & Henn.) and 77-1 77A, 77-2 and 104 B of leaf rust (*P. striiformis* West.) and powdery mildew (*Erysiphe graminis tritici* M. Marchal) was also recorded at Wellington. Rust reactions were recorded by combining the severity (percent infection) and response (type of infection) at adult plant stage while powdery mildew was scored on 0 to 4 scale. A few accessions belonging to A and D genomes were artificially inoculated in boot with Delhi isolate of karnal bunt (*Neovossia indica* (Mitra) Mundkar) using hypodermic syringe (Ajula et. al., 1982). The infection percentage among inoculated ear heads was calculated. The infected grains were also graded according to severity of karnal bunt infection on 0-4 scale. The data is not presented in the table because the species tested exhibited more or less similar infection type and pattern, but results are discussed in the text.

## RESULTS AND DISCUSSION

Results are presented in Tables 1 and 2. Among the progenitors of the common wheat (*T. aestivum*), einkorn wheats, *T. boeoticum* ssp. *aegilopoides* exhibited spectacular resistance to leaf rust, stripe rust and powdery mildew at adult plant stage, while spp. *thoudar* was resistant to all the three rusts and powdery mildew. The accessions of *T. monococcum* also exhibited resistance to leaf rust, but resistance to stripe rust was of moderate magnitude. The accessions G1872, G2508, PI427446, PI427447 amd PI427481 of *T. boeticum* and SWAN 181 of *T. monococcum* were also resistant to stem rust. The strains of *T. urartu* in general were recorded susceptible to stem rust and stripe rust and moderately susceptible to leaf rust. However, the accession TMUO1 showed immunity to stem rust while G2035 and G3249 exhibited low reaction to stripe rust. Cultivated einkorn wheat *T. sinskajae* was found to carry resistance genes for all the three rusts and powdery midew. This species is morphologically similar to *T. monococcum* but free threshing. The accessions of *T. boeoticum* have been shown a high level of resistance in other geographical areas also (Zohary et al., 1969; Gill et. al., 1983).

