REVIEW OF LITERATURE
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2.1. Wheat improvement through transfer of rust resistance genes:

In the breeding of crop plants it is always a prerequisite to look for new sources of germplasm for disease resistance. In polyploid genera complex, species related to the cultivated species provide an important reservoir of genes for use in resistance breeding. In wheat, Riley and Kimber (1966) provided the first comprehensive work on the transfer of alien genetic variation. Recent reviews by Sharma and Gill (1983), Knott (1987), Gustafson and Dera (1989), Islam and Shepherd (1991), Reddy and Alok Saikia (1992), Gustafson and Sears (1993), Jiang et al. (1994) and Reddy et al. (1996) provided an extensive list of the use of alien genetic variation for wheat improvement. Wiese (1987) and Knott (1989) reviewed specifically the wheat diseases caused by different biological organisms, while Roelfs et al. (1992) reviewed the literature pertaining to the three wheat rusts with reference to description, methods of control, isolation and utilization of disease resistance.

The wild as well as cultivated relatives of bread wheat form a large pool of genes of value to wheat breeders for disease resistance and other desirable attributes. Kochumadhavan et al. (1980) screened more than 2000 indigenous and exotic wheat varieties/stocks for stem, leaf and stripe rust resistance, and a large number of wheats were shown to possess high degree of resistance to various rusts. A number of rust resistance genes (Sr, Lr, Yr) have also been identified in these wheats (Nagarajan et al., 1987), and some of them have been successfully incorporated into some Indian wheats by simple backcrossing (Sharma et al., 1991; Ranadhawa et al., 1992). This technique is also used to transfer rust resistance genes from wild (diploid and tetraploid) wheats and other close relatives of bread wheat into cultivated wheat. For example,
stem rust resistance gene Sr22 from _T. monococcum_ (The, 1973), leaf rust resistance genes Lr21 and Lr22 from _Ae. squarrosa_ (Rowland and Kerber, 1974), stem rust resistance genes Sr36 and Sr37 from _T. timopheevi_ (Gale and Miller, 1987) and a number of undesignated leaf and stem rust resistance genes from _Elymus giganteus_ (Singh _et al._, 1987), stem rust resistance gene Sr33 from _T. tauschii_ (Kerber and Dyck, 1979) have been successfully transferred to cultivated wheats.

The use of alien species in wheat breeding has greatly increased in the last few decades. Initially, these species were used as sources for disease and pest resistance, but they have also contributed genes for adaptation, quality and grain yield (Knott, 1987). Distant relatives of wheat have useful characters of potential value in wheat improvement and therefore, attempts have been made to transfer these characters into cultivated wheats by using special methods like (i) transfer of genomes, (ii) transfer of individual chromosomes, (iii) transfer of a chromosome segment and (iv) transfer of a specific gene. However, except triticale, the other intergeneric hybrids produced involving genome transfer were purely of an academic interest. Similarly, the wheat-alien addition and substitution lines, which carry either an extra additional chromosome/chromosome pair from the donor parent or a single or a pair of chromosomes of the donor parent in place of wheat chromosome(s), are also not suitable for direct commercial use, since these lines were unstable, agronomically inferior to wheat, and associated with undesirable traits. The radiation-induced translocations, employed for transfer of chromosome segments from alien donor parent to wheat, was also a laborious process as it involves a large amount of cytological work, while most of the translocations thus produced involves non-homoeologous chromosomes and were found to be deleterious (Sears, 1972, 1993). In view of the difficulties involved in the above three approaches, more emphasis, therefore has been given to the fourth
method, where the transfer involves only the desired specific gene. Wheat has a genetic system, where homoeologous recombination is restricted by Ph1 gene located on long arm of chromosome 5B (Sears and Okamoto, 1958; Riley and Chapman, 1958). Three approaches have been suggested for transfer of desirable gene(s) from alien chromosomes into wheat, involving the Ph gene, which include (i) removal of chromosome 5B, (ii) suppression of Ph gene effected by the genome of Ae. speltoides, and (iii) wheat mutants of 'Chinese Spring' carrying the recessive Ph allele or a deletion of Ph locus (Sears, 1977, 1981). The absence of Phi, the major pairing suppressor, induces a high level of homoeologous pairing. This technique has been successfully used in inducing homoeologous recombination between wheat - Agropyron (Wang et al., 1977; Kibirige-Sebunya and Knott, 1983), wheat - Aegilops (Sharma and Gill, 1986), wheat - Hordeum (Islam and Shepherd, 1991), and wheat - Secale (Asiedu et al., 1990). The recombinants were further backcrossed to the recurrent wheat parent to reduce the undesirable alleles.

