6. SUMMARY

6.1. Transfer of rust resistance genes to Indian wheat cultivars:

Resistance genes for leaf rust, stem rust and stripe rust were transferred from alien sources into two Indian wheat cultivars namely, HD 2009 and HD 2380. The alien sources include four hexaploid wheat stocks, one rye addition line and one *Agropyron* addition line, carrying four leaf rust resistance genes (*Lrl9*, *Lr24*, *Lr26*, *Lr28*), four stem rust resistance genes (*Sr25*, *Sr26*, *Sr27*, *Sr31*) and one stripe rust resistance gene (*Yr9*), present individually and/or in combination (linked). Rust resistance genes from hexaploid wheat stocks were transferred by simple backcrossing, while the genes from alien addition lines were transferred by manipulating 5B system of wheat, through the use of homozygous recessive *ph* (*phph*) mutant.

Selection was practiced both at BC$_2$ and BC$_4$ generations, and finally one line each in BC$_2$F$_5$ and BC$_4$F$_5$ were constituted from each of the 12 cross combinations. All the constituted lines were tested against respective rust races both at seedling stage in glasshouse and at adult plant stage in field condition. High degree of rust resistance provided by these genes both at seedling stage and at adult stage, strongly advocate the use of specific rust resistance genes for durable resistance. Rust resistance provided by some of the genes like *Sr25*, *Sr31* and *Lr26*, seems due to the combination or interactive effect.

The agronomic characters like plant height, tiller number per plant, spike length, number of spikelets per spike, 1000-grain weight and grain yield per plant, recorded in BC$_2$F$_5$ plants were much superior to those recorded in BC$_4$F$_5$ plants, although the performance of various agronomic characters in
BC₄F₅ were also comparatively better than those recorded in the recurrent parents. Number of tillers/plant, number of spikelets/spike and 1000-grains weight are most important agronomical characters in determining the grain yield/plant in the constituted lines. The superiority of BC₂F₅ over BC₄F₅ population is due to occurrence of transgressive segregation. The lines selected both in BC₂F₅ and BC₄F₅ though had reasonably very good agronomic characteristics (except one line each in HD 2009 X CS 2D/2M 3/8 and HD 2380 X W 3353 crosses), because of variability in seed quality, some of the lines were not found suitable for commercial use. The lines carrying resistance genes Sr31+Lr26+Yr9 (from rye addition line 1R), Sr27 (only in HD 2380) and Lr28 (only in HD 2009), showed unacceptable variability in their seed characteristics. The above genes also showed depressive effect on grain yield. Therefore, based on seed quality coupled with good agronomic characters, a total of 8 lines each in BC₂F₅ and BC₄F₅ were finally selected.

Yield performance of the constituted lines were tested under rust free condition. BC₂F₅ lines gave significantly higher grain yield than the treated control, while the BC₄F₅ lines gave slightly higher grain yield as compared to the treated control. Constituted lines derived from HD 2009 X CS 2D/2M 3/8 (Lr28) and HD 2380 X W 3353 (Sr27) gave significantly lower yield when compared to treated control. Constituted lines carrying rust resistance genes from rye addition line 1R, though gave higher yield over untreated control, but the yield was comparatively lower when compared to treated control.

Presence of morphological markers of the donor parents such as awnless, lax spike, cluby tip, waxy colour and red grains in the hybrid/derivatives obtained in different crosses between Indian wheats x donor parents, suggests the successful transfer of rust resistance genes from the donor parents to the recipient Indian wheats. Constituted lines when crossed with universal rust susceptible wheat variety Agra Local, the F₁ plants exhibited complete
resistance, while the F₂ plants segregated into 3:1 ratio for resistant to susceptible. The segregation pattern for the same showed 1:1 ratio in BC₁, indicating that the resistance in the constituted lines each was due to a single dominant gene, thereby confirming the successful transfer of the genes. Significant increase in the nuclear DNA in the constituted lines also suggest the possible incorporation of alien gene (DNA) into the Indian wheat background. Significant increase in total free phenol, tannin and soluble protein, and a significant increase in peroxidase activity and altered activity in ribonuclease and nuclease, also suggest the manifestation of rust resistance in the constituted lines, thereby confirming the successful transfer of rust resistance genes.

6.2. Improvement of hexaploid triticales and bread wheats:

By making reciprocal crosses between each of the seven hexaploid triticales with two hexaploid bread wheat cultivars, improvement in both triticale and wheat were achieved for yield and yield contributing characters. In addition to these, earliness (about 10-12 days) could also be achieved in triticales. Improved lines showed increase in grain size and grain weight.

