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Utilizing Genetic Diversity in CIMMYT Global Wheat Breeding Programme

Ravi P Singh[1], Velu Govindan[1], Suchismita Mondal[1], Sridhar Bhavani[2] and Pawan K Singh[1]
[1]CIMMYT, Carretera México-Veracruz, El Batán, Texcoco, Edo. De México, México
[2]CIMMYT, ICRAF Center, Nairobi, Kenya

Wheat is grown on over 215 million hectares worldwide and provides about 20% of calories and proteins to humans. About 1.6% annual productivity increase is needed to meet the future demands caused by population and prosperity growth. The global wheat cultivation expands to very diverse environments exposing the crop to a range of biotic and abiotic stresses and therefore enhancing genetic yield potential together with resistance/tolerance to key stresses and nutritional/processing quality are important breeding objectives for CIMMYT and National breeding programmes. Being an allohexaploid, wheat possesses a wide genetic diversity in the progenitors of the three genomes and has the ability to absorb chromosomal segments of varying sizes from related species and genera. Systematic incorporation of alien chromosome segments possessing numerous race-specific resistance genes to important diseases, e.g. rusts, has been a great example of enhancing the genetic diversity in cultivated wheat germplasm pool.

The existing genetic diversity and targeted incorporation of new diversity for traits that have promise to enhance productivity are of paramount importance to breeding programmes for continuing to make genetic progress. Because grain yield, abiotic stress tolerance and durable resistance to diseases and pests are under complex and quantitative genetic control, most breeding programmes are often reluctant to utilise landraces or other diverse genetic resources as identifying and extracting minor or small effect genes are tedious process often requiring 2 or 3 complete breeding cycles before competitive varieties can be developed. To overcome this limitation trait/gene based pre-breeding is an attractive approach to enrich the most recent breeding germplasm pool. The success of pre-breeding depends on a reliable phenotypic selection of the trait or linked molecular marker based incorporation of targeted genes.

CIMMYT spring wheat breeding programme continually incorporates new genetic diversity for different traits or genes present in diverse breeding materials available to CIMMYT, e.g. winter/facultative wheat germplasm and synthetic wheats. Utilisation of synthetic wheats in wheat breeding has facilitated transferring diversity from the D-genome progenitor *Triticum tauschii* for resistance to diseases, pests and tolerance to heat and drought stresses. It is now common to find synthetic wheat derived varieties grown by farmers.

About half of the catalogued genes conferring resistance to stem (black) rust and leaf (brown) rust were transferred to wheat from related species and genera. In case of stripe (yellow) rust about 20% genes are derived from alien origins. Some resistance genes were identified in landraces indicating the importance of continued search for the existing diversity in wheat genepool. Deployment of these single race-specific resistance genes to rust or powdery mildew fungi, irrespective of their origin, leads to rapid evolution and selection of virulence. A majority of the race-specific genes effective against the Ug99 race group of stem rust fungus are of alien origin and some important genes like *Sr24* and *Sr36* were overcome by the new variants of Ug99. The improper utilisation of resistance genes that is common at present highlights the important issue of protecting the incorporated disease resistance diversity through proper utilisation as multiple combinations of resistance genes. Developing diagnostic molecular markers for resistance genes located in alien chromosomal segments has been easier than for genes of wheat origin. The longevity of these resistance genes can be enhanced by ensuring that all released varieties have at least three effective resistance genes and these genes are not deployed singly, which has not been possible so far. As some rust resistance genes have been cloned and new techniques allowing accelerated cloning of race-specific resistances genes offer great promise, use of multiple *cis*-genic cassettes concept has been proposed. These cassettes where multiple genes will inherit together can simply breeding and selection by using a single molecular marker or selection for

**Author for Correspondence: Email- R.Singh@cgiar.org*

resistance in field conditions. However, it is not known yet whether *cis*-genic wheat varieties will be acceptable to consumers.

Utilisation of genetic diversity for multiple minor, slow rusting resistance genes with additive effects has proven to be an excellent alternative in achieving durable resistance to wheat rusts and other important diseases. Diversity for these genes can be found in improved wheat varieties as well as landraces. The identification of three pleiotropic multi-pathogen resistance genes, viz. *Lr34/Yr18/Sr57/Pm38/Sb1/Bdv1*, *Lr46/Yr29/Sr58/Pm39*, and *Lr67/Yr46/Sr55/Pm46*, and the cloning of two of them shows their novel nature in conferring disease resistance. The slow rusting gene *Sr2*, transferred to hexaploid wheat from tetraploid emmer wheat, is also known to confer durable resistance to wheat stem rust fungus including the Ug99 race group. Various genetic and mapping studies have shown that combinations of any of these well characterised resistance genes with 3 to 4 additional minor genes, often mapped as quantitative trait loci; result in conferring a high level of durable resistance that is comparable to immunity. Resistance to wheat rusts and other important pathogens in a large proportion of CIMMYT wheat germplasm that is distributed annually worldwide is often based on diverse combinations of these genes.

With climate change new, more aggressive and virulent races of common wheat pathogens are expected to emerge and migrate to new areas. Moreover, new pathogens can also evolve and cause severe damage to wheat crop. One example is the wheat blast disease, first detected in Brazil in the 1980s, then spread to some other countries of South America, and in 2016 reported to have migrated to Bangladesh in South Asia causing severe losses in affected areas. Identification and utilisation of genetic resistance in improved wheat germplasm, landraces, related species and genera are likely to play a crucial role even though only moderate resistance has been identified so far.

A recent and successful utilisation of genetic resources is in enhancing grain Zn and Fe concentrations in wheat under the HarvestPlus project. The modern semi-dwarf wheat varieties usually have moderate levels of these micronutrients with limited diversity. Extensive search for genetic resources with high Zn and Fe identified some tall varieties, landraces, spelt wheat (*T. spelta*), tetraploid wheat (*T. dicoccum)*, and some synthetic wheat accessions. Targeted breeding initiated about a decade back to develop high yielding wheat germplasm with enhanced Zn content and adaptation in South Asia. The non-destructive, high-throughput phenotyping for Zn is now possible by using a XRF machine and calibrations that accurately determine grain Zn and Fe concentrations. High yielding competitive wheat varieties with 20-40% higher grain Zn concentration could be developed; one variety 'Zinc Shakti' (Chitra) released and disseminated to thousands of farmers in eastern Gangetic plains of India. This is a great example of fast delivery of end-product from utilisation of genetic resources. In addition, various genomic regions involved in increasing grain Zn were identified and this diversity will be useful in continuing to increase grain Zn further. Enhanced grain Zn is often associated with enhanced grain Fe and thus, a further value is added.