It is equally important to verify whether the alien gene/segment from alien genera/species has really been incorporated into wheat genetic background or not. Rye genes in wheat were identified on the basis of morphological markers like hairy peduncle, brown spike and red grain (Singh, 1987). Rust inheritance, as observed through monosomic analysis, also provided clues regarding the presence of alien genes in wheat genetic background (Mahamoud et al., 1987; Singh, 1991; Riede et al., 1995). Presence of leaf rust resistance genes Lr10 and Lr14a, in two bread wheat cultivars, were confirmed by Nayar et al. (1988), on the basis of rust reactions in F2 seedlings derived from the crosses with susceptible Agra Local wheat variety. Sharma et al. (1995) identified the chromosomes of Thinopyrum intermedium, in wheat genetic background, through chromosome pairing and RFLP analysis. The confirmation of the transferred gene, in wheat background, was also
achieved by its effect on some biochemical parameters. Tyagi and Khanna (1987) observed that in powdery mildew resistant wheat genotypes the contents of soluble proteins were increased, while there was also significant increase in peroxidase and polyphenol oxidase activity. Sherif et al. (1989) have shown that leaf rust resistant wheat cultivars Giza 155 and Sakha contain higher peroxidase, catalase and polyphenol oxidase activity. Saini et al. (1989) observed that in leaf rust infected leaves of wheat, there was a significant reduction in phenol content, and an altered activity in peroxidase and its isoenzymes.

The transfer of alien gene to wheat generally results in variation in the yield of the recurrent parent. The yield will be either increased or decreased, depending upon whether the transferred gene is associated with undesirable linkages or not. The derivatives carrying leaf rust resistance gene Lr19 from A. elongatum could not be used because of the presence of linked genes for inferior baking quality (Knott, 1978). The et al. (1988) compared the effect of eight sources of stem rust resistance on grain yield in nine Australian wheats. They observed significant yield depression in some of the resistant lines as compared to the susceptible with Sr26 and Sr21 giving 9% and 7% lower yield, respectively. However, Labachev (1992) showed that in addition to high degree of leaf rust resistance, Lr19 also had a favourable effect on grain yield.

2.2. Improvement of hexaploid triticales and bread wheats:

Several studies have earlier been conducted involving triticale-wheat hybridization (Kiss and Trefas, 1970; Zeller, 1973; May and Apples, 1982; Shigenaga et al., 1983; Lukaszewski and Gustafson, 1983). Crosses gave triticales with improved fertility, day length insensitivity, dwarfness, better grain yield and improved seed type. Similarly, resistance to leaf blotch (Septoria tritici) has been introduced into wheat from triticale (May and Apples, 1982). Many of the 'Veery' series wheats, possess short arm of chromosome 1R replacing
the short arm of 1B, which is mainly responsible for the wide adaptation and productivity. In other studies, it has been shown that some of the derivatives carry wheat-rye translocations and have higher protein level than bread wheat (Lukaszewski and Gustafson, 1983; Skovmand et al., 1984).