6.3. Cytogenetic studies in triticale:

A) Giemsa C-banding technique was used to analyse rye chromosome composition in 68 hexaploid triticales (62 spring types and 6 winter types). Sixteen triticales retained full complement of rye chromosomes (seven pairs as revealed as 14 banded chromosomes), 13 had one pair of replaced rye chromosomes, 24 triticales had two pairs of replaced rye chromosomes and the remaining 15 triticales had three pairs of replaced rye chromosomes. Among the six winter triticales, five of them had full complement of rye chromosomes, while the lone triticale Largo had a replaced rye chromosome pair. Among the seven rye chromosomes, 2R was replaced in maximum number of triticales.
(40), either individually or in combination. However, when the 68 triticales were reanalysed through a study of chromosome pairing in F₁ hybrids, derived from triticale x wheat ditelos crosses, it was revealed that only 2R/2D substitution was confirmed, while the other so called substitutions are simply due to modification (due to deletion or reduction of telomeric heterochromatin) of rye chromosomes. Further, triticales with a 2R/2D substitution and/or a modified rye chromosome(s) exhibited 'medium' to 'very low' degree of kernel shrivelling. 2R/2D substitution also had a favorable effect on seed setting. Triticales with full complement of rye chromosomes showed 'medium' to 'high' kernel shrivelling and low seed set.

B) The data on nuclear DNA content, proportion of heterochromatin, average number of univalents and micronuclei were analysed in twenty five hexaploid triticales. A significant positive correlation between nuclear DNA and heterochromatin content, and a significant positive correlation between number of univalents and proportion of heterochromatin was noticed. The number of micronuclei also showed a dependence over heterochromatin and a significant correlation over univalents were noticed. These results suggest a definite role for heterochromatin in meiotic instability in triticales.

6.4. Induced mutations in wheat and triticale:

Using gamma rays (10, 20, 30kR), EMS (0.5% - 6,8,10h) and their combination (10kR+10h; 20kR+8h; 30kR+6h), mutations were induced in a diploid wheat (Triticum monococcum) strain WG-1, a tetraploid wheat CV. Jairaj, a hexaploid wheat CV. WH 147 and two hexaploid triticale cultivars Borba and TL 419. A reduction in seed germination, survival, seedling height, and an increase in stomatal index, chlorophyll variants and pollen sterility were noticed in mutagen treated M₁ plants. An increase in chromosomal abnormalities such as quadrivalents, univalents, laggards, bridges, fragments
and micronuclei, and a decrease in ring bivalents and chiasmata were observed in mutagen treated plants. Among the three wheats, diploid wheat was found to be highly sensitive to the mutagens, while triticales were more sensitive than hexaploid wheat.

A total of ten types of chlorophyll mutants and twenty two types of morphological mutants were isolated in $M_2$ generation. Combined treatments produced wider spectrum and higher frequency of mutants. Among the five genotypes, the spectrum of chlorophyll and morphological mutants increased with increase in ploidy level, while the frequency of specific chlorophyll or morphological mutants were higher either in diploid wheat or in hexaploid triticales. High frequency of chlorophyll mutants in hexaploid triticale compared to hexaploid wheat was attributed to unstabilized genomic condition of the former. Individual treatments of EMS were found highly effective, while the combined treatments were found to be more efficient in producing mutations. ‘More than additive’ effects were noticed in combined treatments. All the 10 types of chlorophyll mutants and 14 out of 22 morphological mutants showed clear cut segregation of 3:1 for normal to mutant, indicating their monogenic recessive nature. Their true breeding behaviour was also confirmed in $M_3$ generation.

A total of ten agronomically desirable mutants were isolated in $M_2$ generation. The mutants exhibited better agronomic performance both in $M_2$ and $M_3$ generations. The mutants not only performed better in the trait for which they were selected but also showed improvement in other quantitative characters. A total of 45 mutants exhibiting complete resistance to rusts, and 4 mutants showing slow rust behaviour was also isolated from segregating generation. Slow rust behaviour was confirmed by studying various slow rusting parameters such as incubation period, latent period, CDL, AUDPC and TS. Genetics of plant height mutants indicate that the two dwarf mutants (dwarf I
and dwarf II) in tetraploid wheat Jairaj, each controlled by a single recessive gene, however, the two genes are non-allelic and complementary to each other. In hexaploid wheat, the two plant height mutants (dwarf I and dwarf II) though controlled each by a single recessive gene, but they are non-allelic to each other. Genetics of three plant height mutants (double dwarf, dwarf and semidwarf) in triticale Borba indicate that each of the mutants was controlled by a single recessive gene, and semidwarf mutant showed dominance over dwarf and double dwarf, while the dwarf mutant was dominant over double dwarf. Early flowering mutant in triticale Borba was controlled by two recessive genes. Grain mutants (bold and plump) in triticale TL 419 were found to be each controlled by a single recessive gene. Leaf rust mutant (WH 147-LM-1) in hexaploid wheat WH 147 was found to be controlled by one dominant and one recessive gene.

Induced variability for eight quantitative characters, in Jairaj, WH 147 and Borba were analysed both in M₂ and M₃ generations. The mean values of spike length, days to flowering and 100-grain weight were shifted in positive direction, while for the remaining five quantitative characters, viz., plant height, tiller number/plant, number of spikelets/spike, harvest index and grain yield the mean values shifted in negative direction. Irrespective in change of the mean, the coefficient of variation increased in all the mutagenic treatments. The increase in variability thus offers an opportunity for selection and recovery of micromutations. High heritability and genetic advance were observed for most of the quantitative characters under study.