**Table 1 : Adult plant reaction to rusts (*Puccinia* spp.) and powdery mildew in wild diploid wheats**

| Species/accessions | Genome | Range of reaction to | | | |
|---|---|---|---|---|---|
| | | stem rust | leaf rust | stripe rust | powdery mildew |
| 1 | 2 | 3 | 4 | 5 | 6 |
| Einkorn wheats | | | | | |
| *Triticum boeoticum* Bioss. ssp, *aegilopoides* (2n = 2x = 14), G2508, G1872, PI427446, PI427447, PI427481 | AA | 0 | 0 | 0 | 0 |
| ssp. *thaudar* Revt. | | 0 | 0 | 0-TS | 0 |
| G2171 | | 20S-50S | 0-TR | 0 | 0 |
| 102-1, G1848, G2398, G1372 | | 30S-60S | 0 | 0 | 0 |
| *T. urartu* Tum. (2n= 2x=14) | AA | | | | |
| SWAN171, SWAN172, 199-1, G1953 | | 30S-60S | 5MR-20MR | 20S-70S | 1 |
| TMU 01 | | 0 | 5MR-30MR | 30S-50S | 0 |
| G2035, G3249 | | 50S-70S | 40S-50S | TS-5S | 2 |
| *T. monococcum* L. (2n=2x=14) | AA | | | | |
| SWAN 181(IARI) | | 0 | 0 | 0 | 0 |
| TMM 01, G1481, G2927, G683, G1372, G1471, ssp.*flavescemce, vulgare, nigraflavescence, hormanii* | | 20S-70S | 0 | 10MS-15MS | 0 |
| G1483 | | 30S-60S | 0 | TMS-5S | 3 |
| *T. sinskajae* A. Filat & Kurk. | AA | 0 | 0 | 0 | 0 |
| Sitopsis group | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| *Aegilops speltoides* Tausch. (2n=2x=14) | SS | | | | |
| K, TS 08, 2-3, ligustica, SWAN 471, PI369602, A, EC331772, EC331782 | | 0 | 0 | 0 | 0 |
| EC331782, EC331783, EC331784, EC331785, M, TS 01, TS 05, *typica* | | 0 | 5S-10S | 0 | 0-1 |
| EC331780, *ligustica tyoica* 3-1 | | TMX-20MX | 0 | 0-TS | 0 |
| D, 2-1 | | 10MS-40S | 0 | 20S-40S | 0 |
| *Ae. bicornis* Forsk. (2n=2x=14) | $S^bS^b$ | | | | |
| SWAN 121, *typica* 4-1, *mutica*, *SWAN481 EC160080, EC160182* | | 0 | 40S-60S | 30S-40S | 0 |
| EC162412 | | 0 | 20S-30S | 0 | 0-1 |
| SWAN657, *typica* 5-1, TB 01 | | 30S-50S | 10S-40S | 0 | 0 |
| *Ae. longissima* Schw. et Musch. | $S^lS^l$ | | | | |
| SWAN 144, G130B, PI318697 | | 0 | 0 | 0 | 0 |
| G609, SWAN 143 | | 5MR-60MS | 50S-60S | 40MR-50MR | 0 |
| *Ae. aucheri* Boiss.2n= 14, SWAN151 | SS | 0 | 0 | 0 | 0 |
| SWAN 152 | | 0 | TR-10R | 40S-60S | 0 |
| *Ae. sharonensis* Eig. (2n=2x=14) | $S^sS^s$ | | | | |
| G614, G1315, EC162416 | | 0 | 0 | 50S-70S | 2 |
| SWAN 156, EC160079 | | 0 | 40S-70S | 60S-70S | 0 |
| *Ae. searsii* | $S^sS^s$ | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| TS 01, EC160086, TS 10 | | 0 | 0 | 30S-50S | 0 |
| *Ae. squarrosa* L. (2n=2x=14)var. *typica*, EC331750, SWAN 475 | DD | | | | |
| SWAN 476, EC164801, EC331786 | | 30S-50S | 0 | 30S-60S | 3 |
| *strangulata**, EC 164800*, EC331751* | | 40S-60S | TR-TS | 0 | 0 |
| EC162403, EC331756, EC331757, EC331787, EC331788* | | 30S-50S | 50S-80S | TMS-10MS | 1-2 |
| A, PI220641, *anthera*, typica 2-1, *meyeri*, *squarrosa*, SWAN 477*, SWAN478*, SWAN480* | | 30S-60S | 30S-50S | 60S-80S | 3 |
| *Ae. umbellulata* Zhuk. (2n=2x=14) | UU | | | | |
| 4033, 5901, PI 341797 | | 5S-40S | 0 | 0 | 0 |
| *Ae. comosa* Sibth. and Sm. (2n=2x=14) | MM | | | | |
| A, EC331776, EC331789, EC331790 | | 0 | 0 | 0 | 0 |
| EC162406, EC331753 | | 0 | 15S-40S | 0-TS | 0 |
| G | | 0 | 0 | 5S-20S | 0 |
| *Ae. markgrafii* (Zhuk.) Bowden | CC | | | | |
| PI298888, PI369571, PI551126 | | 0 | 0 | 0 | 0 |
| PI542197 | | SS-10S | 30S-40S | 0 | 0 |
| *Ae. mutica* Boiss. (2n=2x=14) | TT | | | | |
| M&K | | 0 | 0 | 0 | 0 |
| *Ae. uniaristata* vis. (2n=2x=14) | UnUn | 0 | 30S-40S | 0 | 0 |
| PI276995 | | | | | |

*tested against karnal bunt

Three specific genes conferring resistance to stem rust, namely, Sr 21 (McIntosh unpublished), Sr 22 (Kerber and Dyck, 1973) and Sr 35 (McIntosh et. al., 1984) have been transferred from *T. monococcum* to common wheat. However the genes, Sr 21 and Sr 22 were found ineffective to stem rust at adult plant stage (Table 2). Overall the einkorn wheats offer an excellent source of genes for resistance to leaf rust and stripe tust. Most of the accessions belonging to A genome except G2035 and G3249 of *T. Urartu* and G1483 of *T. monococcum* have shown resistance to powdery mildew fungus occurring in the Nilgiris. Only six accessions viz., SWAN 181 and G1481 of *T. monococcum* TMU01 and G1953 of *T. urartu* and G2398 and PI427481 of *T. boeoticum* were inoculated with karnal bunt. All these accessions showed 0 to 5 per cent infection indicating that einkorn wheats are highly resistant to karnal bunt. A large number of accessions are to be tested to draw a more meaningful conclusions.