2.3. Cytogenetic studies in triticale:

Triticales, generally referred as 'hybrid swarm' or a 'polyploid complex' (Muntzing, 1979). Different terms have been used to identify and distinguish between different kinds or types available among triticales. The autogamous strains that are raised as immediate product of chromosome doubling of F₁, resulted from wheat x rye crosses are referred as primary triticales, while substitutional triticales are those produced from crosses between triticale x wheat. Most of the present day 6x triticales resulted from the crosses of 6x triticales with 6x wheats, giving the F₁ hybrids of genomic constitution AABBRD (14₁+14₁). According to Muntzing (1979), if specific chromosomes of the D-genome can substitute only for their homoeologous in triticale constitution, theoretically there will be 128 possible combinations. However, if non-homoeologous pairing, for eg. 5R for 4A (Zeller and Baier, 1973); 1D for 6R and 4D for 6R (Brandes, 1975), the number of possible combinations will be much more than 128. The list of spring triticale varieties given by Skovmand et al. (1984) and Abdalla et al. (1986) provides the information about the substitutional status of the released triticales. In these reports, it has been shown that many spring triticales contain 1-3 R/D chromosome substitutions (replacement of R-genome chromosomes by D-genome chromosomes). Giemsa C-banding technique is widely used to identify rye chromatin in wheat-rye amphiploids and chromosome addition, substitution and translocation lines (Appels, 1982). Due to modifications in rye chromosome morphology (due to deletion or reduction of telomeric heterochromatin), a common feature in the derivatives of triticale x wheat crosses, identification of individual rye
chromosomes is difficult through Giemsa C-banding technique (May and Appels, 1980; Lukaszewski and Gustafson, 1983). Ditelocentric analysis using ditelos for D-genome chromosomes of wheat are employed for identification of presence or absence of specific rye chromosomes in triticale. Gustafson and Zillinsky (1973) were the first to use this technique to confirm 2R/2D substitution in hexaploid triticale Armadillo.

Kernel shrivelling and seed setting in hexaploid triticales were governed by presence or absence of R/D substitutions and modified rye chromosomes. Gustafson and Bennett (1982) observed that, reduction of heterochromatin from 4R and 6R increased kernel plumpness and test weight in triticales. Gustafson et al. (1984a,b) observed a correlation between variation in the heterochromatin and regularity in endosperm development in several advanced triticales.

Greater intraspecific variation in nuclear DNA contents was noticed in several cereals including rye (Boiko et al., 1985). A positive correlation is known to exist between DNA content and the duration of cell cycle in many taxa including wheat and rye (Bennett, 1973), while observations of the early seed development rate within the genus Secale indicated that the increase in heterochromatin content was associated with the decrease in cell cycle duration (Gustafson and Lukaszewski, 1985). Bennett and Kaltsikes (1973) and Bennett (1976) observed that different rate of cell development between the parental species (wheat and rye), which are determined by the qualitative and quantitative difference in their DNA contents help to cause chromosome instability in the hybrid triticale.

Telomeric heterochromatin is known to affect chiasma position in rye (Jones, 1978), and univalent formation in triticale and wheat (Merker, 1976; Naranjo and Lacadena, 1980, 1982). Hulgenhof and Schlegel (1986) observed
that homozygous deletion of telomeric heterochromatin on one or more of rye chromosomes (1R, 4R, 5R) were associated with improvement in meiotic stability.

2.4. Induced mutations:

The concept of producing artificial mutations and utilizing them for breeding cultivated plants was laid down by Hugo de Vries in 1901. By definition a mutation is an inherited stable alteration of genetic changes date back to the beginning of the 20th century (Gager, 1908). The practical proof of induced mutations by genetic changes came only in the late twenties. Study of induced mutations commenced in 1927 by Muller, an entomologist, who discovered the mutagenic property of X-ray in *Drosophila*. Stadler (1928a,b), a plant breeder, demonstrated that mutation could be induced in plants (maize and barely) by X-ray. Since then a series of induced mutation experiments were conducted in a wide range of crop plants utilizing both physical and chemical mutagens (Ehrenberg, 1954, 1960; Bhatia, 1960; Goud, 1967a,b; Brock, 1970; D'Amato, 1959; Konzak *et al.*, 1961; Sree Ramulu, 1971; Auerbach, 1965; Nilan *et al.*, 1973). In recent years more emphasis has been given to the use of combination treatments of physical and chemical mutagens in order to produce wider spectrum and higher frequency of mutations (Cheng and Gao, 1988). Induced mutagenesis has thus assumed an important role in plant breeding by increasing variability for yield and its component characters. It has been clearly shown in a number of plant species that the effect induced, varies with the varying mutagens and with variation in doses. Thus selecting a mutagen and its optimum dose for a genotype in any plant species is important for the mutation breeding work. On the basis of available literature it is found that about 844 mutant varieties have been produced, approved and released for cultivation in different countries (Micke *et al.*, 1987; Gupta, 1995).
Studies made by MacKey (1954a,b) on basic and applied aspects of mutagenesis in *Triticum*, encouraged the use of wheat as an object of investigation by a number of workers. In India, mutation breeding in wheat was initiated by Ranjan (1940). However, a systematic way of induced mutagenesis for wheat improvement in India was started in early 1960's (Natarajan *et al.*, 1958; Swaminathan, 1961). Preliminary studies on the effect of various mutagens on several biological parameters were studied in wheat and triticale (Bhatia and Swaminathan, 1963; Varughese and Swaminathan, 1968; Chaudhury and Nirmala, 1976; Yanev, 1985). In these studies, it has been reported that there was a very narrow difference between a lethal dose and a potent mutagenic dose. Studies by Goud (1967a,b) have shown differences in varietal response to mutagenic treatments in wheat. Assessment of radiosensitivity of diploids and polyploids through the study of cytological abnormalities was attempted in wide range of plants such as wheat and barley (Swaminathan, 1957,1965; Bhaskaran and Swaminathan, 1960, 1961a,b), *Crepis* (Kagramanyan, 1975), *Vicia faba* (Evans, 1961), *Physalis* (Gupta and Roy, 1985) and *Petunia* (Padmaja and Sudhakar, 1989). In these studies, it was reported that polyploids are more tolerant to the mutagens.

A few chlorophyll mutants were also recorded in mutagenic populations of wheat and triticale (Bhatia and Swaminathan, 1963; Varughese and Swaminathan, 1968; Reddy and Gupta, 1989). Mutants exhibiting variation in chlorophyll pigment and morphological characters were isolated in EMS derived M₁ and M₂ generation in wheat monosomics (Sham Rao and Sears, 1964). Monogenic recessive chlorina chlorophyll mutant was reported in durum wheat (Klindworth *et al.*, 1995), the alleles of this mutant was found to be allelic to chlorina mutant of hexaploid wheat. Chopra and Swaminathan (1966) reported negative synergism between EMS and ethylene imine in inducing chlorophyll mutants in emmer wheat. Both positive and negative synergistic
effects for chlorophyll mutations were observed due to combined treatment of gamma rays, EMS and sodium azide in triticale, barley and wheat (Reddy, 1992). In barley, Balchonene et al. (1985) recorded highest mutation frequency of albina mutants at moderate doses of gamma rays.