**Table 2. Adult plant response of specific genes against stem rust, leaf rust and stripe rust**

| Stocks | Gene(s) present | Range of reaction to | | | Powdery mildew |
|---|---|---|---|---|---|
| | | stem rust | leaf rust | stripe rust | |
| Transfer | Lr9 | 60S-90S | 0 | 30S-40S | 3 |
| CS/Add. A 6U 7813-2 | Lr9 | 50-S70S | 0 | 30S-50S | 3 |
| RL5406/Thatcher*6 | Lr21 Sr 33 | 20MS-30MS | 20MR-30MS | 60S-70S | 4 |
| RL5404/Thatcher*6 | Lr22a | 80S-90S | 20MR-40MS | 5MR-10MR | 4 |
| CS 2A/2M 3/8 | Lr28 | 80S-90S | 0 | 5MS-10MS | 1 |
| RL5497-1 | Lr32 | 50S-70S | 0 | 60S-70S | 3 |
| C 78.10/Condor | Lr 36 | 40S-60S | 10R-20MR | 20S-40S | 3 |
| Einkorn-*T.monococcum* | Sr21 | 30S-50S | 10MS-30MS | TS-5S | 1 |
| *Marquis/Stewart/ T. monococcum* | Sr22 | 30S-40S | 10MS-30MS | 40S-60S | 3 |
| W3531 | Sr32 | 10MR-20MR | TMS-5MS | 10S-30S | 2 |
| W3725 | Sr32 | 10MR-20MR | TS-5S | 10S-20S | 2 |
| Compair | Sr34Yr8 | 70 S-90S | 10MS-30X | 10S-15S | 2 |
| Hexaploid derivative | Sr35* | - | - | - | - |

*Seed not available: - not tested

Among the sitopsis group, *Ae. speltoides* showed a high level of resistance to stem rust, leaf rust and powdery mildew. Only a few strains exhibited resistance to stripe rust. The accessions of *Ae. bicornis* and *Ae. sharonesis* were found resistant to stem rust and powdery mildew except the accession EC162412 of *Ae. bicornis* which showed resistance to stripe rust also. An accession of *Ae. aucheri,* similar to *Ae. speltoides* showed immunity to all the three rusts under heavy natural infection. In general, the species belonging to sitopsis group possess genes for resistance to stem rust and leaf rust, but resistance to stripe rust is inadequate. The accessions of *Ae. searsii* were found highly susceptible to stripe rust only. Most of the accessions belonging to S genome showed resistance to powdery mildew fungus prevailing in the Nilgiris. These species were not tested for karnal bunt resistance. The gene Lr28 is highly effective against the Indian leaf rust races while Sr32 and Lr36 conferred moderate degree of resistance to stem rust and leaf rust respectively (Table 2). The major gene pool represented by the sitopsis section remains largely untapped for disease resistance. These results of screening of the genes alongwith the unidentified resistance indicated that the specific resistance (s) are very effective against Indian rust race flora. Dhaliwal et. al., (1986) evaluated a large collection of wild wheats and identified many accessions to have genes for resistance to different diseases. A high frequency of resistance to powdery mildew and leaf rust occured among the *Aegilops* species (Gill et. al., 1985).

Most of the *Ae. squarrosa* accessions tested at Wellington or at Delhi showed susceptibility to stem rust, but a few accessions have exhibited high level of resistance to leaf rust and only two accessions were found resistant to stripe rust. Kihara et. al. (1965) in a study concluded that *Ae. squarrosa* possess numerous forms with resistance to both stem and leaf rusts occuring in Japan. Kerber and Dyck (1978) determined a high frequency (44%) of forms resistant to leaf rust than to stem rust in a study of 85 accessions of *Ae. squarrosa.* The variant *strangulata* used by them for leaf rust resistance was found free to leaf rust and stripe rust races prevailing in the Nilgiris. Only three accessions of *Ae. squarrosa* var. *strangulata*: EC 164800, EC 331775 and EC162403 possess high to moderate degree of resistance to powdery mildew fungus. Eight accessions were inoculated with the Delhi isolate of karnal bunt disease and they were found to carry a high degree of resistance. Resistance to karnal bunt has earlier been identified among wild wheats and *Aegilops* species (Dhaliwal et. al., 1986; Warham et. al., 1986). Multani et. al. (1988) screened synthetic amphiploids involving susceptible *T. durum* with *T. monococcum, T. boeoticum* and *Ae. squarrosa.* In their study all the synthetic amphiploids except one were free from Karnal bunt disease indicating that wild progenitors of common wheat, *T. monococcum, T. boeoticum* and *Ae. squarrosa* carry genes for karnal bunt resistant and the resistance is expressed in the presence of *T. durum* compliment.

Only three accessions of *Ae. umbellulata* were tested for rusts and powdery mildew. All the three strains were found to carry resistance genes for leaf rust, stripe rust and powdery mildew. However, these accessions were observed to be susceptible to stem rust.

All the seven accessions of *Ae. comosa* showed adult plant resistance to stem rust while two of them were found susceptible to leaf rust. Low infection of stripe rust was recorded on *Ae. comosa* G and EC162406. Although both the genes, Sr34 and Yr8 deriving resistance from *Ae. comosa* are ineffective, the resistance available among other accessions may be very useful, if utilized.

Four accessions of *Ae. markgrafii* (syn. *Ae. caudata* L.) were screened at adult plant stage against four races of leaf rust and two races of stem rust for two seasons at Delhi only. Except the accession PI542197, all were found to possess resistance to stem rust and leaf rust. Only two accessions of *Ae. mutica* (syn. *T. tripsacoides* Jaub. & Spach.) showed a high degree of resistance to stem rust and leaf rust in adult plant stage at Delhi. The only accession of *Ae. uniaristata* tested, was observed susceptible to leaf rust, but possess a high degree of adult plant resistance to stem rust, stripe rust and powdery mildew.

Overall, the study revealed that the wild diploid wheats possess multiple resistance to diseases. Most of the species except *Ae. squarrosa* are potentially useful and may prove to be an excellent and diverse source of disease resistance. Interspecific and intergeneric hybridization in the *triticeae* (Muzeeb-Kazi, 1993) could be attempted for improvement of wheat and to enhance bio-diversity for searching new genetic recombinations. Work on the transfer of disease resistance and other desirable attributes from wild species into common wheat is under progress.

## REFERENCES

Aujla S.S., A.S. Grewal, K.S. Gill and I. Sharma. 1982. Artificial creation of karnal bunt disease of wheat. Cereal Res. Comm. **10** : 171-176.

Dhaliwal H.S., K.S. Gill, Paramjit Singh, D.S. Multani and B.B. Singh. 1986. Evaluation of germplasm of wild wheats, *Aegilops* and *Agropyron* for resistance to various diseases. Crop Improv. **13** : 107-112.

Gill B.S., L.E. Browder, J.H. Hatchett, T.L. Harvey, T.J. Martin, W.J. Raupp, H.C. Sharma and J.G. Waines. 1983. Disease and insect resistance in wild wheats. Proc. 6th Int. Wheat Genet. Symp. Kyoto, Japan. pp. 785-792.

Gill B.S., H.C. Sharma, W.J. Raupp, L.E. Browder, J.H. Hatchett and T.L. Harvey. 1985. Evaluation of *Aegilops* species for resistance to powdery mildew, wheat leaf rust, Hessian fly and green bug. Plant Diseases **69** : 314-316.

Kerber E.R. and P.L. Dyck. 1973. Inheritance of stem rust resistance transferred from diploid wheat *Triticum monococcum* to tetraploid and hexaploid wheat and chromosome location of the gene involved. Can. J. Genet. Cytol. **15** : 397- 409.

Kerber E.R. and P.L. Dyck. 1978. Resistance to stem and leaf rust of wheat in *Aegilops squarrosa* and transfer of a gene for stem rust resistance to hexaploid wheat. Proc. 5th Int. Wheat Genet. Symp, New Delhi 23-28 Feb. 1978. pp. 358-364.

Kihara H., K. Yamashita and M. Tanaka. 1965. Morphological, Physiological, genetical and cytological studies in *Aegilops* and *triticum* collected from Pakistan, Afghanistan and Iran. Results of the Kyoto University Scientific expedition to the Karakoram and Hindukush 1955, Vol. 1: 1-118.

McIntosh R.A., P.L. Dyck, T.T. The, J.E. Cusick and D.L. Milne. 1984. Cytogenetical studies in wheat. XIII. Sr35 a third gene from *triticum monococcum* for resistance to *Puccinia graminis tritici*. Z. Pflanxenzuchtg. **92** : 1-14.

Muzeeb-Kazai, A. 1993. Interspecific and intergeneric hybridization in the *Triticeae* for wheat improvement. Biodiversity in Wheat Improcement. (ed.) A.B. Damania. John Willey and Sons, U.K. pp. 95-102.

Multani D.S., H.S. Dhaliwal, Paramjit Singh and K.S. Gill. 1988. Synthetic amphiploids of wheat as a source of resistance to karnal bunt (*Neovossia indica*). Plant Breed. **101** : 122-125.

Warham E.J., J. Jaheir and A.M. Tanguy. 1982. A study of an amphiploid between *Aegilops squarrosa* Tausch and *Triticum dicoccum* Schubl. Cereal Res. Comm. **10** : 55-59.

Warham E.J., A. Muzeeb-Kazi and V. Rosas. 1986. Karnal bunt (*Tilletia indca*) resistance screening of *Aegilops* species and their practical utilization for *Triticum aestivum* improvement. Can. J. Pl. Pathol. **8** : 65-70.

Zohary J., J.R. Harlan and A. Vardi. 1969. The wild diploid progenitors of wheat and their breeding value. Euphytica **18** : 58-65.