Swaminathan (1964) classified morphological mutations based on their identification either on individual plants (micromutations) or group of plants (macromutations). Viable morphological mutants having changes in the phenotype for one to several morphological characters were reported in mutagenic treated populations of durum and bread wheat (Bhaskaran and Swaminathan, 1960; Yanev, 1987, 1989) and triticale (Reddy and Gupta, 1988). EMS induced lethal dwarf mutants were reported in hexaploid wheat (Sham Rao and Sears, 1964). Reddy and Reddy (1986) induced various morphological mutants in hexaploid triticale in M₃ generation by irradiating with gamma rays at four stages (seedling, tillering, meiotic, gametic). A male sterile mutant was induced in durum wheat cv. Russeiio using combination treatment of physical and chemical mutagens (Giorgi, 1991). In these above studies, it was reported that the mutation frequency was random for different morphological characters and varied within the treatment. Genetics and breeding behaviour of some induced morphological mutants were also reported in a few studies. An awned (bearded) mutant found to be true breeding and the mutant arose either a criptic deletion or from intragenic changes at the ‘B’ locus (Chopra and Pai, 1979). Awnless mutant in wheat variety C-591 was found to originate as a dominant awn inhibitor or a deletion or a mutation at the awn producer loci (Natarajan et al., 1958). ‘Lax-spike’ - a morphological mutant for spike character in wheat was found to be monogenic recessive (Xu, 1985). In triticale, some of the dwarf mutants isolated by Grzesik and Nalepa (1985) were found to be controlled by two partially dominant genes.

Mutants of practical importance in wheat and triticale were also reported
in few studies. Varughese and Swaminathan (1968) isolated amber grain mutants in wheat by giving combination treatments of gamma rays and ultraviolet rays. Leont'ev and Abramov (1990) selected bread wheat mutant lines, which out yielded the control. Yanev (1985) obtained mutants with longer spike and more number of spikelets in several durum wheat cultivars by treating with various physical and chemical mutagens. Early flowering mutants (24 days earlier than control) in barley was reported earlier (Devreux et al., 1972; Prasad and Ramesh, 1996). Bozzini and Monti (1969) using gamma irradiation isolated desirable dwarf mutants in durum wheat. Wheat mutants with increased tiller number was reported by Goud (1967a,b). Mutagen induced dwarf mutants were also reported in triticale (Reddy and Gupta, 1988). Mutants with improved fertility and grain filling was also reported in several triticales (Shakoor et al., 1980; Singh and Joshi, 1985). The application of induced mutations for disease resistance in wheat has been extensively reviewed (Konzak, 1956; Favret, 1965; Peusha et al., 1978; Simons, 1979; McIntosh, 1977; Micke, 1983, 1987). Both physical and chemical mutagens have also been utilized to create new variability for rust resistance in wheat (Bhatia et al., 1961; Sawhney et al., 1979a,b; Sharma et al., 1989). Sigurbjornsson (1977) reported that atleast thirteen cereal cultivars which possess better resistance to different diseases owe their origin to induced mutations. Bhatia et al. (1961), and Sharma et al. (1989) used single rust race for detecting mutants resistant to stem rust in wheat. Using a mixture of stem, leaf and stripe rust races, Sawhney (1987) isolated a total of twenty rust resistant mutant lines under field condition. Borojvic and Worland (1988) isolated three mutant lines in wheat variety San Pastore by treating with gamma rays, and the mutants were found free from leaf, stripe rusts, and powdery mildew. A high yielding wheat mutant line completely immune to stripe rust, was induced with fast neutrons (Feng, 1991). Mahajan et al. (1990a,b) using gamma rays, EMS and
sodium azide, isolated several wheat mutants, showing less severity for leaf rust. Ibrahim et al. (1988) using gamma rays and EMS, isolated a total of 1269 mutant plants for wheat smut in M₂ generation.

There are many studies, involving polygenic variability created by various mutagenic agents in several crops including wheat and triticale. Swaminathan (1969) reported shifting of mean values towards earliness in a late strain and lateness in an early strain of wheat in M₃ progeny. Goud (1967a,b) also reported both negative and positive shifts in the mean values for tillering in wheat. Negative shift in mean values for a few other quantitative characters were also noticed in wheat (Bhatia and Swaminathan, 1962) and triticale (Reddy, 1989; Singh and Joshi, 1985). Scossiroli et al. (1966) reported that the irradiation of wheat seeds caused a decrease in the mean of quantitative parameters in the M₁ and M₂ generations, where as in M₃, there was a decrease of this effect.